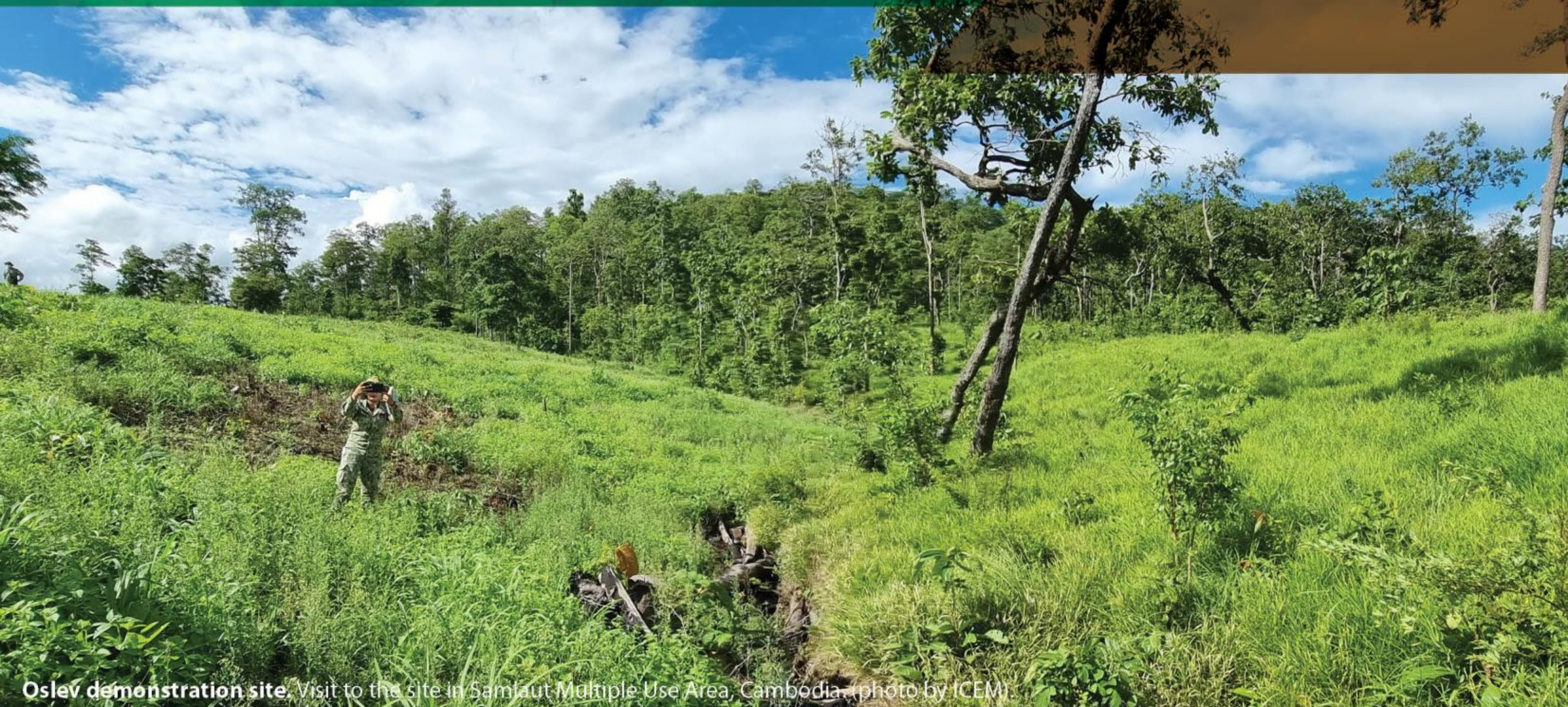
Climate Change Risk and Adaptation Options Assessment – Sangker River Basin, Cambodia (Draft)

Investing in Climate Change Adaptation through Agroecological Landscape Restoration: A Nature-Based Solution for Climate Resilience

February 2024



Oslev demonstration site. Visit to the site in Samlaut Multiple Use Area, Cambodia (photo by ICEM).

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Deliverable summaries

TA-6539 Investing in Climate Change Adaptation through Agroecological Landscape Restoration: A Nature-based Solution for Climate Resilience led to the preparation of the following knowledge products:

- KP1 (1): Landscape Restoration Country Profile: Philippines
- KP1 (2): Landscape Restoration Country Profile: Cambodia
- KP3: Business Models to Encourage Private Sector Participation in Sustainable Land and Forest Landscape Management
- KP4 (1): Climate Change Risk and Adaptation Options Assessment – Sangker River Basin, Cambodia
- KP4 (2): Climate Change Risk and Adaptation Options Assessment – Manupali Watershed, Mindanao River Basin, the Philippines
- KP5: Good practices manual on biodiverse forest and landscape restoration
- KP6: Community-based Climate Vulnerability Assessment and Adaptation Planning for Resilient Agroecosystems
- KP 7: Applying Advanced Technologies in Support of Landscape Restoration and Climate Change Adaptation
- KP8 (1): User Manual: Sangker River Basin Decision Support System
- KP8 (2): User Manual: Mindanao/Manupali River Basin Decision Support System
- KP8 (3): Admin Manual: Sangker River Basin Decision Support System
- KP8 (4): Admin Manual: Mindanao/Manupali River Basin Decision Support System
- KP9 (1): Restoration plans for demonstration areas in Cambodia and the Philippines
- KP9 (2): Gender and Social Inclusion in the Mindanao River Basin, the Philippines, and the Sangker River Basin, Cambodia
- KP 10: Integrating the principles of ecological agriculture into upland farming systems of Manupali Watershed, the Philippines

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Photo credit

Cover page: **Oslev demonstration site.** Visit to the site in Samlaut Multiple Use Area, Cambodia. (photo by ICEM).

Back page: **Green space.** Plants in Oslev demonstration site (photo by ICEM).

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Abbreviations

ADB	Asian Development Bank
CA	conservation agriculture
CFWT	conservation farming with trees
FAO	Food and Agriculture Organization
FS	future scenario
GCM	general circulation model
GDP	gross domestic product
ICEM	International Centre for Environmental Management
ICRAF	International Centre for Research in Agroforestry (World Agroforestry)
INREMP	Integrated Natural Resources and Environmental Management Project
M&E	monitoring and evaluation
MJP	Maddox Jolie-Pitt Foundation
MoE	Ministry of Environment
MRC	Mekong River Commission
Mt	metric ton
MUA	multiple use area
NGO	nongovernmental organization
NVS	natural vegetative strips
PES	payment for ecosystem services
RCP	Representative Concentration Pathway
SLM	sustainable land management
SWC	soil and water conservation
SWAT	soil and water assessment tool
TA	technical assistance
WOCAT	World Overview of Conservation Approaches and Technologies

WEIGHTS AND MEASURES

C	Celsius
ha	hectare
mm	millimeter
km^2	Square Kilometer
t	ton

SUMMARY

The Asian Development Bank (ADB) project Investing in Climate Change Adaptation through Agroecological Landscape Restoration, Climate Change Risk and Adaptation/Restoration Option Assessment aims to assist Cambodia and the Philippines to develop, evaluate, and promote innovative approaches to scale up climate change adaptation interventions through agroecological landscape restoration; and to strengthen the capacity of communities to restore and manage their climate-resilient landscapes for food and nutrition security through agroecology. The project is contributing to the implementation of landscape restoration measures within target watersheds.

In Cambodia the project focuses on the Sangker River Basin, and addresses the urgent need for climate resilience through agroecological landscape restoration, leveraging nature-based solutions to enhance community capacity in managing climate-resilient landscapes for food and nutrition security. The project highlights the watershed's critical role in biodiversity, agriculture, serving as a vital resource for local communities and farms and settlements downstream.

The Sangker River Basin, Cambodia confronts significant environmental changes due to climate variability, including alterations in precipitation patterns and temperature increases, which pose severe risks of flooding and drought. Analysis conducted by the project demonstrates that deforestation and unsustainable land use will exacerbate the impacts of climate change. The analysis also highlights the critical need for strategic interventions to mitigate these impacts, focusing on enhancing the region's resilience through adaptive management practices and sustainable development strategies. In particular reforestation and the introduction of agroforestry practices in the upper watersheds of the Stung Sanker River basin is recommended to overcome the potential negative impacts of climate change on the basin's hydrology.

A critical component of the project is the identification and development of pilot sites to demonstrate sustainable approaches to landscape management. Thirty-three community forests were assessed for their potential role in biodiversity conservation and ecosystem services provision. The assessment involved consultations with farmers and community forest management groups, leading to the selection of four community forests based on their degradation level and management commitment to restoration. The sites were chosen to showcase restoration strategies that could be replicated across the landscape, highlighting the importance of community involvement in planning and implementing restoration activities to ensure ecosystem resilience and function enhancement in the Sangker basin. At each site the project team worked closely with the local community to develop restoration plans to fulfill the objectives identified at each site.

Scaling up the approach taken at the pilot sites should address the critical drivers of environmental degradation within the Sangker Basin. These include soil erosion, land degradation, and decreasing soil fertility due to intensified agricultural practices and deforestation, exacerbated by population pressures. A vicious cycle of land degradation, unsustainable land management, leads to a decrease in soil fertility and structure, thus making the land more susceptible to erosion. The ongoing degradation of the landscape not only reduces the productivity of the land but also contributes to greater runoff and sedimentation, affecting water storage and increasing flood risks for downstream communities.

A watershed-wide strategy should continue to focus on community forests as essential components in biodiversity conservation and ecosystem service enhancement. Community forests can serve as crucial stepping stones in maintaining biodiversity and improving soil and water conservation. Prioritizing these areas for restoration will benefit both the local environment and the communities dependent on these ecosystems for their livelihoods. Various adaptation strategies can work to reverse the negative impacts of land and water degradation. These include watercourse stabilization techniques, sustainable agriculture practices to prevent recent deforestation trends, and soil conservation methods. Establishing nurseries for reforestation efforts, promoting, and promoting

conservation agriculture, as well as implementing water harvesting measures to address the increasing severity and length of dry seasons will also be essential.

Future adaptation planning that encompasses both landscape and forest restoration at the watershed level, should target the most degraded areas first, gradually expanding efforts to achieve a comprehensive watershed management system that benefits both the environment and local communities.

1 INTRODUCTION

1.1 The Project

The Asian Development Bank (ADB) project Investing in Climate Change Adaptation through Agroecological Landscape Restoration, Climate Change Risk and Adaptation/Restoration Option Assessment aims to assist Cambodia and the Philippines to develop, evaluate, and promote innovative approaches to scale up climate change adaptation interventions through agroecological landscape restoration; and to strengthen the capacity of communities to restore and manage their climate-resilient landscapes for food and nutrition security through agroecology. The project is contributing to the implementation of landscape restoration measures within target watersheds.

In Cambodia, the project is led by the Ministry of Environment (MOE) with technical support from the International Centre for Environmental Management (ICEM) and the International Centre for Research in Agroforestry (ICRAF). Following detailed assessments, MOE identified the Sangker River basin as a suitable target river basin to demonstrate the landscape restoration planning process and tools and implement restoration plans for specific community forests working with local government and communities. The emphasis is on forest restoration, agroforestry, and agroecology to build climate change resilience, biodiversity gains, and livelihood enhancement.

1.2 The Stung Sanker River Basin

The western Tonle Sap Lake river basin group is particularly well suited to the project as the river headwaters are Cambodia's most important protected areas in the Card, flowing through agricultural areas to the Tonle Sap Biosphere Reserve.

The Stung Sanker River is part of this western Tonle Sap Lake river basin group that drains much of the northern slopes of the Cardamom Mountains and provides resources and ecosystem services to agriculture, fisheries, industry, and urban settlements downstream. The Sanker catchment is the third-largest tributary of the Tonle Sap Lake river basin system, with a drainage area of 6,051 km^2. Its headwaters are sourced in an extensive tropical rainforest designated as the Samlaut Multiple-Use Area (MUA), which is under pressure from intensive community activity and a growing population. Downstream, the river flows through the agricultural land and wetlands of the Battambang Plain, part of Cambodia's vitally important, food-producing 'rice bowl' including Battambang itself, Cambodia's second-largest city, and down to the Tonle Sap Biosphere Reserve with its flooded forest and fisheries.

The project has concentrated on the upper Sanker River basin comprising 14 sub-basins upstream of the confluence of the Stung Sanker and Stung Chamlang Kouy and upstream of the Treng Reservoir.[1]

1.3 The Purpose of this Report

This report aims to set out the approach to implementing landscape restoration in the upper Sanker River basin. This is only an initial phase in what will need to be a multi-phased project to implement climate change adaptation measures throughout the whole river basin. The report is a guide to a realistic approach for scaling up the landscape restoration practices undertaken in the pilot areas.

The report sets out the climate change risks to the river basin and surrounding area in Chapter 2 as outlined in the baseline assessment and to the river basin itself as identified in the soil and water assessment tool (SWAT) analysis undertaken by this TA. These climate risks were used to determine criteria to select degraded pilot areas for which appropriate adaptation interventions and restoration plans were prepared in consultation with the communities (Chapter 3). In consultation with communities and local government, it was decided to focus on community forests, which form a network of degraded forest pockets across the agricultural landscape, forming the buffer for the Samlaut MUA. The aim is to demonstrate restoration approaches implemented by community forest groups, which can be progressively rolled out across the upper catchment with the forest pockets as

[1] The Treng reservoir is locally known as Sek Sork reservoir.

stepping stones to reestablish biodiversity connectivity, improve water security, and bring a wide range of other ecosystem services to local communities.

Chapter 4 sets out a realistic approach for future scaling up of the landscape restoration practices undertaken in the pilot areas to the whole upper basin. This report should be used in conjunction with other project outputs, particularly the Good Practices Manual on Biodiverse Forest and Landscape Restoration and the individual restoration plans for each pilot area.

2 CLIMATE RISK ASSESSMENT

2.1 Regional Overview - Climate Risk and Vulnerability Hotspots

2.1.1 Rainfall and Temperature

Precipitation data collected from six weather stations between 2007 and 2018 around the Sangker River Basin showed that the average annual precipitation in the region changed little in the last ten years. Mean annual precipitation varied from 1,308 mm at Moung Ruessei station to 1,577 mm at Samlout station. Similarly, in the 90 years from 1920 to 2012, the annual precipitation amount did not change significantly. However, there has been a shift in the annual precipitation pattern, with the wet season receiving more rainfall while and the dry season experiencing the dry season experienced less. The precipitation peaks also shifted from two peaks a year in May and September to have given way to a single peak a year in September or October. This trend implies a concentration of precipitation towards the end of the wet season. The precipitation pattern change is likely to worsen flood event severity in the watershed. Climate change modeling suggests that by 2050, when climate change is considered, Battambang's total rainfall during the wet season is projected to increase by about 8.3%, while dry season rainfall could decrease by more than 10% (Figure 1).

Annual temperatures in the Sangker River Basin are projected to increase with climate change, leading to an increase in heat waves and the risk of wildfires. Sangker River Basin's average daily maximum temperature during the dry season could increase by 1.3°C to 1.4°C (Figure 2). The combined effects could increase the frequency and intensity of severe droughts and floods. People living in remote areas and relying heavily on agricultural production are particularly vulnerable to these changes. Decreased agricultural production can negatively impact food security and put rural gross domestic product (GDP) per capita at risk.

Figure 1: Dry Season Precipitation in the Western Tonle Sap Lake River Basin Group Projected to 2050

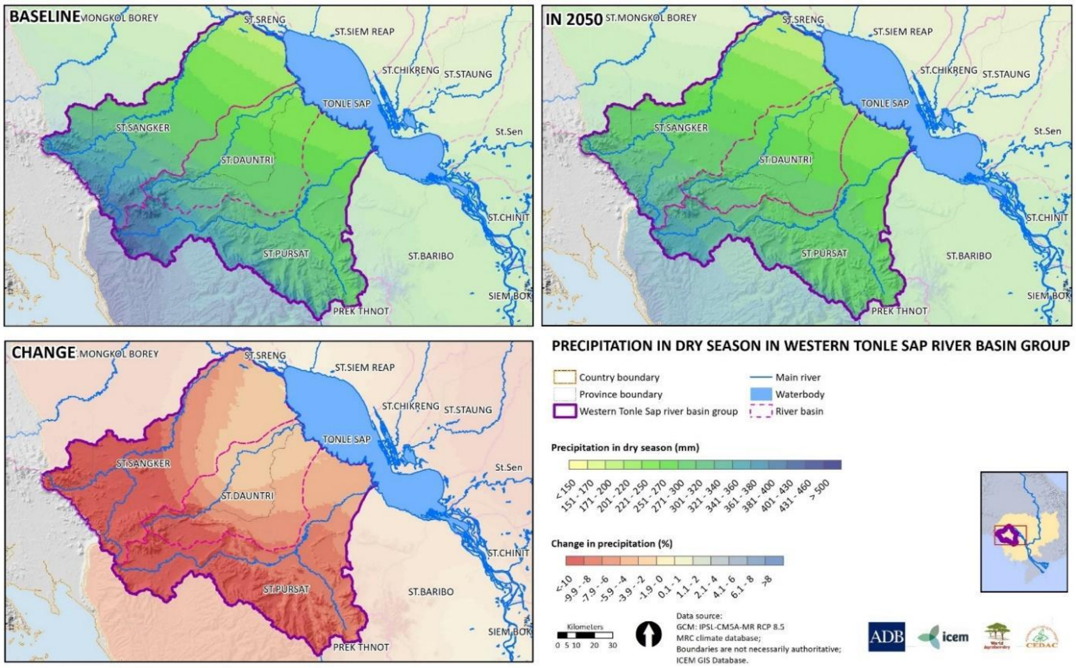
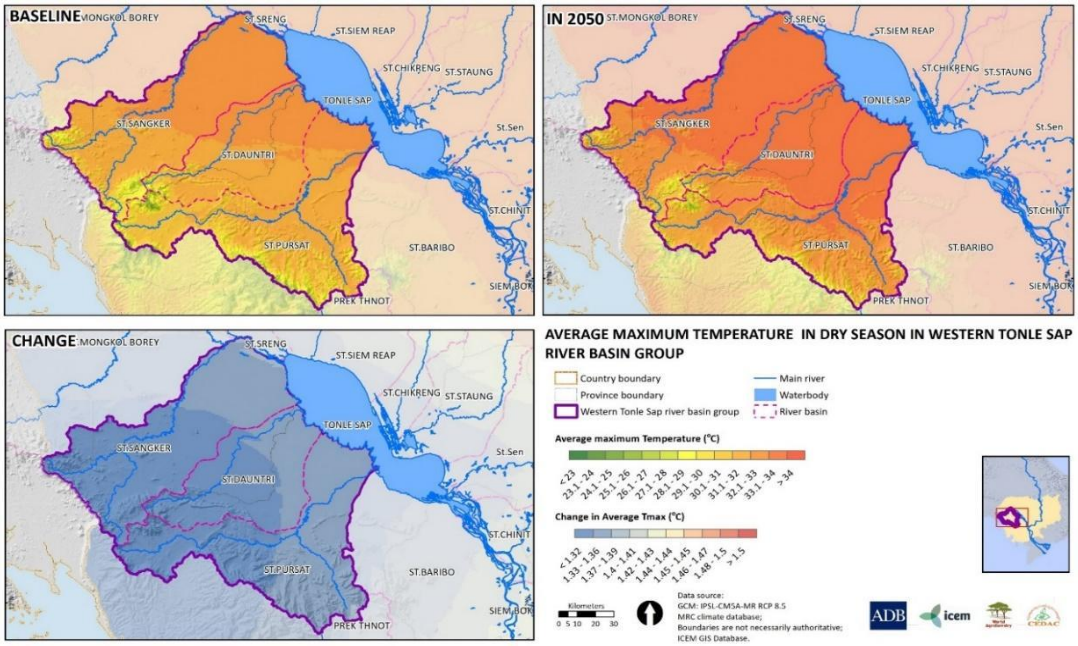


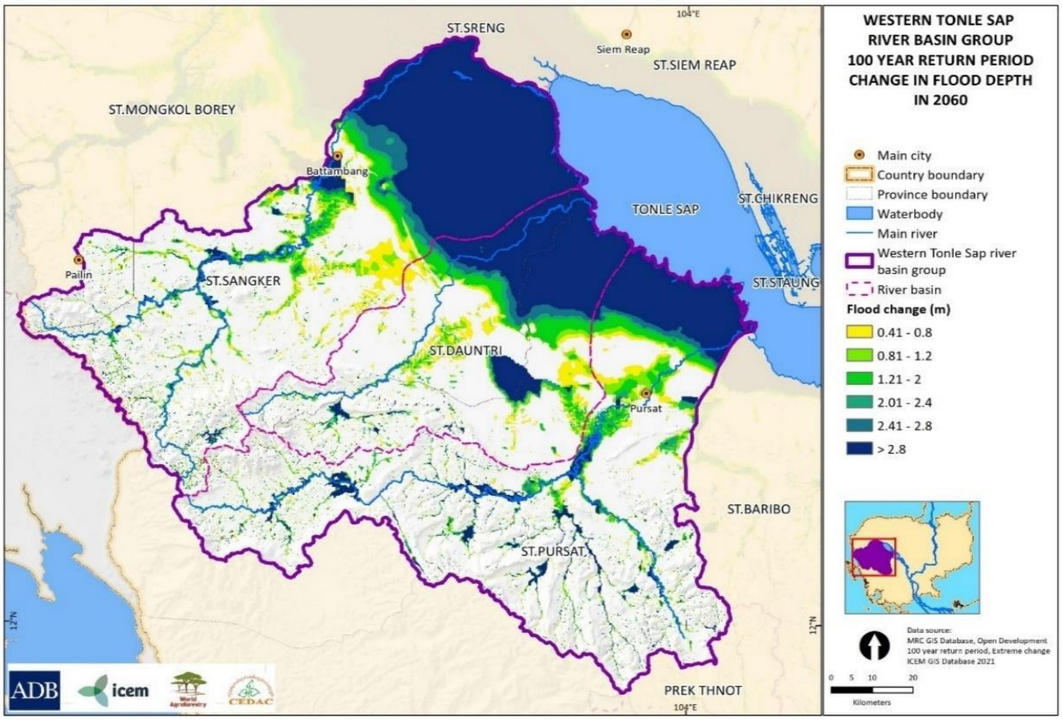
Figure 2: Dry Season Average Maximum Temperature in Western Tonle Sap Lake River Basin Group Projected to 2050



2.1.2 Flood and Drought Vulnerability

The Sangker River basin experiences an annual cycle of floods and droughts due to too much water during the wet season (May–October) and too little in the dry season (November–April). These extreme events severely disrupt livelihoods and services and cause significant economic damage. More extended and more intense periods of precipitation are likely to lead to a higher risk of relatively long-duration flooding in the future, especially in the east of the basin group close to the Tonle Sap lake (Figure 3). Flash flooding might become more severe in higher elevations – particularly where forests have degraded.

Figure 3: Projected 100 Y Flood Depths in 2060



Since 2000 the Sangker basin has experienced severe droughts almost annually, particularly in 2002, 2003, 2004, 2005, 2015, and 2016. The 2016 drought was considered the worst disaster in Cambodia in 100 years. Most of the country was negatively affected. Two and a half million people were severely affected, and 170,000 ha of rice fields (6.7% of the total rice area) were significantly damaged, especially in Battambang Province. In the dry season, severe and moderate droughts have affected large rice cultivation areas in the Sangker River basin. The central area of the basin is most susceptible to drought and can experience more than 7 to 9 months of drought per year (Figure 4).

Figure 4: Annual Drought Frequency in Cambodia

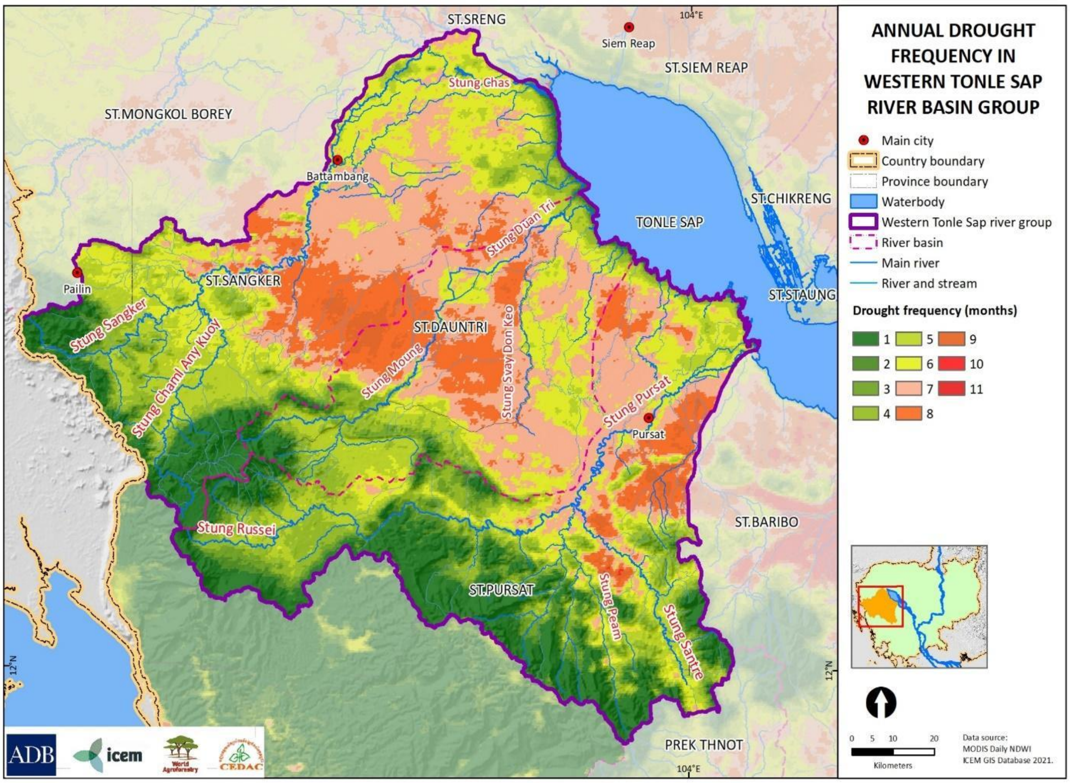
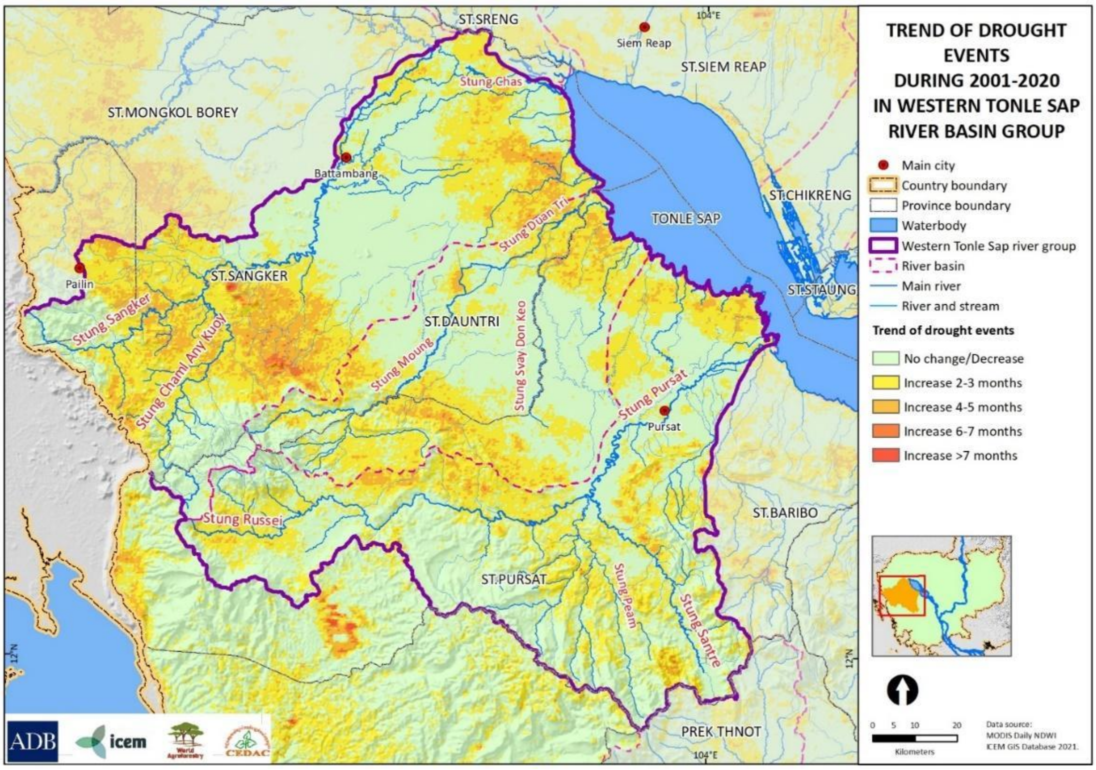


Figure 5 shows the change in precipitation over Cambodia using the Mekong River Commission (MRC) 2019 general circulation model (GCM) projection under the Representative Concentration Pathway (RCP) 8.5 scenario. Focusing on the Sangker basin, precipitation during the dry season is expected to decrease by more than 15% in some areas. The decrease in rainfall will worsen the region's already serious drought condition, putting more pressure on water resources and increasing water competition and conflict. Figure 5 also shows that the most significant increases in drought in the past decade have been in the upper watershed of the Sangker, reflecting the impacts of forest loss and land use and land cover changes discussed in the next section.

Figure 5: Trend of drought in western Tonle Sap Lake River Basin from 2001 to 2020



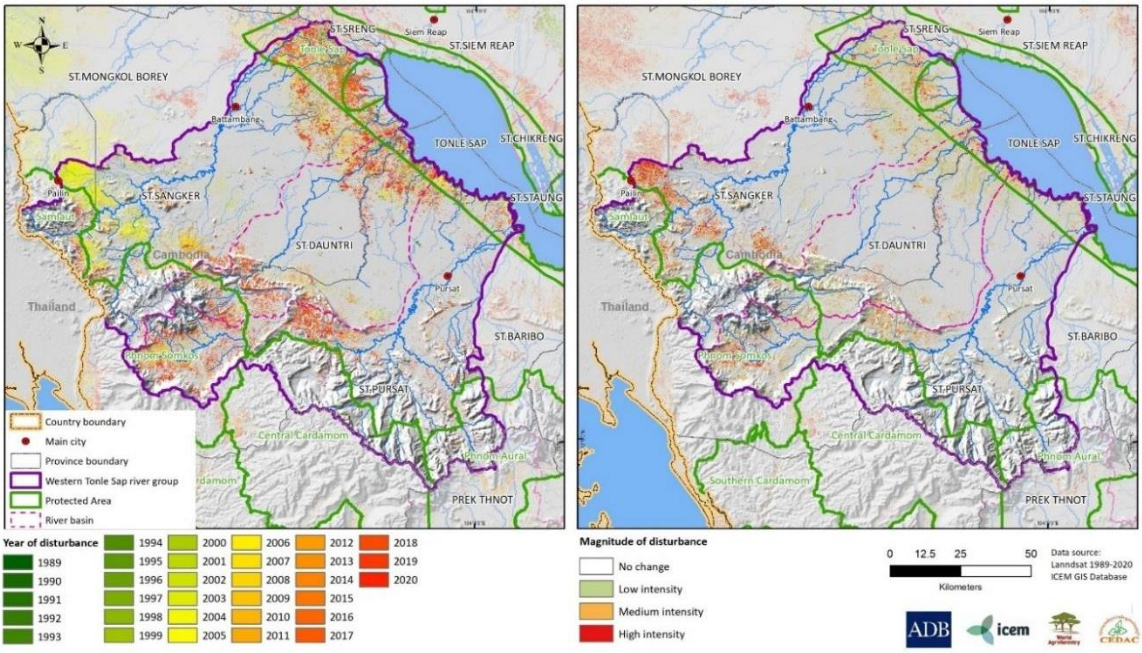
Between 2018 and 2021, the average Tonle Sap Lake water volume was below a previously recorded long-term average (from 1997 to 2005). In the 2020 wet season, the total volume of the reverse flow was only 18.89 km^3, which is less than half of the long-term average annual volume of 43 km^3.

2.1.3 Land Cover/Land Use Changes

According to the Ministry of Environment (MoE), between 1965 and 2016, civil war, population growth, and agricultural expansion caused forest cover to decline from 73% to 48% of the country. The average annual loss rate from 2014 to 2016 was about 121,328 ha or 0.67% of the total forest area. Although forest cover remained almost constant from 1976 to 19 in the Tonle Sap region, large areas of dense forest were degraded. Since 2000, and particularly since 2010, the patchwork of deforested areas and agricultural land such as paddy rice fields, field crops, horticulture, rubber, and oil palm has increased. This expansion of agricultural land has shifted from lowland to upland, adding more pressure on the remaining forest in areas of higher elevation and slopes.

The trend is apparent throughout the Sangker basin, where most vegetation loss has occurred since the 2000s (Figure 6). Deforestation occurred in the Samluat and Prek Toal Corea multiple-use areas and high-intensity buffer zones. The deforestation rate within the Sangker River Basin is estimated to range from 0.138% to 1.762% per annum, rates that, if continued, would mean the loss of all forest within 40 years.

Figure 6: Vegetation Loss in the Western Tonle Sap Lake River Basin Group from 1989 to 2020



2.1.4 Summary of Regional Trends

While total precipitation has not changed significantly, the rainfall pattern has shifted from bimodal to unimodal, with rainfall concentrated in September–October, increasing the potential for flooding.

Annual temperatures are projected to increase, likely increasing the frequency and intensity of drought. Already, the Sanker basin experiences severe droughts on an almost yearly basis. A projected decrease in dry-season rainfall will exacerbate drought conditions. A greater incidence of flood and drought disrupts livelihoods and causes significant economic damage.

Partly due to population pressure and partly as a response to a changing climate, agriculture is moving out of the plains and into the hilly, forested headwaters of the river basin with resultant deforestation, much of which has occurred since around 2010. This, in turn, increases runoff and soil erosion, leading to flooding and reducing base flow, exacerbating droughts.

2.2 The Stung Sanker River Basin

The MoE identified the Sangker River basin as a suitable basin to demonstrate restoration measures, given the acute pressures on the Samlaut MUA and its buffer zone. As part of this TA project, a SWAT analysis assessed the impacts of land use, land cover changes, and climate change on the basin's hydrology and sediment transport processes.

The Sangker River basin is undergoing a steady process of degradation and is subject to flood and drought events of increasing severity, projected to become more significant with climate change. Understanding how to manage the basin's land use is critical to water supply, water quality, agricultural productivity, the effective functioning of hydropower and irrigation infrastructure, and the protection of other strategic infrastructure. The SWAT modeling results are important to understanding and defining the restoration measures required to safeguard the basin's livelihoods, infrastructure, and ecosystems.

This section draws on the SWAT modeling and analysis. It introduces the broader river and upper basins where pilot interventions are concentrated and climate risks.

2.2.1 SWAT Analysis

Ecosystems, agriculture, and agroforestry rely on river basins for their hydrological needs. However, agricultural and urban developments can significantly affect hydrology and sediment transport processes. Changes in land use and land cover can change the timing and volumes of runoff, which, in turn, can change water availability in the dry season and increase the likelihood of flooding in the wet season. Furthermore, increases in flooding and the removal of native vegetation may exacerbate erosion, potentially leading to the loss of valuable topsoil, damaging crops and arable land adjacent to waterways.

Climate change can also alter the timing and volumes of runoff, affecting the capacity of river basins to sustain functioning agricultural systems and ecosystems. Durations and the timing of dry periods may change, potentially leading to more severe droughts. Changes in the transitions between the wet and dry seasons may affect the timing of planting and harvesting crops.

SWAT models provide valuable insights into hydrologic and sediment processes and the impact of climate change and landscape change. SWAT models have been used for over 40 years to study rainfall-runoff and erosion processes[2], including studies in Cambodia, the Mekong River basin, and the Sangker basin.

SWAT is an open-source model that can run through its interface or with commonly used geographical information systems (ArcGIS and QGIS). It can be calibrated manually or automatically and runs on a daily time step, the most common format for rainfall data inputs.

2.2.2 Location, River Network and Sub-basins

The location of the Sanker River basin is shown in Figure 7, and its 55 sub-basins are shown in Figure 8. With a total drainage area of 6,051 km^2, the Stung Sangker River is the third-largest tributary in the Tonle Sap Lake basin system. The river is 250 km long and flows through six districts and 27 communes in Battambang province before draining into the Tonle Sap Lake. The lower basin includes part of Cambodia's 'rice bowl,' a crucial food-producing area, and Battambang, the country's second-largest city.

For this study, the upper catchment, where the pilot areas are located, is defined as upstream of the confluence of the Stung Sanker and Stung Chamlang Kouy, just upstream of the Treng Reservoir and comprising 14 sub-basins—number 38 and numbers 43–55 (Figure 8).

[2] Arnold et al. 2012. *SWAT: Model use, calibration, and validation.* Transactions of the ASABE Vol. 55(4): 1491-1508.

Figure 7: The Upper Sanker River Basin Main Drainage Corridors

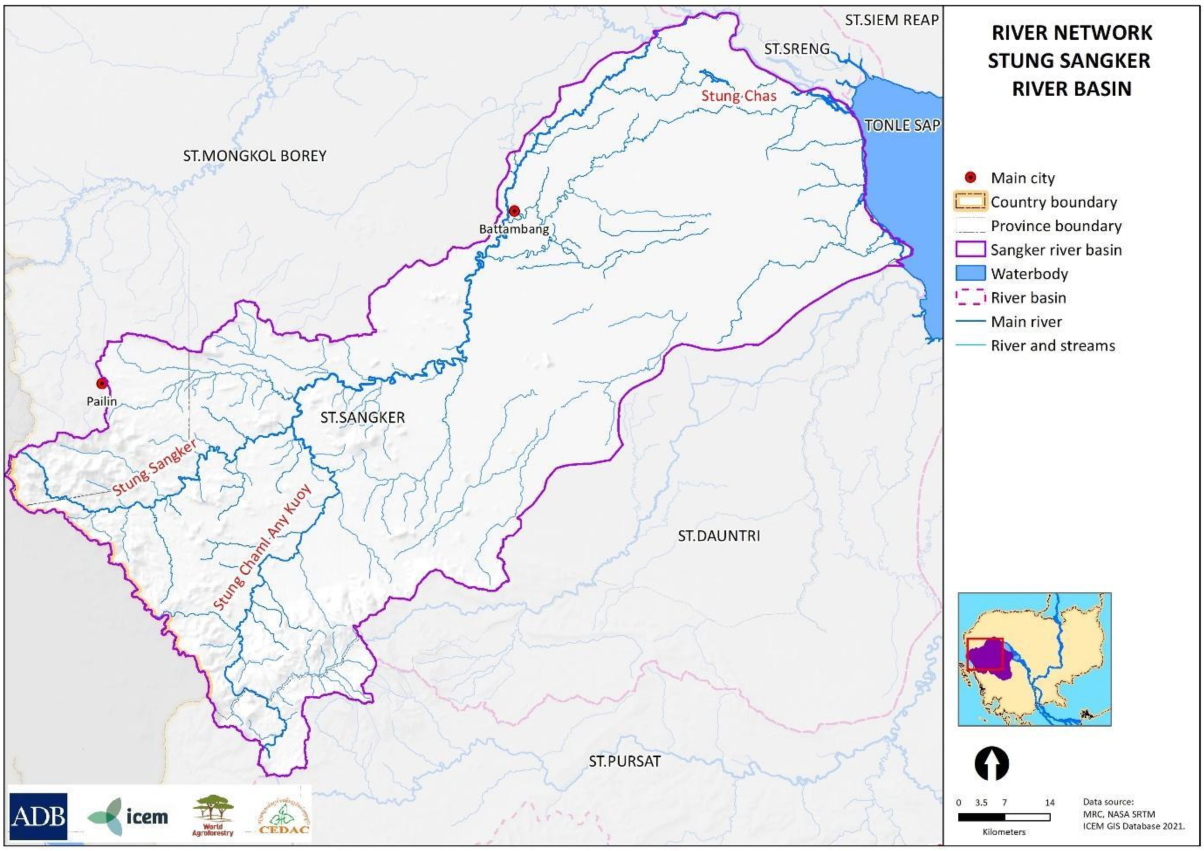
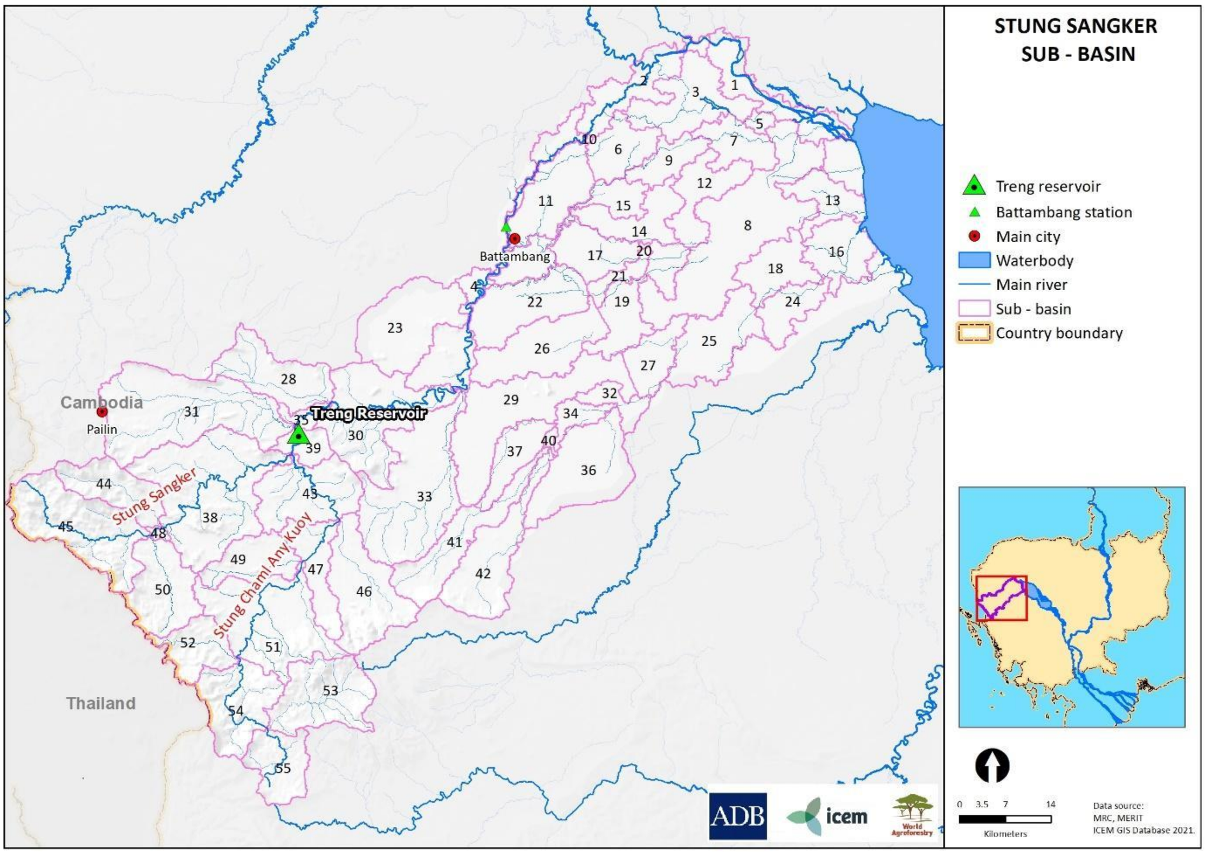


Figure 8: Sub-basins of Sangker River Basin



2.2.3 *Topography and Slope*

The basin consists of two separate regions: a flat lowland region immediately upstream of the Tonle Sap Lake and a highland region towards the south and west of the basin, where elevations extend to around 1,500 m (Figure 9). Figure 10 shows the slope classes by sub-basin with steeper Class 4 and Class 5 slopes (4%–15%) in the upper basin while the lower basin is flat. The flat lower basin has been cultivated for a long time, but the upper basin's steeper hills have only been cleared for cultivation relatively recently.

Figure 9: Sangker River Basin Topography

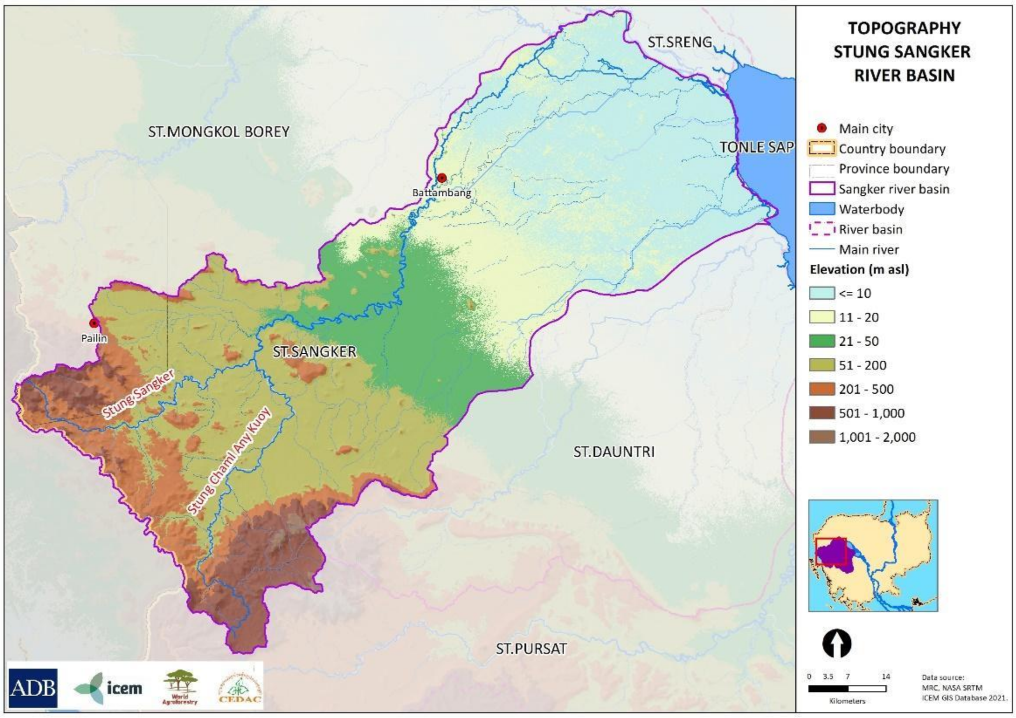
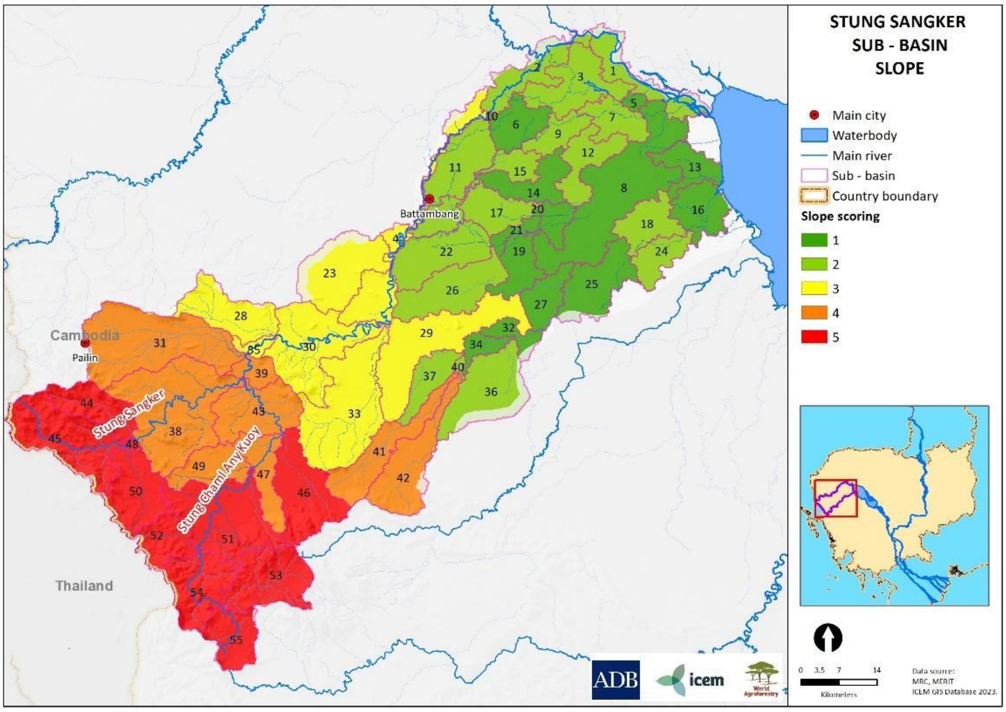


Figure 10: Sangker River Base - Sub-basin Slope Classes



2.2.4 Rainfall

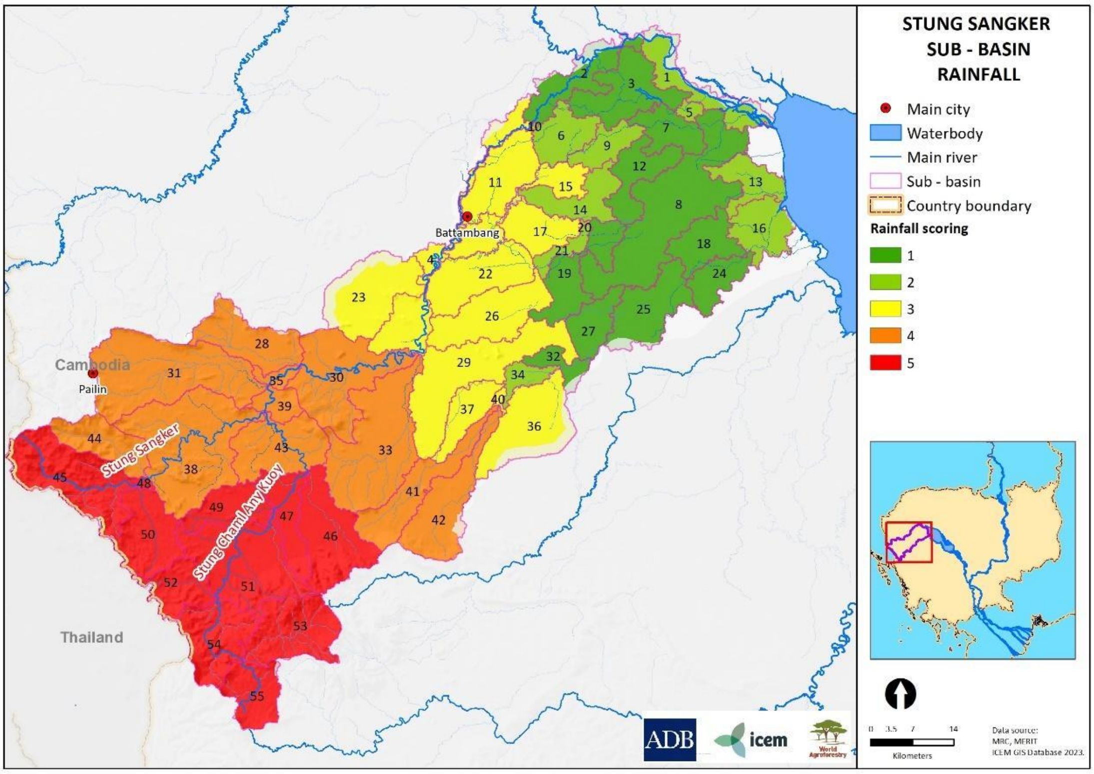
Rainfall within the Stung Sangker River basin is recorded on a number of gauges. However, only the Battambang gauge has records for 20 years or more. Between 2000 and 2021, the average rainfall at Battambang was 1,289 mm, with a maximum of 1,810 mm and a minimum of 813 mm. The average disguises an increase in average rainfall between 2001 and 2016 and a decrease between 2017 and 2021.

Rainfall at Battambang varies significantly throughout the year, with a distinct dry season between December and March, a wet season that builds in strength between May and October, and transitional months in April and November. These patterns are consistent with the meteorology of the lower Mekong basin, which experiences a southwest monsoon between April and October and a weaker northeast monsoon between November and December.

While there is little evidence of any significant trend in annual rainfall from 2000 to 2021, maximum monthly and maximum daily rainfall show minor upward trends. Although no trends are apparent in the wet season, dry periods (consecutive days of zero rainfall) are increasing in length, consistent with climate change projections of increasing severity and frequency of extreme events.

Figure 11 shows rainfall classes by sub-basin. In the upper basin, this ranges from Class 5 (1,595 mm in sub-basin 48 to 2,090mm in sub-basin 55) to Class 4 (1,424mm in sub-basin 39 to 1,570mm in sub-basin 44).

Figure 11: Sangker River Basin - Annual Rainfall (mm) by Sub-basin



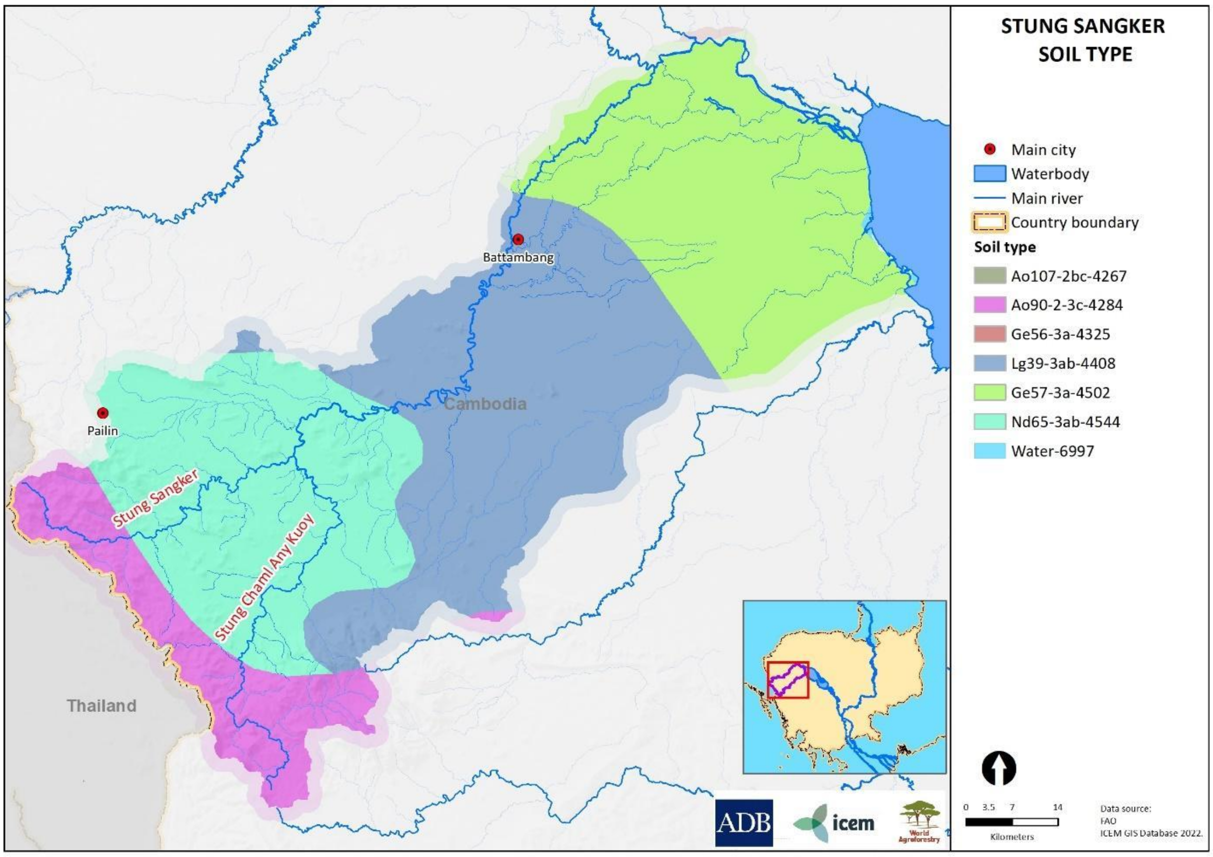
2.2.5 Soils

Figure 12 shows the soils of the Sangker basin. In the upper basin, the soils have been mapped as Ao 90 2-3c covering most hilly areas, Nd 65 3ab for most of the upper basin, and a smaller area of Lg39 3ab along the southern boundary. The SWAT notations refer to soils classified under the FAO 1974 Soil Map of the World classification.

In brief, the three soil classes mapped in the upper basin are:

- Ao - Orthic Acrisols: Deep, well-drained, acid, infertile, erodible sandy loams to clays in hilly topography;
- Nd - Dystric Nitisols: Deep, well-drained, strongly structured, moderately fertile clays in undulating topography; and
- Lg - Gleyic Luvisols: Deep, poorly drained, seasonally waterlogged, fertile clays in gently undulating to flat topography.

Figure 12: Sangker River Basin Soils



Note: Ao soils are Orthic Acrisols, Nd Dystric Nitisols, and Lg Gleyic Luvisols. The numbers' 2' and '3' refer to the texture class, with '2' being medium textured (sandy loam, sandy clay loam, clay loam) and '3' fine textured (clay and sandy/silty clay) while the suffixes a,b,c refer to the topography where 'a' is level to gently undulating (0-8% slope), 'b' is rolling to hilly (8-30% slope) and 'c' is steeply dissected to mountainous (>30% slope).

Acrisols are soils developed on old land surfaces with a hilly or undulating topography in seasonally dry and humid tropical and monsoon climates. **Orthic Acrisols** are typical Acrisols. Closed or open woodland is their natural climax vegetation type. Prolonged weathering and advanced soil formation have led to a predominance of kaolinitic clays and a general loss of nutrients. These soils often suffer from aluminum toxicity and strong phosphorus fixation. They are easily eroded, which imposes severe limitations on their potential for agriculture and highlights the need for forest restoration in areas where forest cover has been lost.

Acrisols have poor chemical and physical properties characterized by a strongly acid subsoil, often saturated with aluminum; therefore, surface soil preservation is imperative. Topsoils are generally thin with a low organic matter content. Removing forest cover almost inevitably destroys any organic matter present and causes a significant yield decrease.

Nitisols exhibit deep, dark red, brown, or yellow clayey compositions characterized by a distinct shiny, nut-shaped structure. They differ from comparable soils, such as Acrisols, due to the migration of clay to considerable depths, creating a prominent angular blocky structure with glossy pressure surfaces. Despite containing over 35% clay, Nitisols often undergo substantial biological activity, leading to the homogenization of the upper meter of the soil.

The high clay content in Nitisols contributes to improved chemical properties, while their physical attributes are better due to their depth, stable structure, high water-holding capacity, and permeability. However, **Dystric Nitisols** exhibit lower fertility than other Nitisols, with a base saturation percentage of less than 50%, signaling heightened contemporary leaching. Overall, Nitisols are highly productive soils in tropical regions, extensively utilized for plantation crops and food production.

Luvisols, characterized by subsurface accumulation of high-activity clays, take on the prefix "gleyic" (**Gleyic Luvisol**) when evidence of groundwater saturation and iron reduction manifests through grey and blue-green colors. These soils showcase clay migration from the surface to an accumulation horizon at some depth, commonly found in flat or gently sloping terrain. However, Gleyic Luvisols are exclusive to flat or very gently sloping land.

While Luvisols are generally fertile due to their mixed mineralogy, relatively high nutrient content, and the presence of weatherable minerals, the periodic groundwater saturation during parts of the year limits their suitability for a broad spectrum of agricultural uses.

2.2.6 Land Cover/Land Use, Land Use Change, Forest Cover

Figure 13 shows the basin's land cover/land use, and Figure 14 shows the change in land use between 2001 and 2017 in the Sangker River basin. Land use patterns are closely linked to topography and soil types, with cropland and paddy rice dominating the middle basin and orchard and plantation forest and grassland more prevalent in the upper basin. Mixed Forest is now confined mainly to the extremities of the upper basin.

Figure 13: Sangker River Basin - Land Cover/Land Use Map

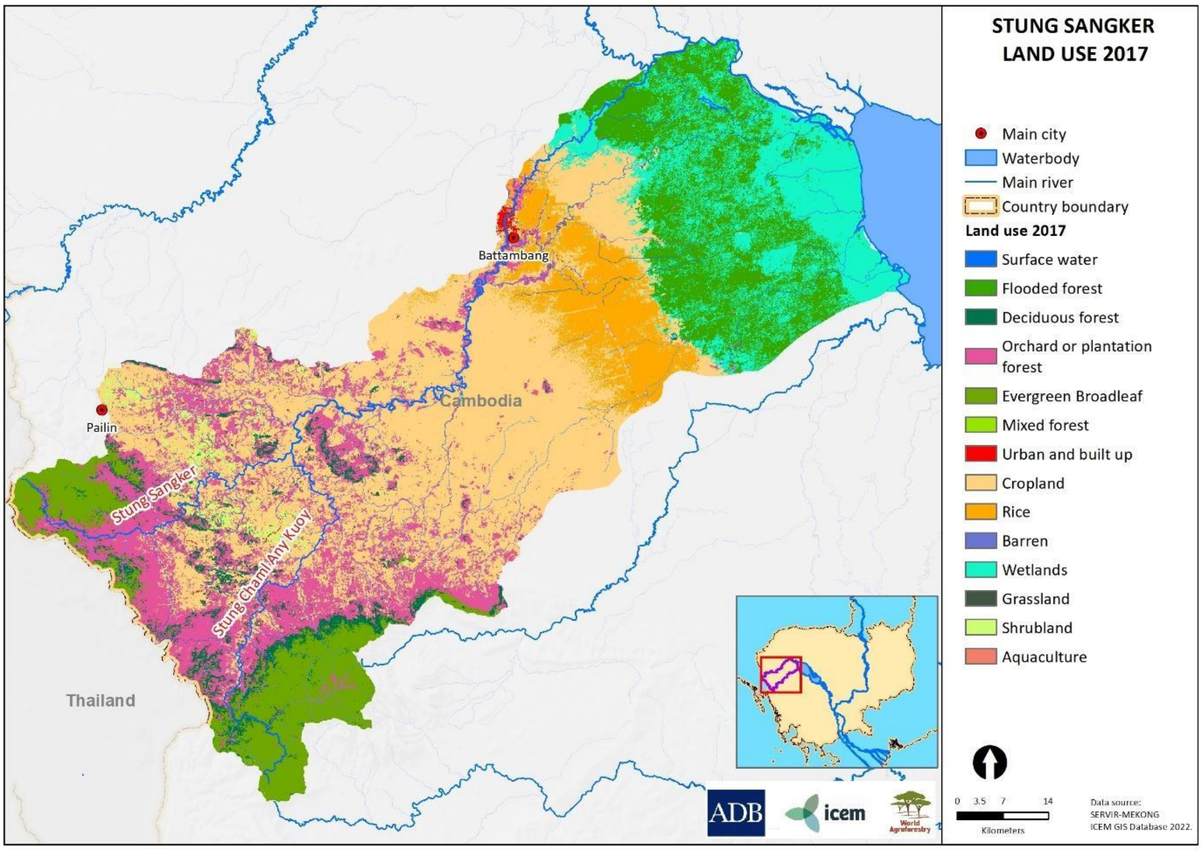
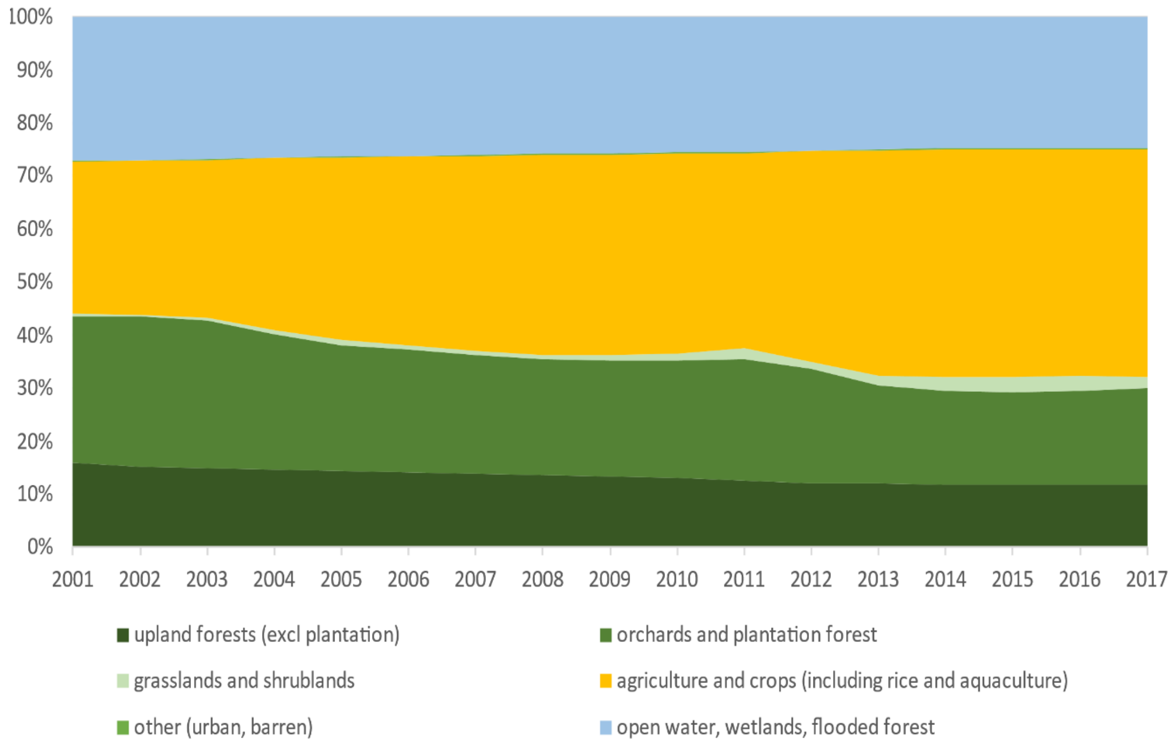


Figure 14: Stung Sanker Land Use Change 2001 to 2017[3]



Between 2001 and 2017, agriculture and grasslands displaced significant amounts of forest and orchards. Overall forest cover (evergreen, deciduous, and mixed forest) declined from 44% in 2002 to 29% in 2017, orchards and plantations from 28% to 18%, while agriculture and Cropland grew from 29% to 43%. Such extensive land use changes are likely to significantly increase surface runoff and soil erosion rates with implications for downstream reservoir storage, flooding, and the severity of droughts.

[3] ICEM GIS Database 2022

Figure 15: Sangker River Basin - Forest Cover by Sub-Basin

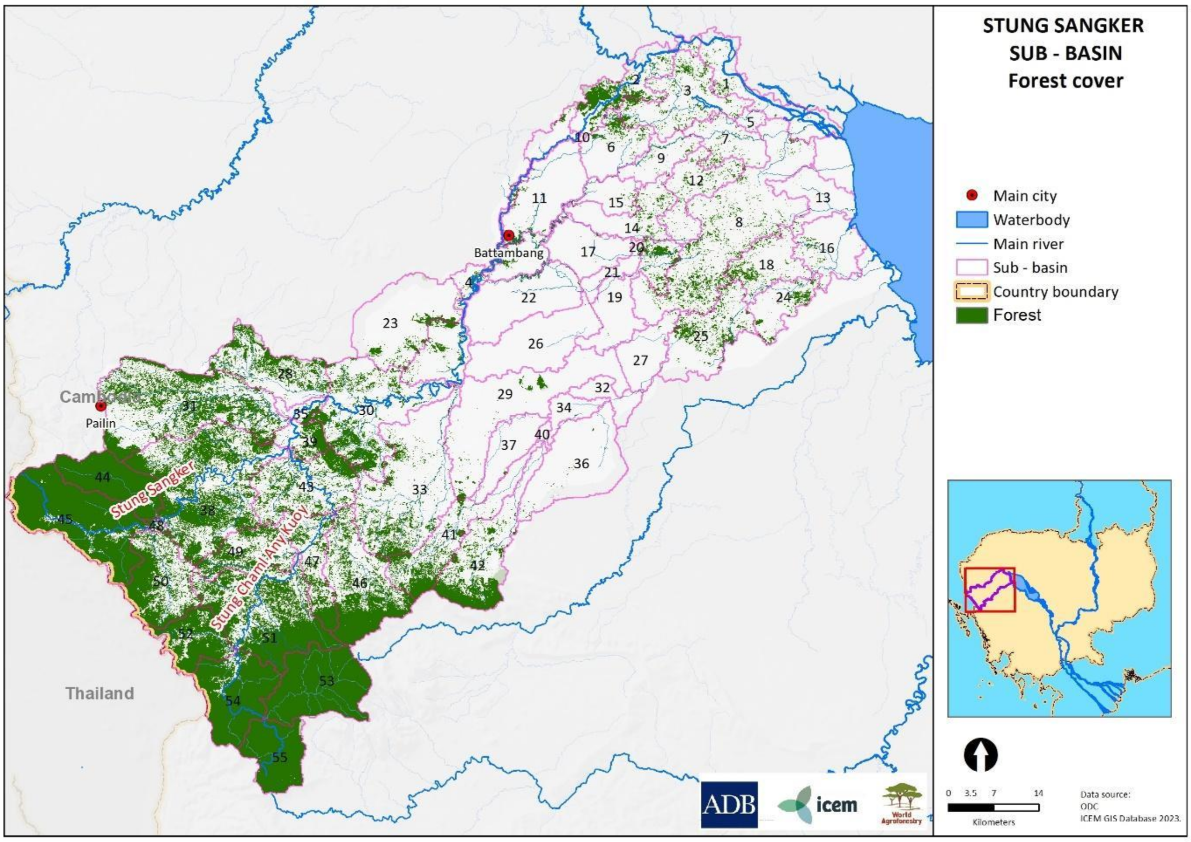
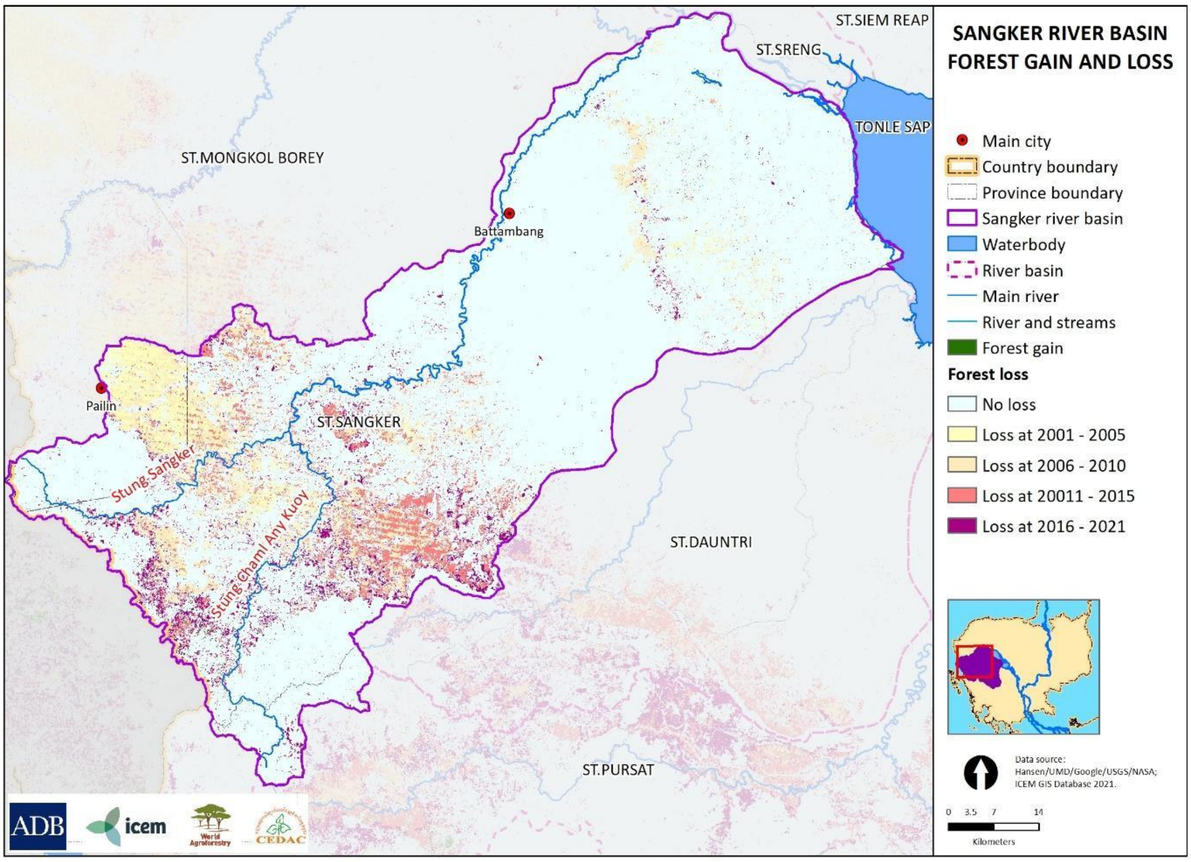


Figure15 shows the forest cover by sub-basin. It highlights the concentration of forests in the upper basin at its extremities, with remnant forested hills in the center of the upper basin.

Figure 16: Sangker River Basin - Areas of Forest Loss



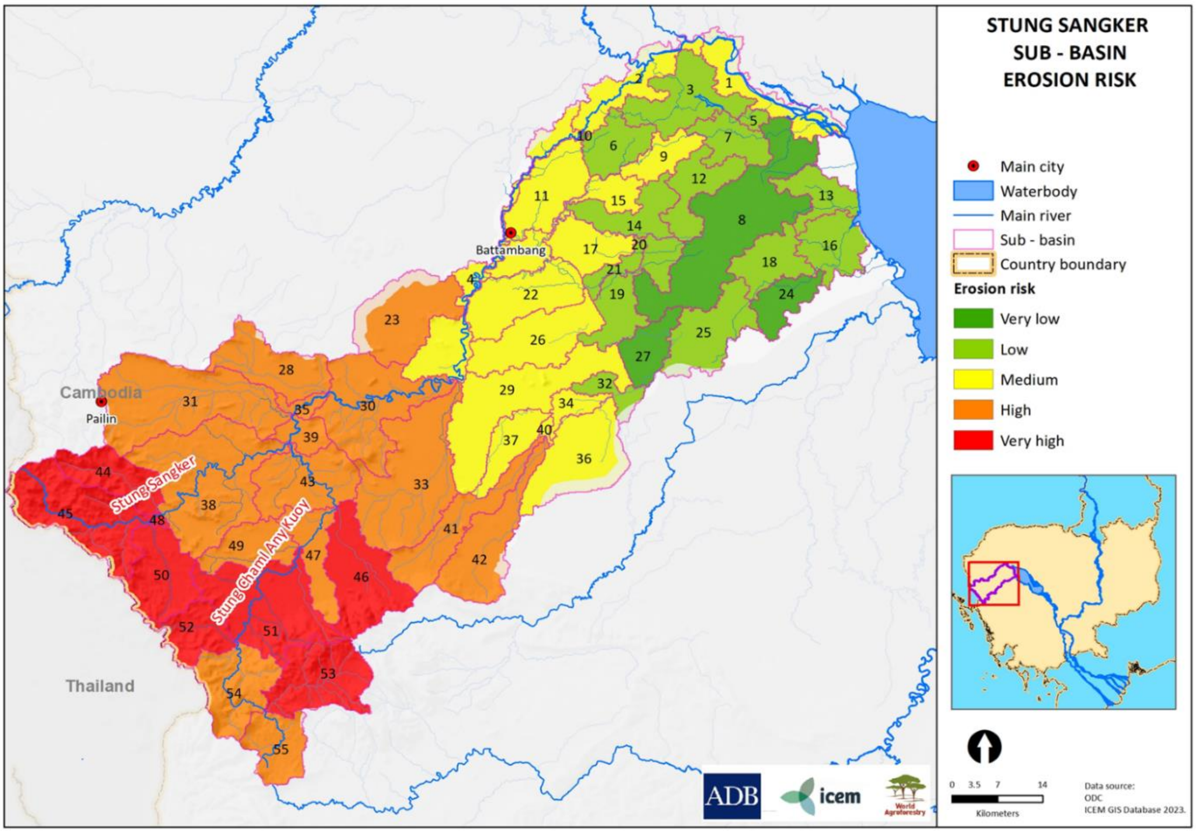
The extent and timing of forest loss and conversion to agriculture are shown in Figure 16, demonstrating that between 2001 and 2005, deforestation was concentrated in the upper watershed of the Stung Sanker to the east of Pailin. Between 2006 and 2010, it occurred primarily in the interfluve between the Stung Sanker and Stung Chaml Any Kuoy Chamlang Kouy. Between 2011 and 2015, it was mainly east of the Stung Chaml Any Kuoy Chamlang Kouy, and most recently, between 2016 and 2021, deforestation occurred higher up in the basin close to the Thai border and east of the Stung Chaml Any Kuoy Chamlang Kouy.

This trend was corroborated in the field, with stakeholders noting that most deforestation since 2016 has been largely on marginal, steeper slopes for cassava production.

2.2.7 Soil Erosion Hazard and Sediment Yield

As part of the SWAT analysis, soil erosion hazard was assessed using rainfall intensity, soil type, slope, land cover, and land management inputs (Figure 17). Sub-basins in the upper basin are all at very high or high risk of soil erosion, suggesting that this is where restoration activities should initially be concentrated.

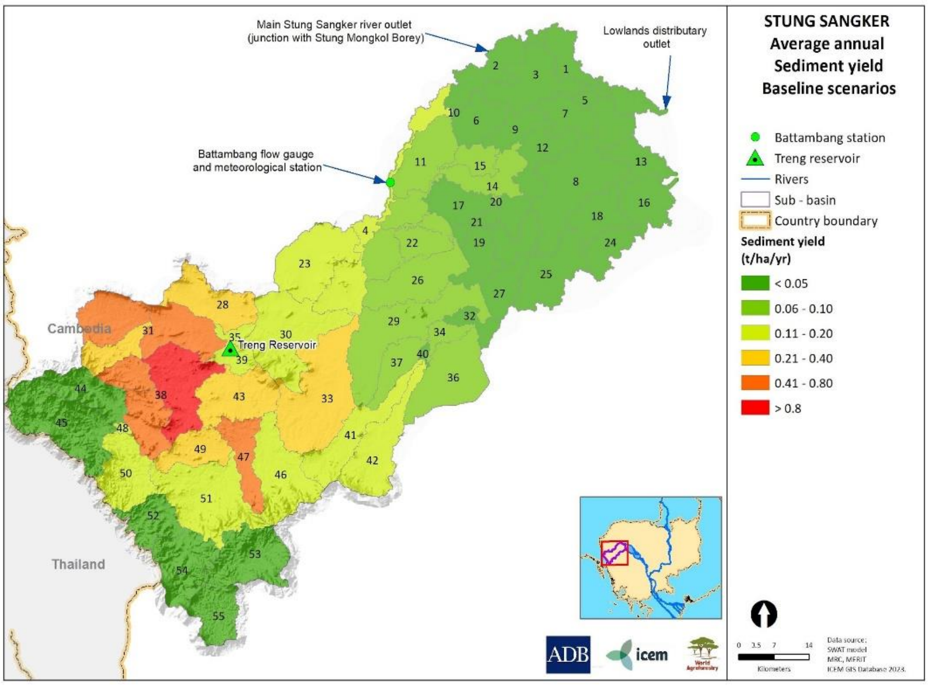
Figure 17: Sangker River Basin - Soil Erosion Hazard by Sub-basin



The SWAT analysis also investigated sediment yield rates across the sub-basins, illustrating the sources of sediment flows (Figure 18). The areas with elevated sediment yield align closely with those posing the greatest erosion hazard, particularly in the sub-basins immediately upstream of the Treng Reservoir. A notable increase in recent deforestation, forest degradation, and conversion to agricultural land has led to higher soil erosion rates.

This poses a significant concern for the long-term viability of the Treng Reservoir, emphasizing the imperative for focused forest and landscape restoration efforts, especially in these upper basin watersheds. The SWAT analysis explored three scenarios: future scenario 1 (FS1) modeled the basin's changes by 2055 considering climate change without adaptation measures; FS2 involved reforestation of upland areas and conversion of agricultural land in the upper basin to agroforestry as a climate adaptation intervention; and FS3 introduced conservation agriculture to lowland areas.

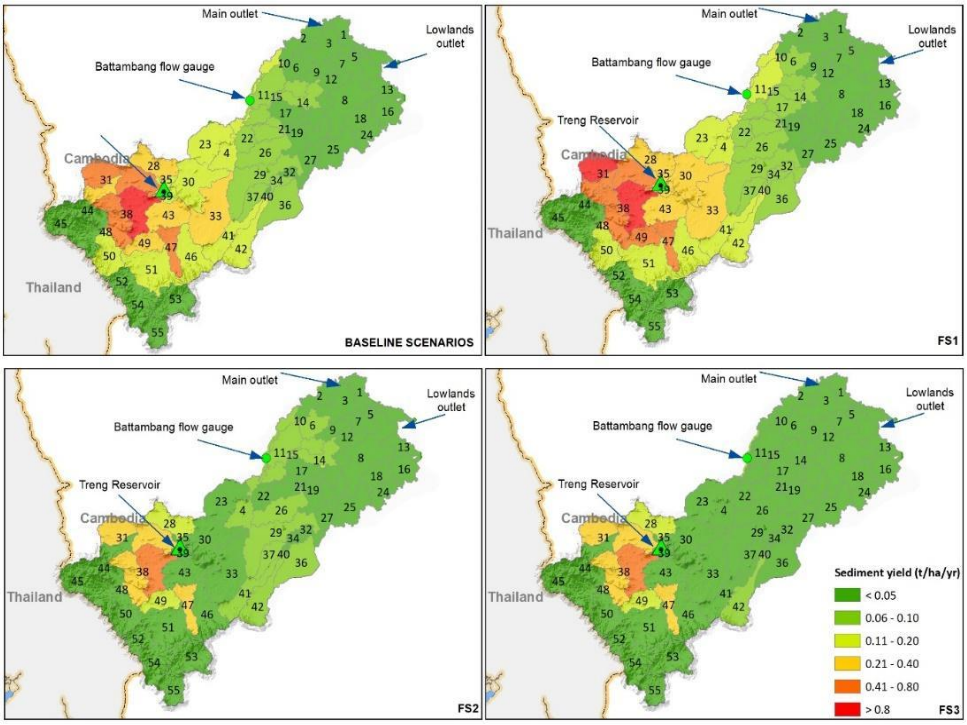
Figure 18: Sangker River Basin - Sediment yield from Catchment Areas for BL Scenario



FS1 predicted a 26% increase in average annual sediment yield[4] with an increase of sediment load into the Treng Reservoir of 12%. FS2, however, showed a 52% decrease in sediment yield, and FS3 a 59% decrease, indicating that forest restoration and agroforestry in the upper basin are likely the most effective means of reducing soil erosion while maintaining livelihoods.

[4] Sediment yield is the amount of sediment per unit area removed from a watershed by flowing water during a specified period of time. Sediment load is the amount of sediment that is transported through a stream cross section over 1 year.

Figure 19: Sangker River Basin - Sediment Yield from Catchment Areas for BL (Upper Left), FS1 (Upper Right), FS2 (Lower Left), and FS3 (Lower Right) Scenarios[5]

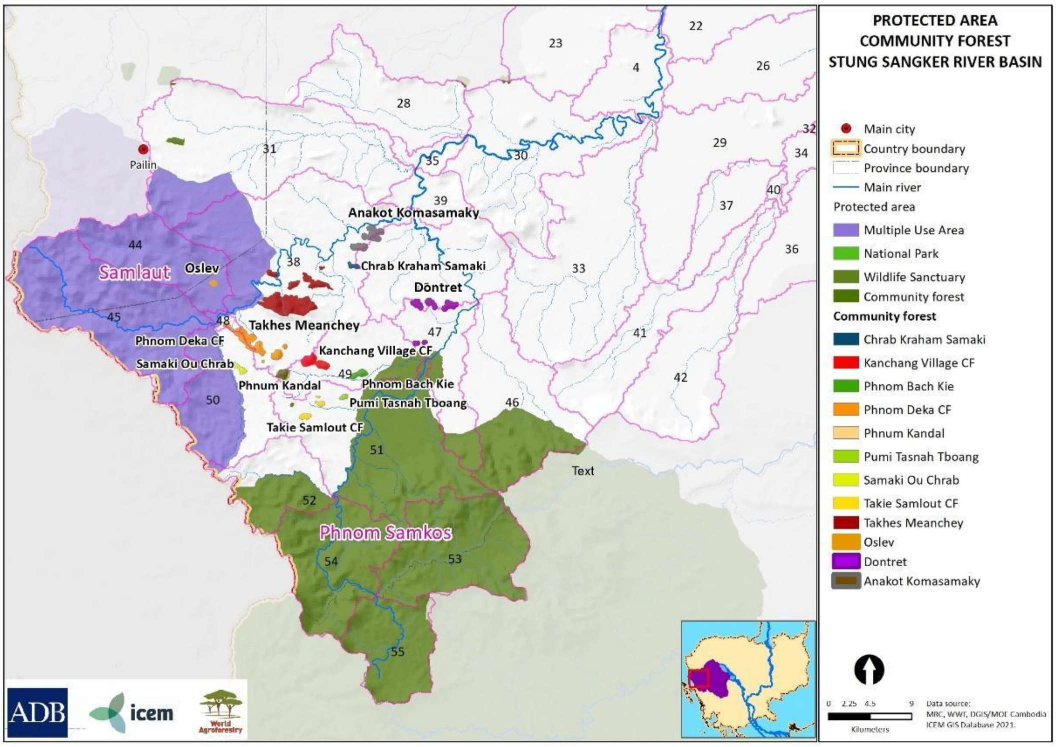


2.2.8 Protected Areas and Community Forests

Figure 20 shows the protected areas and the community forests in the upper basin. There are two nationally important protected areas, the Phnom Sankos Wildlife Sanctuary at the headwaters of the Stung Chaml Any Kuoy Chamlang Kouy and the Samlaut Multiple Use Area at the headwaters of the Stung Sanker. Both areas have suffered deforestation. However, the Samlaut area is more affected and has changed its status from a National Park to an MUA in recognition of population pressure and agricultural expansion. Under the Cambodian Law on Natural Protected Areas and its regulatory framework, MUAs are accessible areas for passive economic development and leisure activities with the assurance of natural stability of water, forestry, wildlife, and fishery resources—they are still intended as non-exploitative areas for the protection and maintenance of biodiversity.

[5] Project SWAT Analysis

Figure 20: Sangker River Basin - Protected Areas and Community Forests



In addition to the two main protected areas, there are 33 community forests concentrated in the interfluve between the Stung Sanker and the Stung Chamlang Kouy. These areas correspond to hills with steeper slopes in the landscape.

2.3 Outcomes of SWAT Analysis of Sanker River Basin

There has been no discernible long-term trend in average annual rainfall or wet season rainfall between 2000 and 2021, the period for which data is available. However, the length of zero rainfall periods has increased in the dry season, indicating that droughts are becoming more severe and more frequent, consistent with the climate change projections.

Although trends in rainfall are unclear, hydrological gaugings on the Stung Sanker River show that average annual flows, wet season flows, and dry season flows have all decreased over time. The decrease in average annual flows and wet season flows is consistent with the conversion of forest to agriculture. Similarly, declining dry season flows are compatible with land use changes and increased days with zero rainfall.

Despite the overall pattern of decreasing flow trends, direct runoff during the dry season does not decrease over time, indicating that the risk of flash flooding is not reducing and may even increase as upland areas are converted from forest to agriculture.

No sediment gaugings are available for the Stung Sanker basin. However, erosion rates for catchment areas of the basin are estimated at 1.9 to 4.5 Mt/year. These soil erosion rates are relatively low by international standards, where tolerable soil loss (T)[6] is usually between 2-11 t/ha/y. By contrast, the total sediment load from the basin to the Tonle Sap Lake is estimated at 0.18 to 0.30 mt/year. This suggests that between 1.5 and 4.3 million tons of sediment are deposited annually in the basin waterways, including the Treng Reservoir.

[6] Tolerable soil loss (T) is the maximum amount of soil loss in tons per hectare per year that can be tolerated and still permit a high level of crop productivity to be sustained economically and indefinitely. FAO Agro-ecological Land Resources Assessment for Agricultural Development Planning, 71/2 1992.

To determine how climate change may affect the hydrology and sediment transport processes of the Stung Sanker river basin, the SWAT model was calibrated and verified to simulate the impacts of land use change, climate change, and soil and water conservation measures.

Applying the SWAT model to the historical baseline scenario showed that high levels of runoff and very high sediment loads enter the river from the upland watersheds in the southwest of the basin. These enter the main Stung Sanker River, with the river's discharge gradually increasing as tributaries add more flow until the main Stung Sanker River outlet is reached. The lower parts of the basin discharge directly to the Tonle Sap Lake by a separate distributary, which derives from a relatively smaller area, and consequently, discharges into this distributary are lower.

As for runoff, sediment loads entering the river are highest in the steep, sloping upland watersheds. The sediment load carried by the river tends to decrease as the river flows downstream and away from these upland areas as flow velocities in the river decrease, and much of the sediment load is dropped, even before the Treng Reservoir is reached. Still, sediment loads reaching the Treng Reservoir are relatively high, around 2.4 to 2.6 mt/year. There is, therefore, concern that sediments retained in the reservoir may reduce the available storage of the reservoir at a rate of 8% to 9% per year.

Three future scenarios were developed, which depict the incremental impacts of climate change (FS1), climate change combined with land use change from agriculture to agroforestry/reforestation (FS2), and climate change combined with land use change and implementation of conservation farming measures on lowland areas of the basin (FS3).

FS1 demonstrated that climate change and resulting changes to annual rainfall patterns could increase average annual flows (Table 1), erosion (Table 2), and the risk of flooding in the wet season and drought in the dry season.

Table 1: Average Annual Discharge for the Baseline and Future Scenario 1

	Baseline discharge (m3/s)	Future Scenario 1 discharge (m3/s)	Change
Treng reservoir	38	40	5%
Main Stung Sangker river outlet	54	57	6%
Lowlands distributary outlet	18	20	9%
Total basin outflow	72	77	6%

Table 2: Sediment Loss Rates from Catchment Areas for the Baseline and Future Scenario 1

	Baseline	Future Scenario 1
Basin-wide annual average sediment yield (t/ha/yr)	0.13	0.16
% Change from baseline		23%

FS2 revealed that converting agricultural areas to agroforestry in upland watersheds of the basin would decrease discharge rates and so the risks of flooding in the wet season (Table 3) and decrease erosion rates (Table 3). These results indicate that agroforestry and reforestation would be highly effective for climate change adaptation.

Table 3: Average October Discharge for the Baseline, Future Scenario 1 and Future Scenario 2 on the Upper Watersheds and Main River

		Baseline	Future Scenario 1	Future Scenario 2
Treng reservoir	Discharge (m^3/s)	110	133	128
	Change from Baseline		20%	16%
Main Stung Sangker river outlet	Discharge (m^3/s)	164	202	192

By contrast, dry season flow rates and annual sediment load rates estimated by the SWAT model under FS2 were not significantly improved compared to FS1, possibly due to the overriding influence of climate change (Table 4).

Table 4: Minimum and Average Dry Season Discharge for the Baseline, Future Scenario 1 and Future Scenario 2 with Three Agroforestry Options

		Baseline	Future Scenario 1	Future Scenario 2 (Orchards)	Future Scenario 2 (Deciduous)	Future Scenario 2 (Evergreen)
Treng reservoir	Minimum month discharge (m^3/s)	6.2	4.2	2.8	2.5	2.9
	Average dry season discharge (m^3/s)	12.8	12.3	9.9	6.4	10.3
Main Stung Sangker river outlet	Minimum month discharge (m^3/s)	10.5	8.0	5.0	4.9	5.5
	Average dry season discharge (m^3/s)	18.8	18.1	13.4	10.4	14.6

Additional adaptation measures to promote water retention in streams during the dry season and reduce sediment loads in waterways are needed to encourage water retention in streams during the dry season and reduce sediment loads in waterways. The introduction of reforestation and agroforestry efforts to the upper watersheds of the Stung Sanker River basin is recommended to overcome the potential negative impacts of climate change on the basin's hydrology. The SWAT model assessed the impact of three different land use types to represent agroforestry efforts: orchards (ORCD) to represent agroforestry options that would involve significant community interactions with the landscape, deciduous forestry (FRSD) and evergreen forestry (FRSE) to represent full reforestation efforts. All three agroforestry options showed similar results with dry season discharges significantly reduced.

The results suggest that drought-tolerant trees with low water dry-season water demands should be preferred to minimize the risk of drought intensification in areas where agroecology projects are proposed. Evergreen forests show the least decline in discharge compared to the baseline and FS1 scenarios, and so appear to be the most promising form of landscape restoration. By contrast, deciduous forests showed the lowest discharges under dry season conditions.

FS3 demonstrates that employing conservation farming practices in the lowland agricultural areas effectively reduced sediment loads entering the Tonle Sap Lake (Table 5). However, the SWAT model assesses the effects of conservation farming on sediment loads only by modifying sediment loss rates from land areas without considering any hydrological changes that may occur. Consequently, the effectiveness of conservation farming alone in addressing flood and drought risks needs to be further studied, and additional climate adaptation measures will need to be considered.

Table 5: Annual Average Sediment Load Estimates for Baseline, Future Scenario 1 and Future Scenario 3 on Lowland Areas of the Basin

		Baseline	Future Scenario 1	Future Scenario 3
Lowlands distributary outlet	Sediment load (Mt/year)	0.008	0.010	0.008
	Change from Baseline	-	25%	-1%
Total basin outflow	Sediment load (Mt/year)	0.26	0.29	0.28
	Change from Baseline	-	11%	7%

2.4 Summary Climate Change Risk Assessment for the Sangker River Basin

The climate change risk assessment for the Sangker River basin was obtained from regional analysis, SWAT modeling, and communication with stakeholders.

A number of trends and risks were identified:

- a shift in the rainfall pattern, resulting in increased rainfall towards the end of the wet season and elevating the risk of flooding;
- rising temperatures and a decline in dry season rainfall heighten the probability of droughts;
- prolonged dry spells during the dry season, leading to more severe and frequent drought periods;
- reduced river flows due to diminished upstream storage resulting from a land use change from forest to agriculture.;
- escalating runoff and an augmented risk of flash flooding and soil erosion;
- land use changes, with agricultural expansion into hilly areas causing deforestation and forest degradation and leading to decreased water retention in the headwaters, amplified runoff, heightened soil erosion, sediment transfer, and an increased risk of floods and droughts;
- an increase in soil erosion, deemed tolerable, but sediment flow into the Treng Reservoir diminishes storage by 8%–9% annually;
- modeling future scenarios without adaptation shows a surge in annual flows, runoff, soil erosion, and sediment yield, resulting in increased flood risk during the wet season and heightened drought risk in the dry season;
- reforestation and agroforestry in the upper basin have the most significant impact, reducing runoff, soil erosion, and sediment yield (with a 52% reduction in sediment yield) and mitigating flood and drought risk;
- a pressing need to advocate for retaining rainfall in the headwaters and water in streams through reforestation and agroforestry development to curb soil erosion and sediment generation;
- communities expressing that drought was their primary concern due to crop destruction, water shortages, and fire hazards (Despite this, they did not perceive themselves as particularly vulnerable to drought and adapted by increasing rainwater harvesting, digging wells, and adopting drip irrigation.); and

- communities acknowledging that soil erosion and degradation were attributed to upstream deforestation, climate change, and increased use of agricultural chemicals.

Assessing climate change threats, impacts, and vulnerability hotspots in the river basin highlights a heightened risk in the upper Sangker basin (upstream of the Treng Reservoir). Recent land use changes, particularly the conversion of forested areas to agriculture, significantly influence this region's runoff generation, soil erosion, and sediment transfer. Therefore, focusing adaptation measures in the upper Sangker basin, specifically upstream of the Treng Reservoir, is crucial. Implementing adaptation strategies in this area will benefit the local environment and extend downstream, impacting the entire river basin.

3 Pilot Area Restoration Plans and Adaptation Options

3.1 Selection of the Target Community Forests

The climate risk assessment identified the upper Sangker basin as a critical area for forest and landscape restoration adaptation measures. The rationale of the restoration is to restore the headwaters of the upper basin by using nature-based and hybrid solutions. Given the scale of the issue, a landscape and ecosystem adaptation approach is necessary. Given the timescale and budget of the project, targeted site-specific activities are being conducted to demonstrate restoration options in the field that need to be rolled out across the entire landscape.

The Maddox Jolie-Pitt Foundation (MJP) partners with ICEM and ICRAF to implement restoration activities. MJP is an NGO with a long-established community support and forest restoration program in the Samlaut area. In consultation with farmers, MJP identified community forests (CFs) suitable for restoration interventions with strong support from the community forest management groups. Community forests were established between 2008 and 2010 by the Ministry of Agriculture, Forestry and Fisheries and provincial forest administration as a response to the rapid deforestation of the Samlaut area between 1998 and 2008 and the conversion of forest land to agricultural land, a mosaic of plantations of durian, longan, mango, cashew, rubber and fields of cassava, maize, rice, soybean, and sugarcane. The CFs are largely forested hilly areas, but the forests are degraded and are being encroached by agricultural development.

There are 33 CFs in the upper Sangker basin. Figure 20 shows several community forests scattered throughout the central part of the upper basin. These CFs presented an ideal opportunity to trial an approach to implementing adaptation options since they comprise relatively recently degraded forest and agricultural encroachment and are communally owned and managed. At this stage, the aim is to trial a range of restoration interventions targeting improved biodiversity for community benefit that can then be replicated over a wider landscape in time.

The importance of the CFs in the landscape is that remnant forested hills are often the headwaters of micro-watersheds like forested islands in a sea of cultivated land. The reforestation of these 'islands' should be a priority since they can act as 'stepping stones' in biodiversity conservation and provide improved ecosystem services and soil and water conservation that will benefit the local population and agricultural land downstream.

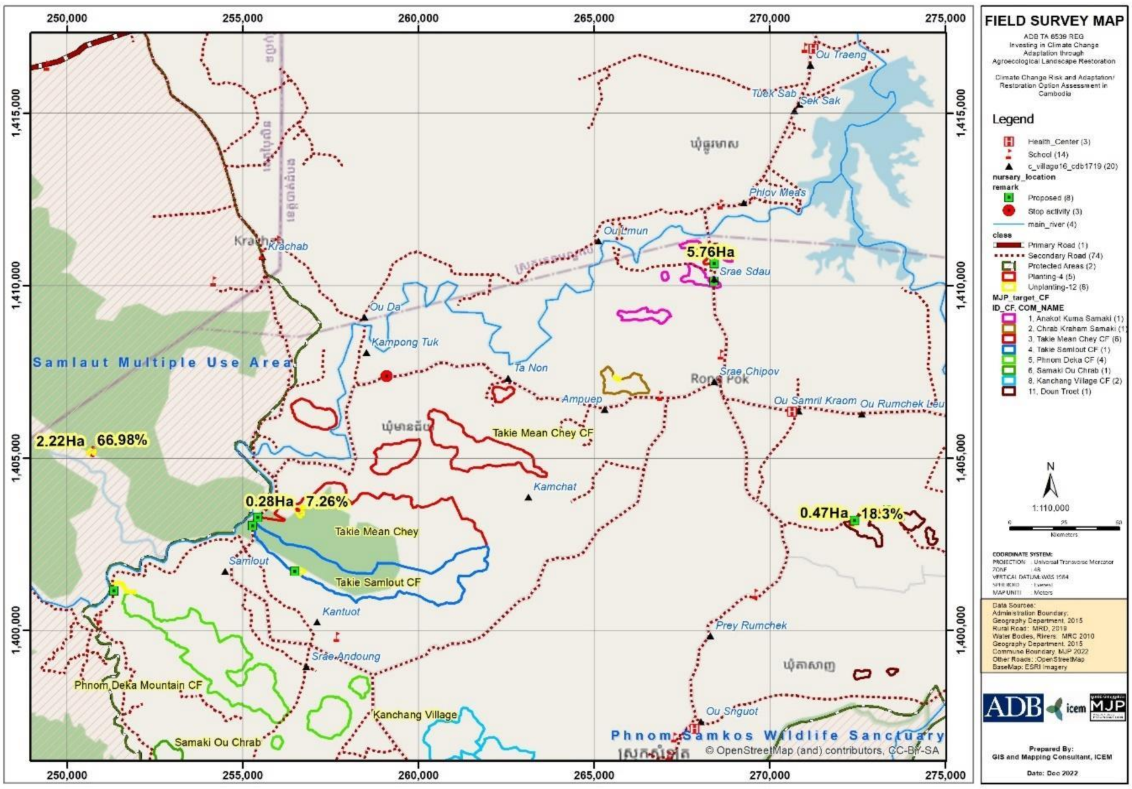
Watershed logic indicates that interventions should first target upstream areas and work downstream by restoring drainage corridors and edge buffers in agricultural allotments across the landscape. They should target the most degraded areas initially. The best results are obtained from working with farmers at the micro-watershed level (c.200–500 ha) and in clusters of micro-watersheds.

Experience in other parts of the world has shown that watershed management gives the best chance of succeeding at the micro-catchment level, where the communities manage the watershed and are involved in the planning from the beginning.

The CFs then present an opportunity to secure stream headwaters through forest restoration and demonstrate adaptation options through the active involvement of communities in planning, implementing, and monitoring interventions. The activities undertaken in the CFs are the first phase in what needs to become a multi-phase operation to restore ecosystem function and biodiversity in the upper Sangker basin landscape.

Eleven CFs were initially identified as potentially suitable for restoration based on the degree of degradation and commitment of the respective CF management groups to restoration. Following a field visit in May 2022, six sites were selected, later reduced to four sites based on the need to concentrate project resources for the greatest demonstration impacts. They are Oslev within the Samlaut MUA and Anakot Komasamaky, Takhes Meanchey, and Dontret Community Forest areas in the Samlaut buffer between the Stung Sanker and the Stung Chaml Any Kuoy Chamlang Kouy (Figure 21).

Figure 21: Location of Pilot Community Forests in the Upper Sangker Basin



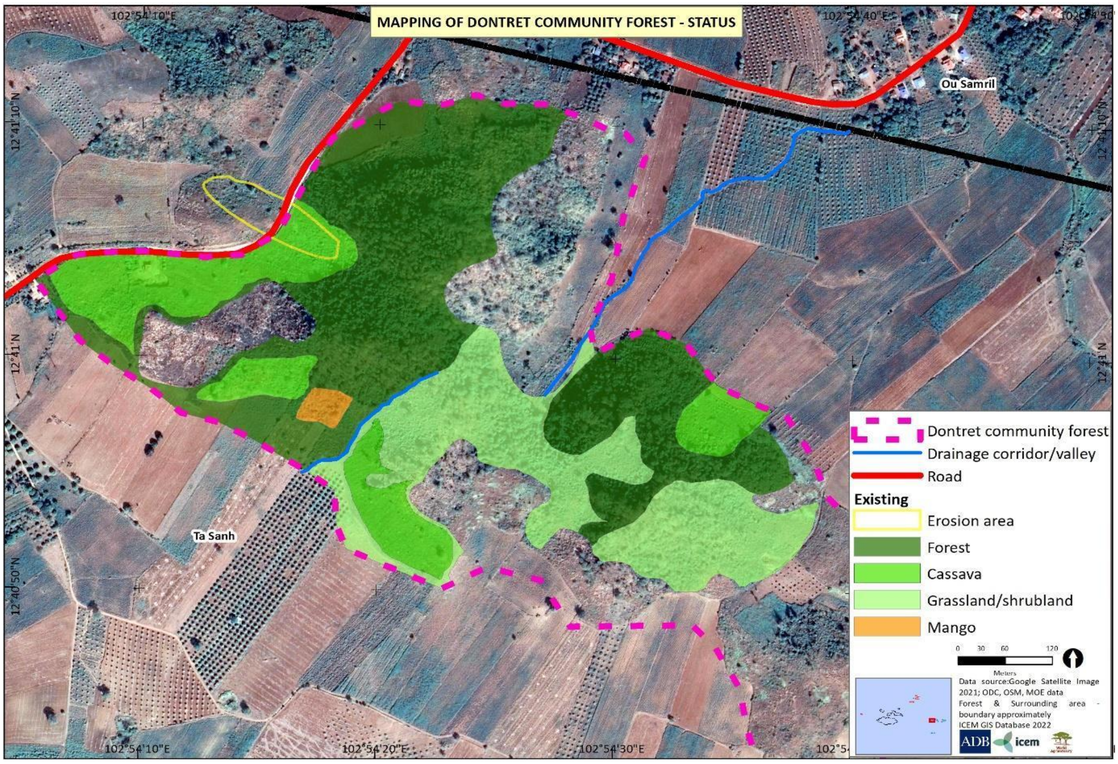
3.2 Pilot Area Restoration Plans

The Pilot Area Restoration Plans were drawn up for the selected CFs through an iterative process of community consultations and field surveys. Field visits to each site by the project team and MJP and intensive participatory mapping processes were conducted where community members defined specific areas within each CF requiring restoration and possible NbS and agroforestry options.

The target CFs were surveyed in detail on the ground and by drone. Initial restoration needs and potential livelihood activities were identified. Community members mapped the current status of their watershed onto hard copy AO satellite images and their proposed interventions and land use changes.

A broad range of landscape restoration measures were identified and discussed. These emphasized NbS for forest rehabilitation, erosion control, drainage corridor management, forestry, and agroforestry approaches for biodiversity conservation and livelihood improvement.

Example of Participatory Mapping Exercise and Output of Current Land Use Map (Credit: Project team)



3.2.1 *Goals and Objectives of the Restoration Plans*

The goals and objectives of each pilot site were different, as reflected in Table 6.

Table 6: Goals and Objectives of Forest/Landscape Restoration at Pilot Sites[7]

Site	Goal	Objectives
Oslev	Restore the forest integrity through reforestation with native species found in the	1. Reestablish the arboreal vegetation cover with native forest species to restore and extend the Samlaut forest ecosystem and biodiversity value.

[7] Source: Site restoration plans

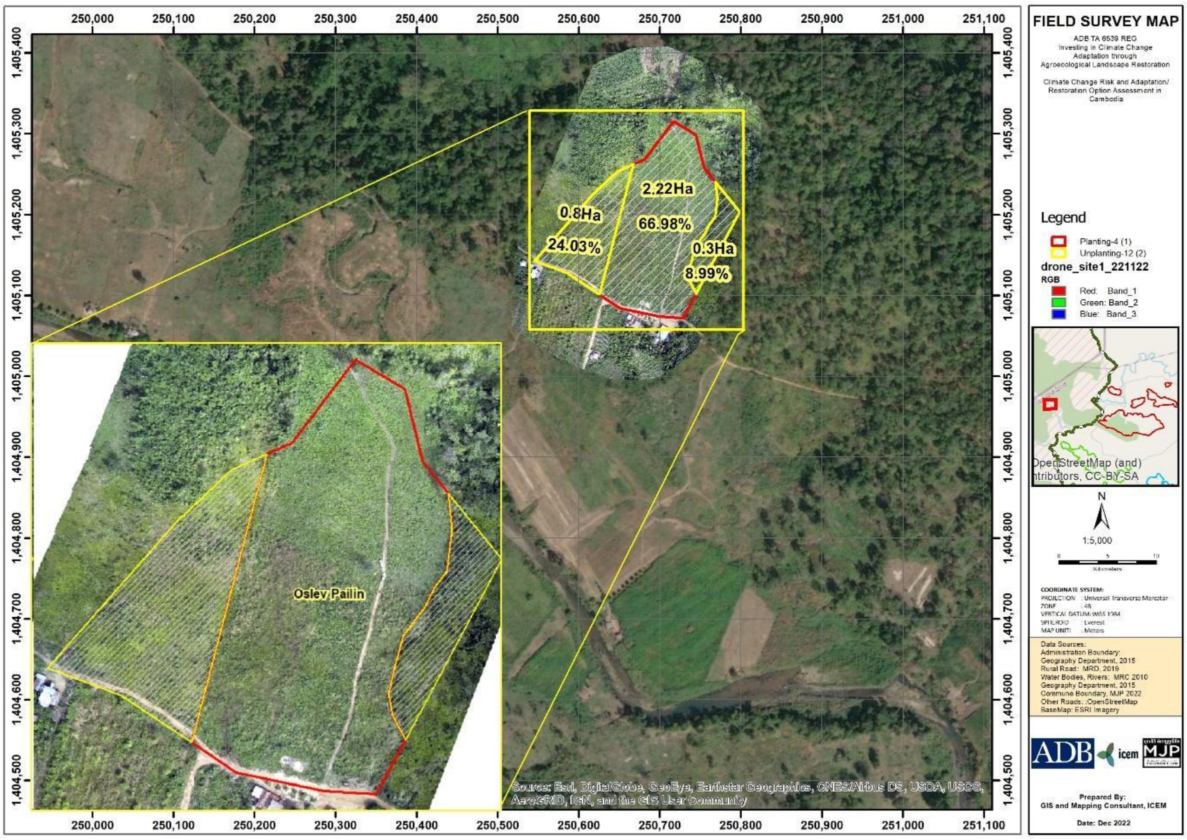
Site	Goal	Objectives
	natural forest of the protected area	2. Secure the drainage line that originates in the forest hill above.
Anakot Komasamaky	Restore the site to an area with a species composition similar to the pre-disturbance forest that, along with neighboring community forest hills, can act as stepping stones in biodiversity conservation and as a demonstration site for further action in other areas.	1. Re-establishment of pre-disturbance vegetation cover with biodiversity, soil, and water conservation benefits. 2. Develop a demonstration site for community forest rehabilitation and visitor attraction. 3. Develop new economic opportunities for the local community.
Takhes Meanchey	Increase the forest canopy cover and restore the species' composition to one similar to its original state. This will reinstate the linkage between the site and the Samlout MUA and reestablish the forest's ecosystem services for the downstream agricultural land and forest plantations.	1. Reestablish the arboreal vegetation cover, which will provide a linkage to the Samlout Multiple Use Area (MUA) 2. Provide improved ecosystem services, including biodiversity, climate change adaptation, and soil and water conservation, that will benefit the local population and the agricultural and forestry plantations downstream from the community forest area. 3. Explore opportunities for payment for ecosystem services.
Dontret	Reestablish the forest cover within the boundary markers of the community forest.	1. Strengthen the existing forest areas with the re-establishment of natural vegetation with native tree species and improved biodiversity. 2. Introduce agroforestry and conservation agriculture systems that will protect soil and water resources and give a variety of products to improve local livelihoods.

Oslev Demonstration Area: Oslev is located within the Samlout Multiple Use Protected Area. The local community have cleared an area of around 180 ha, of which the planned restoration area covers 11.2 ha. The issue of encroachment is still to be resolved, with expanding encroachment on the MUP and population in the settlement greatly complicating management by the MOE and DOE rangers.

Most of the cleared area is grassland and shrub regrowth, with some mango plantations further south, close to the river. A drainage line runs down from the forest in the north towards the track in the south. Soil erosion is not an issue since the land is not yet intensively cultivated, and ground cover is present throughout the year.

The goal for the site is to restore the forest integrity through reforestation with native species found in the natural forest of the protected area. This will lead to improved biodiversity as a demonstration and step in rehabilitating the Samlout Multiple Use Protected Area. The feasibility of continuing the restoration work on this site is under review, given the complex political situation that must be resolved.

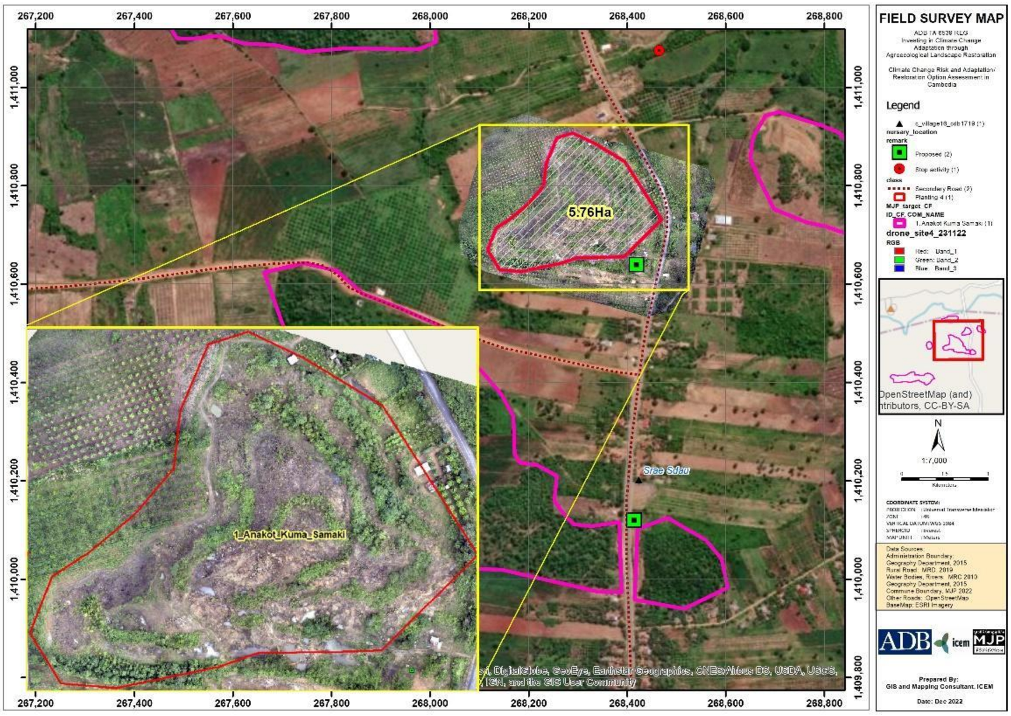
Oslev Restoration Site Map and Drone Image (Credit: Project team)



Anakut Koma Samaki: Anakut Koma Samaki is a small, previously wooded hill, sitting in a landscape of agricultural land with other still wooded small hills that are part of the same community forests surrounding the site. The site forms part of the Anakut Koma Samaki community forest complex but is the only hill that has been severely denuded. The site is notable for its lack of vegetation and extent of bare rock and soil bare rock and soil extent, having been used as a source of laterite for road building in 2016 with no subsequent restoration.

The south of the site is largely bare rock and deeply weathered subsoil with some ponds created by the excavation. Steeper slopes with scrub vegetation characterize the north of the site. Steeper slopes with scrub vegetation characterize the north of the site. Some natural regeneration of trees and shrubs has occurred during the three years since the last available satellite image. The only current land use is as grazing land for a few cattle.

Anakut Koma Samaki Restoration Site Map and Drone Image (Credit: Project team)



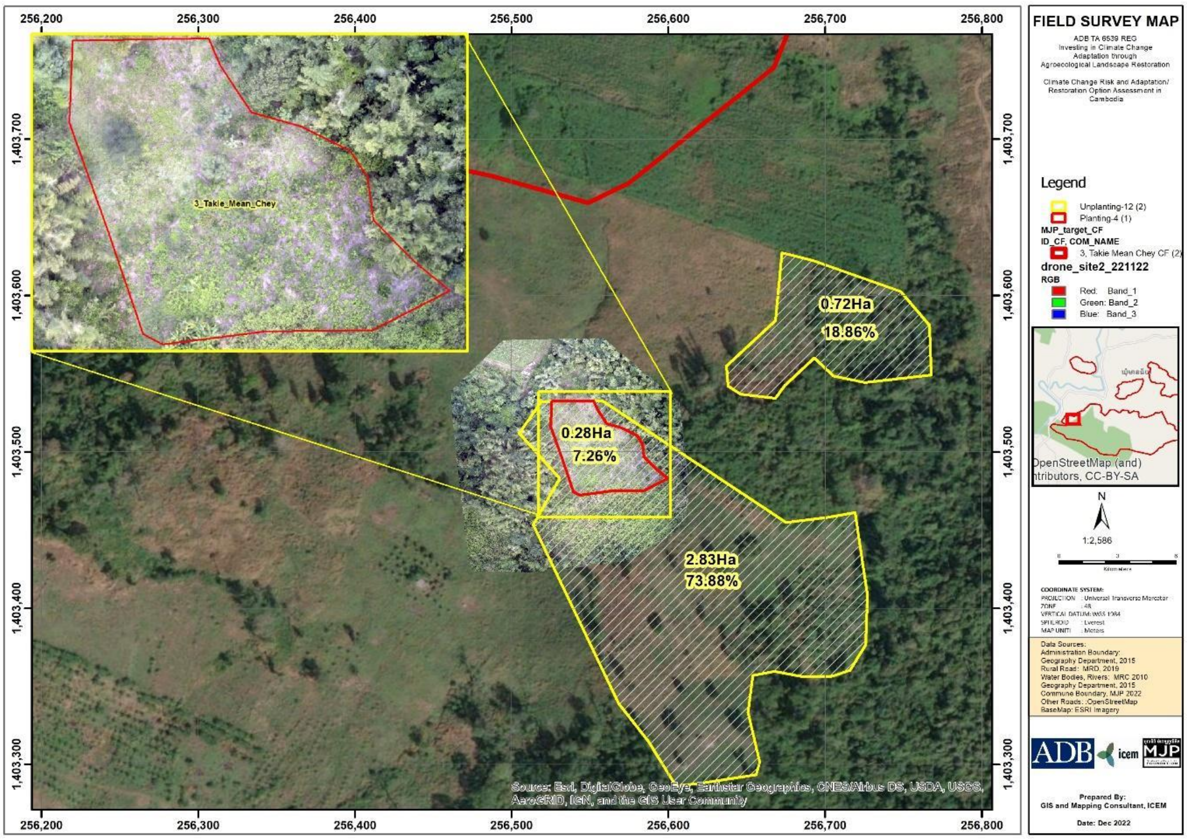
The goal is to restore the Anakut Koma Samaki community forest site to an area with a species composition similar to the pre-disturbance forest that, along with neighboring community forest hills, can act as stepping stones in biodiversity conservation and as a demonstration site for further action in other areas. Local benefits will be due to biodiversity, soil, and water conservation, including using ponds created by the former excavation to develop a broader wetland area with enriched flora and fauna.

The rehabilitation initiative aims to designate Anakut Koma Samaki as a showcase site and a visitor attraction, leveraging its accessibility and elevated vantage point. The strategic location presents opportunities for tourism and the generation of economic benefits.

Takhes Meanchey: The site forms part of a ridge of hills running ENE-WSW for about 5 km east of the Sangker River that is the boundary of the Samlaut Multiple Use Protected Area, and in essence, is an extension of this area with remaining significant biodiversity values and wildlife corridor. The ridge has been encroached by cultivation along its length, and the remaining forest cover now varies in width between 450 m and 1.7 km. The hills sit in a flat to gently undulating landscape of agricultural land dominated by cassava cultivation interspersed with some fruit tree plantations of mango, cashew, gently undulating landscape of agricultural land dominated by cassava cultivation interspersed with some fruit tree plantations of mango, cashew, and longan.

The site forms part of the Takhes Meanchey Community Forest but has been encroached upon and degraded over time, with the remaining forest largely confined to the steeper slopes of the central ridge. The site for rehabilitation is only part of the Community Forest. It consists of native forest, bamboo, land cleared for cassava cultivation, and land currently under cassava that is rotated with maize.

Takhes Meanchey Restoration Site Map and Drone Image (Credit: Project Team)



Two drainage lines run through the site to the north at the western and eastern boundaries. Flooding is not reported to be an issue. Areas of soil erosion associated with forest clearance for cassava cultivation have been identified and mapped.

The goal of restoring the Takhes Meanchey Community Forest site is to increase the forest canopy cover and to restore the species composition to one similar to its original state. This will reinstate the linkage between the site and the Samlout PA to the west and reestablish the forest's ecosystem services for the downstream agricultural land and forest plantations through a reduction in runoff and soil erosion, as well as ensuring a more stable water resource in the two rivulets running from the site.

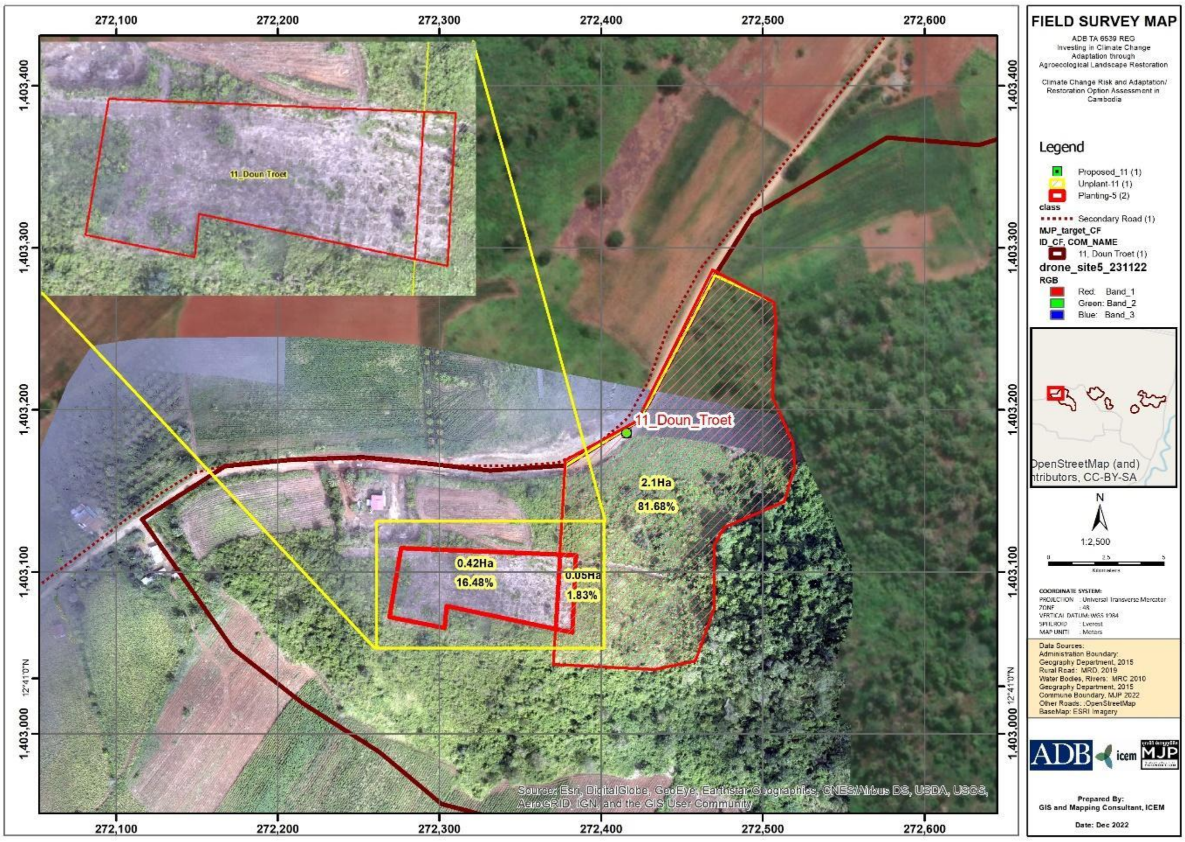
Forest restoration in the community forest will replace the cassava cultivation inside the area's limits and much of the degraded bamboo grassland and shrubland, improving carbon sequestration and enhancing biodiversity with the potential of developing eco-tourism as a port of entry to the protected area.

Dontret: The site is a ridge of hills running ENE-WSW just over a kilometer in length and varying between 180-510 meters in width. The hills sit in a flat to gently undulating landscape of agricultural land dominated by cassava cultivation interspersed with fruit tree plantations of mango, cashew, gently undulating landscape of agricultural land dominated by cassava cultivation interspersed with fruit tree plantations of mango, cashew, and longan.

The demonstration site forms part of the Dontret Community Forest. It has been degraded over time and is now a mosaic of remaining secondary forest largely confined to steeper slopes and degraded forest in the process of being converted to grassland and shrubland and land either cleared for cultivation but not planted or planted with cassava with many areas of visible soil erosion.

Two drainage lines were mapped, and areas of soil erosion associated with cassava cultivation were identified. There is no practice of conservation agriculture practice, with cassava ridges and furrows running straight up and down the slope instead of following the contour. Flooding is not reported to be an issue, but the need for increasing the application of agricultural chemicals to offset reduced soil conditions and reduced productivity is reported by farmers.

Dontret Restoration Site Map and Drone Image (Photo Credit: Project Team)



The main objectives for site rehabilitation are to improve the existing forest areas with the re-establishment of natural vegetation with native tree species and improved biodiversity and to introduce agroforestry and conservation agriculture systems that will protect soil and water resources and give a variety of products to improve local livelihoods.

3.2.2 Adaptation Options/Interventions Selection

The project's 'Good Practices Manual on Biodiverse Forest and Landscape Restoration' presented a suite of potential intervention measures, although communities were encouraged to select their own interventions. The adaptation options presented in the manual are largely nature-based solutions and hybrid measures to increase biodiversity while restoring the landscape. They are relatively low-cost in terms of labor requirements and could be implemented quickly. They include the approaches of Conservation Agriculture and Conservation Farming with Trees (CFWT) and the techniques or measures of Conservation Tillage, Composting and Mulching, Natural Vegetative Strips (NVS), Farm boundary Stabilization, Vegetative Fences, Area Closure, Brushwood Checkdams and Soil Bunds.

At the pilot sites and during the participatory mapping exercise, the communities decided that restoration of forest cover and watercourse stabilization were the key interventions and that monoculture would be excluded from the sites (Table 7).

Table 7: Measures to be undertaken at Pilot Sites

Site	Actions/Interventions
Oslev	• Reforestation with suitable native species • Restore 10m buffer of drainage line using native species • Construct two 'Leaky Dams' or 'Brushwood Check-dams' in the drainage line
Anakot Komasamaky	• Reforestation with a mix of suitable native and exotic species • Create on-site community nursery • Complement tree planting with direct seeding in the field and support natural regeneration. • Practice Area Closure to avoid livestock entering the site • Plant around wetland/pond area and link small drainage corridors with native tree species • Install brushwood checkdams in the pond area • Install vegetative fencing around the wetland/pond area • Establish community buildings • Develop the site as a demonstration site and visitor attraction
Takhes Meanchey	• Reforestation with a mix of suitable native and exotic species • Create on-site community nursery • Rehabilitate the main drainage line by clearing bamboo and removing debris • Use material cleared to create 'Leaky Dam(s)' to pool water for wildlife • Replace bamboo in the channel with native species • Replace cassava/maize cultivation with native and exotic trees to form biodiversity corridors. • Infill furrows with unrequired plant material. • Establish vegetative fencing, such as cashew living fences • Explore opportunities for PES
Dontret	• Reforestation with a mix of suitable native and exotic species • Create on-site community nursery • Replace cassava/maize cultivation over time with native and exotic trees to form biodiversity corridors. • Infill furrows with unrequired plant material and create small check dams with rocks and natural debris in furrows every few meters. • Establish vegetative fencing such as cashew living fences.

These interventions were put in place in September 2022 with seedlings purchased from local nurseries and the provision of appropriate equipment. At each site, the initial planting program was agreed upon with the community, followed by training on planting techniques, including seedling maintenance and developing a community work plan for effective long-term maintenance and restoration activities.

At Dontret, Anakot, and Meanchey, field training preceded seedling planting, outlining the stages of planting, including seedling preparation at nurseries, seedling selection, seedling transport, ground preparation for planting, planting, and maintenance. Five thousand mixed seedlings were then planted in previously agreed and cleared areas.

A cluster planting method was used with nine seedlings planted 1m apart in a 2m x 2m cluster with 4m between clusters. The aim is for plants to rapidly establish in the planting area and create a microclimate that shades out weeds within the cluster, ensuring the planted seedlings' survival. Over time and once mature, the plants can flower and seed, colonizing nearby areas. The space between the clusters can be used either for agroforestry or to allow native species to seed and increase biodiversity.

At Oslev, a simpler planting technique was applied, in which only native species were planted three meters apart.

Issues identified at this time included the provision of water sources, building or expanding ponds at Oslev and Anakot, providing a water tank at Dontret, establishing community nurseries at each site, and seedling protection at Oslev.

These issues were first addressed in November 2022, when plans were made to overcome potential water shortages at each site, and the potential to revive a community nursery at Dontret and establish nurseries at the other three sites was examined. In addition, a propagation and planting plan for 35,600 and 23,200 seedlings, respectively, was drawn up in 2023. Training was also provided in nursery management and on-site maintenance, and a monitoring survey was begun.

Field work with farmers in 2023 has emphasized establishing and managing community nurseries at each site and permanent water sources – in addition to expanding the plantings. The initial planting was conducted at the end of the wet season. During the dry season, losses of seedlings from approximately 10% to 40% occurred because of challenges with water supply. That experience provided important lessons and has led to replacing lost seedlings in all sites and to prioritizing consolidating the water storage and distribution facilities. Work on soil conservation and slope stabilization has also begun through terracing, leaky weirs, and clearing weeds and bamboo-choked drainage corridors. While this restoration work continued, livelihood support was provided through training and support to honey production and provision and planting of fruit trees.

4 Adaptation Options - Scaling Up

4.1 Drivers of degradation

Soil erosion, land degradation, and declining soil fertility frequently stem from population pressure, manifested through intensified cultivation on fertile land and the expansion of farming onto steeper, less productive terrains. Many of the sub-basins have been categorized as posing a very high risk of soil erosion, leading to sediment transfer that is diminishing the lifespan of the Treng Reservoir. The rate of soil erosion is likely exceeding the rate of soil formation.

Key environment-development linkages relate to land degradation, food insecurity, energy, water access, and livelihoods. This interlinkage includes unsustainable agricultural land management practices such as cultivating steep slopes without protective measures and increasing exposure to drought.

The need for cropland accelerates the rate of deforestation and erosion. At the same time, the removal and/or burning of crop residues, rather than returning this organic matter to the soil, causes a decline in soil fertility and deterioration in soil structure. The degraded land is then more prone to erosion, leading to further loss of fertility in the topsoil and a reduction in soil depth, which can reduce soil depth and adversely affect crop yields. The consequences of deforestation and degraded soil structure include greater runoff, which contributes to erosion and siltation; less infiltration of rainfall, which diminishes groundwater recharge; and reduced water storage capacity in the soil, which makes crops less able to withstand drought.

In turn, the loss of forest cover is generally associated with greater hydrological variability. Associated sedimentation compromises productivity and shortens the lifespan of water infrastructure for river regulation, municipal water supplies, agriculture, and hydropower generation. The reduced regulation capacity also increases flood risks for downstream communities, posing a threat to the poorest, who tend to live in the most vulnerable locations.

Soil degradation is a self-reinforcing and accelerating process (a downward vicious cycle), with impacts that invariably lead to declining rural living standards. Soil degradation is initiated by human activities, under pressure from population expansion and in the absence of effective alternatives.

Effective restoration and soil conservation require breaking this cycle of degradation; technical responses to soil erosion are well known, but the causes are usually social, economic, and political.

Key issues, therefore, are population increase leading to increased land pressure, which, when coupled with land tenure insecurity, leads to soil erosion and land degradation. These manifest themselves in land use change in terms of sudden change, such as clearing of land for agriculture, as well as gradual change (land cover degradation) through biomass collection.

The soil and water conservation adaptation measures, coupled with many other interventions intended to improve livelihoods, aim to reverse the soil erosion and land degradation in the sub-basin

4.2 Use of Community Forests as 'Stepping Stones'

Approximately 12 Community Forests are situated between the two rivers, with four selected as pilot areas (Figure 20). While still predominantly forested, these areas have experienced degradation, resembling forested islands amidst cultivated land. Prioritizing the reforestation of these "islands" is essential, as they can serve as pivotal 'stepping stones' in biodiversity conservation. Additionally, the restoration efforts will enhance ecosystem services, soil conservation, and water conservation, ultimately benefiting the local population and agricultural land downstream.

4.3 Watercourse stabilization

Watercourse stabilization is vital in protecting all watersheds but is particularly important for streams in upper basin watersheds and areas of deforestation. The rehabilitation and protection of watercourses should be a priority, with buffer zones using native species and networks of leaky dams or brushwood dams as necessary to enhance water management and releases, especially during the dry season.

4.4 Recent Deforestation and Sustainable Agriculture

The most recent deforestation (since 2016) has been driven by the development of a market for cassava as animal feed and raw materials in Thailand, resulting in an expansion of cultivated land, particularly for cassava, on steep slopes. Farmers in the upper watershed do not practice erosion control, soil conservation, or contour farming, as evidenced by cassava grown on prominent ridges perpendicular to the slope.

There is a need for training and demonstration in conservation agriculture. Since cassava cultivation is relatively recent, soil degradation should be recoverable with better land management.

Older cultivated areas have evolved into a more mixed farming system (*chamkar*) than recently established land, and the adoption of conservation agriculture and conservation farming with trees should be feasible.

The level of knowledge of conservation agriculture is very low. In addition, there are few agriculture and forest extension officers for the whole of Battambang Province. Farmers will need an extensive awareness-raising program with training on conservation agriculture to improve sustainable land use.

4.5 Soil Conservation

Soil data is scarce, with only three soil units mapped to cover the upper basin. Acrinols should be prioritized for forest restoration since they are the most erodible and least fertile. With appropriate management and recurrent inputs of lime and fertilizer, the soils will be suitable for plantation or fruit crops such as cashews and pineapple. Acrinols occur at the headwaters of the Sangker and Chami Any Kuoi, areas largely still forested, and ideally, any areas degraded or converted to agriculture (particularly cassava) should be reforested since sustainable cropping is likely to prove uneconomic but could be catastrophic in terms of soil erosion.

The most extensive soils in the upper basin are Nitisols, which have good physical characteristics and generally higher, which have good physical characteristics and are generally higher in fertility than Acrinols. They would be amenable to conservation agriculture with sustainable land management.

4.6 Nurseries

Nurseries will be required to produce native species suitable for reforestation and native and exotic species for conservation farming with trees. Nurseries should have an appropriate mix of plants and not only exotics. The ongoing pilot areas are planning on establishing and reviving nurseries and lessons learned on establishing and reviving nurseries, and lessons learned from these interventions can be passed on for future use. Nurseries can be an important source of income generation for the community forest management groups. However, they will need support through national and provincial green programs and ongoing technical guidance to be sustainable.

4.7 Composting and Mulching

Composting and mulching is an integral part of conservation agriculture, and organic matter as fertilizer will be required to rehabilitate degraded soil and land. Awareness raising and training in the production of compost and the use of mulch will be required.

4.8 Water Harvesting

The likely increased length and severity of the dry season will place greater importance on water harvesting measures. Communities have indicated that drought is their primary concern and are already adapting in the demonstration community forests by increasing rainwater harvesting, digging wells, and adopting drip irrigation. Techniques such as hand-dug wells, networks of micro ponds, underground cisterns, percolation ponds, infiltration ditches, and rooftop water harvesting should be assessed for suitability and acceptance.

4.9 Future Adaptation Planning

The selection of pilot areas for landscape and forest restoration involved evaluating watershed climate risks and opportunities, identifying key issues, and determining the necessary functions of the landscape restoration options within the pilot watersheds.

The next phase will involve scaling up forest restoration activities to include the wider watershed, i.e., at the landscape level, and moving from the largely forest restoration interventions used in the pilot watersheds to both landscape and forest restoration interventions at the watershed level. This landscape approach allows a more integrated analysis of interlinked problems, functions, and solutions for restoring a watershed.

Interventions target upstream areas first and then work downstream, emphasizing the rehabilitation of drainage corridors. They should also target the most degraded areas in clusters of micro-watersheds.

Watershed management offers the greatest likelihood of success at the micro-catchment level, where communities actively manage the watershed and participate in the planning process from the outset. Interventions in watershed management within the Sangker Basin primarily stem from historical deforestation, land degradation, and the imperative to diminish river sediment loads. To ensure the effectiveness of these interventions, it is crucial to enhance the livelihoods of the communities directly affected. Without tangible benefits to these communities' economic and social interests, their investment in watershed management may be limited, jeopardizing the realization of the ultimate objective.

This adaptation planning assessment aims to show how landscape and forest restoration activities could be scaled up from the pilot areas to encompass the whole upper Sangker watershed.

4.9.1 Adaptation Options Long List

The primary functions of the restoration measures in the watersheds are to control erosion, increase landscape connectivity, and strengthen biodiversity while improving livelihoods. A number of options that can provide these required functions, which are nature-based solutions and relatively low cost, are outlined in companion knowledge products from this project. These options were put to the communities in the field, and a number of them were selected for the pilot areas.

Table 3 below shows the long list of adaptation options divided into three categories: conservation approaches, soil and water conservation (SWC) technologies, and water harvesting technologies. Conservation approaches are the ways and means to implement a technology, and several technologies may be included in an approach, such as Conservation Agriculture.

A brief description of the options is included here; a longer description is included in the project manual for restoration.

Conservation Agriculture (CA) combines agricultural methods to optimize yields and profits while preventing land degradation. It aims to minimize the decline of soil structure, composition, and natural biodiversity. Conservation agriculture treats the soil as a living body, emphasizing protecting the topsoil, the upper 20cm of soil, that has the most biological activity and contains much of the which has the most biological activity and contains many nutrients but is also the most prone to erosion. In general, conservation farming has three core principles:

1. Minimum soil disturbance
2. Maintenance of permanent or semi-permanent soil cover
3. Crop rotation

Attributes of appropriate technologies for conservation farming could equally well be used for all adaptation measures.

Superior. The adaptation of choice must be better than current practice and easy to implement

Compatible. The adaptation must match local values, experience, needs, and farmers' aspirations.

Simple. It must be easy enough to be understood and practiced by farmers

Affordable. The measure should not be too expensive both for the farmers and development bodies supporting it

Adaptable. Can be easily adjusted according to farmers' time and resources

Impacts. Must provide short-, medium- and long-term benefits to soil, landscape, and farmers

Conservation Farming with Trees (CFWT) integrates the principles of conservation farming with agroforestry, combining the benefits of both approaches. By incorporating nitrogen-fixing tree species, CFWT enhances crop cultivation, stabilizes field boundaries, and provides additional resources such as fruits, fodder, and timber.

Water Harvesting involves various methods for conserving water and yields more immediate and visible benefits in water-stressed areas than soil conservation.

Nursery establishment and maintenance are essential to ensure a steady supply of seeds, seedlings, and saplings, supporting numerous Soil and Water Conservation (SWC) technologies and interventions, including reforestation and watercourse stabilization.

Watercourse stabilization focuses on rehabilitating degraded streams and rivers by reintroducing vegetation and constructing structures like leaky dams and brushwood check dams in interconnected networks.

Reforestation is restoring previously forested areas to their natural state, ideally utilizing native species.

Table 8: Adaptation Options Long List and Criteria

Adaptation Measure/Selection Criteria	Reduce Soil Erosion	Reduce Flood Damage	Increase resilience to drought	Increase food security	Increase Biodiversity	Technical capacity needed	Institutional Capacity, Training needed	Affordability
Conservation Approaches								
Conservation Agriculture	xxx	x	x	xx	x	xx	xx	xx
Conservation Farming with Trees	xxx	x	xx	xxx	xx	xx	xx	xx
Water Harvesting	x		xxx	xxx	-	xxx	xxx	x
Nursery Establishment and Maintenance	-	-	x	xx	x	xxx	xxx	x
Watercourse Stabilisation	x	xxx	xx	x	xx	x	xx	xx
Reforestation	xx	xxx	xxx	x	xxx	x	xx	xx
Soil & Water Conservation Technologies								
Conservation Tillage	xx	x	xx	xx	x	xx	xx	xx
Composting & Mulching	xx	x	xx	xx	x	xx	xx	xx
Natural vegetative Strips	xxx	x	x	x	x	xx	xx	xxx
Grass Strips	xxx	x	x	x	x	x	x	xxx
Boundary Stabilisation	xx	x	x	x	x	x	x	xxx
Vegetative Fencing	xx	x	x	x	x	x	x	xxx
Area Closure	xx	x	x	x	xx	x	x	xxx
Brushwood Checkdams	x	xx	x	x	-	xx	xx	xx
Leaky Dams	x	xxx	x	x	-	xx	xx	xx
Soil bunds	xxx	x	x	x	-	xxx	xxx	0
Water Harvesting Technologies								
Hand dug wells	-	-	xxx	xxx	-	xx	xx	xx
Microponds	-	-	xx	xxx	x	xx	xx	x
Underground cisterns	-	-	xxx	xxx	-	xxx	xxx	0
Percolation ponds	x	x	xx	xxx	x	xx	xx	x
Infiltration ditches	x	x	xxx	xx		xx	xx	x
Rooftop water harvesting	-	-	xxx	xxx	-	x	xx	0
Key	-	no impact/requirement						
	x	low-moderate impact/requirement						
	xx	moderate-high impact/requirement						
	xxx	high-very high impact/requirement						
	0	negative impact/requirement						

Conservation Tillage, encompassing reduced and zero tillage, is a fundamental component of Conservation Agriculture. It involves minimizing soil manipulation, such as plowing, and retaining crop residue on the soil surface, even during seeding.

Compost-making is a cost-effective measure for improving soil fertility, enhancing water storage in the soil profile, and reducing surface runoff and soil erosion.

Mulching involves covering the soil surface with crop residues (or compost), protecting against raindrop splash erosion, improving soil quality, and conserving moisture. Trash bunding is a form of mulching where plant residues are aligned in ditches or furrows along the contour.

Natural Vegetative Strips (NVS) comprise live barriers consisting of naturally occurring grasses and herbs, designed to be narrow in size. This low-cost technique requires minimal labor for establishment and maintenance and can be planted with trees, as in Conservation Farming with Trees (CFWT).

Grass strips are vegetative barriers planted in narrow strips along the contour, effectively controlling erosion on gentle slopes. However, their effectiveness diminishes on slopes exceeding 5% to 8%, requiring alternation with bunds above 15%. Grass strips cause minimal interference, utilize little arable land, and are cost-effective compared to physical structures.

Stabilizing existing farm boundaries involves planting crops, grass, shrubs, and trees to fortify boundaries, particularly soil bunds. This protects against rain, runoff erosion, and cattle trampling and makes the boundary productive for fodder production, fuelwood, timber, or fruit trees.

Vegetative fencing involves planting materials in rows along with grass and legumes sowed behind these rows. The method is used to protect and enrich reclaimed areas like gullies, farm boundaries, and community assets like ponds. Vegetative fencing helps control runoff and erosion and allows for planting valuable trees behind the fence.

Area closure is an agroforestry and forage development technique wherein a degraded land area is closed to grazing animals, allowing natural regeneration or planting with high-value agroforestry species.

Brushwood check dams are vegetative measures to stabilize small gullies, ideally composed of branches, poles, twigs, and plant species that can grow from shoot cuttings. The aim is to retain sediment, slow runoff, and enhance the revegetation of gully areas.

Leaky dams use locally sourced whole tree trunks or bamboo placed across a stream to reduce flood peaks by allowing a controlled amount of water. Suited for smaller watercourses, they entail low installation and maintenance costs.

Soil bunds are impermeable structures designed to retain all rainfall, increasing soil moisture and decreasing runoff and soil erosion. While serving as entry points for further land stabilization, soil bunds can be planted with agroforestry species and fodder crops once established.

Hand-dug wells provide water for irrigation or livestock in the dry season. They are typically 1.5-3m in diameter (or wider in unstable soils), deep enough to reach the water table, and strategically located to

Micro ponds can be created by constructing dams across watercourses (embankment ponds) or through excavation (excavated ponds). The choice depends on soil type and geology. Micro ponds serve various purposes, including groundwater recharge and irrigation for high-value crops and livestock watering.

Underground cisterns require extensive excavation, materials, and expertise. They retain water for longer periods due to lower evaporation rates.

Percolation ponds, relatively large and constructed in areas marginal for cultivation, aim to recharge groundwater while providing water for irrigation and livestock watering.

Infiltration ditches are dug along the contour in cultivated areas to collect water from roads and other runoff. They are closed at one end, allowing water to percolate into the soil.

Rooftop water harvesting involves capturing water from corrugated iron roofs into tanks. The method is recommended for all public and private buildings with suitable roofs.

4.9.2 Selected Adaptation Options

The conservation approaches complement each other with the reforestation of steeper terrain and watercourse stabilization, reducing runoff and providing more stable watercourses, reducing flooding downstream. On cultivated land, adopting conservation agriculture over time can reduce soil degradation and provide alternative income for fruit, fodder, and timber.

Nurseries will be required to cater to the increased demand for seeds and saplings, and it will be most important to ensure that markets are available for the forecast increase in produce.

Water harvesting is a valuable intervention in areas with a long dry season, particularly where the season is becoming longer and the onset of rains more erratic.

Many SWC techniques are integral to conservation agriculture and conservation farming with trees, in particular, conservation tillage, composting and mulching, and natural vegetative strips. Techniques such as grass strips, vegetative fencing, and boundary stabilization can be used with CA and CFWT as the environment and needs dictate. Area closure is a valuable and practical technique in areas where extensive grazing is common but will be of limited use in the upper Samlaut sub-basin. Soil bunds are extremely good in reducing soil erosion on moderate slopes but are costly in time and labor requirements, so they are not deemed suitable.

Leaky dams and brushwood check dams are integral to watercourse stabilization and to improve watercourse stabilization and infiltration and water release during the dry season. They are a relatively cost-effective means of regulating stream flow and reducing flooding in small streams. Hand-dug wells and micro ponds are relatively low-cost water harvesting techniques that can provide water for irrigation and livestock through the dry season; however, underground cisterns and rooftop water harvesting may be too costly. Percolation ponds are a means of recharging the groundwater that can be planned for at a later stage in the development of the subbasin.

5 Scaling Up, Future Strategy

The approach described in sections 1 to 3 and the adaptation options outlined in section 4 are the first phases in what will need to be a multi-phased approach to the restoration of forests and wider landscape restoration of the upper Sangker basin. The ongoing adaptation interventions in the pilot areas aim to reestablish forests and protect headwaters and waterways in those community forests. In time, the whole landscape will need to adopt adaptation measures, which will mean embracing conservation agriculture and converting some currently cultivated areas to agroforestry or back to forest cover.

This chapter provides an outline approach to scaling up the forest and landscape restoration process to the who outlines an approach to scaling up the forest and landscape restoration process to the Sangker sub-basin.

5.1 Outline Priority Areas

Within the overall goal of restoring ecosystem services in the upper Sangker basin, there needs to be a targeted and phased approach following the ongoing pilot phase in which areas are prioritized.

Experience worldwide has shown that community mobilization and planning take up to about one year, and implementation typically requires 3 to 5 years. The basis for planning and watershed rehabilitation should be the micro-basin, which covers areas of around 350-500ha. Good results can be obtained from planning and implementation in adjacent micro-basins covering an area of up to 2,000ha. Above this, capacity and manpower tend to become overstretched.

Overall Priority areas are:

Areas in the upper watersheds recently subject to deforestation. Predominantly under cassava cultivation, they lack adequate soil and water conservation practices. Inconsistent planting patterns, with crops along the contour in some areas and across the slope in others, further contribute to the challenge. Although the soils presently maintain good depth and structure, primarily consisting of acrisols, their ideal state is reforestation. Implementing suitable Soil and Water Conservation (SWC) measures or reforestation can effectively manage soil erosion, fostering sustainable farming practices. Options include tree planting from nurseries or transitioning to conservation agriculture with trees, composting, and mulching. Trash bunding, especially suitable in cassava fields, necessitates training, nursery plants, and compost development.

Community Forests within the upper basin exhibit signs of forest degradation or deforestation. These areas demand restoration to their natural forest state, emphasizing the use of native species. As demonstrated in the pilot phase, this entails establishing local nurseries, planting, and ongoing maintenance. Prioritizing Community Forests aligns with their role as biodiversity conservation stepping stones, enhancing ecosystem services and promoting soil and water conservation, ultimately benefiting local populations and downstream agricultural land.

Streams and watercourses connecting the designated priority areas must themselves be prioritized for effective water flow management and sediment trapping upstream. This involves rehabilitating and protecting watercourses in upper watersheds by installing leaky dams or brushwood dams and planting native species in buffer zones on both sides of the corridor. This prioritization ensures improved water management, reduced soil loss, controlled sediment transport, enhanced biodiversity, and potential for fisheries and aquatic products. Collaboration with individual farmers and community forest management groups is imperative for successfully rehabilitating watercourses running through agricultural land.

The first scaling phase should also address highly degraded areas requiring urgent restoration, including deforested areas with severe soil erosion, denuded hillsides with excessive runoff, or former quarry sites like the Anakot pilot site. Identifying these areas falls under the purview of the local authority.

Reforestation and implementing SWC measures are crucial in all priority areas but may take time to yield benefits. Recognizing the escalating trend of prolonged drought periods, the immediate introduction of rainwater harvesting technologies (wells, pond networks, rooftop collectors) emerges as a priority adaptation measure. This intervention provides swift benefits by ensuring water availability, which is crucial for sustaining young plants during dry seasons.

Upon successful restoration of priority areas, the process can extend to other sites in the upper basin. This includes introducing conservation agriculture to areas characterized by mono-cropping (maize, cassava) and establishing buffer zones around the Samlaut Multiple Use Area (MUA) and the restored community forests. Over time, broader adaptation measures such as conservation farming with trees can be implemented across the entire basin, where a mixed farming system already combines cereal cultivation with interspersed fruit trees.

5.2 Targeted Specific Priority Areas

Specific priority areas were identified during the project, centered around the community forests and the drainage corridors flowing between and connecting them. The areas correspond to upper basin watersheds with a high soil erosion risk where agriculture has encroached upon the CFs, and the Samlaut MUA has been deforested.

Three specific areas have been identified in the upper basin (Figure 22): The wider Takhes Mean Chey Community Forest and surrounding agricultural land, the Phnom Deka and Samaki Ou Chrab CFs to the south, and Kanchang Village and other CFs further south again.

Figure 22: Priority Areas for Intervention

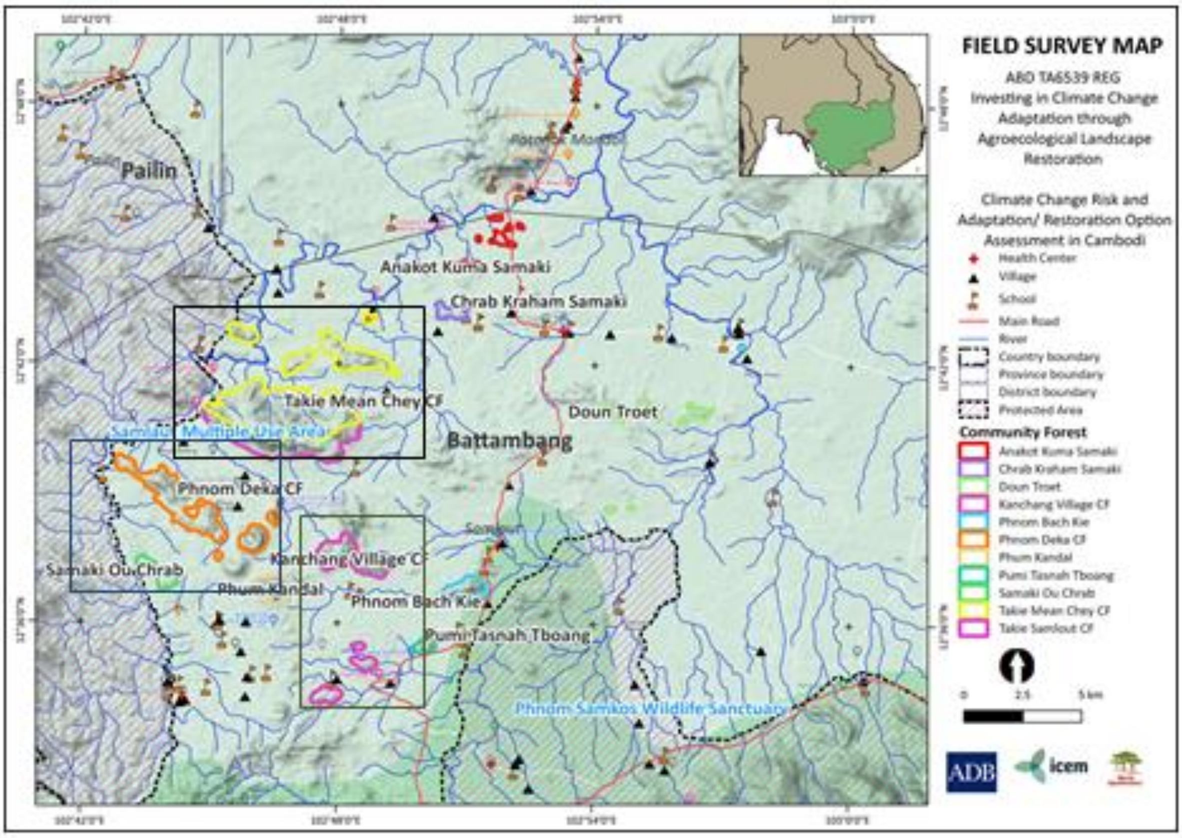


Figure 23: Takhes Meanchey Community Forest areas and drainage corridors

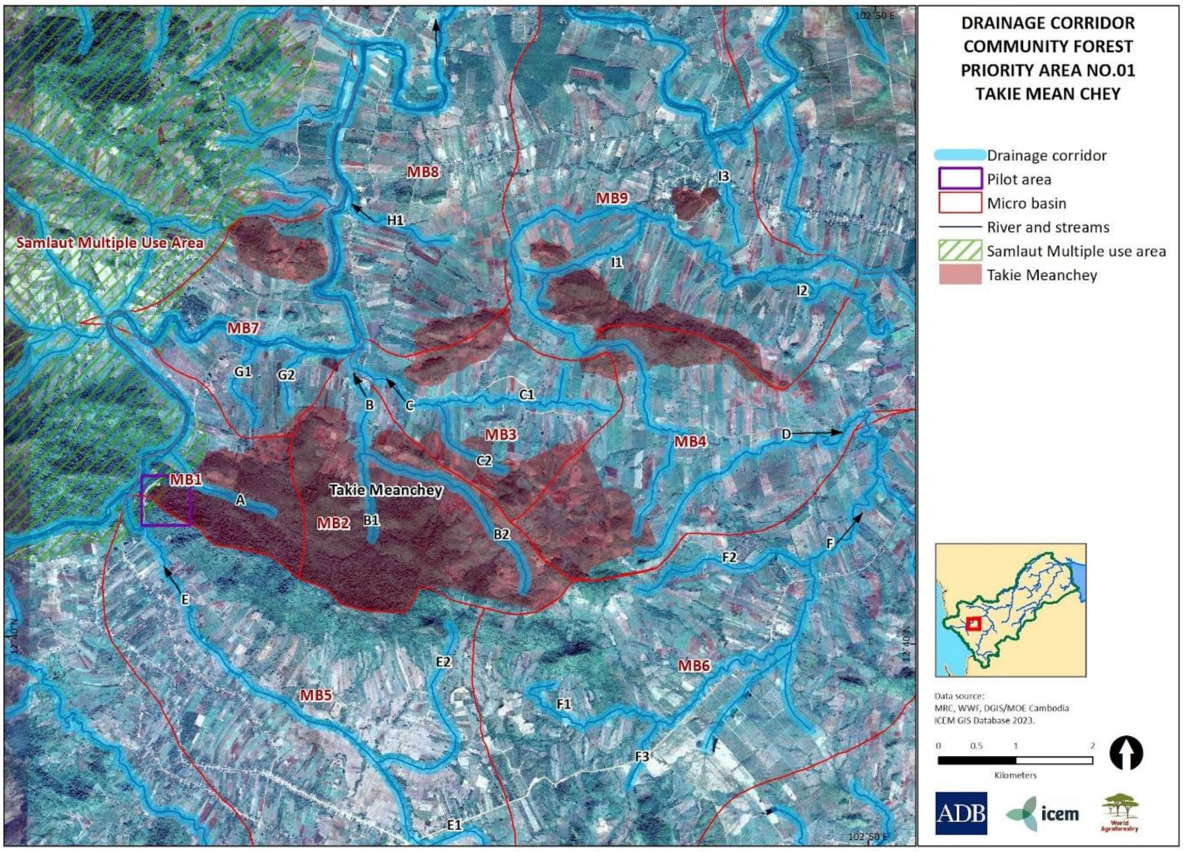


Figure 24: Phnom Deka and Samaki Ou Chrab CF areas and drainage lines

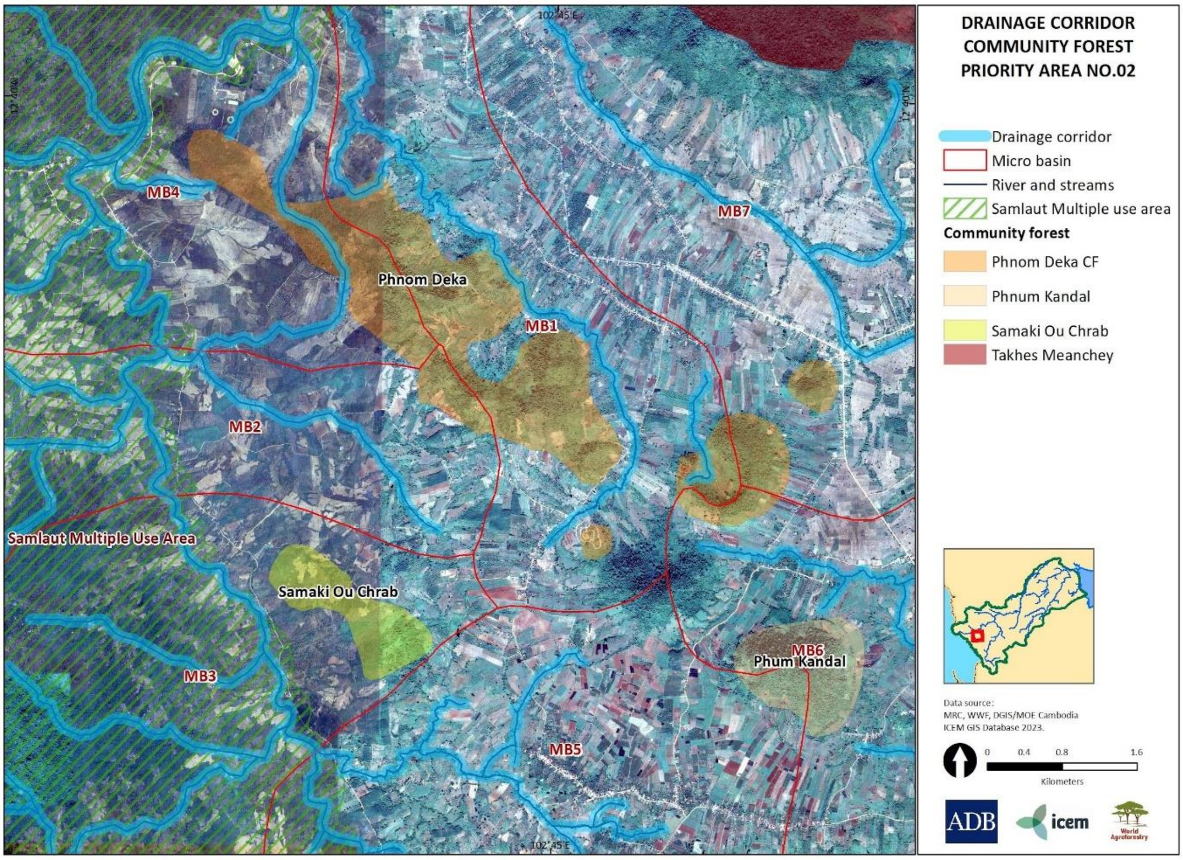
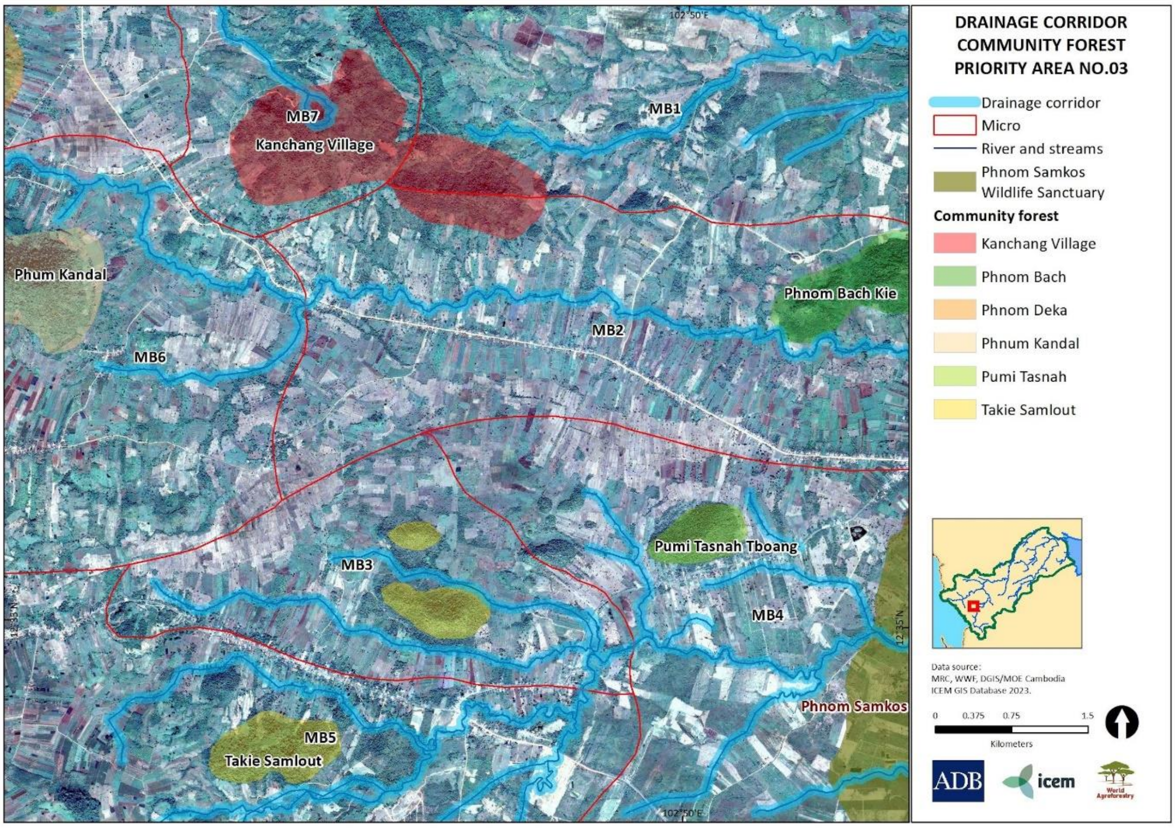


Figure 25: Kanchang Village and five other Community Forest areas and drainage lines



Outline micro-basins have been mapped at Takhes Meanchey to provide a rough idea of how the approach undertaken in the pilot phase could be rolled out across the wider landscape of the upper Samlaut basin. This will be a strategic and phased systematic ecosystem approach based initially on the restoration of community forests and associated drainage lines, followed by areas with increasing agricultural land.

The Takhes Meanchey CF area has been subdivided into nine micro-basins ranging in area from about 300ha (SB1 containing the pilot area) through 875ha for SB4 to the east of the main CF area to areas of over 1,000ha further away from the core CFs – SB5, SB6, SB8, SB9 (Figure 23).

The first phase of scaling up should concentrate on the core areas of the CF, such as SB1, SB2, and SB3. These micro-basins are still largely forested, although the forest is degraded and has been encroached by agriculture. Lessons learned during the pilot phase can then be applied to the restoration and rehabilitation of the forest land as well as to the restoration and rehabilitation of drainage lines A (in SB1), B1 & B2 in SB2, and C1 & C2 in SB3. This will concentrate on forest restoration, replacing exotics with indigenous tree species, drainage line restoration, and constructing leaky dams or brushwood check-dams to reduce runoff and enhance dry season flow.

An increasing area of cultivated land occurs as work progresses from SB1 to SB2 and SB3. The measures applied to this land will differ from those applied to the forests and drainage lines. Adopting conservation farming techniques and agroforestry to conserve soil, reduce runoff, and increase production will need to be introduced to the farmers on this land. Ideally, this will require awareness raising and training before the micro-basin can be included in the restoration rollout process.

The planning phase for adaptation interventions typically spans about a year, while implementation extends over 3-5 years. Consequently, the proposal outlines the planning of interventions for three micro-basins in Takhes Meanchey (SB 1, SB 2, and SB 3) in Year 1 and implementation between Years 2 and 5. As the initiative progresses, insights into the effectiveness of different strategies can be used to shape the subsequent planning phase for interventions in SB4 to SB9.

The speed and scale of the of the rollout of interventions will depend on a number of factors, including the capacity of MJP to oversee and administer the process, the willingness and ability of communities to become involved, the political will from local and national government particularly in relation to training agricultural extension staff and the perceived benefits derived from the interventions by the local community.

Depending on the level of community interest and the capacity of MJP (and other NGOs) and local government to lead the process, the approach can be rolled out to other priority areas shown in Figure 29 and Figure 30

5.3 Additional Requirements

The provision of landscape and forest restoration and rehabilitation approaches and techniques is integral to restoring the sub-basin. However, this process will require the provision of additional interventions if the process is to be sustainable.

These are:

Nursery Development. Almost all the adaptation measures include tree planting. There is, therefore, a requirement to expand existing nurseries and to establish new nurseries. The approach focuses on 'the right tree in the right place for the right purpose' with an additional focus on native species for reforestation and watercourse stabilization. Additionally, fruit, fodder, and timber trees will be required for many adaptation measures, such as CFWT. The ongoing pilot phase is planning the establishment of community nurseries at each site, and other project knowledge products set out requirements for nursery establishment and production in some detail, including location, design, tool requirements, plant types, planting medium, water requirements, and the production process, including field plantation and planting density.

Training. Field visits have indicated a low knowledge base in sustainable land management, forest management, and soil and water conservation techniques. A large training element will be required to plan and implement suitable interventions. Training has been an integral part of the pilot program, with training in tree planting and maintenance and nursery management undertaken. The adoption of conservation agriculture focused on minimal or no tillage and incorporation of organic matter into the soil, as well as the use of compost and mulch and the creation of natural vegetative strips, are likely to be new approaches and require training.

Markets. The importance of markets and marketable products to offset the cost of investment in conservation cannot be overstated. It is difficult to sustain watershed management on increased productivity of food crops alone; diversification for cash crops adapted to local markets or other income-generating activities is an essential part of the mix, particularly with the proposed use of fruit and other tree crops.

Allied to market development is **value chain** development, an integral part of strategic planning, the results of which can feed into the trees that farmers will choose to grow and the seeds that nurseries will need to produce. The ability to add value to a product by identifying its optimal use and optimal time for harvest can be of enormous value to the growers.

5.4 Scheduling

Watershed development, including landscape restoration, is not a quick-fix solution. It is best undertaken at the micro-basin level, ideally in clusters at the priority locations. Community mobilization and planning generally takes about one year; implementation typically requires 3 to 5 years. An outline plan for a schedule of interventions is provided below. A fully funded project implementation plan should be undertaken before commencement; this could take a year to complete.

Year 1

- Identify Priority Areas (e.g. SB1, SB2 & SB3 Takhes Meanchey)
- Sensitize the population and undertake intervention/adaptation requirement assessment – this will inform the training needs assessment
- Estimate the number of trees required for the priority areas
- Assess current nursery output and plan for increased production and establishment of new nurseries
- Undertake training in, e.g., conservation agriculture, soil & water conservation, nursery management, water harvesting
- Identify key indicators in the M&E plan and undertake a baseline assessment

Years 2-5

- Undertake interventions in the priority areas – phasing to be worked out in year 1
- Perform M&E to:
  - Inform future phases of progress and identify issues
  - Guide training requirements
  - Identify what works and what does not – change interventions depending on results.
- Check on nursery production, identify issues, and change if required
- Start market and value chain assessment to be in place when, e.g., fruit crops are produced in year 5
- Identify the next areas for intervention

Subsequent years

- Undertake interventions as required – phasing to be worked out as the project progresses
- Perform M&E to:
  - Inform future phases of progress and identify issues
  - Guide training requirements
  - Identify what works and what does not – change interventions depending on results.
- Check on nursery production, identify issues, and change if required
- Continue market and value chain assessment to be able to change as national and international needs dictate
- Identify further areas for intervention (e.g. SBs 4-9 in Takhes Meanchey and/or (depending on capacity, demand, and progress) Phnom Deka and Samaki Ou Chrab CF and Kanchang Village CFs)
- Publicise method for uptake in other parts of Cambodia

5.5 Monitoring & Evaluation

Participatory Monitoring and Evaluation (M&E) will play a vital role in watershed development and will require the identification of indicators against which the project's progress and success can be measured.

For the landscape restoration of the upper Sanker sub-basin, M&E must be an ongoing process to monitor progress and promptly identify interventions that may not achieve their goals, allowing for necessary adjustments. Monitoring tree planting and survival is currently underway at the pilot sites.

The M&E plan should establish indicators early in a follow-up investment project to facilitate a baseline assessment. The Baseline Evaluation aims to determine pre-project conditions and establish a comparison base against which future changes can be measured.

The primary purpose of these evaluations is to assess project progress toward goals and, initially, to evaluate different approaches and delivery pathways. Log frame indicators can be adjusted based on evaluation outcomes.

Annual evaluations will enable an assessment of the previous year's results, a review of different approaches, and a determination of whether the project is on target. If necessary, targets and indicators can be adjusted for the following year.

Regular monitoring ensures the project stays on track and promptly addresses issues. Given the inherent uncertainty in predicting the project's status in the coming years, regular monitoring, yearly evaluations, and adjustments are essential.

Upon project completion, an end-line evaluation to gather information on indicators will enable a comprehensive evaluation of project impacts. This evaluation should encompass both process and impact assessments. A process evaluation examines how the project progressed over its lifetime, focusing on the effectiveness and relevance of interventions. An impact evaluation aims to assess outcomes and impacts outlined in the log frame, gauging the extent to which project activities have contributed to observed impacts. The required information can be gathered through structured interviews and quantitative data collection.

6 Conclusions and Recommendations

An evaluation of climate change trends and associated risks reveals a shift in rainfall patterns, transitioning from a bimodal distribution to an unimodal concentration towards the conclusion of the wet season. This change heightens the risk of flooding, while reduced rainfall during the dry season exacerbates drought conditions.

Agricultural practices, driven partly by population pressure and partly as a response to climate change, are migrating from the plains to the hilly, forested headwaters of the river basin. This shift, primarily occurring over the last decade, has led to deforestation, escalating runoff, soil erosion, flooding, decreased base flow, and worsening drought conditions.

An analysis of soil erosion, considering factors like rainfall intensity, soil type, slope, land cover, and management, indicates very high or high risks of soil erosion in the sub-basins of the upper basin. Consequently, the initial focus of restoration efforts should be on these sub-basins. Areas with elevated sediment yield coincide with those facing significant erosion hazards, particularly in sub-basins immediately upstream of the Treng Reservoir, characterized by recent deforestation, forest degradation, and conversion to agricultural land.

SWAT modeling reveals a projected 26% increase in sediment yield by 2055 without landscape rehabilitation, contrasting with a 52% decrease with the adoption of agroforestry in the upper basin.

As a result, the upper basin was chosen to trial four pilot areas. Adaptation options chosen by pilot area communities focus on reforestation, stream rehabilitation, and excluding cultivation from the sites.

However, the pilot sites represent just the initial phase of landscape restoration. The proposed approach outlines the scaling up of the forest and landscape restoration process throughout the entire upper Sangker sub-basin.

Various background factors and drivers influence adaptation planning, including using Community Forests as 'stepping stones,' the role of watercourse stabilization, recent deforestation, sustainable agriculture, extension, training, awareness raising, soil characteristics, nursery development, and water harvesting techniques.

A comprehensive list of potential adaptation options was scored against criteria such as effectiveness in reducing soil erosion and flood damage, enhancing drought resilience, food security, biodiversity, technical capacity and training requirements, and affordability. The subsequent shorter list of prioritized adaptation options considers areas for implementation, and additional requirements such as nursery development, training, market, and value chain development are discussed. The document concludes with reflections on scheduling, monitoring, and evaluation requirements.

Green space. Plants in Oslev demonstration site (photo by ICEM).

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