SOBA 5.1 ECONOMIC VALUATION OF ECOSYSTEM SERVICES IN THE AYEYARWADY BASIN

AYEYARWADY STATE OF THE BASIN ASSESSMENT (SOBA)

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Disclaimer
"The Ayeyarwady State of the Basin Assessment (SOBA) study is conducted within the political boundary of Myanmar, where more than 93% of the Basin is situated."

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NCEconomics

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
AIRBMP	Ayeyarwady Integrated River Basin Management Project
ARB	Ayeyarwady River Basin
BANCA	Biodiversity and Nature Conservation Association
BCA	Benefit Cost Analysis
CSO	Central Statistical Organization
DPSIR	Drivers, pressures, state, impact, response
DWIR	Directorate of Water Resources and Improvement of River Systems
ESV	Ecosystem Value Estimation
FAO	Food and Agricultural Organisation of the United Nations
GDP	Gross Domestic Product
GEP	Gross Ecological Product
GoM	Government of Myanmar
ha	Hectare
HEZ	Hydro-Ecological Zone
HIC	Hydro-Informatics Centre
ICEM	International Centre for Environmental Management
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute
IWT	Inland Water Transport
JICA	Japan International Corporation Agency
KBA	Key Biodiversity Area
kg/ha	kilograms per hectare
kL	Kilolitre
km	kilometre
km^2	Square kilometres
l/p/d	Litres per person per day
LIFT	Livelihoods and Food Security Trust Fund
m	Metres
M&E	Monitoring and Evaluation
MEA	Millennium Ecosystem Assessment
MMK/ha	Myanmar kyat per hectare
MOECAF	Ministry of Environmental Conservation and Forestry
NCEconomics	Natural Capital Economics
NGO	Non-Government Organisation
NWRC	National Water Resources Committee
PEM	Protein-energy malnutrition
PMU	Project Management Unit
SOBA	State of the Basin Assessment
t/ha	Tonne per hectare
TEV	Total Economic Valuation
UN	United Nations

UNESCO-LNTA	United Nations Educational, Scientific and Cultural Organisation-Lao National Tourism Administration
USc	United States cents
USc/kL	United States cents per kilolitre
USD	United States dollar
USD/ha/year	United States dollar per hectare per year
WCS	Wildlife Conservation Society
WHO	World Health Organisation
WTP	Willingness-to-pay
WWF	World Wildlife Foundation

EXECUTIVE SUMMARY

The Ayeyarwady Basin is vitally important to the stock of natural capital[1], the nation's economy, and the livelihoods of the people of Myanmar. If the Ayeyarwady Basin is not well managed, there are significant risks to the physical integrity and condition of the basin's natural capital. The physical impacts of poor management could be profound and will have consequences that interfere with socio-economic values.

Developing an understanding of the economic values attributable to the Ayeyarwady Basin (the ecosystem services) is vital to appreciating the current benefits of good Ayeyarwady Basin management and to providing insight for assessing the planning, management, and investment options for the Ayeyarwady Basin in the future.

This report provides an economic valuation of key ecosystem services in the Ayeyarwady Basin. It covers approaches undertaken to estimate the value of ecosystem services and applies appropriate methodologies to value different ecosystem services for: irrigation, inland water transport, fisheries and aquaculture, potable water supply, biodiversity, and ecotourism. The scope of this assessment is significantly broader than previous economic assessments in Myanmar that focussed on biodiversity. The sectors and ecosystem services assessed were identified as priorities during consultation in August 2017 and relate directly to key departments and their portfolios of responsibility. This ensures our quantitative assessments are more directly relevant to decision-makers and investors.

We estimate the aggregate value of the ecosystem services that we have assessed is in the range of $2.5 billion United States dollars (USD) to USD 6.9 billion per annum. This is shown in Table 1. We have also undertaken a qualitative assessment of the reliability of our range of estimates – how confident we are that the actual value falls within our range presented. This is largely a function of the quality of data inputs. We have used a simple 'traffic light' approach to reflect this, specifically:

(green)	We are reasonably confident in our estimates
(amber)	We are somewhat confident in our estimates
(red)	Treat estimates with extreme care

[1] Natural capital is the stock of natural assets, including soil, water, and all living things (e.g., forests). Humans directly and indirectly derive a wide range of services from the stocks of natural capital, often called ecosystem services, which make human life possible.

Table 1 - Annual value of ecosystem services (NCEconomics estimates)

Ecosystem service	Estimated values (USD million)			Reliability of range of estimates
	Low	Medium	High	
Ecosystem services quantitatively estimated				
Agriculture (irrigation water supplies provisioning services)				
Yield gains in monsoon	29	40	50	
Ability to produce crops outside monsoon	62	91	121	
Freight (inland rivers – modal substitution provisioning services)				
Freight task savings	8	13	23	
Fisheries (protein replacement provisioning services)				
Freshwater capture	350	440	530	
Aquaculture	380	490	600	
Potable water supplies (water quality regulation services only)				
Treated tap water	57	91	125	
Local treatment	129	321	514	
Biodiversity (supporting services)				
Forests	1,300	2,645	4,418	
Wetlands	4	7	10	
Mangroves	146	297	497	
Ecosystem services not quantitatively estimated				
Agriculture (provisioning services excluding irrigation water supplies)				
Soil retention and fertility, nutrient cycling, pollination, pest control, and non-irrigation water.	Insufficient data to value. Likely to be significant across irrigated cropping, dryland cropping, and stock.			n/a
Potable water supply (water provisioning				
Supply of groundwater and surface water (volume) for consumptive use in households (drinking, cooking, personal hygiene, clothes washing, etc.).	Insufficient data on consumption volumes and economic values of alternative water sources (including replacement costs) to develop estimates. Insight from international water supplies suggests these values would be significant (greater than the regulating ecosystem services that have been estimated).			n/a

Flooding (regulating and provisioning services)		
The Ayeyarwady Basin's natural flooding regime (locations, frequency, and extent) results in risks (damage to property, lives, and crops) as well as soil replenishment. Ayeyarwady Basin management will change the flooding regime, the marginal benefits, and the costs attributable to flooding.	Data on locations and extent of flooding available are insufficient to estimate economic values. Values are likely to be significant.	n/a
Hydro-power (intermediate provisioning service)		
River flows, in conjunction with built capital (dams and turbines), provide an intermediate provisioning service to electricity generation. These values would ideally be assessed against any trade-offs relating to specific hydro-projects (e.g., costs of relocating communities).	Insufficient data available on costs of electricity to be supplied and costs of next best substitute to estimate marginal benefit of hydro-power. Values will be project specific. Values are likely to be significant.	n/a
Gravels and natural quarrying products (provisioning service)		
These products are often extracted from riverbeds in the Ayeyarwady Basin for use in building homes, other buildings, and public infrastructure (such as roads and bridges).	Insufficient data on extraction rates, costs of extraction, and costs of substitutes to establish credible estimates at this stage. Values are likely to be significant.	n/a
Ecotourism (cultural service)		
The Ayeyarwady Basin's natural beauty will be one of the drawcards for the emerging tourism industry. This provides a major cultural ecosystem service.	There are insufficient data on tourism and ecotourism, although the sector has significant potential to be a major contributor to economic activity.	n/a
Total ecosystem services	**> 2,464 > 4,435 > 6,888**	

It has been necessary to estimate a range of values for each ecosystem service due to the availability and quality of input data and the need to make assumptions in our economic modelling. Given the numerous types of ecosystem services provided, and the availability of data and resources to generate estimates, several relatively simple economic valuation techniques have been necessary. However, all our estimates are of economic value added attributable to the ecosystem services provided.

Valuation techniques are outlined in Section 2 and the specific chapters relating to key sectors and ecosystem services. Whilst we have a reasonable level of confidence in our range of estimates for most ecosystem services, we are less confident of our estimates relating to biodiversity (that account for more than 50% of the overall estimated value). Furthermore, the economic values of some critical ecosystem services have not been estimated, namely: hydropower, some elements of the country's potable water supply, and the positive and negative elements of floods. Therefore, care should be taken when using these estimates and the limitations of the study should be recognised.

The estimates demonstrate the relative economic importance of ecosystem services. Our current aggregate estimates are equivalent to between 6% and 16% of Gross Domestic Product (GDP) per capita. Given the fact that the scope of ecosystems estimated is relatively narrow, the actual contribution of the ecosystem services is likely to be significantly higher.

The analysis outlined in this report provides important insight and information, but work is still required to enhance and mainstream this economic knowledge into Ayeyarwady Basin planning, management, and ongoing investment.

1 INTRODUCTION

1.1 Overview

The Ayeyarwady Basin is a significant and defining landmark in Myanmar, expanding more than 400,000 square kilometres (km^2) (approximately 59% of the Myanmar's total landmass). Figure 1 depicts the Ayeyarwady Basin, the regions located in the basin, and the major waterways. The population of the Ayeyarwady Basin is approximately 33.2 million or 64% of Myanmar's population (ICEM, 2017a). The Ayeyarwady Basin supports all the key sectors within the country, including agriculture, forestry, fishing, and mining. Figure 2 illustrates land use throughout the Ayeyarwady Basin.

The Ayeyarwady River is the most prominent waterway within the Ayeyarwady Basin, traversing 2,170 kilometres (km) through the centre of the country, flowing north to the south. The river forms the cultural and economic heart of Myanmar, connecting many of the country's diverse cultural groups, from the Kachin State in the upper reaches down to the Ayeyarwady Delta. In addition, the Ayeyarwady River is Myanmar's most important commercial waterway, providing economic benefits through many services, such as enabling the transportation of goods, supporting the delta's growing rice production, and facilitating the emerging tourism industry.

Rapid development within the Ayeyarwady Basin (including along its waterways) has led to concerns about its future. As an example of unsustainable development trends in Myanmar, recent estimates indicate that the country lost 35% of its natural capital between 1995 and 2010 (Emerton, 2013). As such, in recognition of the importance of the Ayeyarwady Basin to Myanmar's development, and the need to develop a sustainable plan for utilising its resources, the Government of Myanmar has received $100 million United States dollars (USD) from the World Bank to plan for the Ayeyarwady Basin's future. The project is titled the Ayeyarwady Integrated River Basin Management Project (AIRBMP).

1.2 Context of this Activity Within the AIRBMP and SOBA

The aim of the AIRBMP is to assist Myanmar in undergoing national and basin water reform. The purpose of the reform is to develop the institutions and tools needed for sustainable and informed management of Myanmar's water resources and implement integrated river basin management for the Ayeyarwady Basin.

A key building block in the development of integrated river basin management for the AIRBMP is the development of a comprehensive environmental, social, and economic baseline for the Ayeyarwady Basin. The baseline, to be documented in a State of the Basin Assessment (SOBA) report, will explore the historical and future trends of key characteristics of the Ayeyarwady Basin and how it is used for the economic benefit of communities and the country. The SOBA report highlights issues, opportunities, risks and uncertainties, to be addressed in the subsequent Ayeyarwady Basin master planning process. To support development of the SOBA report, the AIRBMP has developed six packages of work covering the natural, economic, and social systems of the Ayeyarwady Basin.

This report provides an economic valuation of ecosystem services in the Ayeyarwady Basin and is referenced as SOBA 5.1 (Activity 4).

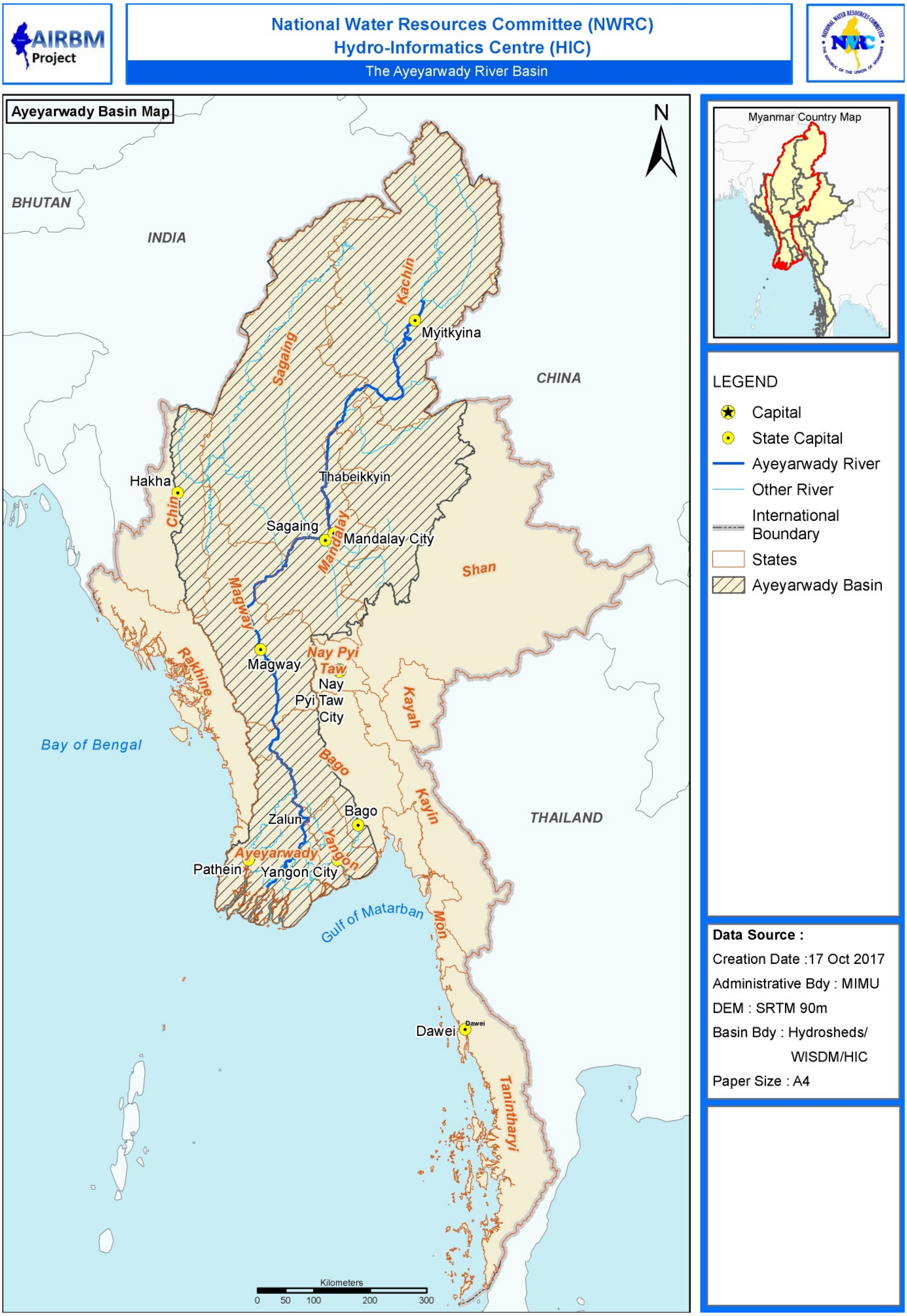

Figure 1 – The Ayeyarwady River Basin

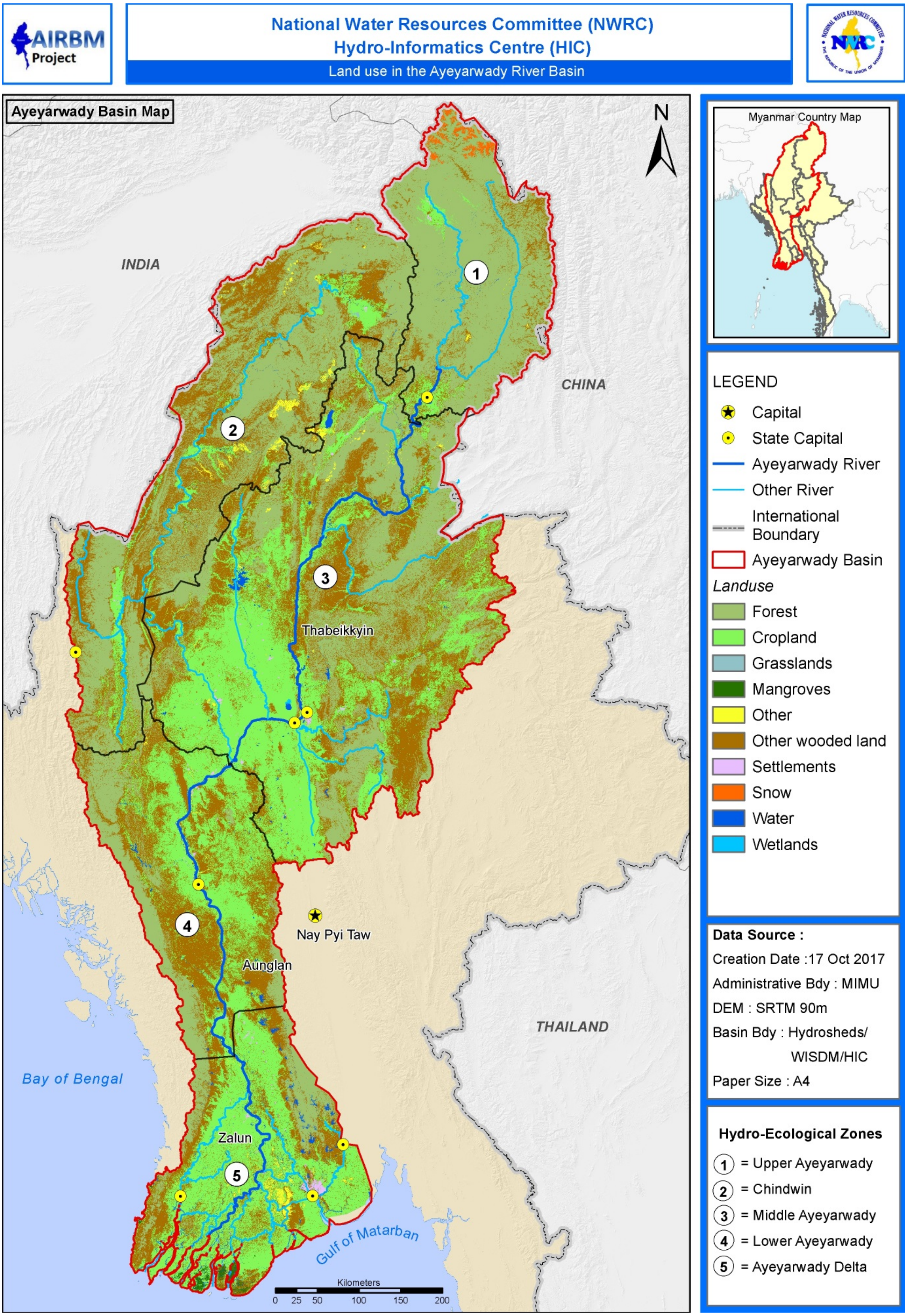

Figure 2 – Land use in the Ayeyarwady River Basin

1.3 The Importance of SOBA 5.1 (Activity 4)

This Activity has been undertaken to assist the Hydro-Informatics Centre (HIC) value the ecosystem services of the Ayeyarwady Basin, so that a quantified understanding of the Ayeyarwady Basin's natural capital can enhance the understanding of its economic production. The valuation will inform decision makers of the estimated values of the numerous ecosystem services within the Ayeyarwady Basin. The ecosystem services quantitatively valued in this report relate to key sectors and include the following:

- Irrigated agriculture
- Inland Water Transport
- Fisheries
- Potable Water Supply
- Biodiversity
- Ecotourism

In addition, several other ecosystem services are identified and scoped. However, there is insufficient data, at this time, to generate quantitative estimates of their values. This work will feed into the development of the Ayeyarwady Basin Master Plan and subsequent components.

1.4 SOBA 5.1 (Activity 4) Objectives

This project has three major objectives:

1. Review the existing information and characterise the state of the ecosystems in the Ayeyarwady Basin that provide important services to market and non-market activities.

2. Review existing ecosystem services valuation methodologies and propose a replicable and defensible approach suitable for Myanmar (taking into account information available in the Ayeyarwady Basin).

3. Undertake a rapid assessment for the Ayeyarwady Basin, quantifying the ecosystem services of the basin and the groups in society reliant on these ecosystem services.

1.5 Snapshot of the Ayeyarwady Basin

Myanmar is the largest country within Southeast Asia at approximately 676,578 km^2. It is bordered by Thailand and Laos to its east, China to its north and northwest, and India and Bangladesh to its west. The Bay of Bengal lines Myanmar's west coast, and the Andaman Sea is to its south. As highlighted previously, the Ayeyarwady Basin is the largest and most economically significant river basin in Myanmar. It is home to a majority of the country's population and contributes significantly to national employment and productivity. Myanmar's rapid growth can be partly attributed to utilising the Ayeyarwady Basin's natural resources. With proper management, the Ayeyarwady Basin can play a pivotal role in improving living conditions for the country's population and underpin sustainable development.

An investigation into the Ayeyarwady Basin's socio-economic themes (SOBA 5) provides a snapshot of its importance:

- The Ayeyarwady Basin has 7.5 million hectares (ha) of agricultural land, approximately 59% of agricultural land nationally.

- Nationally, the Ayeyarwady Basin accounts for approximately 87% of mining activity, with Kachin, Sagaing, and Mandalay accounting for 84% of the national figure.

- The Ayeyarwady Basin holds most the of the country's on-shore energy resources, contributing approximately 40% to national oil production, 45% to national biomass production, and 63% to national hydropower production.

- The waterways of the Ayeyarwady Basin represent approximately 71% of navigable inland water routes nationally.

- From 2014 to 2015, 75% of registered manufacturing enterprises were in Ayeyarwady Basin's states and regions.

1.6 Structure of the Report

This report is structured as follows:

Introduction
Project context and project objectives
Overview of the Ayeyarwady Basin

Ecosystem services
Overview of ecosystem services and how they are valued
Understanding the ecosystem service analysis

Sectoral chapters
Overview of issues
Approach and data sources
Distributional issues
Results
Gaps and implications

Aggregation and conclusions
Major scope limitations
Aggregate estimates of ecosystem values and Gross Ecological Product
Synergies and trade-offs
Monitoring and evaluation
Implications for Ayeyarwady Basin planning

Bibliography

Annex I: Valuation techniques used for economic modelling
Valuation framework and approaches
Overview of valuation techniques
Calculating a social discount rate

Annex II: Overview of previous ecosystem service valuations in Myanmar
Ecosystem services
Literature review (including availability and suitability of data)

2 ECOSYSTEM SERVICES AND THEIR VALUATION

2.1 What are Ecosystem Services? What is Ecosystem Service Valuation?

Ecosystem services are the benefits people obtain from the natural environment (Millennium Ecosystem Assessment [MEA], 2005). MEA (2005) outlines four main ecosystem services. These include the following:

1. Provisioning services – Consist of all the products obtained from ecosystems, such as food, water, and raw materials.

2. Regulating services – The benefits obtained from the regulation of ecosystem processes. In the case of the Ayeyarwady Basin, these include maintaining water quality, flood risk management, climate regulation, waste treatment and disease control, and natural hazard regulation.

3. Cultural services – Related to non-material benefits, such as recreation, tourism, and aesthetic cognitive, and spiritual benefits.

4. Supporting services – Consist of soil formation, photosynthesis, and nutrient cycling. The supporting services category is the basis of the remaining categories. In other words, if supporting ecosystem services cease to function, the other ecosystem service categories (provisioning, regulating, and cultural) can no longer function.

Simply, ecosystem service valuation provides a framework through which an evaluation of the economic benefits for ecosystems can be undertaken. These benefits can then be used to compare the advantages and disadvantages of a given decision. The dollar value of the ecosystem service is presented as a key finding in this assessment.

2.2 Understanding Ecosystem Services and Their Benefits

Table 2 provides examples of the type of ecosystem benefits that are derived from the four main types of ecosystem services.

Table 2 - Overview of ecosystem service types and their benefits (MEA, 2005)

Type	Ecosystem services	Example of provided benefits
Provisioning	Food	Fish, vegetable foods, and rice
	Raw materials	Fuel, wood, charcoal, sand, and gravel
	Genetic/genepool	Biodiversity protection
	Water	Drinking water and irrigation water
	Biogenic minerals	Fossil fuels
	Medicinal resources	Biochemicals
	Energy	Hydropower
Regulating	Carbon sequestration	Carbon sequestration (carbon dioxide storage)
	Climate regulation	Prevention of floods, erosion, extreme events, and storm and coastal protection
	Waste decomposition	Water and air purification
Supporting	Nutrient cycling	The movement and exchange of organic and inorganic matter back into the production of living matter
	Primary production	The synthesis of organic compounds from atmospheric carbon dioxide
	Soil formation	Improved soil fertility on the floodplain
	Biologically mediated habitats	Nurseries and breeding habitats

Type	Ecosystem services	Example of provided benefits
Cultural	Cultural	Books, national symbols, and non-use values
	Spiritual and historical	Heritage value of nature
	Recreational	Ecotourism
	Science and education	Scientific discovery

2.3 Valuation Approaches Relevant for This Project

In undertaking this project, we reviewed the relevant literature relating to the valuation of ecosystem services, consulted widely, and assessed the availability and quality of the data available to underpin our research. The assessment of ecosystem services necessarily requires a range of valuation approaches. As such, a suitable valuation method has been adopted for the analysis of each sector as shown in Table 3. A more detailed coverage of ecosystem service valuation is provided in Annex I, while Annex II summarises our review of previous ecosystem service research relevant to Myanmar.

For some critically important ecosystem services, there is not sufficient data to estimate values at this time. Those ecosystems are shown in shaded rows.

Table 3 - Potential valuation approaches and linkages across the SOBA package of works (NCEconomics)

Type	Example	Valuation approaches and linkages to other soba packages
Provisioning	Irrigated water supply for agriculture	**Crop production function model** to measure the economic value of productivity gains from the availability of water for irrigation. This would require working closely with agricultural experts in Myanmar.
Provisioning	Urban water supply	**Production function approach** to measure the difference between the current costs of supply versus the cost of the next best alternative. This would require working closely with water utilities and establishing economics models for different water supply systems (e.g., large scale and small scale).
Provisioning	Hydro power	**Production function approach** to measure the difference between the cost of hydropower and the next best alternative. This would require consultation with energy agencies and economic modelling for different systems as they are relatively custom-made.
Provisioning	Agriculture (excluding irrigation)	**Production function approach** to measure the net increase in economic value added attributable to soil retention and fertility, nutrient cycling, pollination, pest control, and non-irrigation water.
Provisioning	Household water supplies (volumes)	**Replacement cost approach** to estimate the cost of replacing the supply of groundwater and surface water (volume) for consumptive use in households (e.g., drinking, cooking, personal hygiene, and clothes washing).
Provisioning	Gravel and minerals	**Replacement cost approach** to estimate the cost of replacing materials extracted from riverbeds in the Ayeyarwady Basin for use in building homes, other buildings, and public infrastructure (e.g., roads and bridges).
Provisioning	Commercial and subsistence fishing	**Production function or replacement cost approach** to estimate the economic value of changes in catch rates and production values. There are direct linkages to SOBA 4 for biodiversity and fisheries information and SOBA 5 for demographic and socio-economic condition information.

Regulating	Water quality	**Production function approach** to assess the marginal change in water treatment and delivery costs attributable to changes in water quality. There are direct linkages to Activity 1 and 2 (water resource information) and SOBA 5 (demographics and socio-economic condition).
Regulating	Flooding risk	**Cost avoided**. Scenario modelling of flood mitigation (severity or frequency) and estimate the avoided damage cost. This would involve working closely with government agencies to identify costs of previous flood events. There are direct linkages to Activity 1 and 2 (water resource information) and SOBA 5 (demographics and socio-economic condition).
Cultural	Ecotourism	**Assessment of activity levels** and economic returns to tourism operators (data permitting). Potential for benefit transfer of recreational values where data on recreational use for locals is significant.
Supporting	Biodiversity and habitat	**Benefit transfer.** Typically, the value of many of these services is estimated based on revealed preferences due to the non-market nature of the underlying ecosystem services. This was not possible for this study due to timing and resource constraints. Therefore, a benefit transfer approach was used where a meta-analysis of previous studies was performed, and unit values are applied to physical estimates in the Ayeyarwady Basin.

2.4 Understanding the Ecosystem Service Analysis

While monetary estimates of ecosystem values can be useful during assessments, it should be emphasised that it is not always possible to quantify the value of all ecosystem services with great confidence – and this project is no exception. For example, the analysis undertaken for this project has been constrained, in part, by limited biophysical data recording the extent and condition of ecosystem services provided by the Ayeyarwady Basin. Further, many of the estimates have been derived through issue-specific models and benefit-transfer approaches that have also relied on limited data sources.

3 ECOSYSTEM SERVICE: IRRIGATED AGRICULTURE

The broad significance of agriculture to the Ayeyarwady Basin is summarised in detail in the socio-economic project reports (see SOBA 5; ICEM, 2017d).[2] The agricultural sector derives several ecosystem services from the Ayeyarwady Basin. These ecosystem services underpin productivity and form an intermediate input to agricultural production systems. Key ecosystem services underpinning agricultural production can include soil retention and fertility, nutrient cycling, pollination, pest control, flood control, and water provisioning.

This section covers the ecosystem services attributable to the Ayeyarwady Basin, particularly through the use of irrigation water. The benefit estimation focuses on the additional economic benefits for rice cropping activities and some other crops that are derived through an ability to irrigate in a controlled manner. While the scope of our assessment is not entirely comprehensive, the rationale for focussing on the benefits of irrigation areas is that irrigation is linked to a provisioning ecosystem service that can be actively managed by the Government of Myanmar. Additionally, the sole focus on an irrigation water provisioning service is driven by the difficulty in accounting for other important ecosystem services, such as soil retention due to limited data availability. These ecosystem services are generated in conjunction with the use of built capital, human effort, and investment. This section does not estimate the entire economic benefit of all agriculture on the basin. That analysis is provided in SOBA 5.

3.1 Overview of Issues

Agriculture is a significant contributor to the Myanmar economy. In 2000, the agricultural sector contributed 57.2% to Myanmar's gross domestic product (GDP). However, by 2015, the GDP contribution from the sector had declined to 26.7% before a modest increase in 2016 to 28.2% (see Figure 3). While the proportional contribution to GDP is declining, this is not because the sector is contracting. Rather, it reflects the relatively mature state of the agriculture sector and the rapid growth of other sectors, particularly the service sectors. This is typical in most developing countries. The agriculture sector remains a critical source of food and income for many of the 34 million people in the Ayeyarwady Basin.

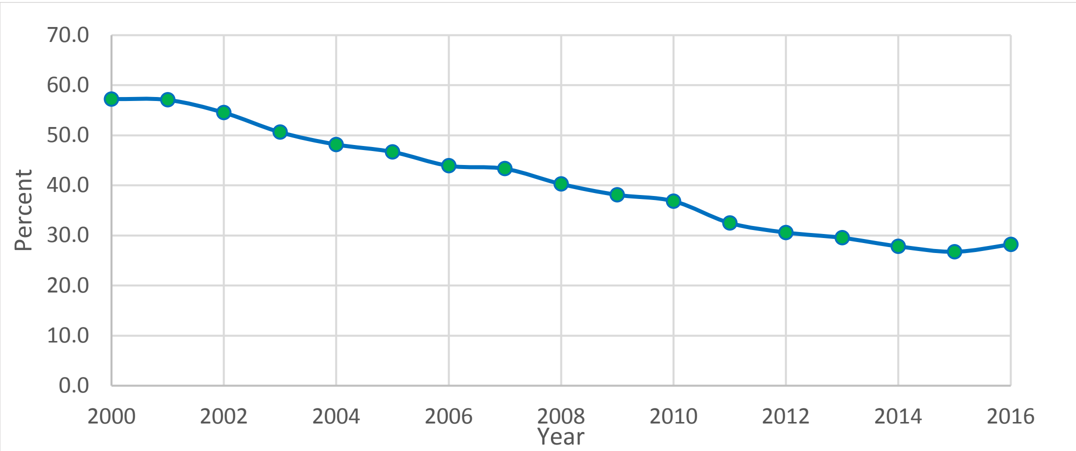

Figure 3 – Agriculture value added to GDP (%) for period 2000 to 2016 (World Bank, 2017b)

[2] It should be noted that some figures in this chapter differ from the ICEM estimates. This is due to differences in geographic scope (Ayeyarwady Basin vs. national data).

An estimated 67% of Myanmar's population resides in rural areas (ICEM, 2017d). The agriculture sector plays an important role for these rural populations as a major source of employment and food. Agriculture, forestry and fishing employ the largest proportion of the population in all states and regions, except in Yangon (ICEM, 2017b). It is estimated that the sector employs more than 60% of the labour force (Lwin, 2015). Thus, many of the rural population are directly affected by severe impacts on agricultural production, such as variability in rainfall and other extreme weather events, and are reliant on maintaining productive agricultural landscapes into the future.

Agriculture in Myanmar is dominated by cropping of rice, but several other crops are also grown. Table 4 provides data on area planted, area harvested yield, and total production for some of the key crops grown in Myanmar, noting multiple crops are produced from much of the paddy area in a given year. Rice is the dominant crop in terms of areas planted and harvested, crop yields per ha, and total production. This reflects the importance of rice as a staple food source and income source for the people of Myanmar.

Table 4 – Myanmar crop statistics (GoM, 2010)

Crop	Planted area (1,000 ha)	Harvested area (1,000 ha)	Yield (tonnes/ha)	Production (1,000 tonnes)
Rice paddy	7,212	7,098	3.99	28,307
Pulses	4,656	4,653	1.37	6,396
Sesame seed	1,640	1,621	0.59	954
Groundnuts	955	952	1.63	1,556
Sunflower	466	466	0.99	459
Pigeon seeds	53	53	1.88	100

The Ayeyarwady Basin is a key region for agricultural production and is often referred to as the 'rice bowl' of Myanmar, with more than 50% of the country's rice production coming from the Ayeyarwady Basin. Figure 4 shows the cropland across the Ayeyarwady Basin, including irrigated cropland. The majority of the Ayeyarwady Basin's cropland is in the central (south of Sagaing City to Magway City) and lower regions (the Ayeyarwady Delta area).

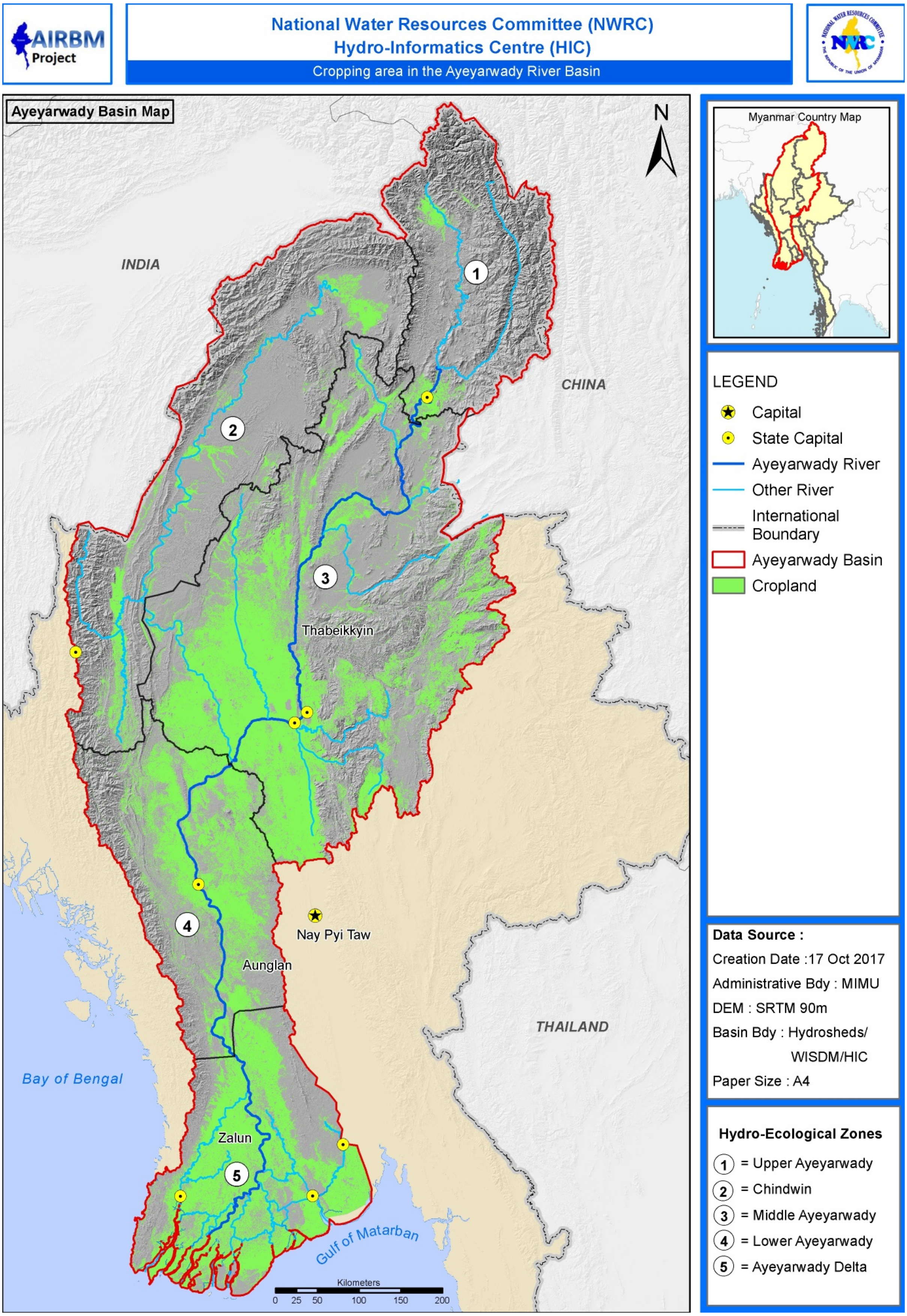

Figure 4 – Cropping area in the Ayeyarwady River Basin

In the monsoon season, farmers tend to grow a primarily rain-fed rice crop. However, some farmers, particularly in the dry-zone areas, often irrigate their monsoon rice crop. Subsequent rice crops in the summer/dry season may also be grown; however, these crops are dependent on irrigation (International Water Management Institute [IWMI], 2015). Due to the limited access to irrigation infrastructure and unstable rice yields (because of insufficient access to water), many farmers are not able to grow the generally preferred rice staple in the dry season, which is why some choose to grow pulses, such as green gram and black gram. A 2016 survey found that in the Ayeyarwady and Yangon areas, 53% of the land parcels were allocated to green gram, while 26% were allocated to rice and 4% to black gram (Cho et al., 2017).

While there is plenty of water in the basin, the use of the water for irrigation is largely limited by the sparse infrastructure. The areas under irrigation in the Ayeyarwady Basin are shown in Table 5 by Hydro-Ecological Zone (HEZ). This includes areas that are under a single, double, or triple crop regime.

Table 5 - Irrigation areas by Hydro-Ecological Zones (HEZ) (ICEM, 2017d)

Land Use	Upper Ayeyarwady	Chindwin	Middle Ayeyarwady	Lower Ayeyarwady	Ayeyarwady Delta
Irrigated - single crop	1,100	10,900	29,700	19,100	529,500
Irrigated - double crop	11,300	156,200	620,600	98,700	711,000
Irrigated - triple crop	400	15,300	36,600	31,000	136,300
Total	12,800	182,400	686,900	148,800	1,376,800

According to a survey by Cho et al. (2017), 83% of farmers in the Ayeyarwady and Yangon Regions reported growing crops in the dry season. The main crop grown in the dry season was green gram (53% of land parcels), paddy (23%), and black gram (4%). An estimated 19% of the land parcels were left uncultivated in the dry season (Cho et al., 2017). The average paddy yield in the dry season was 3.82 tonnes per hectare (t/ha) (Cho et al., 2017). Denning et al. (2013) found that irrigation plus related drainage structures help to stabilise production and reduce the risk of flooding. Therefore, access to irrigation has two key benefits for paddy growers: 1) an increase in yield for the wet season crop due to availability of reliable water, and 2) the ability to grow subsequent paddy crops in the dry season. However, consultation with stakeholders revealed that the protection of irrigation land from floods has an unintended consequence of limiting the replenishment of soil nutrients from flooding. In effect, achieving an irrigation ecosystem service can come at the expense of another important service (nutrient replenishment of the soil).

3.2 Approach and Data Sources

An analysis was undertaken to estimate the value of the Ayeyarwady Basin's irrigation water to the agricultural sector. The analysis was undertaken by estimating the value of additional rice yield from irrigated land parcels in the monsoon season and the ability to grow subsequent crops in the dry season. Data used for estimating the value of irrigation water came from a range of sources, including articles and datasets published by the World Bank, the Food and Agriculture Organization of the United Nations (FAO), the IWMI, and academic journals.

In our analysis, we have focused on the value added created by using irrigation water to increase the production of key crops – a provisioning ecosystem service. Specifically, we focused on the value added from the use of irrigation water as an intermediate input to rice production, where the net increase in value added (increased revenues less increased costs) from applying irrigation water provides a proxy measure of the ecosystem service attributable to the water's use. A production-based economic model was developed. The model used available data to estimate the change in yield for rice and other staples (green gram and black gram). Within this model:

- Yield and production gains per ha attributable to irrigation were calculated. This includes yield gains from irrigating in the monsoon season and rice cropping in the dry season.
- Yield gains were multiplied by proceeds received by farmers to estimate marginal changes in revenue per ha.

- Marginal changes in production costs (e.g., labour inputs and fuel) were also calculated, reflecting the additional inputs required to manage irrigation and harvest the additional yield.
- Net changes in value added per ha were estimated.
- Per ha estimates were aggregated to total estimates for the Ayeyarwady Basin, using available statistics on irrigation areas (monsoon, 2nd crop in dry season, 3rd crop in dry season).
- As with all variables, a range of input data and assumptions were used. Therefore, a range of estimates are produced through the modelling.

Table 6 and Table 7 provide a summary of the key assumptions and input parameters used to estimate the benefits of using the Ayeyarwady Basin's water for irrigation. These assumptions and estimates are for rice cropping.

Table 6 - Summary of key assumptions used to estimate the benefit from gains in the monsoon rice yield

Benefit 1: Monsoon rice yield gain		
Variable	**Assumption**	**Source**
Yield with no irrigation	2,456 kg/ha	World Bank (2016), average monsoon yield for 5 eco-regions in Ayeyarwady and Sagaing. Sensitivity analysis was conducted one standard deviation each side of the mean from the available data.
Rice yield gain with irrigation	5.1%, 6.8%, 8.5% (range for sensitivity analysis)	Based on a study of yield benefits before and after a household had access to Swar Dam irrigation water in Yedashe (Oo et al., 2017). High (8.5%) and low (5.1%) gains to enable sensitivity analysis.
Price	180 MMK/kg	Monsoon price averages for Ayeyarwady and Sagaing (World Bank 2016).
Additional fuel, harvest and post-harvest cost	2,227 MMK/ha	World Bank (2016), Based on ratios and averages from 5 ecoregions in the Sagaing and Ayeyarwady regions.

Notes:
kg/ha = kilograms per hectare
MMK/kg = Myanmar kyat per kilogram
MMK/ha = Myanmar kyat per hectare

Table 7 - Summary of key assumptions used to estimate the benefit from dry season rice cropping

Benefit 2: Dry season cropping		
Variable	**Assumption**	**Source**
Yield	3,004 kg/ha	Average dry season yield in Ayeyarwady and Sagaing (World Bank, 2016).
Price	199 MMK/kg	Average price for the dry season rice in Sagaing and Ayeyarwady (World Bank, 2016).
Variable costs	493,064 MMK/ha	Average total costs per hectare for the dry season based on total costs from the Ayeyarwady and Sagaing Regions (World Bank, 2016).

In addition to the possible increases in rice production due to irrigation, the model developed for this project can also incorporate an opportunity cost of non-rice crops that are displaced by irrigated rice. Specifically, this includes green gram and black gram. Key parameters are outlined in Table 8 and Table 9. However, because such large areas of cropping land are left fallow during the dry season anyway, it is relatively unlikely that current irrigation areas are materially displacing green gram and black gram at a national scale.

Table 8 - Summary of key assumptions used to estimate the benefit from dry season green gram cropping

Opportunity cost: Dry season green gram cropping		
Variable	**Assumption**	**Source**
Yield	970 kg/ha	Average for green gram in Sagaing and Ayeyarwady (World Bank, 2016).
Price	943 MMK/kg	Average price for green gram in Sagaing and Ayeyarwady (World Bank, 2016).
Cost	283,446 MMK/ha	Average total costs per hectare for the dry season based on the total costs from Ayeyarwady and Sagaing Regions (World Bank, 2016).

Table 9 - Summary of key assumptions used to estimate the benefit from dry season black gram cropping

Opportunity cost: Dry season black gram cropping		
Variable	**Assumption**	**Source**
Yield	783 kg/ha	Average for black gram in Sagaing and Ayeyarwady (World Bank, 2016).
Price	607 MMK/kg	Average price for black gram in Sagaing and Ayeyarwady (World Bank, 2016).
Cost	202,331 MMK/ha	Average total costs per ha for the dry season based on total costs from Ayeyarwady and Sagaing Regions (World Bank, 2016).

3.3 Results

The gains in economic value added from rice production in the Ayeyarwady Basin attributable to irrigation provide a proxy estimate of the ecosystem service to agriculture. The value added that we have estimated are net of any additional input costs associated with irrigation (capital and incremental increases in fixed and variable operating costs). Our estimates are shown in Table 10.

Table 10 - Estimated annual gains in economic value added from irrigation (USD million) (NCEconomics)

Increase in value added	Low	Medium	High
Yield gains in monsoon	29	40	50
Ability to produce crops outside monsoon	62	91	121
Total	91	131	171

Using the base assumptions, it is estimated that the value of access and use of irrigation water in both the monsoon and dry seasons is worth between USD 91 and 171 million per year (2017 dollars). Thus, there are significant economic benefits that are gained by local communities who have access to irrigation water to be able to grow crops more than one season per year. The local communities also benefit from higher yields in the monsoon season. Such gains help to boost employment, incomes and food security year-round. However, appropriate strategies must be established to protect the ongoing health and therefore productivity of the soils.

3.4 Distributional Consequences

Most of the farms in the Ayeyarwady Basin are considered small. An estimated 45% of the farming households own less than 5 acres (approximately 2 ha) of land. There are also issues of unequal land distributions. A third of the population with the smallest farms in Ayeyarwady and Yangon regions own just 3% of the cropland (Cho et al., 2017). These small landholders largely rely on agriculture for subsistence living. Thus, to best benefit the most vulnerable, any irrigation infrastructure should seek to address these inequalities. This is particularly important because a significant proportion of the population is reliant on these small farms for both family food security and some limited cash crop income. A survey in Sagaing, Magway, and Mandalay found that 62% of the respondents derived their income from the agricultural sector and that the poorest households were more reliant on agriculture for income (LIFT, 2012).

Access to the Ayeyarwady Basin's irrigation water has direct and indirect benefits for the population. Direct benefits are those accruing to local farmers who utilise the water to grow more crops in a year and any yield gains. These types of benefits will accrue to both subsistence and commercial farms with access to irrigation infrastructure. However, it is likely that the indirect benefits could be larger than the direct benefits (Hussain, 2007). Indirect benefits are all other benefits from irrigation less those accruing to the farmer. Indirect benefits accrue to the country as whole or to certain individuals or groups in the country. For example, increased land productivity to meet local and export demand at competitive prices benefits the whole country. Agricultural production risk (due to rainfall instabilities and droughts) is also mitigated by access to irrigation. This stabilises supply and, to a certain degree, the price of food. This is particularly important for staples, such as rice. Individuals or groups that enjoy indirect irrigation benefits include farm input suppliers (e.g., from an additional 2nd crop), farm produce handlers (e.g., exporters), farm labourers (e.g., extended employment days and reduced income variability), and consumers (e.g., improved food security).

While Myanmar produces surplus rice, there are still states and regions that produce less than their consumption amounts. For example, Chin, Magway, Mandalay, and Yangon produce 62%, 85%, 56%, and 86%, respectively, of their rice consumption, (ICEM, 2017d). Continued surplus rice and other crop production in Myanmar relies on sustainable production practices and access to irrigation water. Food security is heavily reliant on rainfall, and thus, dry spells have rapid and precarious impacts on food security for farming households (IWMI, 2015).

3.5 Gaps and Implications

Data availability was a key issue in estimating the value of access to Ayeyarwady Basin water for agricultural activities. Such data included detailed data on crop areas, yields, and costs for rice and non-rice crops that benefit from irrigation. Improving these data would significantly improve the understanding of the value of ecosystem services attributable to irrigation.

It would also be helpful to have more specific data on actual locations where irrigation infrastructure is available, including mapping of paddy areas and areas under other irrigated crops. When all other crops are considered, the estimated value should be higher, but rice is likely to still be the main source of irrigation benefit, because rice is more widely grown in the Ayeyarwady Basin than any other crop.

The design and establishment of formal irrigation areas can reduce the likelihood of beneficial flooding of production areas that can replenish soils and improve crop yields. Consultation with relevant departmental officials indicated that this was an area needing further research. This would also provide important insight into understanding the actual value added from irrigation.

Climate change is likely to exacerbate weather and climate risk for the agriculture industry in Myanmar. Access to irrigation water will becoming important to stabilise farm outputs in the monsoon and dry seasons. For example, issues with late rains can be overcome by drawing water from water supplies. However, such actions must be undertaken with the consideration of the impacts on the environment and the overall community socio-economic outcomes. This is particularly so with the Ayeyarwady River, because it is a key driver for different industries, including fisheries, transport, and ecotourism.

4 ECOSYTEM SERVICE: INLAND WATER TRANSPORT

This section briefly summarises the ecosystem services of the Ayeyarwady Basin's main rivers used for transport. Undertaking any transport task requires the input of machines (e.g., boats, trucks, and locomotives) and infrastructure (e.g., docks, roads, and rail systems). The Ayeyarwady River and its tributaries are to inland water transport (IWT) what the rail and road networks are to rail and road transport. The rivers are natural capital that, in conjunction with built capital (boats and ports), provide an alternative means of transporting people and freight around the Ayeyarwady Basin.

4.1 Overview of Issues

A broad overview of the transport sector is provided in the socio-economic SOBA reports (SOBA 5; ICEM 2017e). The commentary below outlines some of the critical issues relevant to understanding the ecosystem services attributable to Inland Water Transport.

4.1.1 Inland water transport

There are approximately 5,000 km of navigable waterways in Myanmar, and 2,400 km of these make up the primary inland waterway network. Almost all of the navigable inland waterways in Myanmar are in the Ayeyarwady Basin. The IWT system is primarily managed by the IWT Department. Built infrastructure includes the major ports of Yangon and Mandalay and a number of smaller regional ports, such as Megwa and Bhamo (northern most port). The total carrying capacity of the Myanmar IWT fleet is 70,000 tonnes across 240 vessels. Dominant commodities identified in official statistics include rice, cement, coal, grains, and fuel; however, most freight is counted as 'miscellaneous,' indicating the diversity of the goods freighted. There are a number of documented deficiencies in the port infrastructure, particularly relating to the lack of port and dock infrastructure to handle larger and more bulky items. In addition, the vessel fleet (passenger and freight) is aging and in need of refurbishment or replacement. These deficiencies are a major reason why the Myanmar IWT modal share has declined in recent years.

4.1.2 Road transport

Myanmar has 130,000 km of roads in total. The road network remains the primary means of transport. The core road network (38,000 km) provides access to most of the country's regions and nearly half of these are paved to all-weather standards. Nonetheless, the road density is low, at 40 km per 1,000 km^2, compared to other countries, such as Vietnam (480km^2) and Thailand (350km^2). There are a number of public and private road transport providers for both passengers and freight. Road transport has a major advantage over IWT as it is generally quicker and often does not require expensive changes of mode (e.g., road-river-road for a single transport task).

4.1.3 Rail transport

At present, the length of the railway network is approximately 4,000 km, which includes 926 stations after a period of significant expansion in recent years. Most of this expansion took place in remote regions of the country to improve connectivity and accessibility across the country's transport infrastructure. Nonetheless, there have been limited funds to maintain and improve the new rail network as many of these are in remote and mountainous areas. Also, the new railway lines have so far carried limited traffic. Many of the older parts of the rail network need maintenance and modernisation.

Figure 5 shows major road, rail, and river transport corridors.

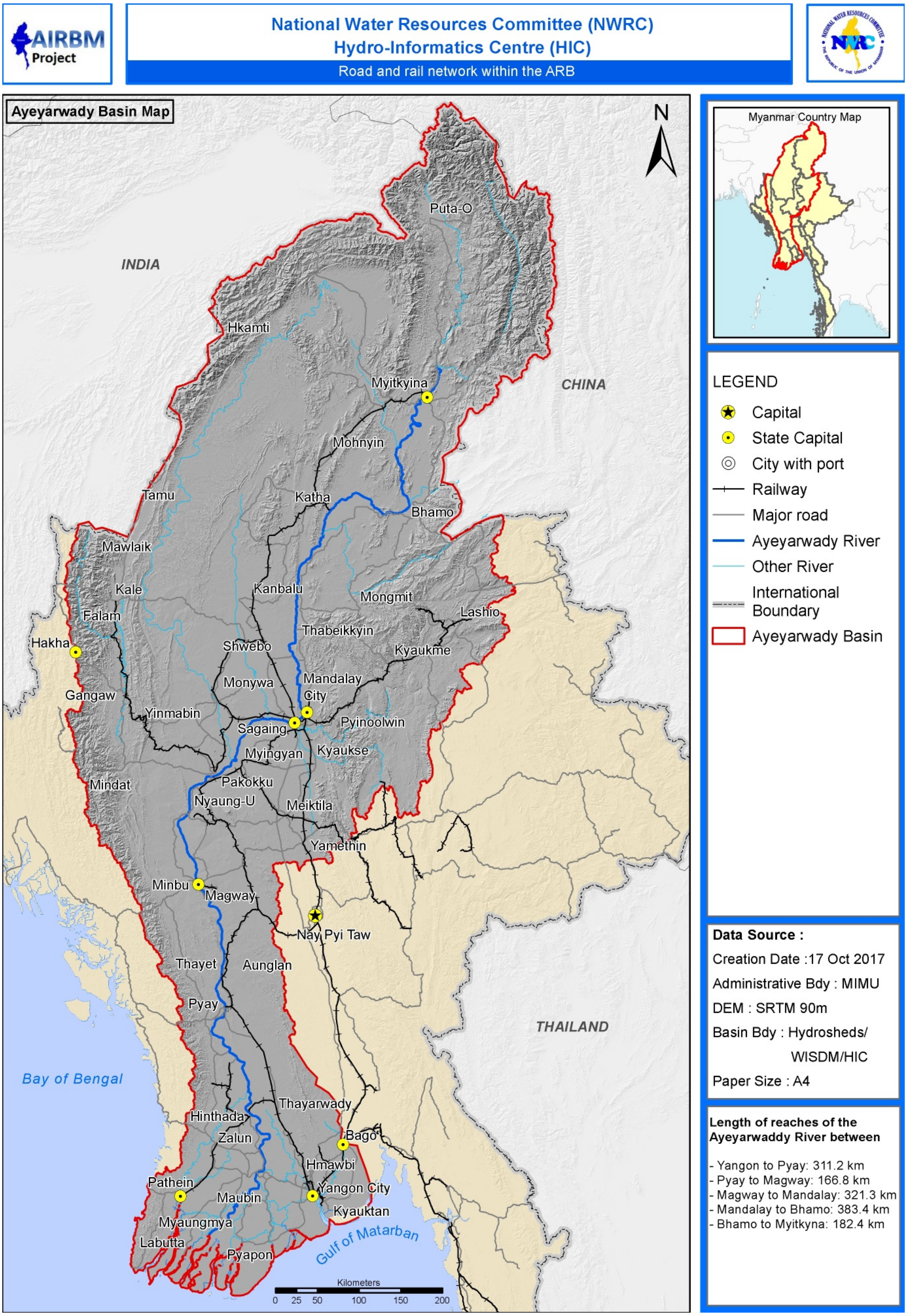

Figure 5 – Road and rail network within the Ayeyarwady Basin

4.2 Approach and Data Sources

The rivers of the Ayeyarwady Basin provide an important provisioning ecosystem service to the transport industry by providing navigable waterways for passenger and freight vessels. To the degree that IWT provides for passenger and freight transport tasks at a lower economic cost than other modes, the cost savings can be attributable to the ability to utilise rivers as transport infrastructure. These economic savings are a form of a provisioning ecosystem service.

The main sources of information for this assessment are the following:

- Statistics on the annual passenger and freight transport tasks for IWT and viable alternative modes (road and rail transport).
- The relative economic costs of transport for the different modes.
- Insight and data provided by the IWT Department, one of the enterprises under the Ministry of Transport and Communications.

4.3 Results

4.3.1 Passenger transport estimates

From 2010 to 2015, total passenger km on inland waterways averaged approximately 610 million (or 9%) of a total passenger transport task of approximately 6.2 billion passenger km (Central Statistical Organization [CSO], 2015). Figure 6 shows the official statistics for modal share for 1995 to 1996, 2000 to 2001, 2005 to 2006, and for the period of 2010 to 2015. The key points to note are:

- There is a significant degree of variability in the market shares for each mode when comparing individual years. The standard deviation of estimates for the period 2010 to 2015 is 300 million passenger km. It is unclear whether this is due to actual short-term modal choice variations, sampling errors in the data, or a combination of the two.
- While the market share of the inland river passenger transport has averaged 9% in the latest 5 years of data available, the trend shows a decline. This is likely to be in response to several drivers including: improvements to road and rail services in recent years that have changed relative travel times, and relative prices of different modes and differences in passenger comfort. Consultation revealed that the river passenger fleet delivers relatively low levels of comfort due to the condition of the fleet.
- It should be noted that the market share of IWT is higher than other survey-based estimates developed by Japan International Corporation Agency (JICA) that indicate river transport is approximately 2% of the total passenger transport task of Myanmar. However, for our analysis we have used the official statistics, because the JICA estimates are based on surveys that do not necessarily capture the total transport task.

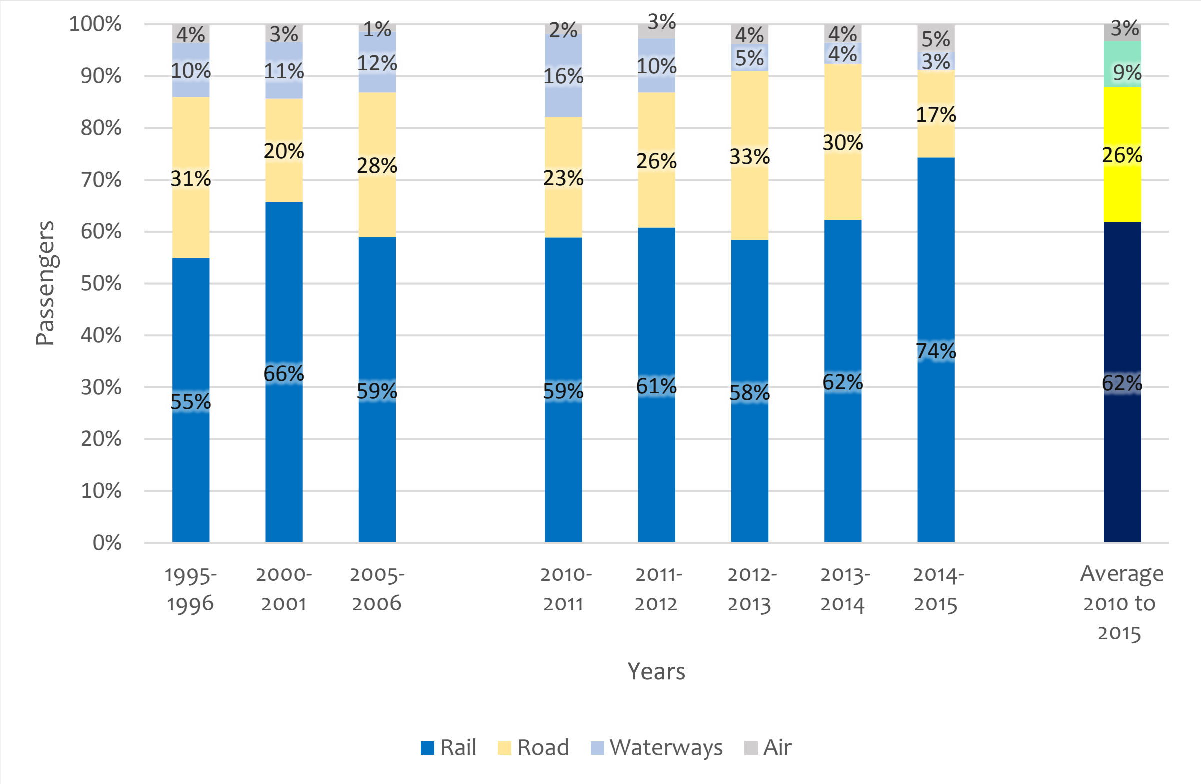

Figure 6 – Passengers proportions per transport mode (CSO, 2015)

4.3.2 Freight estimates

For internal river freight (excluding direct imports and exports from coastal ports) for the period 2010 to 2015, total freight tonne kilometres on inland waterways averaged approximately 700 million (32%) of a total internal freight transport task of approximately 2.2 billion tonne kilometres. Figure 7 shows the official statistics for modal share for 1995 to 1996, 2000 to 2001, 2005 to 2006, and for the period of 2010 to 2015. The key points to note include the following:

- There is a significant degree of variability in the market shares for each mode when comparing individual years. The standard deviation of estimates for the period 2010 to 2015 is 295 million freight tonne kilometres. Similar to passenger freight, it is unclear whether this is due to actual short-term modal variations, sampling errors in the data, or a combination of the two.

- The market share attributed to IWT has averaged 32% and is typically within the range of 26% to 35% (with the exception of 2010 to 2011 when the reported market share was 43%).

- It should be noted that the market share of IWT is higher than other survey-based estimates developed by JICA.

Other research undertaken by JICA and used by the Asian Development Bank (ADB) for transport modelling suggests that modal share of river freight is highest in a small number of corridors, specifically the Magway-Mandalay, Mandalay-Tamu, Yangon-Pathein, Yangon-Pyay-Magway, and Mandalay-Myitkyna.

Based on the data presented below, we have assumed annual average freight tonne kilometres are currently 700 million.

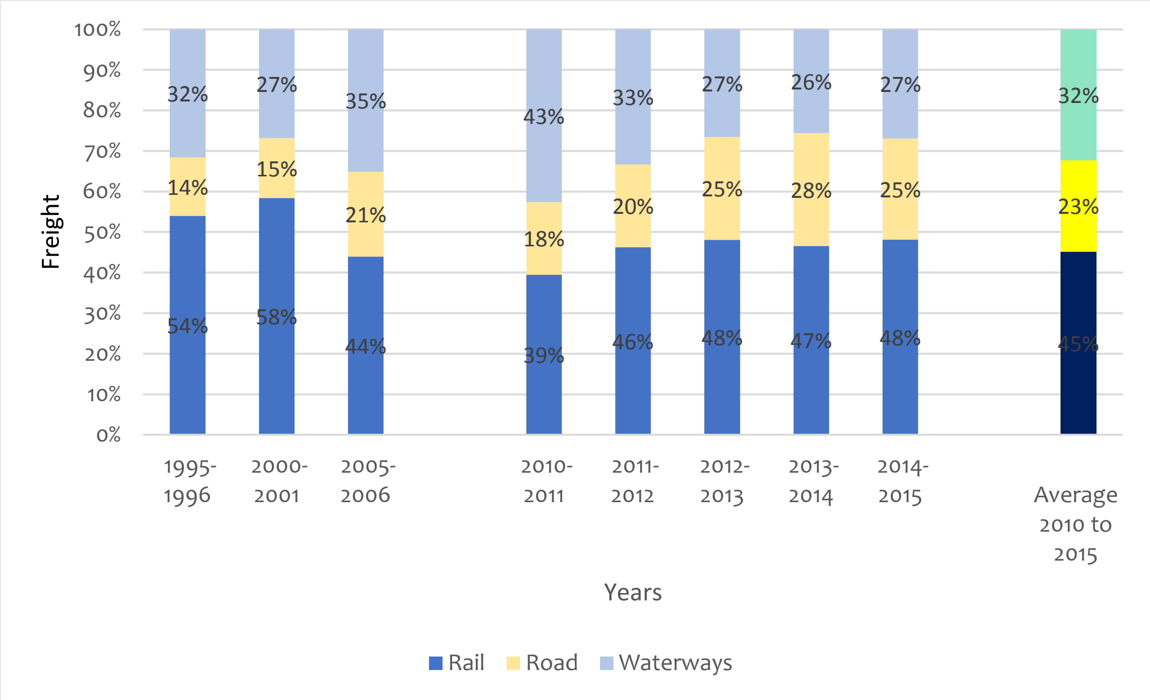

Figure 7 – Freight proportions per transport mode (CSO, 2015)

4.3.3 *Comparison of modal costs*

The difference in marginal costs between river-based transport and other competing modes needs to be estimated to determine the value of the transport ecosystem services of the rivers within the Ayeyarwady Basin. To ensure estimates across modes are comparable, all fixed, variable, and other costs needs to be incorporated. This includes the following:

- Infrastructure costs – This is the cost of fixed infrastructure required to underpin the transport task. This includes costs, such as road infrastructure, rail infrastructure, and ports.
- Fixed costs – These are the fixed costs of transport operations, such as scheduled maintenance, and management.
- Vehicle capital costs – These are the costs associated with vehicle ownership, including depreciation and interest payments.
- Variable costs – These are the costs of transport service provision that change with the amount of transport activity, such as distance travelled and volume of freight. Examples include fuel and casual labour.
- Carbon emissions – These are valued at $36/tonnes, representing the full social cost of carbon emissions (US Government, 2016).

4.3.4 *Passenger costs*

The cost analysis presented in Figure 8 for passenger services is an updated version of a major bottom-up costs exercise undertaken by the ADB (ADB 2016). We have also included the costs of carbon emission for completeness.

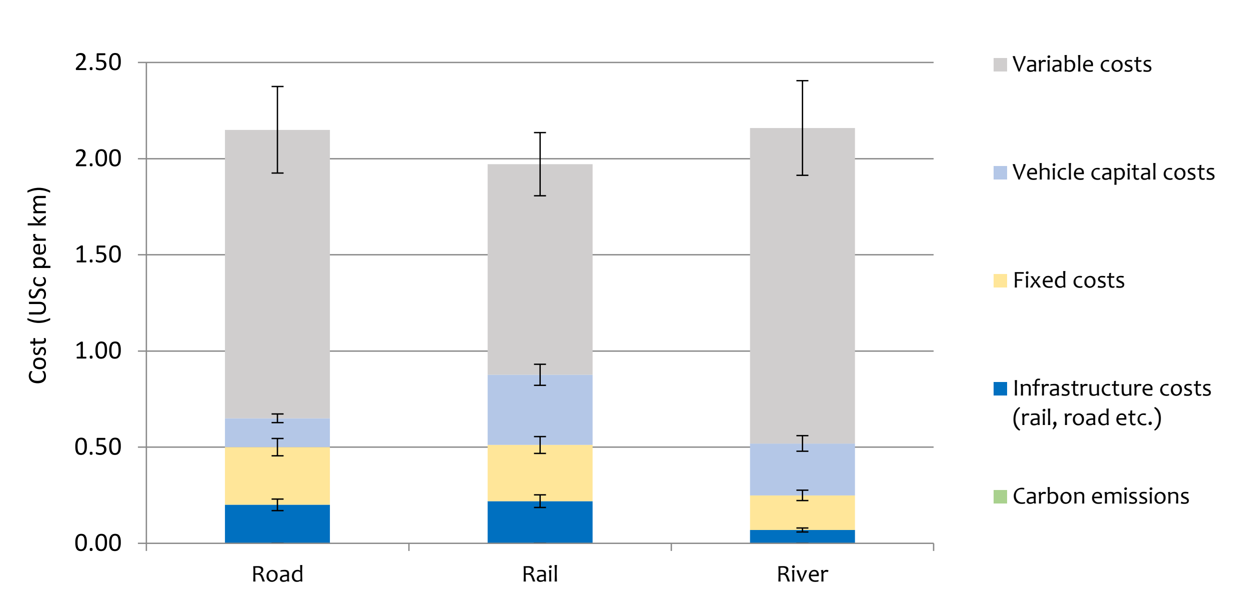

Figure 8 – Economic costs of passenger movements (USc per passenger kilometre) (NCEconomics estimates)

The key points to note from the analysis are the following:

- Rail transport generally has the lowest overall costs per passenger kilometre, while road has the highest costs. While rail and ferries exhibit lower costs, road transport is becoming more prominent as travel times become more important to decision makers. This is one of the key drivers of the modal shift.
- Variable costs dominate the costs for all modes, but particularly for road and boat transport that tend to use higher fuel inputs per passenger kilometre.
- Road and rail fixed infrastructure is relatively significant and should be included in the analysis. For river transport, these costs are lower.
- There is a degree of variability and uncertainty in the estimates as indicated by the error bars. There are multiple drivers of this variation, including trip distance, region (costs are generally higher outside the Yangon-Mandalay corridor), vehicle scale (bus, train, vessel), and the quality of the input data used.

Key costs are also shown in Table 11. It should be noted that while the table shows no cost for carbon emissions, this is due to the scale at which the data are presented (i.e., cost per passenger kilometre). However, the inclusion of carbon costs in the modelling result in significant cost for the annual whole transport task. Based on the tabulated data below, it has been assumed that costs for passenger transport per passenger kilometre are 2.2 cents (road), 2.0 cents (rail), and 2.1 cents (river).

Table 11 - Estimated cost components of passenger transport (cents per passenger kilometre) (NCEconomics estimates)

Cost component	Road	Rail	River
Carbon emissions	<0.0	<0.0	<0.0
Infrastructure costs (e.g., rail, road)	0.2	0.2	0.0
Fixed costs	0.3	0.3	0.2
Vehicle capital costs	0.2	0.4	0.3
Variable costs	1.5	1.1	1.6
Total	**2.2**	**2.0**	**2.1**

4.3.5 Freight costs

Costs analysis for freight transport is shown in Figure 9. The approach used to develop the estimates is the same as for passenger transport although the measure for comparisons is in tonne kilometres. The key points to note from the analysis are the following:

- River transport costs are significantly lower than rail costs (2.1 cents compared to 3.4 cents per tonne kilometre), which are also lower than road transport costs (4.9 cents). While river and rail freight both exhibit lower costs, road is often preferred as it enables a door-to-door service without the need for changing modes and double handling, which may be required using river or rail transport (when the final destination is not adjacent to a port or rail line). This is one of the key drivers of the modal shift toward road freight in recent years.

- Variable costs dominate the costs for all modes.

- Road and rail fixed infrastructure are relatively significant and should be included in the analysis. For river transport, these costs are lower, largely a reflection of the fact that rivers are natural capital.

- There is a degree of variability and uncertainty in the estimates, as indicated by the error bars. There are multiple drivers of this variation, including trip distance, topography, region, and the quality of the input data used.

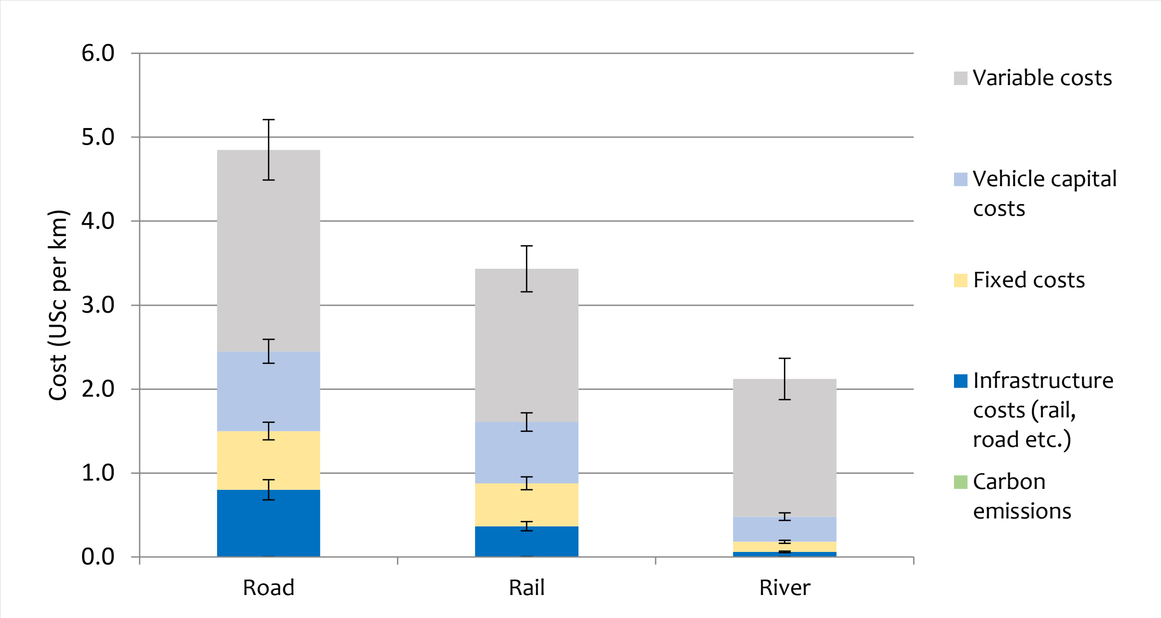

Figure 9 - Economic costs of freight movements (USc per tonne kilometre) (NCEconomics estimates)

Key costs are also shown in Table 12. It should be noted that while the table shows no carbon cost, this is due to the scale of the data presented (i.e., cost per tonne kilometre). However, the inclusion of cost in the aggregate modelling results in a material measure at the national scale for the whole transport task. Based on the above data, we have assumed costs for freight transport per tonne kilometre are 4.9 cents (road), 3.4 cents (rail), and 2.1 cents (river).

Table 12 - Estimated cost components of freight transport (cents per tonne kilometre) (NCEconomics estimates)

Cost component	Road	Rail	River
Carbon emissions	<0.0	<0.0	<0.0
Infrastructure costs (e.g., rail and road)	0.8	0.4	0.1
Fixed costs	0.7	0.5	0.1
Vehicle capital costs	1.0	0.7	0.3
Variable costs	2.4	1.8	1.6
Total	**4.9**	**3.4**	**2.1**

Using estimates of freight transport tasks and marginal freight costs, the economic modelling demonstrates significant savings attributable to the ability to utilise the river network when compared to other modes. This provides a proxy estimate for the ecosystem service and is shown in Table 13. We estimate that the annual value of the ecosystem service is in the range of USD 7.8 to 22.7 million. Our medium estimate is based in the current modal share and marginal costs for each mode and equates to USD 12.6 million.

Table 13 - Estimated annual freight cost savings (USD millions) (NCEconomics estimates)

Cost component	Low	Medium	High
Freight task savings	7.8	12.7	22.7

It should be noted that these costs do not include the potential avoided future costs for road and rail augmentations. If these costs were known and incorporated, the economic estimates would be higher.

While the costs of any double handling attributable to modal shift are not included, given the fact that significant volumes of freight are still moved by IWT, it can be assumed that those costs are already embedded into modal choices.

4.4 Distributional Issues

Modal choice for both passenger and freight transport will typically be made on the basis of timing, price, and other consumer-driven parameters across the entire transport task (including the need for changing modes).

Maintenance of reliable inland water passenger transport services is vital for people along the river systems, because these services provide a convenient and affordable service, often to sections of the population that cannot afford more expensive modes. Furthermore, it is often easier to also carry small freight items on IWT passenger services. The continuation of affordable IWT passenger services, underpinned by ensuring safe river passages, will be a vital pro-poor policy moving forward.

For freight services, to the extent that IWT offers a lower cost alternative to other transport modes, this will benefit both the user of the transport services and the end consumer of goods that are shipped. In effect, the benefits are more diffuse than the benefits to passenger transport.

4.5 Gaps and Implications

The estimation of the ecosystem values of the Ayeyarwady Basin for IWT have been developed using limited data sources. More regionally, specific transport tasks and cost data would enable significant improvements in the estimates. However, given that the Ayeyarwady Basin covers most of Myanmar’s IWT systems, we conclude it reasonable (given the data available) to assume that the ecosystem value estimates cover most of the relevant transport activity.

Improving Ayeyarwady Basin management, specifically actions to reduce sediment generation, maintenance of channels, and improving port infrastructure (built capital to complement the natural capital of river systems) will ensure ecosystem services can be realised in the long-term.

5 ECOSYSTEM SERVICE: FISHERIES

Fisheries, including aquaculture, are a major industry in the Ayeyarwady Basin, providing an important and affordable source of protein to the people of Myanmar. This section briefly outlines the linkage between the Ayeyarwady Basin and the fisheries ecosystem services. This section draws on the detailed analysis of the sector undertaken for SOBA 4 and that technical analysis is not repeated here.

5.1 Overview of Issues

The Ayeyarwady Basin provides habitat and nursery services for a number of Myanmar's key fisheries, including the Ayeyarwady River capture fishery and the majority of aquaculture operations in the country. These fisheries, in turn, play an important role in Myanmar for food security (providing approximately 67% of animal protein for a typical Myanmar diet) as well as livelihoods (some 3.2 million, or 6.3% of the total population of Myanmar, are directly employed in the fishery and aquaculture sector).

Changes in the quality of the Ayeyarwady Basin are likely to have a material impact on fishery productivity and, in turn, food security outcomes/livelihoods for the people of Myanmar. Where fisheries and aquaculture productivity decline significantly due to declines in the condition of the Ayeyarwady Basin, consumers would need to find a replacement source of protein. Where substitute proteins are more expensive, there will be a reduction in consumer surplus (benefits of fish consumption less the costs of acquiring fish) attributable to protein consumption. This is the direct economic impact of a loss of fisheries productivity to consumers.

In addition, there are potential health impacts from substituting protein sources that would be dependent on what substitutes are used. Health-related impacts of protein substitution include the following:

- For middle-income households, a shift in consumption toward more packaged-processed proteins (such as tinned fish or tinned meat) and chicken is expected. These substitute proteins are much higher in sodium (a major contributor to hypertension) and fat (compared to fresh fish). Impacts would be increased incidence of hypertension and cardiovascular disease, which are already high amongst the adult population (at 23%) and is the most significant food-related risk factor in Myanmar (World Health Organisation [WHO], 2014).

- For lower-income households and households whose livelihoods are affected by reduced fish productivity, food consumption patterns would be expected to shift toward more noodles and rice (non-protein, low nutrition value) as these households cannot afford more expensive protein substitutes. This dietary change would contribute to greater protein-energy malnutrition and associated stunting and 'wasting' amongst children – which already affects more than 40% of the children under 5 years. It would also contribute to higher rates of iron-anaemia, which is occurring in almost 60% of children (WHO, 2014).

Negative health outcomes have a wider impact on the economy. The economic costs of health impacts include direct costs, such as the increased burden on the health care system, and indirect costs of lost (labour) productivity.

5.2 Approach and Data Sources

The Ayeyarwady Basin provides two key interrelated categories of ecosystem services relating to fisheries:

- Firstly, the Ayeyarwady Basin is significant habitat for the inland fishing and aquaculture sectors. This, in conjunction with human effort and built capital (e.g., fishing boats and aquaculture pond infrastructure), provides a significant source of protein for human consumption. This source of protein also has secondary benefits to the community in terms of improving productivity and health outcomes. This is a provisioning ecosystem service.

- Secondly, the biodiversity of fish also has an inherent value, a supporting service underpinning the ecological integrity of a major component of the Ayeyarwady Basin.

The provisioning service is the primary focus of this chapter. After a review of the limited data available, it was revealed that while there are updated estimates of catch volumes, there are no credible data on catch effort or costs. Therefore, the only feasible means to assess the value of the provisioning service is through an assessment of the replacement cost of the protein. To do this, we have used existing estimates of catch volumes (tonnes) and multiplied the volume by the incremental cost of replacing fish protein with the next cheapest alternative.

Estimates of catch rates for marine and freshwater fisheries and harvest rates for aquaculture are shown in Figure 10. It is the capture inshore fisheries (863,000 tonnes) and the aquaculture fish (958,000 tonnes) that are reliant on the Ayeyarwady Basin for production and within the scope of any Ayeyarwady Basin assessment (a total of 1,821,000 tonnes). The key points to note are the consistent growth in both the freshwater fisheries and aquaculture capture. This is a function of greater utilisation of the Ayeyarwady Basin's natural capital, human effort, and investment. Furthermore, it is likely that the relative importance of freshwater-based fish proteins is increasing, as the marine catch has remained relatively constant over the past 15 years (potentially declining).

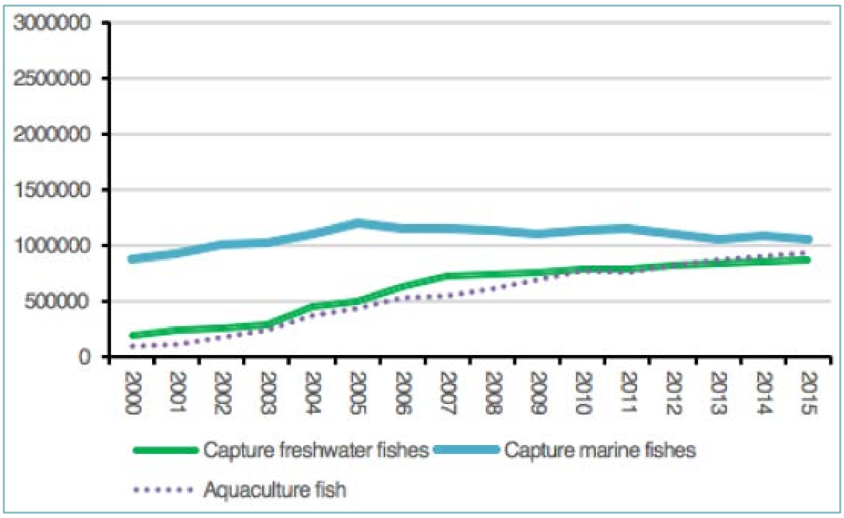

Figure 10 Trends in catch rates for marine and freshwater fisheries and aquaculture (Baran et al., 2017)

Table 14 shows the estimated price of fisheries proteins and key substitutes. The medium estimate is based on the average retail price for the period of 2010 to 2014 (the latest official data available). The low and high estimates are based on one standard deviation either side of the average price.

Table 14 –Protein retail prices (USD/tonne) (CSO, 2015)

Commodity	Low	Medium	High
Chicken	2,179	2,430	2,681
Beef	1,734	2,650	3,566
Pork	2,105	2,594	3,082
Fresh fish	1,713	2,029	2,344
Dried shrimp	712	740	767

The data show that fresh fish and dried shrimp, as a source of protein, are cheaper than substitutes, such as chicken, beef, or pork. In addition, fish and shrimp prices show relatively less variance than the substitutes (chicken is the exception).

Table 15 shows the average incremental price increase of replacing the protein from fishing with other substitutes. For these estimates, we have used the average estimates from the table above and fresh fish as a reference price for calculating the incremental price difference.[3]

The key point to note is that the incremental price increase is estimated at between USD 400 and USD 620 per tonne of protein. We have used this range to estimate the range of ecosystem services to the fisheries sector.

Table 15 – Incremental cost of protein replacement (USD/tonne) (NCEconomics based on CSO, 2015)

Commodity	Medium Estimate
Replacing fresh fish with chicken	401
Replacing fresh fish with beef	622
Replacing fresh fish with pork	565

5.3 Results

Using the volumes of catch for freshwater and aquaculture fisheries in the Ayeyarwady Basin and the incremental price difference borne by consumers to replace the protein derived from fish, it is possible to estimate the annual value of the ecosystem services attributable to fishing. This is shown in Table 16.

Table 16 – Estimated value of Ayeyarwady Basin ecosystem services to fish consumers (USD million/year) (NCEconomics estimates)

Commodity	Low	Medium	High
Freshwater capture	350	440	530
Aquaculture	380	490	600
Total value of ecosystem services to consumers	730	930	1,130

We estimate that the total replacement cost of fish protein, a provisioning ecosystem service from the Ayeyarwady Basin, is between USD 730 and USD 1,130 million per annum. These figures underpin the importance of maintaining the environmental condition of the Ayeyarwady Basin to support the fisheries industry and the livelihood and health of the people of Myanmar.

Given the fact that aquaculture production relies heavily on built capital, the estimates relating to aquaculture may be overstated. However, it should also be noted that these estimates may be underestimates, as the retail prices used to derive these estimates are unlikely to reflect both short-term consumption and long-term health benefits from eating fish rather than chicken or pork. Furthermore, they do not include the value of supporting services, such as fish biodiversity. Recent work in the Mekong has found that the costs and trade-offs go beyond relative costs revealed by market prices. This is because producing substitutes, such as chicken or pork, would require different inputs to production (e.g., land use and water use) and may result in significant external impacts, such as sedimentation attributable to clearing land to accommodate stock (Pittock et al., 2017).

[3] This approach is conservative, as the incremental increases in protein prices from shrimp to the substitute commodities are significantly higher.

5.4 Distributional Issues

New regulations, particularly to fishing rights, should consider the distributional impacts of such changes. According to FAO (2012b), most lowland inland communities rely on fishing and farming depending on the season. According to a survey by Cho et al. (2017) in the Ayeyarwady and Yangon Regions, 58% of the households in the aquaculture sector were found to be landless. Thus, a significant proportion of the population is vulnerable to changes in land rights and fishing access.

Fishing provides a source of income and food for many poor people in Myanmar, including the landless. There are some expectations that freshwater, brackish, and marine aquaculture will expand FAO (2012a). As the local and international markets improve, rural development initiatives should seek to better equip small fishing communities to take advantage of the growing market. Otherwise, these fishing communities are likely to benefit less because of a lack of access to electricity and processing plants to generate value through the export market. Thus, as well as continued fishing access by the poor, the government could seek to support them with access to facilities that they can use to uphold the required standards to be able to sell in the lucrative export market. These initiatives will help bridge the gap between the commercial and small fishers. Should these small fisheries be denied fishing rights, due to changing land rights or higher land leasing costs, the consequence will not only be financial, but there are likely to be food security issues as fish is second to rice in food consumption for Myanmar (FAO, 2003). The fish component of the rice-based diet in Myanmar provides the diet with much of its nutritional value.

While men dominate actual fishing activities, the local marketing of fish has been largely the domain of women (FAO, 2003). Given that both genders are involved in the capturing and marketing of fish, it is likely that both genders in the rural communities benefit from access to fishing.

New fisheries and waterbody governance will require development of policies that ensure sustainable fish production from inland fisheries for the continued support and development of rural livelihoods.

5.5 Gaps and Implications

The estimates above have been developed based on limited data, and estimates with greater accuracy could be possible if more accurate and aggregated fisheries production and price data were available. Improving fisheries data should be incorporated as part of the ongoing Ayeyarwady Basin planning and management processes. This gap is discussed in more detail in the SOBA 4 Package reports.

These estimates also indicate there are potentially significant economic, food security, and health implications for Myanmar if the Ayeyarwady Basin waterways and aquaculture ponds are not managed well. Declining water quality and inadequate fisheries management could put the benefits derived from fishing at risk, if not properly managed. Improving management will require significant efforts in institutional strengthening, capacity building, and more proactive management of the Ayeyarwady Basin and fishery activities (including enforcement).

6 ECOSYSTEM SERVICE: POTABLE WATER SUPPLY

Safe and secure water supplies for communities of all sizes are a fundamental requirement of sustainable development, because it has wide-ranging benefits for human health and productivity. Surface water and groundwater from the Ayeyarwady Basin are a significant provisioning ecosystem service, while the Ayeyarwady Basin also provides significant regulating ecosystem services in the form of maintaining water quality. Virtually all potable water supplies in the Ayeyarwady Basin are impacted by changes in the condition of surface and groundwater supplies, particularly water quality. These services are typically provided in conjunction with built capital, such as water supply infrastructure (e.g., wells, pump stations, and pipelines).

This chapter provides a brief analysis of the regulating ecosystem services for maintaining water quality – particularly for potable uses (drinking, cooking, and personal hygiene requirements). These services are considered most important for the management of the Ayeyarwady Basin in the short-to-medium term, because they directly correspond with the key challenges and issues identified in a number of SOBA packages (e.g., water pollution, groundwater management, hydrology/flows, and sedimentation).

6.1 Overview of Issues

The population of the Ayeyarwady Basin is estimated at approximately 33.2 million or, 64% of Myanmar's population. Of this, an estimated 10.8 million live in urban areas, while approximately 22.4 million live in rural areas (ICEM, 2017a). The urban and rural livelihood chapters of the SOBA 5 project provide a comprehensive coverage of access to water and sanitation (ICEM, 2017a; ICEM, 2017b; ICEM, 2017c).

In rural communities, the principal sources of drinking water are tube well boreholes (33% of households), protected springs (17% of households), and bottled or purified water (11% of households). Waterfalls and rainwater provide drinking water for up to 42% of households in the Upper Ayeyarwady, while pools, ponds, and lakes are the water source for approximately 17% of households in the Ayeyarwady Delta. Rivers, streams, and canals are also a common water source, with approximately 14% of households in the Upper and Lower Ayeyarwady using these sources for drinking water (ICEM, 2017b).

In urban communities, the makeup of water supplies differs. Tube well boreholes are still the dominant source (38% of households) followed by protected springs and wells (16%); bottled water and purifiers (11%); pools, ponds, and lakes (10%); tap water (9%); and rivers, streams, and canals (8%).

The quality of water supply is variable across rural and urban communities. As outlined in ICEM (2017a), approximately 73% or rural households and 74% of urban households have access to safe, affordable water supplies (tap water, tube well bores, protected wells, and bottled water). All water sources (with the exception of bottled water) are at some risk of contamination from inappropriate Ayeyarwady Basin management or pollution management (e.g., contaminated groundwater, pathogens from wastewater, and stock).

Poor water quality is one of the major causes of diarrhoea and gastroenteritis, which are major health issues in Myanmar. According to the Myanmar Statistical Yearbook (CSO, 2015), diarrhoea and gastroenteritis are the highest causes of morbidity in most documented years. Poor water quality is one of the major causes of these conditions, and poor water quality is directly linked to how land and water resources are managed. Studies on urban water quality in Nay Pyi Taw and Yangon in 2013, collected from public pots, non-piped taps, piped taps, and bottled waters, found high levels of specific chemical parameters and coliform bacteria (contaminated water from faeces). In general, the study found that the lake, dam, and river waters had good chemical parameters, but the levels of bacterial contamination were too high – indicating that water treatment was required to make it suitable for drinking. Deep wells, on the other hand, had chemical concentrations that were above acceptable levels. Pots and non-piped taps had the poorest water quality, with advanced treatment required before the water could be considered safe to drink (Sakai et al., 2013).

Risks to water quality are expected to increase over time with changes and intensification in land use and industrial development in the Ayeyarwady Basin. This ultimately triggers a need for expensive water treatment or the use of expensive (alternative, non-public) potable water supplies, such as bottled water. For many lower-income households, this higher cost water will not be affordable.

More information on the nature and extent of water pollution risks in the Ayeyarwady Basin are outlined in SOBA Package 1.3.

6.2 Approach and Data Sources

Currently, the Ayeyarwady Basin provides a relatively reliable and safe source of potable water for approximately 75% of the Ayeyarwady Basin's population. However, in response to development pressures, there is a significant risk of water quality decline in the foreseeable future that could trigger the need to either move to expensive treatment or to use a substitute supply (e.g., bottled water). It is possible to estimate the value of the regulating ecosystem service for potable water from the Ayeyarwady Basin by modelling the water treatment costs avoided and/or the substitute water supply costs avoided by maintaining water quality. It should be noted that this will be an underestimate as only one of the potentially many benefits are valued.

We have modelled the cost avoided through an analysis of available information on demand for potable water, current supply options, and indicative costs of treatment/replacement. To undertake this analysis, the following two key sets of information are required:

1. The annual volume of potable water required for the population of the Ayeyarwady Basin (annual potable water requirements *x* population).

2. The avoided water treatment cost/avoided replacement cost (typically USc/kL).

WHO recommends a minimum potable water requirement of approximately 20 litres per person per day (l/p/d). This provides sufficient safe water for drinking, cooking, and some personal hygiene needs (e.g., brushing teeth). Of this, it is recommended that at least 7.5 l/p/d is safe for drinking and cooking foods that absorb water, such as rice (WHO, 2015). It should be noted that total consumption requirements per capita are higher, when non-potable water uses (e.g., laundry and garden watering) are included. However, we are focusing on potable water requirements in this assessment, as they are most susceptible to any decline in Ayeyarwady Basin environmental conditions and subsequent water pollution.

Annual estimated potable water demand is shown in Table 17. We estimate the total annual potable water requirement in the Ayeyarwady Basin is between 90,885,000 kL and 242,360,000 kL.

Table 17 - Annual potable water requirements (kL/annum) (CSO, 2015; WHO 2015)

Region	Population (million)	Demand at 7.5 l/p/d (kL)	Demand at 20 l/p/d (kL)
Urban	10.8	29,565,000	78,840,000
Rural	22.4	61,320,000	163,520,000
Total	33.2	90,885,000	242,360,000

Where water is not suitable for potable uses, it should be either treated and/or replaced with a safe supply. In larger urban areas, treatment is an effective option, while in smaller areas household-scale treatment or replacement of potable water with bottled water are most likely. Limited data are available in Myanmar as most water is not treated. Therefore, we have inferred costs from other sources, specifically:

- Tap water – The costs of treatment from a recent review of costs across major Southeast Asian cities undertaken by ADB in 2013 averaged approximately US 16c/kL (ADB, 2013b). However, it should be noted that this would need to be applied to all tap water supplied. Available information suggests that tap water consumption in Myanmar is approximately 160 l/p/d.

- Household scale treatment systems – While some rudimentary options are available using a process of flocculation (often using natural products), those options only address some pollutants. The costs of more sophisticated options can vary widely, with capital costs in the range of USD 200 per household to USD 800 per household and substantial operating costs. Consultation with suppliers indicated unit costs of treatment, when equipment is properly maintained, range from USD 2 to USD 8 per kL.

- Bottled water – For some consumers, particularly those with higher incomes, bottled water is used with an estimated cost that ranges between USD 150 to USD 300 kL.

These unit costs are shown in the Table 18.

Table 18 - Cost of treatment/replacement supply (USD/kL) (ABD, 2013b; Consultation with suppliers)

Option	Low	Medium	High
Treatment (large scale) – would need to be applied to all tap supply	$0.10	$0.16	$0.22
Treatment (household scale)	$2.00	$5.00	$8.00
Replacement (bottled water)	$150.00	$225.00	$300.00

The key point to note is that the costs will vary widely based on the options actually available. While the unit costs of large-scale treatments are relatively minor, this option is only realistic in larger centres with reticulation systems. Smaller-scale systems and household-scale systems are likely to have a significantly higher treatment cost per kL, but only a small volume of water per person needs to be treated. Implicit in our assumptions for this modelling is an assumption that all water required for potable use could be at risk from declines in the Ayeyarwady Basin condition.

6.3 Results

To estimate the value of regulating ecosystem services for potable water requirements, we have assumed the following:

- For urban water use accessed from the tap, the benefit is valued at between USD 0.10 and USD 0.22 per kL, and the volume treated is 160 l/p/d. This volume is used as all water would be treated irrespective of final use and totals an estimated 567,650,000 kL per annum.

- For all other uses, the benefit is USD 2.00 to USD 8.00 per kL, and daily volumes requiring treatment are 7.5 l/p/d (annual estimated volume is 66,275,000 kL).

Because all tap water would require treatment, the total volume of polluted water requiring treatment would be approximately 632,000,000 kL per annum.

We estimate the annual value of the ecosystem service for potable water supplies to be in the range of USD 185 million to USD 640 million (see Table 19). This estimate is effectively the cost of treating sufficient water to a drinkable standard if all existing water sources (with the exception of bottled water) became undrinkable due to a major decline in the Ayeyarwady Basin condition and subsequent water pollution.

Table 19 - Annual value of ecosystem service (USD millions) (NCEconomics estimates)

Segment	Low	Medium	High
Treated tap water	56.8	90.8	124.9
Local treatment	128.6	321.4	514.2
Total	185.3	412.2	639.1

Given the very limited data available, these values should be treated as indicative only.

6.4 Gaps and Implications

Data on water quality for human consumption in Myanmar are scarce as is the potential costs of treating poor quality water to drinkable standards. These estimates have a number of limitations including the following:

- The estimates above are based on a narrow scope of ecosystem services relating to human water consumption and significantly underestimate the value of water consumption related to ecosystem services from the Ayeyarwady Basin.

- Data on actual potable consumption are not available, and these estimates are based on potable water requirements.

- The physical cause and response relationships between Ayeyarwady Basin development, changes in water pollution concentrations, impacts on human health and welfare, and optimal treatment solutions are generally understood, but quantitative metrics of cause and effect relationships are not known for Myanmar at this time.

The broad implication for Ayeyarwady Basin planning is the need to recognise the existing regulating ecosystem services from the current levels of human water consumption in the Ayeyarwady Basin. These values are at risk if water quality is not actively managed in the Ayeyarwady Basin, forcing a major cost of water treatment on the community or a major cost to human health and productivity if water treatment is not undertaken.

7 ECOSYSTEM SERVICE: BIODIVERSITY

Myanmar hosts a large and diverse system of landscapes, flora, and fauna. This biodiversity has an inherent value in its own right and provides many of the supporting ecosystem services that underpin key sectors, such as agriculture, and broader natural functions, such as pollination.

7.1 Overview of Issues

Myanmar is globally recognised as a highly important country for biodiversity. The country's forests are some of the most extensive and intact in Southeast Asia (International Union for Conservation of Nature [IUCN], 2017a). Because they are located between the Indian subcontinent and the broader geographic area of Southeast Asia, they host an incredible diversity of significant habitats and species. The threats to these significant values are also equally well known. In an assessment of threats to biodiversity across the country, human encroachment, commercial over-exploitation of animals and fish, agricultural expansion, and logging were identified as the greatest current threats to biodiversity (Wildlife Conservation Society [WCS], 2013).

In terms of biodiversity conservation planning, IUCN is currently working with the Ministry of Environmental Conservation and Forestry (MOECAF) to develop an updated National Biodiversity Strategy and Action Plan for 2015 to 2020 (IUCN, 2017a). There are also many programs and projects undertaken by a range of non-government organisations (NGOs) and local community-based organisations to improve biodiversity conservation across the country.

7.1.1 Significant habitats overview

There have been several assessments of forest types across Myanmar. Recently, Bhagat et al. (2017) completed a GIS-based assessment of forest cover at a national level. In this comprehensive assessment using up-to-date publicly available data sources, the study identified key changes in forest cover between 2002 and 2014, including the following:

- Degraded forests, resulting from overuse for logging, fuel wood consumption, and shifting cultivation (0.47 million ha).
- Other non-forest land uses, such as mining, clear-cutting for agriculture, and infrastructure (1.00 million ha).
- Plantation crops, such as oil palm, rubber, and sugar cane (0.54 million ha).
- Hydroelectric dams and reservoirs (0.07 million ha) (Bhagat et al., 2017).

In addition, the study identified nine key forest change hotspots, where there had been major losses of intact forest. These included large-scale forest clearing, for plantations around Myitkyina along the Ayeyarwady River, and high losses in some less forested areas, such as the mangrove forests of the Ayeyarwady Delta (Bhagat et al., 2017).

7.1.2 Key biodiversity areas

Figure 11 depicts the key biodiversity areas (KBAs) in Myanmar. Several studies have identified and prioritised KBAs in Myanmar based on a range of factors, including species- and site-based vulnerabilities (WCS, 2013). The WCS project defined 132 KBAs and classified them as having high, medium, and low priority in terms of biodiversity conservation. Six sections of the Ayeyarwady River, covering more than 2,000 km^2, were identified as high priority KBAs. Any additional areas linked to the protection efforts associated with the critically endangered Irrawaddy dolphin (covering a further 326 km^2) were also classified as a high priority KBA (WCS, 2013). Importantly, the project identified 15 key conservation corridors across Myanmar. These included the terrestrial habitats of the Upper Ayeyarwady catchment area (101,394 km^2) and the entire length of the Ayeyarwady River itself (2,170 km).

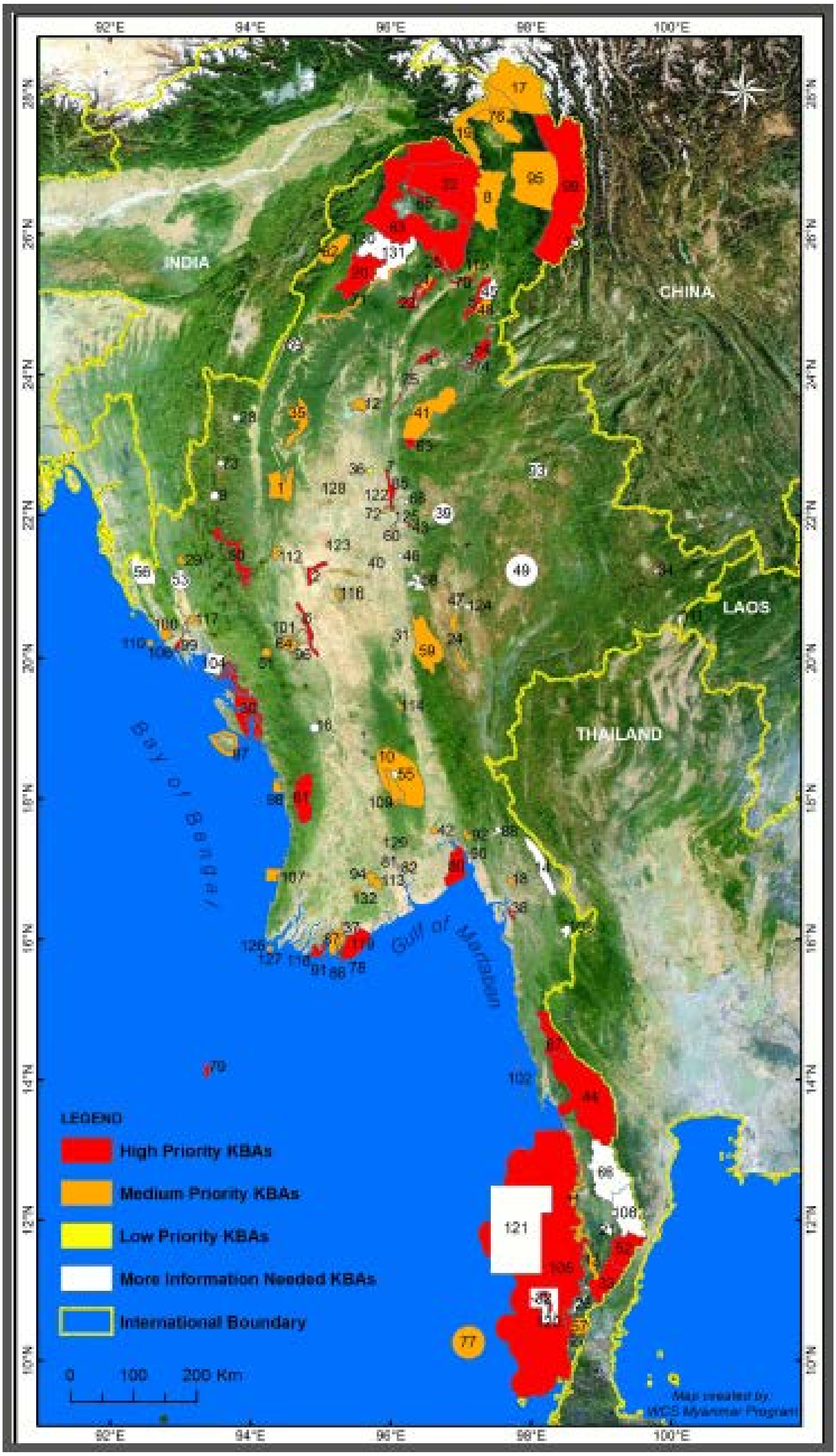

Figure 11 Key Biodiversity Areas in Myanmar (Myanmar Biodiversity, 2017)

As previously mentioned, six KBAs have been established for the Ayeyarwady River. However, these tend to be small in size relative to the Ayeyarwady Basin's total size of more than 400,000 km^2. As can be seen in

Table 20, the largest KBA is 578 km², and the smallest KBA is 75 km². In total, the KBAs of the Ayeyarwady Basin make up 2,038 km² or approximately 0.5% of the Ayeyarwady Basin's total size.

Table 20 - KBAs in the Ayeyarwady Basin (Myanmar Biodiversity,2017)

Area in the Ayeyarwady Basin	Priority of the KBA	Area (km²)
Bagan Section	High	342
Bhamo to Shwegu Section	High	200
Moda Section	High	303
Myitkyina to Sinbo Section	High	578
Sinbyugyun to Minbu Section	High	540
Singu Section	High	75

7.1.3 *Spotlight on the iconic Irrawaddy Dolphin*

The Irrawaddy dolphin is listed by the IUCN as vulnerable. The five known freshwater populations, including those of the Ayeyarwady River, are listed as critically endangered. An important relationship has been established between the dolphins and local communities along the Ayeyarwady River. Interestingly, local fisherman have developed relationships with individual dolphins and, as part of this relationship, they utilise the dolphins to assist with fish capture. In other countries (e.g., Laos), this species is recognised as a sacred animal, and it is also acknowledged to be an important source of income and jobs for communities involved in dolphin-watching ecotourism (World Wildlife Foundation [WWF], 2017).

7.2 Approach and Data Sources

Data capturing the Ayeyarwady Basin's varied biodiversity and ecology were supplied by the SOBA Project Management Unit (PMU). The data received were used to spatially represent the changing land cover across the Ayeyarwady Basin, depicting the coverage of forests, wetlands, and mangroves. The data were then used to determine the area of the land types through GIS-mapping. Next, forest, mangroves, and wetlands were each assigned an ecosystem value in USD per hectare per year (USD/ha/yr). The annual value per hectare was framed by including the state boundaries, the basin outline (including major waterways), and some of Myanmar's major cities. Given that two different sources were utilised to derive the unit-value of forests, wetlands, and mangroves (USD/ha/yr), two different results are presented in this chapter, estimating the values of the Ayeyarwady Basin's ecosystems. The process, along with the results for the economic value of the ecosystems, are explained in Section 7.3.

7.3 Results

Based on an analysis of previous research projects on the values of biodiversity, we were able to calculate the economic value of forests, wetlands, and mangroves in the Ayeyarwady Basin. These are presented as USD/ha/yr. Given that we use two different sources of data, the value estimates are presented in two different tables – Table 21, based on benefit transfer-values (from Emerton and Aung, 2013; Emerton, 2013); Table 22, based on the Ecosystem Value Estimation (ESV) Tool 4. It is noteworthy that the two different sources of data provide widely different estimates for the economic value of forests, mangroves, and wetlands. Even though the estimates in both tables should be treated with caution, they nonetheless give an indication of the significant ecosystem values that the three biomes provide.

In Table 21, the economic unit-values for forests, mangroves, and wetlands are presented with low, medium, and high values, respectively. These unit values are based on the benefit-transfer values (from Emerton and Aung, 2013; Emerton, 2013). Note that the medium value refers to the current baseline value. The low value estimates should be interpreted as the value that forests, mangroves, and wetlands will be reduced to in the future if no investment in conservation is made. The high value estimates should be interpreted as the value that forests, mangroves, and wetlands could increase to in the future if adequate investment in conservation is made. The future benchmark year used in the previous research was 2031. This analysis is important as it demonstrates the values attributable to a change in condition of key biodiversity assets.

Table 21 - Ecosystem values for forest, mangroves and wetlands (benefit transfer) (Emerton & Aung 2013; Emerton 2013)

Ecosystem	Low	Medium (current base-line)	High
Forest (USD/ha/year)	88	179	299
Mangroves (USD/ha/year)	2,004	4,089	6,849
Wetlands (USD/ha/year)	1,329	2,176	3,022

It should be emphasised that the economic ecosystem values presented in Table 21 are based on benefit transfer-values from other Asian countries (e.g., Cambodia, Indonesia, Thailand, and Vietnam). These unit-values are neither based on the Ayeyarwady Basin's ecosystems nor on Myanmar's ecosystems. We have utilised these values to calculate the total economic values of the forests, mangroves, and wetlands in Myanmar. The total values are presented in Table 22.

Please note that a detailed review of economic studies of biodiversity values relevant to Myanmar can be found in Annex II.

In Table 22, the economic unit-values of forests, mangroves, and wetlands in USD/ha/year are presented with minimum (low), mean (medium) and maximum (high) values. These values are based on the ESV tool developed by the Mekong Regional Futures Institute (Smajgl, 2015)[4], in contrast to the values in Table 21, based on the benefit transfer estimates. The ESV values might be more accurate than the values in Table 21 (benefit transfer), as the ESV values are based on the Mekong Region and a larger number of studies and data points.

Table 22 - Ecosystem values for forest, mangroves and wetlands (ESV) (USD/ha/year) (benefit transfer) (Smajgl, 2015)

Ecosystem	Minimum	Mean	Maximum
Evergreen forest (closed)	7,241	17,578	27,916
Deciduous forest (open)	6,665	13,306	19,946
Mangroves	9,692	20,324	30,956
Wetland	9,906	12,776	15,646

Compared to the ecosystem values based on the benefit transfers in Table 21, the unit-values based on the ESV tool (outlined in Smajgl, 2015) are considerably higher. For example, the current (mean) economic value per hectare per year is USD 4,089 for mangroves, according to the benefit transfer-estimates, but USD 20,324, according to the ESV tool. In particular, the current (mean) economic value estimates for forests differ: USD 179 according to the benefit transfer-estimates, and USD 17,578 and USD 13,306 for evergreen and deciduous forests, respectively, according to ESV. The quality of all these estimates is limited. However, given the fact that the estimates in Table 21 are generated specifically for Myanmar and reflect insight from the Myanmar-specific studies, we have used those estimates in our aggregate estimates.

[4] The ESV tool is a simple spreadsheet tool to provide indicative estimates of key ecosystem services, where values are derived from previous studies. This enables simple and cost-effective benefit transfer of values provided by key assets such as forests, wetlands, and mangroves.

It is important to point out that, when estimating ecosystem values, a range of values are usually estimated to reflect input data uncertainty, variability, and the assumptions used. This is why Table 21 and Table 22 present a range of values, from low to high, and from minimum to maximum. A range of values is needed because ecosystems differ from one another, and their values are determined by their geographical location and special biodiversity features. Smajgl (2015) maintains that the 'interpretation of [ecosystem] value ranges must consider that this draws from very different contexts which might not resemble the particular characteristics of the context at hand.' Therefore, we present a range of economic values for the ecosystems of forests, mangroves, and wetlands.

7.3.1 Forests, Mangroves and Wetlands

Based on GIS mapping of the Ayeyarwady Basin (Figure 12), it is possible to calculate the size of some of the Ayeyarwady Basin's ecosystems – that is, the total area of forests, wetlands, and mangroves in hectares. The size of each of these ecosystems can be seen in Table 23[5] and Table 24. Based on the size, we can now estimate their economic value, according to the low (minimum), medium (current baseline/mean) and high (maximum) value estimates.

We present two different ecosystem value results. Table 23 shows the results of the total ecosystem values for the Ayeyarwady Basin, based on the benefit transfer estimates (from Emerton and Aung, 2013; Emerton 2013). Table 24 shows the total ecosystem values for the Ayeyarwady Basin, based on the ESV tool.

7.3.2 Forests

Based on the benefit transfer-values in Table 23, the current economic value of the forests in the Ayeyarwady Basin is as high as USD 2.64 billion (medium) per year. However, it should be kept in mind that this high value is primarily due to the size (14 million ha) of the forests, rather than their economic value per hectare per year. The economic value of the Ayeyarwady Basin's forests can be increased to USD 4.4 billion (high) per year by 2031 – an increase of USD 1.7 billion per year – if investments are made to conserve forests. On the contrary, if no investment into forest conservation is made, the economic value of forests will decline to USD 1.3 billion per year (low) by 2031, which is less than half its current value.

However, based on the ESV tool in Table 24, the current (mean) economic value of the forests (evergreen and deciduous combined) is USD 224 billion per year, which is approximately 100 times the value estimated using the benefit-transfer values. The minimum and maximum values for forests are USD 102 billion and USD 346.8 billion, respectively – also considerably higher than the benefit-transfer values.

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[5] Note that the Ayeyarwady Basin also includes other types of ecosystems and areas, such as cropland, grassland, water, and human settlements.

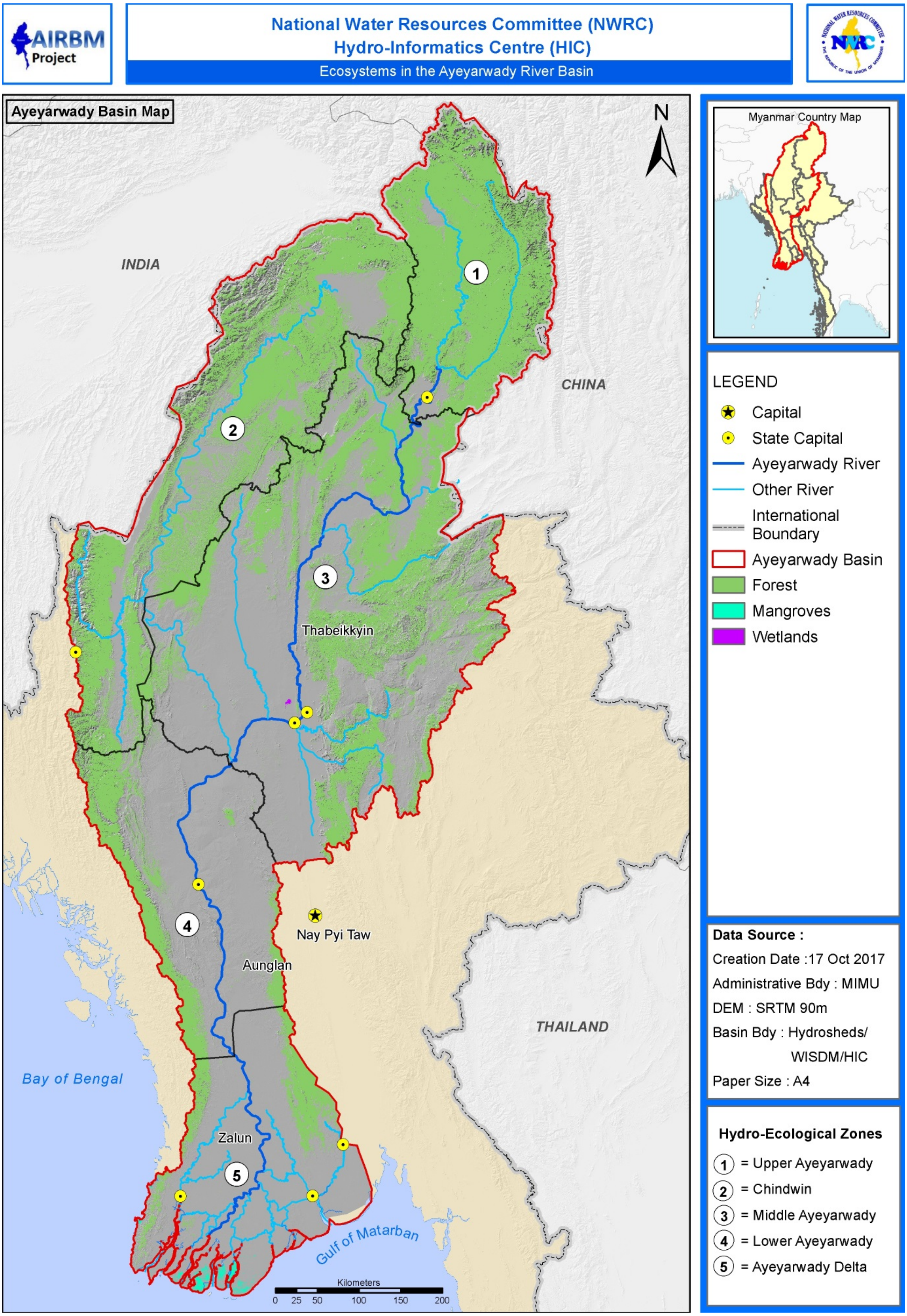

Figure 12 Ecosystems in the Ayeyarwady Basin

7.3.3 Wetlands

Based on the benefit transfer-values in Table 23, wetlands in the Ayeyarwady Basin currently have an economic value of USD 7.2 million per year. If investment into the conservation of wetlands is made, this value will increase to USD 10 million per year by 2031. On the contrary, if no investment into wetland conservation is made, the economic value of wetlands will decline to USD 4.4 million per year.

However, based on the ESV tool in Table 24, the current (mean) economic value of wetlands in the Ayeyarwady Basin is USD 42 million per year, which is nearly 6 times the value estimated above. The minimum and maximum values for wetlands are USD 32 million and USD 52 million, respectively, per year.

7.3.4 Mangroves

Based on the benefit transfer-values in Table 23, mangroves in the Ayeyarwady Basin currently have an economic value of USD 297 million per year. If investment into the conservation of mangroves is made, this value will increase to USD 497 million per year by 2031. On the contrary, if no investment into mangrove conservation is made, the economic value of mangroves will decline to USD 145.5 million per year. Given the small current size of mangrove cover (72,635 ha) relative to forests (14 million ha), the conservation and restoration of mangroves in the Ayeyarwady Basin represent an investment opportunity, as these ecosystems also deliver a range of critical ecosystem functions, including those linked to the sustainability of many fish populations.

However, based on the ESV tool in Table 24, the current (mean) economic value of mangroves in the Ayeyarwady Basin is USD 1.47 billion per year, which is 5 times as high an estimate as the benefit-transfer values. The minimum and maximum values for mangroves are USD 704 million and USD 2.2 billion, respectively. These estimates are also significantly higher than the estimates based on benefit-transfer values.

Table 23 - Total ecosystem values for the Ayeyarwady Basin (benefit transfer)

Ecosystem total value	Area (ha)	Low^ (USD million)	Medium (USD million)	High^ (USD million)
Forests	14,774,489.3	1,300.2	2,644.6	4,417.6
Wetlands	3,325.8	4.4	7.2	10.1
Mangroves	72,635.8	145.6	297	497.5
TOTAL	**14,850,450.9**	**1,450.1**	**2,948.9**	**4,925.1**

^Benchmark year for 'low' and 'high' values are 2031

Table 24 - Total ecosystem values for the Ayeyarwady Basin (ESV Tool) (Smajgl, 2015)

Ecosystem total value	Area (ha)	Minimum^ (USD million)	Average (USD million)	Maximum (USD million)
Evergreen (closed) forest	6,541,523	47,367	114,990	182,631
Deciduous (open) forest	8,232,965	54,872	109,543	164,214
Wetlands	3,325	32	42	52
Mangroves	72,635	704	1,476	2,248
Annual total value		**102,975**	**226,051**	**349,127**
Provisioning Services (annual)		96,139	174,127	252,114
Regulatory Services (annual)		30,221	62,569	94,918
Of which carbon storage		958.5	13,661	26,363
Cultural Services (annual)		2,006	2,052	2,097

7.3.5 Results summary

Based on the benefit-transfer calculations in Table 23, the three biomes of forests, mangroves, and wetlands in the Ayeyarwady Basin together have a total economic value of USD 2.9 billion per year. With conservation investments, this value could potentially increase by almost USD 2 billion by 2031, totalling USD 4.9 billion per year. Without conservation investments, this value is expected to decrease to less than half, to USD 1.45 billion. As with most ecosystem value estimates, the estimates in Table 23 should be treated with caution, because they are based on benefit transfers from other Asian countries (e.g., Cambodia, Indonesia, Thailand and Vietnam).

However, if we utilise the ESV tool[6], based on data from the Mekong Region, we get a somewhat different picture of the total ecosystem values for the Ayeyarwady Basin. These values, shown in Table 24, are also based on low (minimum), medium (mean), and high (maximum) value scenarios. The results from the estimation are outlined in Table 24, and the area is based on our GIS-mapping estimates. Together, the three biomes of forests (evergreen and deciduous combined), mangroves, and wetlands in the Ayeyarwady Basin currently have an economic value of USD 226 billion per year, with a minimum value of USD 102.9 billion, and a maximum value of USD 349 billion per year. The estimates based on the ESV tool are all approximately 100 times larger than the estimates based on benefit-transfer values.

These differences need to be pointed out as they demonstrate a few caveats: 1) different sources of data, 2) different means of calculating ecosystem values, and 3) different assumptions.

7.4 Distributional Issues

The ecosystem services provided to people residing in the Ayeyarwady Basin are important for livelihoods and the sustainability of local economic activities. For example, the ecosystem services in the Ayeyarwady Basin provide vital water for drinking and sanitation: 33% of households in the Ayeyarwady Basin get their sanitation water from tube well boreholes, while 17% get it from protected springs. In terms of safe drinking water, 42% of households get it from waterfalls and rainwater; 17% from pools, ponds, and lakes; and 14% from rivers, streams and canals. It is crucial to conserve the ecosystem services that sustain the availability of drinking water, as only 26% of the Upper Ayeyarwady has access to safe drinking water. The Ayeyarwady River system itself provides important transport access for the rural population, particularly in the lower Delta. Only 24% of the population in the Ayeyarwady Basin has access to roads, compared to 36% for Myanmar (ICEM, 2017b). Furthermore, the biodiversity natural capital in the Ayeyarwady Basin provides a number of regulating services, ranging from climate regulation to pollination.

While limited data exists on fisheries and farm activities, anecdotal data indicate that most of the population in the Ayeyarwady Basin is highly dependent on natural resources for their livelihoods (e.g., fisheries and farm activities). In particular, fisheries are an important source of income for many households in the Ayeyarwady Delta. Transitory poverty (people continuing to fall in and out of poverty) affects 28% of the households in the Ayeyarwady Basin. Transitory poverty levels are linked, in part, to the dependence on natural resources for subsistence but also to the vulnerability of communities to extreme events, such as flooding, droughts, and storms. Actions that increase the availability of natural resources for subsistence and increase the resilience to extreme events are likely to have positive effects on poverty levels and the well-being of the rural poor. This could include conservation of mangroves, forests, and wetlands that will increase the amount of natural resources for subsistence livelihoods and, particularly for mangroves, provide coastal protection and storm 'buffers.'

[6] http://mekongarcc.net/ESV_tool/ESV.html

7.5 Gaps and Implications

Significant gaps in the availability and quality of data exist. While it has been possible to map some of the ecosystems of the Ayeyarwady Basin, in terms of their geographical area, high quality data specifically related to the economic value of the Ayeyarwady Basin's ecosystems are limited. This is why the estimates in this report are based on the (1) benefit transfers from other Asian countries; and (2) an ESV tool based on the economic value of ecosystems in the Mekong Region. We judge the latter to be the most accurate, as these estimates are based on an area that covers Myanmar, among other Asian countries. Also, we found no data on other ecosystems in the Ayeyarwady Basin, such as water, grasslands, and cropland, which means that a calculation of their values has not been possible. Therefore, our results are likely to be underestimates, as they only represent mangroves, wetlands, and forests.

It should be noted that the studies that form the basis of these estimates are often for ecosystems outside Myanmar and/or that comprises a much larger area than only Myanmar (i.e., the Mekong Region). We have inferred values of biodiversity in Myanmar based on these previous studies. Therefore, these results should be treated with extreme caution.

8 ECOSYSTEM SERVICE: ECOTOURISM

The tourism sector in Myanmar is growing quickly and promising to become a major export industry for the country. Moreover, ecotourism in the Ayeyarwady Basin is one of the drivers for tourist visitation due to the uniqueness of the Ayeyarwady Basin's flora and fauna, rivers, and wetlands, all coupled with Myanmar's distinct culture.

According to FAO, ecotourism activities are defined as 'responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education.' Specifically, ecotourism needs to take place in a nature-based setting, incorporate conservation activities, local participation, and the active encouragement of conservation awareness (Friess, 2017).

The United Nations recently adopted a resolution for strengthening ecotourism, calling on "UN Member States to adopt policies that promote ecotourism highlighting its 'positive impact on income generation, job creation and education, and thus on the fight against poverty and hunger.'" It further recognises that 'Ecotourism creates significant opportunities for the conservation, protection and sustainable use of biodiversity and of natural areas by encouraging local and indigenous communities in host countries and tourists alike to preserve and respect the natural and cultural heritage' (United Nations [UN] General Assembly, 2013).

This statement, released by the UN World Tourism Organisation, further emphasises the potential of ecotourism to protect natural resources, conserve ecosystems, and foster poverty reduction. Although there are currently limited data on ecotourism in the Ayeyarwady Basin and Myanmar, the potential of ecotourism to drive environmental, economic, and social progress should not be underestimated. Note that environmental progress includes both environmental protection and biodiversity protection.

8.1 Overview of Issues

Tourism in Myanmar offers a unique experience to visitors with a wide variety of cultural and natural attractions. The tourism industry's current contribution to national GDP is relatively low compared to other countries. However, it is expected to increase in the next decade, specifically:

- The total contribution of GDP is expected to increase to 7% in 2027, from 6.6% in 2016. This is modest in comparison to other Asian countries, where the percentage share of GDP is significantly higher – Cambodia (28.3%), Thailand (20.6%), Philippines (19.7%), and Laos (14.2%).
- The industry is expected to support 7.2% of all jobs in 2027 (up from 5.7% in 2016) (World Travel and Tourism Council, 2015).

The visitation rates and the growth in direct tourism expenditure in Myanmar over the past 10 years can be seen in Figure 13.

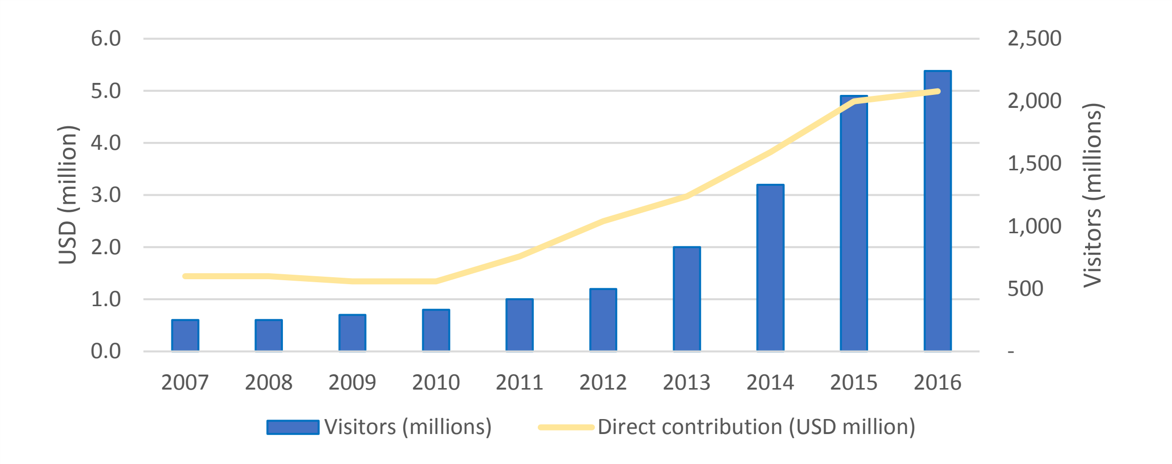

Figure 13 – Tourism visitation and direct expenditure (World Travel and Tourism Council, 2017)

Myanmar welcomes approximately 5.38 million tourists per year (2016 figures) (World Travel and Tourism Council, 2017). Although the direct contribution by tourists was USD 2.1 billion in 2016, it is important to distinguish between the direct and the total contribution that tourists make to Myanmar's GDP. In short, the total contribution of Myanmar's tourism industry to GDP was USD 4.15 billion in 2016, or 6.6% of GDP (WWTC, 2017). The total contribution to GDP should be understood as the tourism's wider impacts on the economy. That is, the total contribution includes direct spending but also indirect spending, such as investment and tax revenues, and induced spending by employees in the travel and tourism industry. Tourism's economic contribution to GDP is shown in Table 25.

Table 25 - Tourism contribution to the economy (World Travel and Tourism Council, 2017)

Measure	USD (millions)
Direct contribution of tourism to Myanmar's GDP	2,100
Total contribution of tourism to Myanmar's GDP	4,600

The Government of Myanmar estimates show that the expenditure per tourist per day is USD 172 and that each tourist stays on average nine days in the country. To the extent that Myanmar can maintain the attractiveness of the Ayeyarwady Basin to tourism, there is a potentially significant cultural ecosystem services attributable to the Ayeyarwady Basin in the form of ecotourism.

8.2 Ecotourism Strategies in Myanmar

An ecotourism strategy for Myanmar has been developed revolving around key natural sites that also complement other cultural and historical attractions to attract visitors and increase their length of stay. Key sites are shown in Figure 14. Most sites are national parks and wildlife reserves that are located in the Ayeyarwady Basin, recognising the appeal of the region to international visitors.

One intention of the strategy is to use ecotourism as an underlying economic rationale for enhanced management of Myanmar's expanding Protected Area network. This is a clear recognition of the cultural ecosystem service provided by the Protected Area estate to the tourism sector.

Furthermore, the strategy is acutely aware of the potential positive distributional benefits and economic opportunities provided by ecotourism to the regional and poorer areas via engaging with communities to:

- Raise awareness of potential opportunities for ecotourism in regional centres.
- Promoting business enterprises that deliver conservation and economic development outcomes.

- Build capacity for local management.

Much of the current focus is on planning and developing and investment strategies for the ecotourism sector. Appropriate management and protection of the Ayeyarwady Basin will ensure that the many ecotourism sites with long-term potential will continue to underpin the diversification of the tourism industry.

Disclaimer: The names shown and the boundaries used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 14 – Key ecotourism sites for Myanmar (Myanmar Ecotourism Policy and Management Strategy for Protected Areas 2015-2025, 2015)

8.3 Approaches and Data Sources

Ecotourism in the Ayeyarwady Basin is a subset of the tourism sector. There is virtually no data on specific tourism activities (e.g., visiting waterways) undertaken within Myanmar or the relative contribution of the Ayeyarwady Basin to attracting tourists. The typical approach to valuing ecosystems for tourism would be:

- To estimate the average expenditure of tourists, based on the total income (expenditure) of the tourism sector and the total number of visits to the place (annually).
- To multiply the above estimates with the direct contribution of tourism to the region's GDP.
- To use current literature on 1) tourism expenditure in the particular region (e.g., for particular activities, such as ecotourism); 2) tourists' willingness-to-pay (WTP) for ecosystem conservation; or 3) willingness of tourists to visit specific natural environments – before/after a change in its environmental quality and using the travel costs approach to estimate the average economic contribution per tourist.

However, virtually none of the data required to undertake the above analysis are available. Therefore, other approaches are required that will provide some insight into the potential values:

- Insight from previous work (benefit transfer) – This approach basically means transferring the estimates from other data sources and studies to our study to obtain estimates that are representative of ecosystem values for tourism. Although such studies are from different countries, they nonetheless provide insights into how various natural environments contribute to tourism.
- Insight from market segments – This could be an analysis of how particular segments in the tourism industry support and sustain tourism economic activity. For instance, in Myanmar, tourists that specifically visit to enjoy river-related activities, such as cruises, are particularly important for sustaining the tourism economy in and around the Ayeyarwady Basin. These types of tourists may spend substantially more than other tourists (e.g., customers of luxury cruises, older tourists, and/or tourists from upper-income Western countries). This is because the daily river cruise rates are typically much higher than the average daily tourism expenditure. It is, therefore, important to consider how tourist segments support the broader tourism industry and how the ecosystems that sustain particular tourism activities can be conserved to attract a higher number of wealthy visitors. This analysis can be extended to include hypothetical 'what if' scenarios to assess the value of ecotourism if it matured to a similar level to tourism destinations in Southeast Asia.

8.3.1 Insights from previous research

When data on a specific country's (or area's) tourism contribution from ecosystems are missing, estimates and insights from other countries, or similar areas, can be used. For Myanmar, countries that have similar environmental attributes (e.g., mangroves, wetlands, river systems, and tropical forests) that could attract visitation, include Vietnam, Laos, Philippines, Thailand, and Cambodia. As such, studies on the value of tourism may be transferred to a Myanmar-context and/or be used to estimate how Myanmar's ecosystems contribute to tourism.

Emerton and Aung (2013) calculated the average daily expenditure per tourist and estimated tourists' WTP for forest conservation (per person, per trip) in Myanmar using estimates from several international studies. Based on these figures, they were able to estimate the contribution of forests to tourism, as shown in Table 26. Also, tourism value, from another study on the values of Myanmar's Moeyungyi Wetland, are shown in the fourth row of Table 26.

Table 26 - Previous estimate of ecotourism values in Myanmar (Emerton and Aung, 2013)

Ecosystem	Benefits provided by ecosystem services	Valuation approach	Unit-type value	USD value
Forests	Nature-based tourism	Direct market pricing	USD/year	9,152,000
Forests	Nature-based tourism	Direct market pricing	USD/day/tourist	140
Forests	Nature-based tourism	Non-market valuation	WTP for conservation/ person/trip	25.42
Wetlands	Tourism	N/A	USD/year	75,480

Based on the figures in Table 26, Emerton and Aung (2013) estimated that forests contribute just over USD 9 million in direct expenditure to Myanmar's tourism economy each year. Each tourist that engaged in forest-based tourism spent, on average, USD 140 per day. These figures make it is possible to calculate how many tourists engage in forest-based tourism in Myanmar: 178 tourists per day or 65,185 tourists per year. Another study reports that the WTP for the conservation of forests is USD 25.42 per forest-tourist per trip. This indicates that there is a specific segment of the market that clearly values forest ecosystems for tourism and are prepared to pay a premium for tourism activities to ensure those ecosystem services are maintained. A third study estimates that the contribution of wetlands to tourism in Myanmar is USD 75,480 per year. It should be noted that these studies had a very narrow scope and were undertaken when the overall tourism market was significantly smaller.

Although the above estimates give some indication of the value of ecosystems to tourism, we are not able to elicit specific unit values (e.g., USD/ha/year, or USD/visitor night). Other studies have reported the value of ecosystems for tourism in USD/ha/year in various Asian countries. These estimates (shown in Table 27) are useful, as they can be used to calculate the value of a particular ecosystem (or natural environment) to tourism.

Table 27 - Previous estimate of eco-tourism values (Emerton and Aung, 2013)

Ecosystem (Country)	Benefits provided by ecosystem services	Valuation approach	Unit-type value	USD 2016 value
Coastal wetlands/ mangroves (Vietnam)	Tourism	Travel cost	USD/ha/year	28.60
Coastal/shores (Philippines)	Tourism	Direct market pricing	USD/ha/year	224.23
Coastal/sea (Philippines)	Tourism	Direct market pricing	USD/ha/year	0.18
Coastal wetlands/ mangroves (Philippines)	Tourism	Direct market pricing	USD/ha/year	214.06
Inland wetlands (Cambodia)	Recreation	Group valuation	USD/ha/year	26.41
Mangroves (Thailand)	Tourism	N/A	USD/ha/year	524.16

For instance, one study finds that the value of mangroves to tourism is USD 524/ha/year in Thailand. Thus, if the size of a particular mangrove's ecosystem in Thailand is available, the total value of that mangrove's ecosystem to tourism in Thailand can be calculated. However, it should be realised that the values in the table above will be influenced by visitation levels, and extreme care should be used when applying these estimates to the Ayeyarwady Basin context.

To be able to estimate the total value of specific ecosystems to tourism in Myanmar, it would be necessary to develop more specific estimates (e.g., the value in USD/ha/year). This will require further research into how tourism benefits from those ecosystems, taking into consideration their geographical size. The available literature provides no quantitative insight into how varying the extent and condition of the Ayeyarwady Basin's natural capital will impact on visitation numbers, activities undertaken, and the economic contribution of the tourism sector.

Contingent behaviour studies have also found a relationship between the extent and condition of natural assets underpinning the tourism sector and tourism activity. A contingent behaviour study investigates the hypothetical economic effects of a change in environmental attributes (e.g., declining water quality) on the tourism sector. Several previous studies have investigated the future economic decline associated with a degradation in environmental quality (e.g., the decline in tourism visitation following a decline in the environmental quality of coral reefs). Contingent behaviour studies could also investigate the hypothetical economic growth following an improvement in environmental quality. For Myanmar, an example of a relevant contingent behaviour study would be to investigate the future (hypothetical) economic growth associated with an improvement in the quality of its ecosystems in and around the Ayeyarwady River. That is, if mangroves, wetlands, and the river's water quality are improved, how many more visits to the Ayeyarwady Basin could be expected? Studies like that would provide useful insights into the expected economic benefits associated with ecosystem conservation.

8.3.2 Insights from segmentation

A general observation from the tourism sector is that the river-based segment exhibits significantly higher daily expenditures than the tourism sector as a whole. While some of the difference will be attributable to higher input costs (e.g., large tourism boats have a higher cost per bed than hotels), some of the price premiums will be attributable to the special attributes of the river-based tourism experience. In Table 28, different rates on river cruises in Myanmar are outlined and then compared to the overall tourism expenditure per day (i.e., USD 172/day).

Table 28 - Rates and premiums for river-based tourism in Myanmar (Various sources – review of river cruise operator offerings)

Type of river cruise	Minimum rate	Maximum rate	Daily price premium over average
Luxury River cruise (Scenic 2017)	USD 436	USD 537	253 – 312%
Themed cruise (The Strand 2017)	USD 258	USD 1,238	150 – 720%
Explorer cruise (Rainforest Cruises 2017)	USD 303	USD 359	176 – 208%

Note that none of the websites for river cruises in Myanmar specifically mention that they are ecotourism focused. Ecotourism is mentioned, in general terms, to be more relevant for particular national parks and tourism providers on-land (not vessels).

As can be seen in Table 29, the number of international tourists undertaking riverine cruises in Myanmar has increased significantly from 2012 to 2016, from 14,635 people to 19,810 per year. In addition to this, the average expenditure per person more than tripled in the same time period: from USD 160 per person in 2012 to USD 530 per person in 2016. The recent surge in riverine cruises, both in terms of demand and tourism expenditure, means that the annual income from riverine cruises in Myanmar has increased from USD 2.3 million in 2012 to USD 10.5 million in 2016. Even though these figures only represent a fraction of the total tourism income in Myanmar, they nonetheless demonstrate a good example of how specific tourism activities can increase in popularity over a short period of time, thereby contributing positively and significantly to local tourism economies.

Table 29 - Riverine cruises in Myanmar (tourist arrivals by special tours) (Myanmar Tourism Statistics, 2016a)

YEAR	Number of people	Income (USD)	Average expenditure per person (USD)
2012	14,635	2,341,315	160
2013	15,809	4,906,305	310
2014	18,077	8,416,289	466
2015	20,816	8,751,254	420
2016	19,810	10,506,074	530

8.3.3 Ecotourism in South East Asia

According to FAO (n.d.), international studies have found the following:

- Nature tourism generates 7% of all world-wide travel expenditure.
- Twenty percent of all foreign tourists to Thailand visit natural sites (but not necessarily ecotourism sites).
- In Malaysia, visitor numbers to ecotourism sites (natural sites) increased 360% from 1984 to 1993.
- Asia had roughly 22.9 million ecotourism international visitors in 2010 (10% of all tourists), which does not include domestic ecotourists.

Other studies provide interesting insights into the ecotourism market segmentation in Southeast Asia. One study (Ly and Bauer, 2014) conducted a review of the ecotourism management in five Southeast Asian countries, namely Malaysia, Thailand, Vietnam, Laos, and Cambodia. This study found that ecotourism is present in all of the five countries; however, the definition of ecotourism by policy makers and the degree to which ecotourism activities are considered to be varies considerably.

For instance, some governments simply define ecotourism as tourism activity being based in nature (Vietnam), in rural and Protected Areas (Laos), or as addressing community needs and the natural environment (Cambodia). Other governments have formulated more specific policies that include the active conservation of natural resources, along with responsible and low-impact travel (Malaysia and Thailand) (Ly and Bauer, 2014). Key findings of this study further emphasise that:

- The role of the government is important in leading the development of ecotourism, especially in the initial stages of implementation.
- The success of the UNESCO-LNTA Nam Ha Ecotourism Project in Laos can be attributed to the government's efforts to create a comprehensive and updated tourism policy and plan, along with the extensive financial and technical assistance of international NGOs. This project managed to combine environmental conservation with cultural heritage preservation and sustainable tourism activities.
- On the contrary, Vietnam's lack of a national ecotourism strategy has been a continuous barrier to successfully developing the country's ecotourism market.
- The lack of communication and cooperation between policymakers and other tourism stakeholders is a barrier to making ecotourism successful and economically viable.
- Successful ecotourism development requires the integrated cooperation between all parties involved – government, tourism industry, tourists, and local communities (Ly and Bauer, 2014).

Quantifying the environmental impacts associated with ecotourism activities are also vital in making the ecotourism activity itself sustainable in the long term, as a degraded natural environment will inevitably lead to reduced income in the future (Friess, 2017). Another study on sustainable tourism in Cambodia revealed a common set of challenges in making tourism activities more sustainable, namely the transition to ecotourism, community engagement, and preserving cultural heritage. This study specifically listed community engagement as crucial for the success of ecotourism, emphasising its associated links to poverty reduction, environmental protection, and the improvement of living standards (Carter et al., 2015).

In short, the key to making ecotourism sustainable is to 'not kill the goose which lays the golden eggs' (Abbas et al., 2015). In other words, conserve the unique natural environments that make ecotourism a possibility in the first place.

8.4 Results

Due to the severe lack of tourism data in Myanmar – and particularly the Ayeyarwady Basin – it has not been possible to develop proper estimates of the value that ecosystems in the Ayeyarwady Basin generate for tourism. Only anecdotal observations suggest that tourism in the Ayeyarwady Basin represents a promising opportunity to grow and prosper in the coming years, especially ecotourism.

Given that the Ayeyarwady Basin boasts pristine and unique ecosystems, particularly wetlands and mangroves, coupled with areas of high biodiversity, this is likely to attract more tourists in the coming years. However, it will require that ecosystems are protected and that conservation efforts are adequate. For instance, the limited evidence available shows that foreign visitors are prepared to pay considerable price premiums (e.g., between USD 250 and USD 1,200 per day) for ecotourism river cruises, which is well above the average daily expenditure per tourist. Therefore, investment into the conservation and protection of ecosystems in and around the river is likely to help sustain this particular market segment of Myanmar's tourism industry – and is required for sustaining the overall river cruise industry. Also, evidence from other Asian countries demonstrates high tourism/recreational values associated with ecosystems (e.g., USD 224/ha/year for coastal areas in the Philippines and USD 524/ha/year for mangroves in Thailand). These figures indicate that intact and well-preserved ecosystems have the potential to generate, and continue to generate, significant economic values for tourism.

Hypothetical – what if 10% of international visitors spent 1 day undertaking an ecotourism activity?

If 10% of all tourists in Myanmar were ecotourism visitors for only 1 day of their trip[7], this would have the following economic effects:

- Average daily expenditure of (any) tourist in Myanmar is USD 172.
- Average daily expenditure of river ecotourism tourists in Myanmar is between USD 258 to USD 1,238, which is an additional USD 86 to USD 1,066 per day per tourist (relative to the overall tourism expenditure per day).
- 10% of Myanmar's current international visitor would equal 538,000 visitors per year.

This hypothetical estimate means that if 10% of all foreign visitors to Myanmar take part in ecotourism activities for 1 day, this could generate an extra USD 310 million per year (mid-point estimate).

It should be emphasised that this hypothetical range is illustrative only and should be treated with some caution. For instance, the maximum extra tourism income is based on the highest daily rate for ecotourism river cruises on the Ayeyarwady River. It is highly likely that the visitors that pay the highest rates for ecotourism river cruises belong to the most lucrative tourist segment (i.e., wealthy tourists that are often older and from industrialised countries).

Nonetheless, ecotourism activities can be many other things than river-based. They can be jungle-trips, rain forest walks, or trips to cultural sites that comprise environmental conservation efforts. The estimates above should, therefore, be interpreted as the potential that Myanmar's ecotourism holds if comprehensive tourism policies and careful planning takes place to enable ecotourism to grow and prosper as a tourism sector.

8.5 Gaps and Implications

While there is some solid evidence to suggest tourism does, at least partially, rely on ecosystem services as a driver of visitation, data on activities undertaken, expenditures, and the importance of the environmental condition of the Ayeyarwady Basin are poorly understood. Data on visitors' activities beyond visitor numbers, average expenditures, and estimated employment are scarce.

The Ayeyarwady Basin is, itself, an interesting tourism destination, given its unique flora and fauna. However, due to the lack of data on tourism activity and expenditure in the Ayeyarwady Basin, it is not possible to obtain a better understanding of how changes to environmental quality in the Ayeyarwady Basin may affect tourism arrivals, expenditures, or employment.

For the stated reasons, it is highly likely that the potential of the Ayeyarwady Basin as a tourism destination is understated. Therefore, more research into tourism potential and economic activity is needed to ensure that the future development and management of the Ayeyarwady Basin does not come at a cost to tourism.

It would be prudent to enhance the understanding of the relationships between the Ayeyarwady Basin's condition and the tourism sector though initiatives such as:

- The need for data on specific tourism segments (e.g., river-based) and activities. This would require enhancements to the way tourism statistics are currently collected and analysed. It is suggested

[7] Each visitor stays on average nine days in Myanmar.

that data collected specifically relate to particular tourist segments, such as river cruises (e.g., visitation rates, vessel numbers, the quality of vessels, and expenditures).

- Analysis of the data to determine the share of tourism activities that utilises the river system or other key Ayeyarwady Basin environmental assets (e.g., wetlands).
- A body of work to properly understand the emerging sector and its relationships to ecosystem services, using suitable valuation techniques, such as contingent behaviour. This contingent behaviour study would make it possible to assess whether an improvement in the quality of the Ayeyarwady Basin's ecosystems would generate an increase in both visitation rates and tourism income.

The risk of not enhancing the understanding of the tourism sector and managing the Ayeyarwady Basin accordingly could be significant.

9 AGGREGATION AND CONCULUSIONS

The Ayeyarwady Basin is vitally important to the livelihoods and the economy of Myanmar. If the Ayeyarwady Basin is not well managed, there are significant risks to the physical integrity and the condition of the Ayeyarwady Basin's natural capital. The physical impacts of poor management could be profound and will have consequences that are beyond environmental – they are economic. The SOBA is the first major step toward robust management and sustainable development in the Ayeyarwady Basin. An understanding of the economic values attributable to the Ayeyarwady Basin (the ecosystem services) is vital to understanding the current benefits attributable to good Ayeyarwady Basin management and a means to assess the planning, management, and investment options for the Ayeyarwady Basin in the future.

While the Ayeyarwady Basin provides a number of ecosystem services across several sectors, they are currently poorly understood and generally not quantified. The continuation of the ecosystem services is contingent on the ability of the Government of Myanmar to actively manage the Ayeyarwady Basin's development and to establish a path toward sustainable development and prosperity for more than 33 million residents in the Ayeyarwady Basin.

To our knowledge, this report is the first attempt to assess a broader scope of ecosystem services in Myanmar beyond those provided by forests, mangroves, and wetlands, and the first attempt to assess the value of ecosystem services at the Ayeyarwady Basin scale.

Section 2 of this report briefly outlined the concept of ecosystem services and the broad approaches used to value the ecosystem services in the Ayeyarwady Basin. Sections 3 to 8 have then attempted to estimate the annual value of a number of key ecosystems services in the Ayeyarwady Basin. These sections do not cover the full scope of ecosystem services provided, but they do provide evidence of the economic importance of ecosystem services to a number of key sectors of the economy.

This section aggregates the values presented in Sections 3 to 8, noting they do not cover the full scope of services. It then establishes a broad range for an estimate of Gross Ecological Product (GEP) and compares that to Gross Domestic Product (GDP) on a per capita basis. We then consider some of the trade-offs in ecosystem service provision; the need to mainstream economic and social data into any Ayeyarwady Basin monitoring and evaluation strategy; and the implications for future Ayeyarwady Basin planning, management, and investment.

9.1 Major Scope Limitations

It should be noted that this report does not cover the full suite of ecosystems services provided by the Ayeyarwady Basin. There are a number of potentially significant ecosystem services that simply cannot be estimated at this time due to data constraints. These include the following:

- Agricultural and irrigation water (provisioning) – The benefit estimation in Section 3 was based on benefits accrual largely through rice cropping. However, given that cropping in Myanmar is quite diverse, it would have been desirable to account for irrigation benefits from other crops. This exercise was not possible in the current report due to data limitations on the types of crops, crop areas benefiting, yield responses, and any additional costs associated with increased cropping and higher yields. There are also other provisioning services to the agriculture sector, such as soil retention and fertility, nutrient cycling, and flood control, among others, for which the benefits were not quantified due to the dearth of data. Lastly, for the indirect, or spill-over, benefits of irrigation to the communities and other sector stakeholders (e.g., farm input suppliers and farm produce handlers), it is worth noting that such benefits are likely to be larger than the direct benefits accruing to farmers (Hussain, 2007). These benefits, however, are more difficult to estimate and attribute to the water provisioning ecosystem services. An extensive data gathering process would be required to quantify such benefits.

- Flood (regulating and supporting) – A number of SOBA packages have identified flooding as both a positive and a negative element of the Ayeyarwady Basin. Flooding provides a benefit to agriculture to the extent that flooding can replenish nutrient level in soils, improving productivity and increasing the economic value added from agriculture. To estimate these values would require data in the extent and frequency of beneficial flooding (area) and the likely change in crop productivity. This could then be incorporated into the model developed for Section 3 to estimate the ecosystem services. Flooding also has a cost in terms of damage to infrastructure, private property, productivity, and human well-being. Probabilistic flood cost curves could be developed using detailed flood risk assessments and indicative damage costs. The ecosystem services of Ayeyarwady Basin management (positive or negative) could then be estimated, where changes to flood risks and, subsequently, flood costs could be assessed by modelling changes in flood cost curves attributable to different projects and management decisions in the Ayeyarwady Basin. This requires significant scientific and economic inputs.

- Hydropower (provisioning) – The Ayeyarwady Basin is home to 14 existing hydropower plants, with a further 32 plants planned. To the extent that hydropower provides a cheaper source of energy than the next best alternative, this cost differential constitutes a provisioning ecosystem service underpinning energy provision. This will differ across all existing and proposed hydropower plants. Furthermore, there may be some losses in other ecosystem services due to hydropower projects, such as cropland foregone. Again, this will be on a case-by-case basis. Ideally, a framework would be developed and applied to assessments of potential hydropower projects to assist the Government of Myanmar to better understand the implications of hydropower investments and to enhance the understanding of the importance of the basin more generally.

- Potable water supply (provisioning) – Section 6 of this report outlines the importance of the Ayeyarwady Basin to potable water, with a specific focus on water quality. However, this report does not estimate the provisioning services attributable to the volume of water provided to the population for potable uses (drinking, cooking, and personal hygiene). Undertaking this assessment would require significant analysis to estimate the consumer surplus (benefits of consumption less economic costs of acquiring water supplies) attributable to the water consumption.

- Minerals extraction (provisioning) – Waterways in the Ayeyarwady Basin support extractive activities, such as mining of sand and gravel for construction. This service is particularly relevant given the sharp rise in construction activities across the country. Riverbed and bank mining provides a source of income for local labourers, especially in the dry season when there is reduced demand for labour in the agriculture sector. Unfortunately, such activities are also destructive, as they disturb riverbank stability and other channel morphology processes. Removal of large amounts of gravel or sand in the river can lead to bank collapses and reduced material deposit downstream. Alluvial gold mining is a common activity that can also increase erosion and sediments loads in Myanmar. While there are no data on the extent and impact of riverbed and bank mining in Myanmar, initial evidence suggests this is a growing problem, particularly for sand mining (ICEM, 2017f). Detecting riverbed mining is difficult, because of the changing nature of rivers, and there are no data on these activities in Myanmar. The value of riverbed mining was not included in the analysis due to lack of data on the economic contribution and the environmental costs of this activity.

In addition to these scoping limitations, there are likely to be a number of smaller or sub-regional specific ecosystem services that have not been covered in this report.

Because of the constraints in the scope of estimates presented in this report, the range of aggregate estimates outlined in this report should be considered significant underestimates. Further work should be undertaken to broaden the scope of economic estimates of ecosystem service values. Only then will the true economic importance of the Ayeyarwady Basin's condition be understood by the community and decision-makers alike.

9.2 Aggregate Estimates of Ecosystem Values and Gross Ecological Product

It is useful to consider the aggregate value of the ecosystem services assessed and consider the relative importance of these services to the broader economy in the Ayeyarwady Basin.

9.2.1 Aggregate estimates of ecosystem services

Because of the types of ecosystem services assessed in Sections 3 to 8 of this report, we have had to apply a number of methodologies to estimate specific ecosystem services. This is entirely appropriate and typical of most estimates of ecosystem services. Furthermore, we have estimated a range of values for each ecosystem service, reflecting both variability in input data and the need to use assumptions in our modelling.

All our estimates have used approaches that measure the net economic value added. This reduces the likelihood of overstating benefits that often occur when using gross values, such as market prices. Furthermore, this does allow some degree of aggregation of the individual estimates, as they are all based on the same economic concept. However, quoting aggregate estimates should still be treated with some care, and the accuracy of the estimates should not be overstated.

Table 30 shows the full scope of the estimates developed in Sections 3 to 8. This includes the range of our estimates and the range of our aggregated estimates. We have also undertaken a qualitative assessment of the reliability of our range of estimates – how confident we are that the actual value falls within our range presented. This is largely a function of the quality of data inputs. We have used a simple 'traffic light' approach to reflect this, specifically:

We are reasonably confident in our estimates
We are somewhat confident in our estimates
Treat estimates with extreme care

We estimate the aggregate value of the ecosystem services that we have assessed is in the range of USD 2.5 to 6.9 billion per annum. This is shown in Table 30.

Table 30 - Annual value of ecosystem services (NCEconomics estimates)

Ecosystems service	Estimated values (USD million)			Reliability of range of estimates
	Low	Medium	High	
Ecosystem services quantitatively estimated				
Agriculture (irrigation water supplies provisioning services)				
Yield gains in monsoon	29	40	50	
Ability to produce crops outside monsoon	62	91	121	
Freight (inland rivers – modal substitution provisioning services)				
Freight task savings	8	13	23	
Fisheries (protein replacement provisioning services)				
Freshwater capture	350	440	530	
Aquaculture	380	490	600	
Potable water supplies (water quality regulation services only)				
Treated tap water	57	91	125	
Local treatment	129	321	514	
Biodiversity (supporting services)				
Forests	1,300	2,645	4,418	
Wetlands	4	7	10	
Mangroves	146	297	497	

Ecosystem services not quantitatively estimated				
Agriculture (provisioning services excluding irrigation water supplies)				
Soil retention and fertility, nutrient cycling, pollination, pest control and non-irrigation water.	Insufficient data to value. Likely to be significant across irrigated cropping, dryland cropping and stock.		n/a	
Potable water supply (water provisioning)				
Supply of groundwater and surface water (volume) for consumptive use in households (drinking, cooking, personal hygiene, clothes washing etc.).	Insufficient data on consumption volumes and economic values of alternative water sources (including replacement costs) to develop estimates.		n/a	
Flooding (regulating and provisioning services)				
The Basin's natural flooding regime (locations, frequency, extent etc.) results in risks (damage to property, lives and crops etc.) as well as soil replenishment. Basin management will change the flooding regime and the marginal benefits and costs attributable to flooding.	Data on locations and extent of flooding available is insufficient to estimate economic values.		n/a	
Hydro power (intermediate provisioning service)				
River flows in conjunction with built capital (dams, turbines etc.) provide an intermediate provisioning service to electricity generation. These values would ideally be assessed against any trade-offs relating to specific hydro projects (e.g. costs of relocating communities etc.).	Insufficient data available on costs of electricity to be supplied and costs of next best substitute to estimate marginal benefit of hydro power. Values will be project specific. Values are likely to be very significant.		n/a	
Gravels and natural quarrying products (provisioning service)				
These products are often extracted from riverbeds in the Ayeyarwady Basin for use in building of homes, other buildings and public infrastructure such as roads and bridges etc.	Insufficient data on both extraction rates, costs of extraction and costs of substitutes to establish credible estimates at this stage.		n/a	
Ecotourism (cultural service)				
The Basin's natural beauty will be one of the drawcards for the emerging tourism industry. This provides a major cultural ecosystem service.	There is insufficient data on tourism and ecotourism in particular, although the sector has significant potential to be a major contributor to economic activity.	n/a		
Total ecosystem services	**> 2,464**	**> 4,435**	**> 6,888**	

The key point to note is that, despite the scope of our assessment being constrained and the limited data availability, there is evidence to suggest that ecosystem services in the Ayeyarwady Basin are economically significant. Therefore, enhancements to Ayeyarwady Basin management to protect and increase ecosystem services derived by the people of Myanmar is worthwhile. Further, the value of ecosystem services is not reflected in market prices for goods and services consumed (i.e., they are non-market values). As such, it is vital to estimate the value of the non-market ecosystem services to understand the economic value of the Ayeyarwady Basin's natural capital.

9.2.2 Gross Ecological Product – the relative importance of ecosystem services

Consultation undertaken as part of this project identified significant interest in understanding the relative value of the ecosystem services of the Ayeyarwady Basin within a more common national accounting framework.

Historically, national accounting measures, such as GDP, have been the key measure of progress at a country level. However, there is a growing concern about the lack of accounting for the loss of environmental resources and the degradation of ecosystem services. In pursuing economic growth and better lifestyles, humans are having a significant impact on the environment. Economic progress, such as increased outputs from mining, agriculture, and manufacturing, have a negative impact on natural ecosystems and, thus, affect the ecosystem services over time. Consequently, several approaches have been developed to provide more information by including aggregated ecosystem values, as an approach for adjusting GDP estimates, to reflect the value of ecosystem services and the impact of degradation on natural capital in monetary terms.

One approach that is gaining interest is the Gross Ecological Product (GEP) measure. GEP is a natural resource accounting approach through which a country's or a region's natural capital can be added to the GDP or compared to the GDP (Guerry et al., 2015; IUCN, 2013; Makower, 1994). GEP can also be used to account for the value of lost natural capital or ecosystem services from the GDP to better reflect a country's 'progress.' Theoretically, the estimated values for ecosystem services can either be positive or negative to reflect the positive contribution of natural capital and the environmental costs incurred by extracting or disturbing ecosystems (Bawa et al., 1990; IUCN, 2013).

GEP for a given country can be quantified by estimating the economic values of its natural resources. The values are aligned with the Millennium Ecosystem Assessment (2005) ecosystem service categories: provisioning, regulating, cultural, and supporting services. Once an appropriate valuation technique has been identified and the monetary values estimated for the different ecosystem services, then the values can be aggregated, as per the equation below to approximate a country's GEP:

$$GEP_t = \sum_{i=1}^{m} PS_t + \sum_{j=1}^{n} RS_t + \sum_{k=1}^{o} CS_t + \sum_{l=1}^{p} SS_t$$

Where:

GEP_t is the gross ecological product at year *t.*

PS_t is the economic value of provisioning services for identified *m* ecosystems at year *t.*

RS_t is the economic value of regulating services for identified *n* ecosystems at year *t.*

CS_t is the economic value of cultural services for identified *o* ecosystems at year *t.*

SS_t is the economic value of supporting services for identified *p* ecosystems at year *t.*

The individual values of the ecosystem services quantified in this report were aggregated as per the equation above. To compare the value added by the ecosystem services, a GEP per capita for the Ayeyarwady Basin was compared to the GDP per capita for Myanmar. Using a per capita calculation for comparisons of GEP and GDP is necessary, as there is no Ayeyarwady Basin-specific estimate of GDP. Myanmar's population was estimated at 52.9 million in 2016, and the GDP was 75.1 billion (World Bank, 2017a). Thus, the calculated GDP per capita for the whole country was USD 1,420. The Ayeyarwady Basin's population is estimated at 33.2 million (ICEM, 2017a). The estimated GEP for the ecosystem services is USD 4.4 billion. The medium GEP per capita estimate is approximately USD 140, and it is equivalent to 10% of the GDP per capita.

Figure 15 provides a comparison of the GEP per capita against GDP per capita. This comparison assumes that the productivity in the Ayeyarwady Basin is the same as elsewhere in the country. Also, the GEP estimate is not exhaustive. Some values, such as cultural and even some cropping activities, are not included due to data limitations. The comparison should be undertaken with these limitations in mind. The three highest-valued ecosystem services were forests, aquaculture, and freshwater capture.

While our estimates should be treated with caution, they do reinforce the importance of the ecosystem services in the Ayeyarwady Basin.

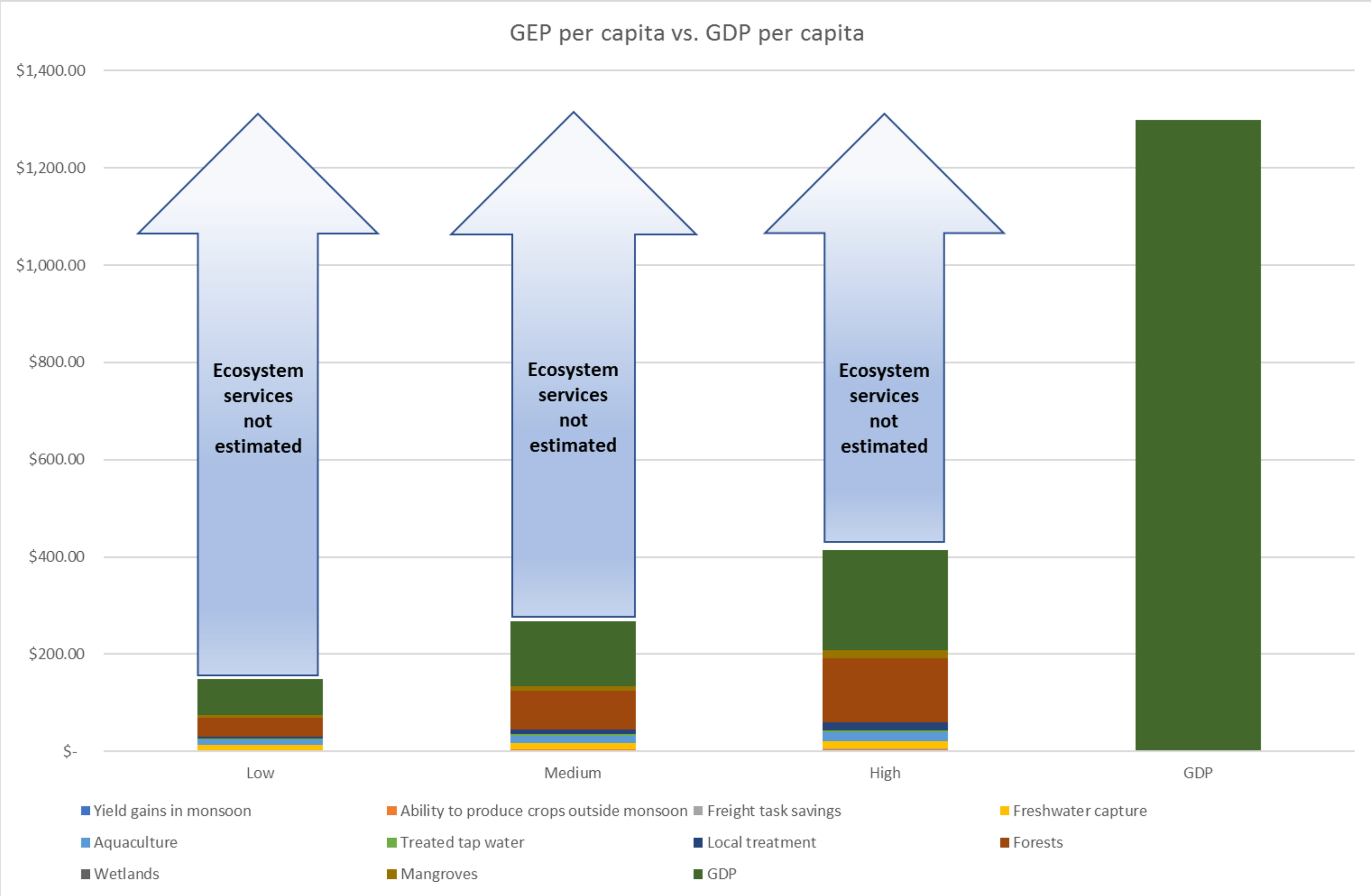

Figure 15 – GEP per capita vs. GDP per capita (NCEconomics)

9.3 Synergies and Trade-offs

In this report, due to data and resourcing limitations, we have effectively treated each ecosystem service as mutually exclusive. This creates two limitations in understanding the ecosystem services in the Ayeyarwady Basin:

1. Synergies – It should be realised that there are likely to be synergistic effects between actions and multiple ecosystem services. For example, actions to reduce sediment loads will simultaneously have impacts on biodiversity, fisheries, water transport, and water quality-related ecosystem services. Data and resources available for this study do not allow for quantification of the synergistic values. However, as information and knowledge improve, these synergistic values should be incorporated into decision-making.

2. Trade-offs – Trade-offs between ecosystem services have not been assessed. For example, does improving ecosystem services attributable to irrigation result in increases in nutrient levels in waterways (and potentially leading to algal blooms) and reduce the ecosystem services of existing potable water supplies (as more expensive treatment may be required)? Future work relating to development and investments should ideally include an assessment of the trade-offs between the supply and value of different ecosystem services. The most obvious example of this, in the short-term, would be potential trade-offs attributable to hydropower projects (e.g., increased energy

[provisioning ecosystem service] vs. changes to environmental flow regimes [underpinning a supporting ecosystem service]).

These limitations will be reduced over time as the Ayeyarwady Basin planning is implemented and monitoring and evaluation are enhanced.

9.4 Monitoring and Evaluation

Program evaluation is a critical part of Ayeyarwady Basin management. It is the primary mechanism through which decision-makers can understand whether interventions are working well or not and the reasons *why*. The primary purpose of evaluation is to support learning for improvement, so interventions can be modified and adapted to be more effective at achieving their intended objectives.

A meaningful evaluation of a program requires a framework within which the monitoring and evaluation can be designed, data analysed, and results interpreted. It is, therefore, highly recommended that a monitoring and evaluation (M&E) framework be developed for the Ayeyarwady Basin management programs.

Contemporary, best-practice evaluation (Donaldson, 2007; Markiewicz et al., 2015) emphasises a number of elements that are of key importance for developing useful, fit-for-purpose M&E frameworks. These include the following:

- To develop a sound and shared understanding of the 'problem/s' the management programs are trying to address[8] and the program design[9]. This forms the foundation of the monitoring and evaluation work. For the Ayeyarwady Basin M&E framework, it may be useful to utilise the DPSIR (drivers, pressures, state, impact, response) system.[10] The DPSIR system can help incorporate economic, social, and demographic insights into natural resource management problems and related program designs, which are supported by quantitative datasets and 'evidence.'

- Key evaluation questions help focus the M&E activities on aspects that are most important to primary stakeholders for their learning and strategic decision-making needs. This practice helps ensure the M&E work delivers on expectations and the highest priority information needs. It also helps to promote a more achievable approach to collecting monitoring information, rather than formulating over-ambitious and over-engineered monitoring plans that tend to lead to poor execution and execution failure.

Furthermore, in the Myanmar context, it will be important to employ a participatory approach to developing the M&E framework (e.g., through interactive workshops). This will help to ensure that there is understanding and ownership of the M&E framework, that it will be successfully implemented, and that knowledge generated will indeed be used to inform decision-making.

Where there is interest, a partnership arrangement between internal (i.e., within the implementing agency of GoM) and external evaluators and consultants could be considered. This will help to build the capacity of GoM to undertake this work and further contribute to ownership.

9.5 Implications for Ayeyarwady Basin Planning

Despite its limitations, this study does identify a number of specific implications for the future of Ayeyarwady Basin planning and management. This includes the following:

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[8] Including the underpinning causes and drivers.

[9] *How* and *why* program strategies are believed to contribute to the intended change.

[10] This exercise will also likely help to refine the design of existing program strategies and identify any gaps.

- **Ecosystem services are important, valuable, and at risk –** Ecosystem services in the Ayeyarwady Basin are important and have a significant economic value. Evidence from the other SOBA packages shows that much of the Ayeyarwady Basin is in decline. These declines reduce ecosystem services that may be expensive to replace (e.g., the need for expensive water treatment) or result in the loss of economic opportunity (e.g., further development of a river-based ecotourism sector).

- **Ecosystem services can be valued, and values should be incorporated into decision-making –** This report has estimated the range of values for a number of different ecosystem services. These values can then be incorporated with other economic values (such as the costs of Ayeyarwady Basin management strategies) within a formal cost-benefit analysis to prioritise which Ayeyarwady Basin management activities provide the greatest net benefits to the people of Myanmar. Importantly, the use of economic analysis is the 'currency' of decision making at key ministries, such as planning and finance, and with the private sector.

- **Data and information M&E –** The analysis in this report has been undertaken based on relatively limited data and information sources. This both constrains the accuracy of the estimates developed and the scope of understanding of the true value of ecosystem services in the Ayeyarwady Basin. The implication of this is that many decisions are not adequately informed, which can lead to inefficient allocations of public funds, or projects that do not adequately consider trade-offs between competing policy objectives. The establishment of a more formalised M&E framework and system for the Ayeyarwady Basin will improve information used for decision-making over time. It will also enhance our understanding of how the Ayeyarwady Basin works, and how to manage it better for the benefit of Myanmar.

- **Capacity building –** Like most aspects of Ayeyarwady Basin management, the development, understanding, and use of economic knowledge to better inform decision making is a long-term strategy. This will require ongoing and regular needs for capacity building among Ayeyarwady Basin managers. This will require ongoing commitments and energy from the Government of Myanmar, stakeholders within Myanmar, and the broader community.

Importantly, the use of economic insight and the incorporation of ecosystem service values into Ayeyarwady Basin planning, management, and investment should be seen as an ongoing means to mainstream Ayeyarwady Basin management as a fundamental contributor to sustainable development in Myanmar.

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ANNEX I – VALUATION TECHNIQUES USED FOR ECONOMIC MODELLING

Total economic valuation

A total economic valuation (TEV) is a tool to assist benefit cost analyses (BCA). A TEV may be used to provide a comprehensive appraisal of the economic value of an environmental asset (OECD, 2006). For this assessment, TEV is the value derived by Myanmar from natural resources. The TEV framework has been illustrated in Figure 16, which shows that a TEV analysis is split into use values and non-use values. As depicted below, use values consider both direct uses and indirect uses, and non-use values consider options/bequests and existence.

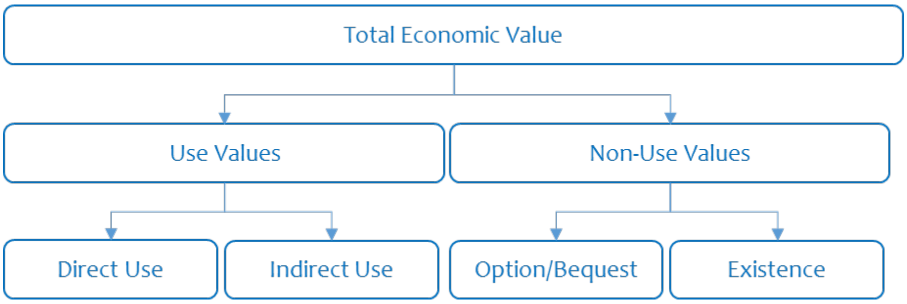

Figure 16 – A simple representation of the Total Economic Valuation framework

Use values

Use values measure the value arising from the actual, planned, or possible use of a given environmental asset. Use values can be direct or indirect. Direct use values relate to a benefit received from directly using the environmental asset (e.g., water consumption). Indirect use values relate to the benefit obtained from the environmental asset by indirect use (e.g., watching a documentary on the mangroves in the Ayeyarwady Delta).

Non-use values

Non-use values refer to the willingness to pay (WTP) to maintain some good in existence even when the individual does not plan to use the resource in the immediate future. As stated above, non-use values are generally separated into option, existence, and bequest values. Option captures a WTP for future use of an asset (e.g., a future visitation to the mangroves in the Ayeyarwady Delta). Bequest refers to a WTP to maintain or improve the condition of an environmental asset for future generations so that they can obtain a similar enjoyment from the asset (e.g., maintaining/improving the condition of the mangroves in the Ayeyarwady Delta). Existence describes the philosophical reasons for protecting the environmental asset, focusing on the value of the knowledge of continued existence of the asset (e.g., the knowledge of the ongoing existence of the mangroves in the Ayeyarwady Delta).

Overview of valuation techniques

A number of possible valuation techniques may be used when seeking to estimate monetary benefits of an ecosystem service. To select the appropriate valuation technique requires an examination of resource availability and constraints (particularly data availability and quality) and time. Valuation techniques are commonly separated into market price methods (where values are revealed through market transactions) and non-market valuation (where values are not revealed through market transactions).

Different approaches to economic valuation are shown in Table 31. This study relied on multiple valuation techniques to value the ecosystem services of the Ayeyarwady Basin.

Table 31–Economic valuation techniques and approaches

Method	Based on …	Useful for …
	Market-based techniques	
Market values	Actual market transactions	Where there are established markets (e.g., farming output)
Productivity-based	Inputs to production of commercial goods	Changes in rice productivity
Replacement cost	Costs of replacing a service or avoiding costs	Cost of water supply services attributable to changes in water quality or change in damage attributable to flooding
	Non-market based techniques	
Hedonic pricing	Values of goods bundled with market traded goods (e.g. aesthetic amenity/view which is accessed through buying a house in a particular neighbourhood)	The recreational and aesthetic value of improvements in water quality
Travel cost	Costs incurred in visiting a site	Valuing tourism, recreation, or cultural use of a site
Stated preference techniques	Surveys and community willingness to pay to protect an asset	The value of the existence of biodiversity and ecosystem functions

Further explanation is provided below for some of the key techniques used during the valuation of the Ayeyarwady Basin's ecosystem services:

- *The production function approach* – When a non-market good or service is used as an intermediate input factor in some production process, and the output of the production process is then sold in a market, the economic value of the non-market input can be defined by the additional value (profit) that the input generates in isolation from other inputs and production technology (e.g., the marginal change in irrigated agriculture values attributable to irrigation water applied to crops). Data are typically available from government and academic sources, and values are sometimes estimated through economic modelling of available data.

- *The damage avoided cost, replacement cost and substitute cost methods* – These are related methods that estimate values of goods and services based on either the costs of avoiding damages due to lost services, the cost of replacing environmental assets, or the cost of providing substitute services. For example, the cost of protein replacement if a fishery is lost. Data for this type of valuation are typically available from existing scientific studies and analysis of cost, revenue, or price data.

- *The travel cost method* – This method is typically used to estimate the value of recreational benefits generated by non-market goods and services, such as lakes and waterways. The travel cost method assumes that the value of a site or its recreational services is reflected in how much people are willing to pay to access the site. To apply the method, surveys of visitors are typically undertaken and economic analysis of the costs of visitation is then calculated to estimate the value of benefits attributable to the asset.

- *Benefit transfer* – This method employs estimates of economic values from studies undertaken elsewhere to infer values for the proposal(s) under consideration. The degree to which benefit transfer is possible is subject to the availability of data from previous studies undertaken elsewhere and the degree to which the proposal is similar to the original study.

It should be noted that each of these non-market valuation techniques requires significant skills and resources to implement properly.

Market price versus economic value

In the measurement of the value of a good or service, a clear distinction must be drawn between economic values and market prices. Market prices for goods and services often fail to fully account for all of the values associated with the use of the asset (i.e. the ecosystem service). A useful way to understand the range of values associated with a given environmental asset is the TEV framework (discussed above). As illustrated in Figure 16 (above), the general TEV framework clearly distinguishes between *use* and *non-use values*.

The market price method estimates the economic value of goods or services that are bought and sold in commercial markets (e.g., potable water or irrigated crops). The market price method can be used to value changes in either the quantity or quality of a good or service. It uses standard economic techniques and observable market data for measuring the economic benefits. This is based on the quantity people purchase at different prices, and the quantity supplied at different prices. A market price represents the value of an additional unit of that good or service, assuming the good is sold through a perfectly competitive market. The advantages of the market price approach are that:

- Price, quantity and cost data are relatively easy to obtain for established markets.
- The method uses observed data of actual consumer preferences.
- The method uses standard, accepted economic techniques.

The limitations of using the market price approach, includes the following:

- Market data may only be available for a limited number of goods and services and may not reflect the value of all productive uses of a resource.
- There may be market imperfections where market prices do not accurately reflect economic value (e.g., where the market price does not capture the value of the ecosystem service).
- Where larger scale change is proposed that may significantly affect supply or demand, future prices (i.e., post project, policy or program) may be significantly different to current prices.

Care must be taken to ensure benefits are not overstated by failing to deduct associated market cost of other expenses (e.g., deducting the delivery costs from the market price of water).

Calculating a social discount rate

Some of our modelling has required the consideration of long-term economic impacts and values. This requires the use of discounting and the social discount rate. In essence, the purpose of the social discount rate is to place a present day value on costs and benefits that occur in the future. Choosing an appropriate social discount rate is crucial for economic analysis (and other forms of project/policy/program evaluation) when the benefits and costs of the proposal are spread over multiple time periods. A relatively high social discount rate, by attaching less weight to benefits and costs that occur in the future, favours proposals with benefits occurring at earlier dates. In contrast, a relatively low social discount rate favours proposals with benefits occurring at later dates. Choice of social discount rate affects not only the *ex-ante* decision of whether a proposal should go ahead, but also the *ex-post* evaluation of its performance (ADB 2013a).

Following Ramsey (1928), a social discount rate can be expressed as follows:

$$r = \rho + \eta . g$$

Where r is the social discount rate, ρ is the pure rate of time preference, η is the elasticity of the marginal utility of consumption, and g is the growth rate of consumption per capita. There is some debate in the economic literature about the value of these parameters, which has received much attention in recent years. This is due to the need to evaluate alternative climate change policies as they are expected to yield benefits and costs over multiple future generations.

In regards to the pure rate of time preference (ρ), the question is one of how much importance we should place on the welfare of future generations. A value of zero means that the welfare of future generations is treated equally to that of present generations, a positive value means that the welfare of future generations is reduced or 'discounted' compared to present generations. Many argue that a pure rate of time preference that is close to zero is most appropriate, thus placing (almost) no discount on the welfare of people in the future just because today these people are young or not yet born (Sen, 1961). Values of ρ found in the literature range from 0.1% to 3%, with most values clustered approximately 1%. In Table 32 below we present social discount rates based on values for ρ of 0.75, 1 and 1.25.

The elasticity of the marginal utility of consumption (η) is a measure of society's concern for equity in income distribution. It is reasonable to value future income at a lower rate than current income. As noted by Garnaut (2008), and supported by Quiggin (2008), there are compelling arguments for using a value of 1. In contrast, Dasgupta (2007) argues that a value of 1 implies the distribution of wellbeing among people doesn't matter much and that a higher value should be used. Empirical estimates suggest values for η typically range from 1% to 2%. In Table 32 we present social discount rates based on values for η of 1, 1.5 and 2.

In Table 32 social discount rates are offered based on the per capita average real economic growth rate (purchasing power parity) for Myanmar for the 10 years to 2016. This growth rate is 7.7% (World Bank, 2017a). As shown in Table 32, together these assumptions yield social discount rates ranging from 8.45% to 16.65%. Often, arguments are made for the use of discount rates at the lower end of the range for environmental evaluations. The current interest rate for Government Treasury Bond (the best market proxy for a risk-free long-term discount rate) is 9.5% for 5-year bond. We have therefore used social discount rate of 8.70% as a base case, with sensitivity analysis around this value.

Table 32 - Social discount rates with a per capita consumption growth rate of 4.85% p.a.

ρ	η		
	1.0	**1.5**	**2.0**
0.75	8.45%	12.30%	16.15%
1.00	8.70%	12.55%	16.40%
1.25	8.95%	12.80%	16.65%

ANNEX II – OVERVIEW OF PREVIOUS ECOSYSTEM SERVICES VALUATIONS IN MYANMAR

Ecosystem services

Ecosystem services are the benefits people obtain from the natural environment (Millennium Ecosystem Assessment [MEA], 2005). MEA (2005) outlines four main ecosystem services. These include the following:

1. Provisioning services – consist of all the products obtained from ecosystems (i.e., food, water, raw materials, and fuel wood).
2. Regulating services – the benefits obtained from the regulation of ecosystem processes. In the case of maintaining water quality and flood risk management, these services include climate regulation, waste treatment and disease control, and natural hazard regulation.
3. Cultural services – related to non-material benefits, for instance recreation and tourism as well as aesthetic, cognitive, and spiritual benefits.
4. Supporting services – consist of soil formation, photosynthesis, and nutrient cycling. The supporting services category is the basis of the remaining categories. In other words, if supporting ecosystem services cease to function, the other ecosystem services categories (provisioning, regulating and cultural) can no longer function.

Simply, ecosystem service valuation provides a framework through which an evaluation of the economic benefits for ecosystems can be undertaken. These benefits can then be used to compare the advantages and disadvantages of a given decision that can be used to influence socio-economic development discourse and decision making. The dollar value of the ecosystem service is commonly presented as a key finding.

For any valuation of an ecosystem service certain realities should be understood and considered:

- Although the broad categorisation of ecosystem service types (highlighted above) is well-accepted, in some situations it is useful to split the ecosystem services into smaller classifications (e.g., food, raw materials, climate regulation, water flow regulation, nursery services etc.).
- In some cases it is difficult to categorise a specific ecosystem (e.g., the degradation of ecosystems, damage costs from extreme weather events etc.) and therefore results of any ecosystem service valuation should be treated with an appropriate level of caution.
- Some ecosystem service values represent several types of ecosystem services and are simply too broad to categorise. Therefore, to overcome this ecosystem service values may be grouped as ‘other’. Even though these service values do not fit neatly into one of the common categories they continue to have an impact and therefore should inform valuations.

Literature review

Our literature review focussed on studies with relevance to ecosystem services Myanmar and the immediate region. The categorisation shown in Table 33 provides a minimum and maximum value for several identified ecosystem services. These have been included to indicate the range of values specified in the literature. From the data presented in Table 33, many ecosystem services (i.e. food, raw materials, medicine and tourism) generally have values less than USD 100/ha/year. Whereas ecosystems such as fish, timber, carbon sequestration, income from rice and subsistence products typically have values between USD 100/ha/year to USD 999/ha/year. In the higher value range (greater than USD 1,000/ha/year) we find a variety of regulating ecosystem services, such as storm protection, GHG emissions (cost) and breeding habitats.

Table 33 – Value ranges for ecosystem service categories from available data

EA category	Ecosystem services	Value Indicator	Minimum (2016 USD)	Maximum (2016 USD)	Sources
Provisioning	Food (13)	USD/ha/year	$2.6	$1,450	Barbier, 2007; Do and Bennett, 2005; Tri, 2002; Samonte-Tan et al., 2007; Bann, 1997; Gerrard, 2004; Janssen and Padilla, 1999; Hamilton and Snedaker, 1984; Chong, 2005; White et al., 2000; Myanmar Ministry of Agriculture and Irrigation. (May 2015).; BANCA, 2014; Emerton, 2013
		USD/year	$446,760	$446,760	
	Genetic (3)	USD/ha/year	$26.41	$7,404	Tri, 2002; Samonte-Tan et al., 2007; Chong, 2005
	Medical (3)	USD/ha/year	$2.57	$52.81	Do and Bennett, 2005; Emerton et al., 2002; Chong, 2005
	Raw materials (16)	USD/ha/year	$0.21	$1,724	Do and Bennett, 2005; Tri, 2002; Sathirathai, 1998; Bann, 1997; Nickerson, 1999; Janssen and Padilla, 1999; Christensen, 1982; Dugan, 1990; Hamilton and Snedaker, 1984; Chong, 2005; White et al., 2000; Emerton and Aung, 2013; BANCA, 2014; Emerton, 2013; Bassi et al., 2016
		USD/year	$7,611	$605,280,000	
	Water (3)	USD/ha/year	$52,81	$132	Chong, 2005; Emerton and Aung, 2013; BANCA, 2014
		USD/year	$85,068	$8,670,000	
	Other (5)	USD/ha/year	$185.03	$3,037	Emerton and Aung, 2013; Barbier, 2016; BANCA, 2014; Emerton, 2013; Brander et al., 2012
Regulating	Carbon sequestration (4)	USD/ha/year	$2.62	$117	Emerton and Aung, 2013; Emerton, 2006; BANCA, 2014; Bassi et al., 2016
		USD/year	$3,198,720	$925,600,000	
	Climate (16)	USD/ha/year	$41.92	$60,871	Barbier, 2007; Sathirathai, 1998; Barbier et al., 2002; Chomitz and Kumari, 1995; Dixon and Hodgson, 1988; Emerton, 2005; Samonte-Tan et al., 2007; Bann, 1997; Gerrard, 2004; Emerton and Aung, 2013; Barbier, 2016; Emerton, 2006; BANCA, 2014; Emerton,
		USD/year	$22,440	$2,837,120,000	
		USD	$1,872,000	$13,900,000,000	

					2013; Bassi et al., 2016; Hale et al., 2009
	Waste decomposition (2)	USD/ha/year	$46.4	$1,493	Gerrard, 2004; Emerton, 2013
		USD/year	$749,840,000	$749,840,000	
Supporting	Nursery (10)	USD/ha/year	$99.8	$67,995	Sathirathai, 1998; Do and Bennett, 2005; Levine and Mindedal, 1998; Nickerson, 1999; Gerrard, 2004; Samonte-Tan et al., 2007; Janssen and Padilla, 1999; Christensen, 1982; Barbier et al., 2002; Emerton and Aung, 2013
		USD/year	$1,175,200,000	$1,175,200,000	
Cultural	Cultural (1)	USD/ha/year	$7.8	$450.32	Emerton, 2013
	Recreational (8)	USD/ha/year	$0.18	$524	Tri, 2002; Samonte-Tan et al., 2007; Chong, 2005; White et al., 2000; Emerton and Aung, 2013; BANCA, 2014; Emerton, 2013; WTTC, 2017
		USD/year	$75,480	$4,152,592,593	
Other	TEV (4)	USD/ha/year	$36,442	$47,481	Sathirathai and Barbier, 2001; Emerton and Aung, 2013; BANCA, 2014; Emerton, 2013
		USD/year	$22,542,000	$7,592,000,000	
		USD	$10,400,000,000	$40,500,000,000	
	Degradation (cost) (2)	USD	$53,000,000	$17,680,000,000	Emerton and Aung, 2013; Brander et al., 2012

It should be noted that these are general observations and some ecosystem service benefits such as food, tourism and carbon sequestration vary considerably. This is most likely due to the fact that the values have been derived from studies that cover different geographical areas that differ widely from one another in terms of their environmental characteristics, utility purposes and qualities. Furthermore, the actual values of some provisioning services (e.g., water, food) will also depend on the population actually accessing the ecosystem service.

Provisioning services

For food, the minimum value per hectare per year was found for food in Vietnam (USD 2.6) while the maximum value was found for fish in Laos (USD 1,450). The only value of food per year was found for rice production in Myanmar.

For genetic resources, minimum value was found for biodiversity protection in Cambodia (USD 26.41), while the maximum was found for biodiversity protection in Vietnam (USD 7,404). Minimum value of medical resources was found for biochemicals in Cambodia (USD 2.57), as this was also where the maximum value was found, but from a different study (USD 52.81).

For raw materials, minimum value per hectare per year was found for the local use of raw materials in Vietnam (USD 0.21), while the maximum value was found for Thailand (USD 1,724). Minimum value of raw materials per year was found for timber in Vietnam (USD 7,611), while the maximum value of raw materials per year was found for industrial wood production in Myanmar (USD 605 million).

For water, minimum value per hectare per year was found for unnatural irrigation water in Cambodia (USD 52.81) while the maximum value was found for drinking water, also in Cambodia (USD 132). The minimum value of water per year was found for irrigation water in Myanmar (USD 85,068), while the maximum was for the TEV of water services in the Moeyungyi Wetland (USD 8.6 million).

Regulating services

For carbon sequestration, the minimum value per hectare per year was found for Cambodia (USD 2.62), while the maximum was found for Thailand (USD 117).

For climate regulation, the minimum value per hectare per year was found for storm protection from mangroves in Cambodia (USD 41.92) while the maximum value was found for the loss of storm protection (cost) from mangrove deforestation in Thailand (USD 60,871). The minimum total value per year was found for the management cost of wetlands in Myanmar (USD 22,440), while the maximum was found for wild insect crop pollination services in forests in Myanmar (USD 2.8 billion). In addition, a total value was given for climate services. For this, the minimum value was USD 1.8 million from damage costs from flooding in Myanmar (excluding Cyclone Nargis), while the maximum value was USD 13.9 billion in damage costs from Cyclone Nargis in Myanmar in 2008.

For waste decomposition, the minimum value per hectare per year was found for water purification of inland wetlands in Laos (USD 46.4) while the maximum was found for flood protection and waste water treatment in Laos (USD 1,493). For the value per year, only one estimate was given, and this was for watershed protection from forests in Myanmar with a value of USD 749 million.

Supporting services

For nursery, the minimum value per hectare per year was found for fish nurseries in Thailand (USD 99.8) while the maximum was found for mangrove's nursery services in the Philippines (USD 67,995). For the value per year only one estimate was found, and this was for mangrove's nursery and breeding habitats in Myanmar (USD 1.17 billion).

Cultural services

For cultural values, only two specific estimates were found. The minimum value per hectare per year was for non-use values from mangroves in Thailand (USD 7.8) and the maximum value was non-use values from wetlands in Vietnam (USD 450.3). These were derived from the same study.

For recreational values, the minimum value per hectare per year was for tourism in the Philippines (USD 0.18), while the maximum was for tourism around mangroves in Thailand (USD 524). The minimum value per year was for tourism around wetlands in Myanmar (USD 75,480) while the maximum value was for the total contribution of tourism to GDP in Myanmar (USD 4.2 billion) noting that this estimate is for all tourism activity.

Other types of ecosystem valuations

The total economic value (TEV) is a value indicator that cannot be neatly categorised into only one of provisioning, regulating, cultural or supporting services. Therefore, it is categorised as 'other'. For TEV, both the minimum (USD 36,442) and maximum (USD 47,481) value per hectare per year was for coastal wetlands and mangroves in Thailand, from the same study. The minimum value per year was the TEV of wetlands in Myanmar (USD 22.5 million) while the maximum value was for the total annual value of forest ecosystems in Myanmar ($7.6 billion). In addition, several total value estimates were given, the minimum value for NPV of forest ecosystems in Myanmar (USD 10.4 billion) and the maximum value for the total net gain from conserving forest ecosystems in Myanmar (USD 40.5 billion). The latter is also the largest estimates encountered throughout all the studies.

For degradation (cost), three estimates were given that all relate to the economic loss associated with the degradation of ecosystems. These were only given as a total value. The minimum value was for the degradation of mangroves in Myanmar (USD 53 million), while the maximum value was for the degradation of forest ecosystems in Myanmar (USD 17.8 billion). Lastly, a few other value indicators were found. However, these are of lesser relevance for our study, but are included here for comparative purposes.

Table 34 - Biodiversity values from other Asian countries

Ecosystem	Country	Valuation method	Unit-value	USD CPI adjusted 2016
Coastal wetlands/mangroves	Vietnam^	Restoration cost	USD/ha/year	7,403
Coastal wetlands/mangroves	Philippines^^	Group valuation	USD/ha/year	30
Inland wetlands (maximum)	Cambodia*	Group valuation	USD/ha/year	53
Inland wetlands (medium)	Cambodia*	Group valuation	USD/ha/year	40
Inland wetlands (minimum)	Cambodia*	Group valuation	USD/ha/year	26

*^ Tri 2002; ^^Samonte-Tan et al., 2007; *Chong 2005*

Table 35 outlines our qualitative assessment of the suitability of the studies that we have reviewed as a basis for robust benefit-transfer of values for this report. We have used a simple 'traffic light' approach to reflect this specifically:

- We are reasonably confident that robust estimates can be developed
- We are somewhat confident that robust estimates can be developed
- Treat estimates with extreme caution

The majority of the estimates we have reviewed should be treated with extreme caution when applied to the Ayeyarwady Basin.

Table 35 – Table highlighting available data (including suitability) for valuing the Ayeyarwady Basin's ecosystem services

Category (total no. of studies)	Ecosystem service (no. of studies)	Which benefit might be useful?	Suitability of data
Provisioning (18)	Food (5)	Any local values associated with food prices, e.g. market value of food items	
	Genetic	E.g. biodiversity	
	Medical	E.g. medicine or biochemicals	
	Raw materials (10)	While some literature included total values unit values ($/ha/year) or market values of raw materials are generally not available.	
	Water (3)	Same as above, but for water use (costs)	
	Energy	E.g., hydropower, or general costs or benefits associated with energy use	
	Biogenic	E.g., Fossil fuels (costs)	
Regulating (21)	Carbon sequestration (7)		
	Climate (13)		
	Waste decomposition (1)	Estimates (either benefits or costs) on water-purification, and/or cost of dealing with waste, in general	
	Pest and disease control		
Supporting (2)	Nursery (2)	It might be beneficial for us to get the costs associated with restoring mangroves for their nursery and breeding habitat services, and compare these with the benefits	
	Nutrient cycling		
	Primary production		
	Soil formation		
Cultural (8)	Cultural	Inspiration, arts, and local values	
	Spiritual and historical	Heritage value, or values based on history	
	Recreational (8)		
	Science and education	Any value associated with science	

Although the value estimates in our dataset differ widely according to study and country, it is clear that Myanmar's ecosystems will have significant economic values.