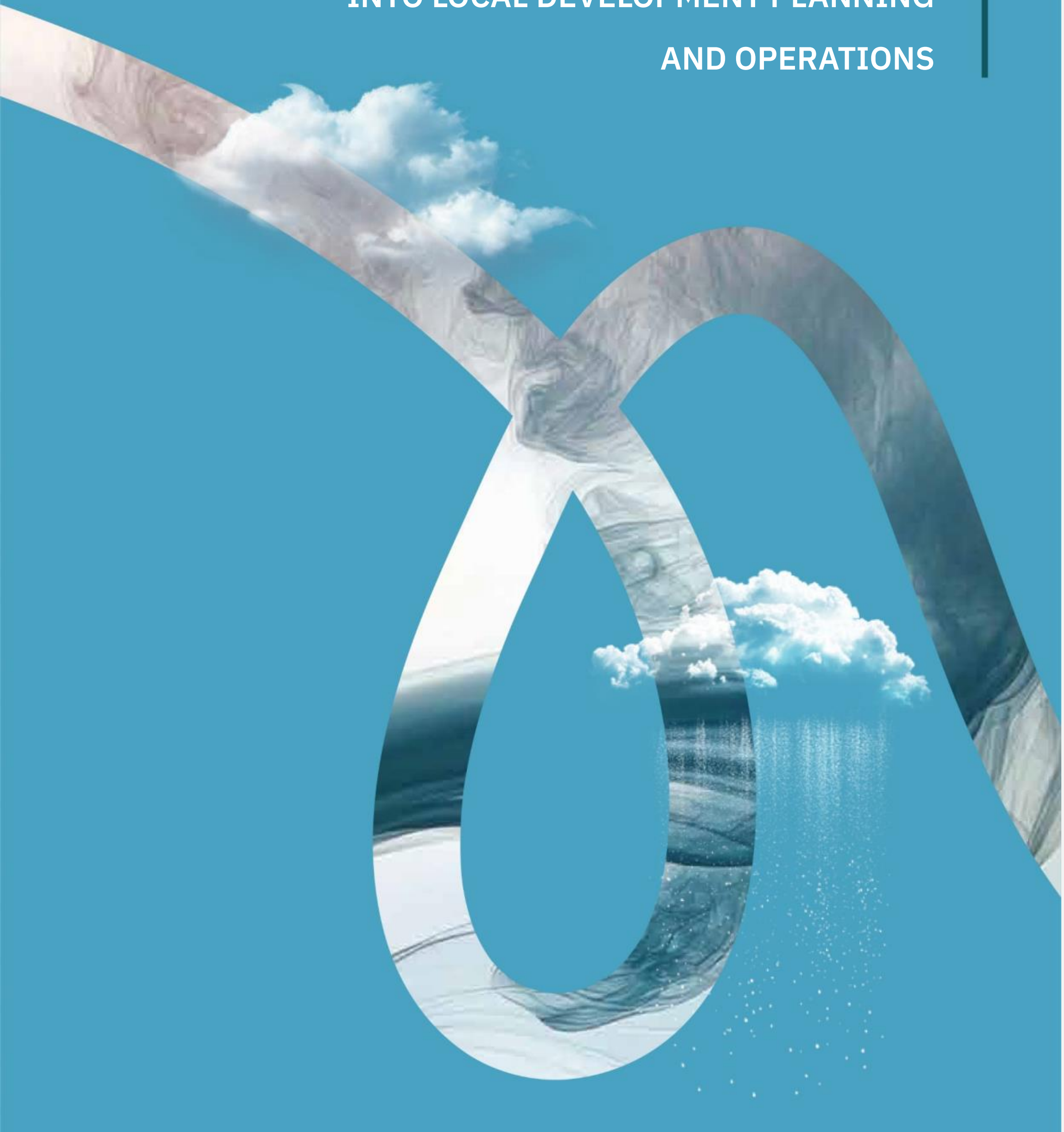
COMPONENT 2

INTEGRATION OF NATURAL CAPITAL ACCOUNTS INTO LOCAL DEVELOPMENT PLANNING AND OPERATIONS



THE INTEGRATION OF NATURAL CAPITAL ACCOUNTING IN PUBLIC AND PRIVATE SECTOR POLICY AND DECISION-MAKING FOR SUSTAINABLE LANDSCAPES

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COMPONENT 2

INTEGRATION OF NATURAL CAPITAL ACCOUNTING INTO LOCAL DEVELOPMENT PLANNING AND OPERATIONS

OUTPUT 2.1.3
DEVELOP AND MAINTAIN A COMPREHENSIVE PROVINCIAL **TOURISM SECTOR** NCA FOR KRABI PROVINCE

OUTPUT 2.1.5
DEVELOP AND MAINTAIN A COMPREHENSIVE PROVINCIAL **WATER RESOURCES** NCA FOR KRABI PROVINCE

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Contents

Tables

Figures

Executive Summary

The natural capital account for Krabi province is constructed based on the UN-SEEA framework, with special reference to the tourism sector and water resources sector. The study area of Krabi province covers a total area 960,789 hectares, comprising of both inland and ocean territories. This area is divided into five major ecosystems, they are, terrestrial, freshwater, marine, marine-freshwater-terrestrial (mangrove), and marine terrestrial (shoreline). Owing to the limitation of data, all the three marine related ecosystems are grouped into just marine ecosystem. The Krabi SEEA comprises of four key accounts, they are, extent accounts, condition accounts, services accounts, and asset account. The project duration is 2016-2020.

The extent account indicates a reduction of 3,700 hectares of terrestrial ecosystem that has overtime became urban and industrial land use. There has also been an increase of additional 1,230 hectares of the tropical/subtropical montane rainforest resulting in a net loss of 890 hectares of tropical/subtropical montane rainforest. For the freshwater ecosystem there has been a reduction of 530 hectares of rice paddies and freshwater aquafarms. These areas turned into crop plantation while the canals, ditches and drains also gained 530 hectares. For the marine ecosystem, there has been a small change of 16 hectares from pelagic ocean ecosystem to sandy shorelines that was a result of beach erosion, while another 37 hectares turned into permanent upland streams.

The condition accounts show an improvement of the freshwater quality where the SEEA index calculated from WQI (Water Quality Index) and Biochemical Oxygen Demand (BOD) improves from 0.60 to 0.86. However, the marine water quality index deteriorates from 0.42 to 0.25. This deterioration provides evidence that the marine ecosystem will need further policy intervention to protect and promote the contribution of marine ecosystem to society.

The services accounts show a 1.06 percent or 3,700 hectares decline of rubber and palm oil plantation areas. This is reflected in decline in the monetary value of both crops. The rice output also declines and thus resulted in a decline in the contribution of freshwater ecosystem to the economy by 23 percent. The marine output in the form of fish landings has been fluctuating from 8,952 tons per year to 27,731 tons per year while the fishery price also fluctuates from 9,859 baht per ton to 16,274 baht per ton. The economic contribution of marine ecosystem also suffers from COVID-19 where the number of the top three marine national parks visitation declines from 2,110,491 to only 378,571 visitors during the five-year period. The pandemic also resulted in the decline of the economic contribution from freshwater ecosystem where water consumption in accommodation sector dropped in 2020.

The aggregation of the economic values enables the project to arrive at the asset account for Krabi natural capital. Over the period of 2016-2020, the asset value of Krabi natural capital declined by about 8 percent from 128,388.71 million THB to 118,038.19 million THB. The terrestrial ecosystem experienced a decline in the asset value of 10.2 percent from 49,040.76 million THB to 44,019.61 million THB. This decline was a result of the decline in plantation areas. As for the marine ecosystem, the asset account shows that marine ecosystem experiences a decline in asset value of 7.8 percent that is explained by the decline in marine fishery and the decline in the number of visitors.

The SEEA results shows that there is justification for the government to protect the Krabi natural capital by designing policy interventions that are aimed at improving agricultural productivity and rehabilitating the condition of the marine ecosystem.

1. Introduction

The **System of Environmental-Economic Accounting (SEEA)** is an international statistical framework that links environmental data with the System of National Accounts (SNA) to illustrate the relationship between the economy and the environment. It consists of two main, complementary frameworks: the **SEEA Central Framework**, the first international standard for environmental-economic accounting adopted by the United Nations Statistical Commission (UNSC) in 2012, which focuses on measuring individual natural resources (United Nations et al., 2014); and the **SEEA - Ecosystem Accounting (SEEA EA)**, officially approved in 2021 with the final complete version published in 2024, which focuses on measuring the value of ecosystems and ecosystem services as a whole (United Nations et al., 2024).

While the **SEEA Central Framework** focuses on accounting for **individual resources**—such as minerals, timber, water, land, and soil—the **SEEA EA** extends this scope to represent **ecosystems as a whole**, where various components function together as a system. This broader perspective highlights **'ecosystem services**,' encompassing both direct contributions to production and other intangible yet essential services for well-being, such as air filtration, water regulation, and recreation. Integrating these two frameworks ensures a complete and multidimensional view of the environment-economy nexus (United Nations et al., 2024).

Consistent with the SEEA EA framework, which emphasizes **subnational-level analysis**, the **Provincial Natural Capital Accounts (NCA)** for the **water resources** and **tourism sector** in **Krabi Province** have been prepared as a key mechanism to support evidence-based policy formulation and systematic natural resource management. The objective of this report is to assess the value of natural capital, monitor ecosystem changes, and illustrate the contribution of ecosystems to the economy and the well-being of local communities. This report is based on the conceptual framework of the **United Nations System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA – EA),** an internationally accepted guideline for natural capital accounting.

Krabi Province is characterized by a highly diverse natural environment, comprising **terrestrial, freshwater, and marine ecosystems**, including mangrove forests, coral reefs, seagrass beds, and numerous islands. These are key sources of water resources, the provision of ecosystem services, and tourism, which generates significant income for the province. However, ecological changes—whether due to land use, water quality degradation, or economic pressures—directly impact the province's development potential and sustainability. Therefore, it is essential to compile empirical data that comprehensively reflects the status and value of **natural capital** and aligns with international standards.

Under the scope of **TOR 133 (Water Resources)** and **TOR 134 (Tourism Sector)**, the development of the provincial NCA aims to establish an integrated spatial economic database that will enable the province to recognize the status of "**stocks**" (i.e., extent/volume and condition/quality) and "**flows**" or ecosystem services that ecosystems provide to the public and the economy, as well as to assess conducting monetary and non-monetary valuations of ecosystem services, particularly water resources and tourism. The process utilizes data sourced from multiple government agencies, which are verified, standardized, and analyzed based on the principles of the SEEA – EA.

This report comprises key components**: Ecosystem Extent Accounts**, **Ecosystem Condition Accounts**, physical and monetary **ecosystem service** accounts, and the Accounting for **Ecosystem assets** in monetary terms. The preparation of **Krabi Province's Natural Capital Accounts** aims to support economic development alongside sustainable natural resource conservation. This will provide the province with accurate and standardized data that can be used to inform decision-making, determine development directions, and maximize the efficiency of natural resource management.

2. Scope & Boundaries

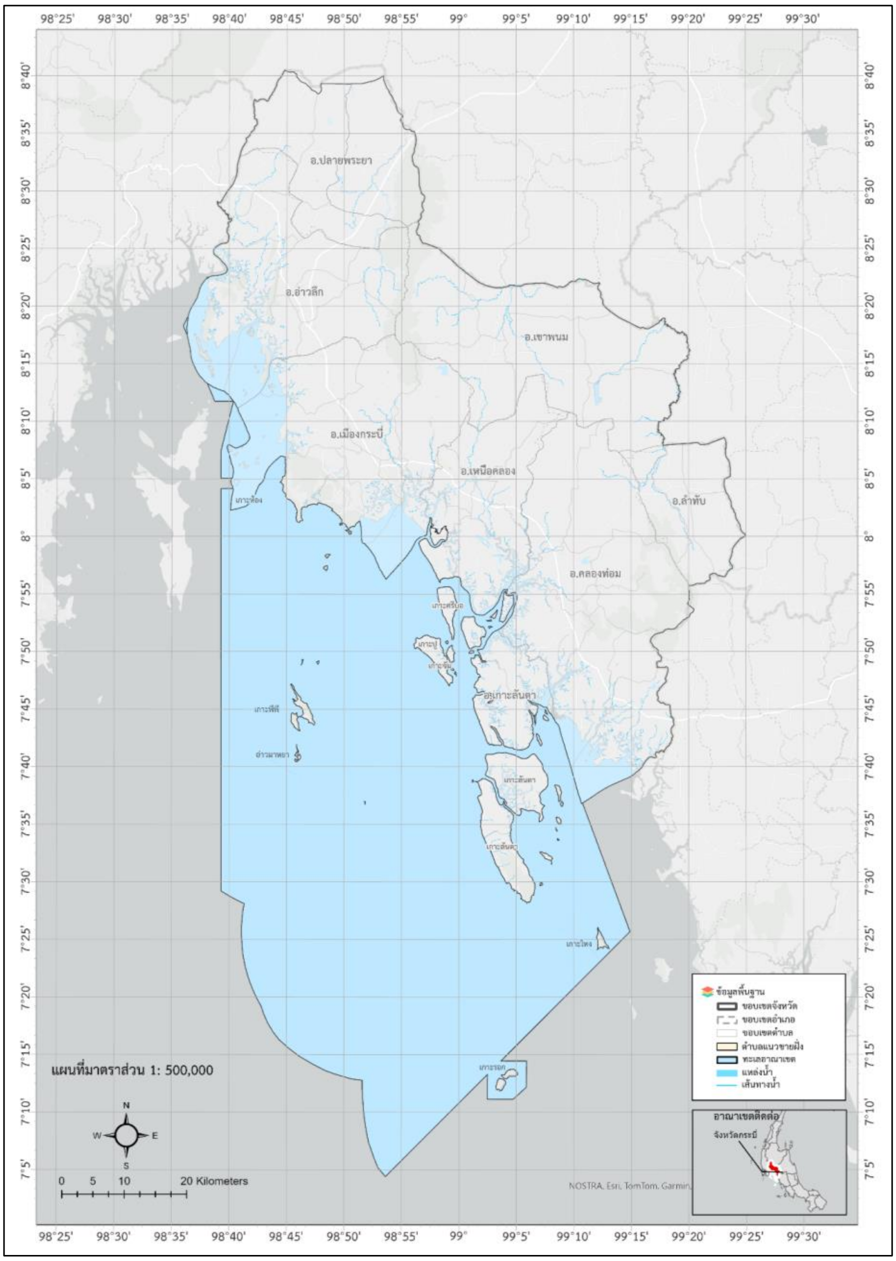
Krabi Province was selected as the **study area** due to its **geographical diversity**, encompassing both **terrestrial** and **marine** environments, and including critical features such as islands, mangrove forests, coral reefs, and seagrass meadows, all of which play essential roles in ecosystem functioning, economic development, and tourism.

In this study, the **scope and spatial boundaries of the provincial natural capital water resource account**, as well as the boundaries of **tourism** use and its associated impacts on watershed, coastal, and nearshore ecosystems in Krabi Province, were established through a **consultative process involving multiple agencies and experts**. These include the Thailand Development Research Institute (**TDRI**), the Office of Natural Resources and Environmental Policy and Planning (**ONEP**), the Geo-Informatics and Space Technology Development Agency (**GISTDA**), the **Department of National Parks**, **Wildlife and Plant Conservation**, the **Royal Thai Navy**, and experts from **Kasetsart University**.

The study area boundary (see Figure 1) was determined using **spatial data** in **Shapefile format**, comprising **maritime boundary** data from the Royal Thai Navy, **land use** data from the Department of Land Development, and **administrative boundary** data from the Department of Provincial Administration. All datasets were verified and adjusted to a common coordinate reference system (**EPSG:4326 – WGS84**) to enable correct co-processing.

Spatial data processing (see appendix 1 for Geospatial Database Development and Spatial Analysis for Krabi Province) was conducted using **QGIS** to integrate and manage spatial datasets, resulting in the delineation of spatial boundaries that accurately represent actual land and marine use, as well as the ecosystem characteristics of Krabi Province. The Union tool was applied to merge **land use**, **administrative boundaries**, and **maritime boundaries** to create a comprehensive study area covering the entire province, **both terrestrial and marine**. The Dissolve tool was then used to remove spatial redundancies. Specific areas were also added, including **Koh Rok** (Koh Rok Nai – Koh Rok Nok) based on references from the Mu Ko Lanta National Park, artificial reef locations for marine learning parks, and areas of **seagrass** and **coral reefs**, ensuring that the study area covers both terrestrial and marine zones relevant to **water resources** and **tourism.** Technical details for preparing the study area boundaries are described in **appendix 1**.

Figure 1 Krabi Province study area



Source: Analysis by TDRI

Ecosystem type reference classification is based on **IUCN Global Ecosystem Typology 2.0**, in collaboration with **ecosystem and environmental experts** from **Kasetsart University**, namely **Prof. Dr. Tunlawit Satapanajaru** and **Assoc. Prof. Dr. Pasinee Worachananant**. This classification enables the spatial boundaries to be utilized for **ecosystem extent accounts** following the United Nations' System of Environmental-Economic Accounting – Ecosystem Accounting (**SEEA EA**) framework, supporting systematic analysis of **ecosystem change**, natural capital valuation, and supports policy decision-making for sustainable development.

Through this methodology, the report demonstrates that the study has successfully defined the **scope and boundaries** of **water resource accounts** and **tourism**-related ecosystem impacts in full compliance with **requirement 133a** – to consultatively determine and agree on the scope, spatial boundaries, and components of the provincial natural capital (NC) water resource account – and **requirement 134a** – to consultatively define the boundaries of tourism use and impacts on watershed, coastal, and nearshore ecosystems.

3. Data Collection

The preparation of the Provincial Natural Capital Accounting (NCA) for Krabi Province requires a robust and comprehensive database that integrates spatial, environmental, and socio-economic information. The datasets collected under this project must support the assessment of natural capital in terms of **stocks (extent, condition, and Monetary asset) and flows (ecosystem services)**, consistent with the SEEA framework.

Under this project, primary datasets were obtained from relevant government agencies, together with **geospatial data** developed by the **Geo-Informatics and Space Technology Development Agency (Public Organization)—GISTDA**. These data sources were selected to ensure reliability, completeness, and readiness for subsequent analytical processes, thereby providing the fundamental basis for establishing Krabi Province's natural capital accounts.

Key governmental agencies contributing essential data include GISTDA,

the Ministry of Tourism and Sports,

the Department of Community Development,

the Department of Fisheries,

the Department of Groundwater Resources,

the Department of Marine and Coastal Resources,

the Department of National Parks, Wildlife and Plant Conservation,

the Department of Provincial Administration,

the Department of Water Resources,

the Electricity Generating Authority of Thailand & Office of Energy Regulatory Commission,

the Environment and Pollution Control Office Region 15,

the Excise Department,

the Land Development Department,

the Office of Agricultural Economics,

the Provincial Waterworks Authority (Krabi),

the Royal Forest Department, and

the Forest Industry Organization (Southern Region),

All data derived from these agencies underwent a thorough verification process to ensure completeness, geospatial accuracy, temporal consistency, and compatibility across different data formats. Following validation, the information was systematically categorized into two major groups: Stock Data and Flow Data**.**

Stock data represent the state and condition of natural capital assets in Krabi Province and encompass information such as **administrative boundaries** at various levels, **maritime territories**, **land use** and land cover data, and **coastal and marine ecosystems**, such as mangrove forests, seagrass beds, and coral reefs. It also comprises data on water volume, **water quality** monitoring, and natural freshwater resources.

Flow data describe the uses and benefits derived from natural capital. These data include domestic and industrial **water consumptio**n, **irrigation** water use, annual **water supply** statistics, and ecosystem services that support the tourism sector. They also cover provincial **tourism statistics**, including the number of **visitors and tourism expenditures**, as in **Table 1.**

Table 1 List and Types of Data Collected

No.	Name of Data	Type	Kind	Extension	Year	Agencies
1	Tourism Statistics	Excel	Table	.xls	2013 – 2021	Ministry of Tourism and Sports
2	Number of Accommodation rooms	Excel	Table	.xls	2016 – 2020	Ministry of Tourism and Sports
3	Population	Excel	Table	.xls	2019/2021/ 2022/2023	Department of Community Development
4	Fisheries and Aquaculture in Freshwater and Marine Environments	Excel	Table	.xls	2016-2024	Department of Fisheries
5	Bodies and Reservoirs & the Water usage for various purposes	Excel	Table	.xls	2016-2020	Department of Groundwater Resources
6	Species Richness of Trees and Birds & Protected Forest Areas and Their Density in Relation to the Total Area of Krabi Province	Hard copy document	Description	Text	2022	Department of National Parks, Wildlife and Plant Conservation

Table 1: List and Types of Data Collected *(Continued)*

No.	Name of Data	Type	Kind	Extension	Year	Agencies
7	Administrative Boundary	Shapefile	Polygon	.shp	2023	Department of Provincial Administration
8	Quantity of Natural water	Excel	Table	.xls	2016-2020	Department of Water Resources
9	Quantity and Price of Electricity Generated from Biomass Power Plants	Excel	Table	.xls	2016-2020	Electricity Generating Authority of Thailand & Office of Energy Regulatory Commission
10	Carbon Price	Text	Description	.pdf	2025	Excise Department
11	Agricultural Yields and Agricultural Commodity Prices	Excel	Table	.xls	2016-2020	Office of Agricultural Economics
12	Irrigation water users	Excel	Table	.xls	2023	Provincial Waterworks Authority (Krabi)
13	Water usage statistics	Excel	Table	.xls	2013-2023	Provincial Waterworks Authority (Krabi)
14	Results of the Acacia species timber auction	Text	Description	.pdf	2024	Forest Industry Organization (Southern Region)
15	Forest Area	Excel	Table	.xls	2016-2020	Royal Forest Department
16	Land Use	Shapefile	Polygon	.shp	2007-2020	Department of Land Development
17	Krabi Maritime Boundary	Shapefile	Polygon	.shp	2019	Royal Thai Navy
18	Sub-district Boundary	Shapefile	Polygon	.shp	2007-2020	Department of Land Development
19	District Boundary	Shapefile	Polygon	.shp	2007-2020	Department of Land Development
20	Province Boundary	Shapefile	Polygon	.shp	2007-2020	Department of Land Development
21	Mangrove Forest Area	Shapefile	Polygon	.shp	2014 & 2019	Department of Marine and Coastal Resources
22	Seagrass Area	Shapefile	Polygon	.shp	2020-2023	Department of Marine and Coastal Resources
23	Coral Reef Area	Shapefile	Polygon	.shp	2011-2020	Department of Marine and Coastal Resources
24	Shipwreck Locations	Text	Description	.html	2013	Department of Marine and Coastal Resources

Table 1: List and Types of Data Collected *(Continued)*

No.	Name of Data	Type	Kind	Extension	Year	Agencies
25	Coastal Water Quality s	Excel	Table	.xls	2023	Environment and Pollution Control Office Region 15
26	Surface Water Quality	Excel	Table	.xls	2023	Environment and Pollution Control Office Region 15
27	Marine water Quality Monitoring Stations	Shapefile	Point	.shp	2023	Data updated to Shapefile (.shp) by GISTDA
28	Water Quality Monitoring Stations	Shapefile	Point	.shp	2023	Data updated to Shapefile (.shp) by GISTDA
29	Crop Diversity	Text	Description	.pdf	2016-2020	Office of Agricultural Economics
30	Soil organic carbon content	Shapefile	Polygon	.shp	2021	Land Development Department
31	Vegetation water content (NDWI) and Vegetation index (NDVI)	Excel	Table	.xls	2016-2023	Geo-Informatics and Space Technology Development Agency (Public Organization)—GISTDA

4. Ecosystem Types

Ecosystem classification for the study area is based on the international standard **IUCN Global Ecosystem Typology 2.0**, which enables the accurate preparation of ecosystem extent accounts.

The classification of Ecosystem Types (ETs) for the study area in Krabi Province was conducted under the framework of the System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA). The classification follows the SEEA ecosystem type reference classification, which aligns with the structure of the IUCN Global Ecosystem Typology (GET) 2.0 (Keith *et al*., 2020)—an internationally recognized functional typology for ecosystem classification. The use of this standardized system ensures consistency in ecosystem accounting at the national level and allows for comparison with other study areas.

4.1 Principles of Classification Based on SEEA and IUCN GET

SEEA EA recommends that ecosystem classifications be aligned with the structure of the **IUCN Global Ecosystem Typology (GET)**, which organizes ecosystems according to their functional properties and ecological processes (United Nations, 2021). The typology consists of three levels:

Level 1: Realms

Realms group ecosystems based on their fundamental ecological structure and function. At the top level, four realms are defined: marine (M), freshwater (F), terrestrial (T), and subterranean (S).

Level 2: Biomes

Biomes are defined as **functional biomes**, representing climatic regimes and structural characteristics of ecosystems. IUCN GET defines 24 biomes, encompassing both natural ecosystems and artificial ecosystems.

Level 3: Ecosystem Functional Groups (EFGs)

EFGs represent **100 functionally similar ecosystem groups** embedded within each biome. This level is particularly important for SEEA EA reporting because it provides a harmonized and internationally comparable unit for ecosystem classification.

Using the SEEA–IUCN GET reference classification ensures that the ecosystem accounting process for Krabi Province is consistent with international standards, comparable to other study areas, and comprehensively supports ecosystem diversity. This is particularly for coastal and marine ecosystems, such as coral reefs, seagrass meadows, mangrove forests, and estuarine systems, as well as for artificial ecosystems such as agricultural areas, urban areas and aquaculture areas, which span multiple realms and biomes. Using such a common reference system ensures consistent data, integration with national databases and is suitable for spatial management and policy planning of natural resources and the environment.

4.2 Ecosystem Type Classification for Krabi Province

This study, the classification of **Ecosystem Types (ETs)** within the **Ecosystem Accounting Area (EAA) of Krabi Province** was conducted following the **IUCN GET 2.0** structure. The classification strictly adhered to the mutually exclusive principle to ensure that every spatial unit is assigned to one, and only one, ecosystem type without overlap. Ecosystems with similar structural characteristics and ecological functioning were grouped under the same ET to facilitate spatial analysis, comparison, and ecosystem accounting according to the SEEA standards.

Examples of ecosystem type reclassification in Krabi Province include:

- "Marine area" → Pelagic Ocean Waters (M2)
- "Seagrass area" → Seagrass Meadows (M1.1)
- "Coral reef area" → Photic Coral Reefs (M1.3)
- "Tropical forest area" → Tropical–subtropical Montane Rainforests (T1.3)

The classification process was conducted in collaboration with **ecosystem and environmental experts** from **Kasetsart University**, namely **Prof. Dr. Tunlawit Satapanajaru** and **Assoc. Prof. Dr. Pasinee Worachananant**, along with the Geo-Informatics and Space Technology Development Agency (**GISTDA**).

Spatial data processing in **QGIS** using the *Filter, Select by Attribute,* and *Field Calculator* to assign **ecosystem type codes** based on the IUCN Global Ecosystem Typology 2.0 to each land-use polygon systematically and accurately. The outputs were presented as maps illustrating the spatial distribution of ecosystem types in Krabi Province to support spatial analysis and ecosystem accounting. These ecosystem type codes were assigned based on the IUCN Global Ecosystem Typology 2.0, and technical details of the classification procedure are provided in **Appendix 2**.

4.3 Results of Ecosystem Type Classification Based on IUCN GET 2.0

The results indicate that Krabi Province has a diverse ecosystem, covering:

- **Level 1:** 5 Realms
- **Level 2:** 13 Biomes
- **Level 3:** 19 Ecosystem Functional Groups (EFGs)

Details of these ecosystem types are shown in **Table 2**.

Table 2 Krabi Province Ecosystem Types Classified According to IUCN GET 2.0

Level 1: 5 Realms	Level 2: 13 Biomes	Level 3: 19 Ecosystem Functional Groups (EFGs)
Terrestrial	T1: Tropical-subtropical forests	T1.3 Tropical-subtropical montane rainforests
	T2: Temperate-boreal forests & woodlands	T2.2 Deciduous temperate forests
	T3: Shrubland & shrubby woodlands	T3.1 Seasonally dry tropical shrubland
	T4: Savanna and grasslands	T4.5 Temperate subhumid grassland
	T7: Intensive land-use	T7.1 Annual Cropland
		T7.3 Plantations
		T7.4 Urban and industrial ecosystem
Freshwater	F1: River and streams	F1.1 Permanent upland streams
	F2: Lakes	F2.1, F2.2, Large and Small permanent freshwater lakes
	F3: Artificial fresh waters	F3.1 Large reservoirs
		F3.3 Rice paddies
		F3.4 Freshwater aquafarms
		F3.5 Canals, ditches and drains
Marine	M1: Marine shelfs	M1.1 Seagrass meadows
		M1.3 Photic coral reefs
	M2: Pelagic ocean waters	M2 Pelagic ocean water (Unable to categorize M2.1 -M2.5)
	M4: Anthropogenic marine systems	M4.1 Submerged artificial structures
Marine-Freshwater-Terrestrial	MFT1: Brackish tidal	MFT1.2 Intertidal forests and shrublands
Marine-Terrestrial	MT1: Shoreline systems	MT1.3 Sandy shorelines

Source: Analysis by TDRI as of 2024

The classification of **Ecosystem Types in Krabi Province** is based on the **SEEA–IUCN GET** framework, which establishes a scientifically robust and internationally comparable foundation for ecosystem accounting. This classification system reflects the diversity of **Krabi's ecosystems**—including terrestrial, freshwater, marine, and coastal ecosystems—and supports evidence-based spatial management, conservation planning, and the development of future natural resource and environmental policies, which is particularly relevant for **water resource** and **tourism sectors**, which are key resources for Krabi Province.

5. Ecosystem Accounting

Effective natural resource management at the provincial level requires accurate and comprehensive data that systematically reflect the linkages between ecosystems and economic activities. Such data are essential to support evidence-based planning and policy-making. The concept of Natural Capital Accounting (NCA) plays a key role in integrating environmental information with economic data in a standardized manner, enabling comparability across both spatial and temporal scales.

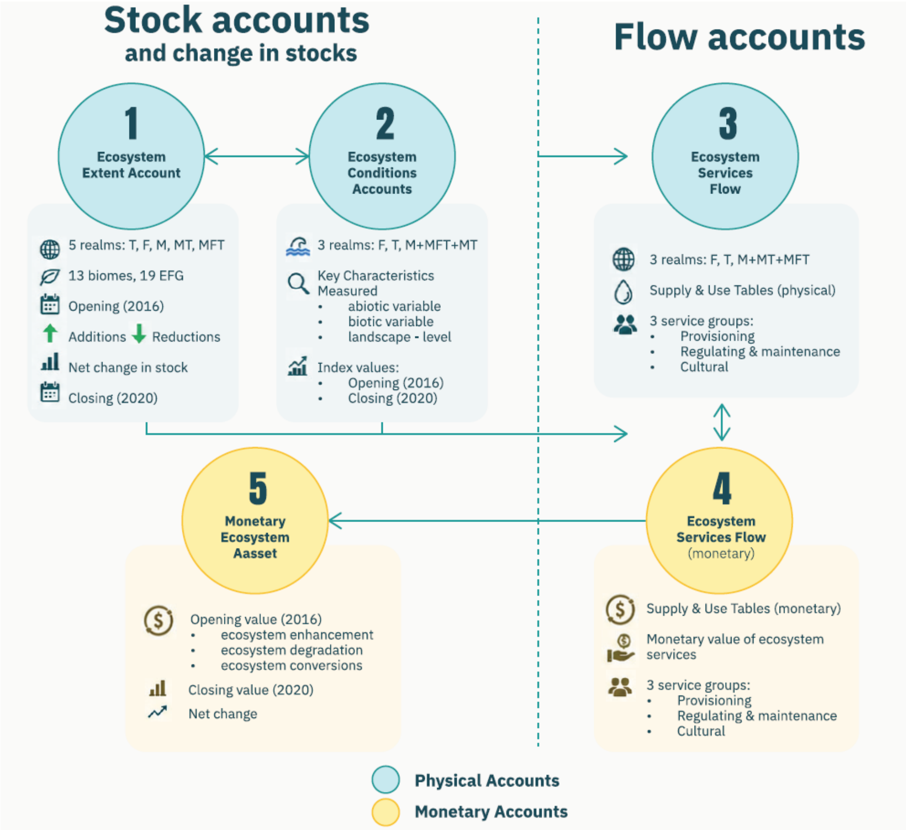
At the international level, the compilation of ecosystem and natural resource accounts follows the **System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA)**, a framework established by the United Nations to ensure that ecosystem data are collected, compiled, and processed systematically. The SEEA EA framework emphasizes the compilation of information on **ecosystem stocks** (i.e., extent/volume and condition/quality) **and flows** (i.e., ecosystem services), both in **physical and monetary terms**. It also includes the valuation of **ecosystem assets** and services to comprehensively capture the contributions of ecosystems to society and the economy at the local level.

The **SEEA EA framework** comprises five main accounts:

1) **Ecosystem Extent Accounts**
2) **Ecosystem Condition Accounts**
3) **Ecosystem Services Flow Accounts – Physical Terms Accounting for Ecosystem services in physical terms**
4) **Ecosystem Services Flow Accounts – Monetary Terms**
5) **Monetary Ecosystem Asset Accounts**

These five accounts are sequentially linked, beginning with the definition of the stock accounts (i.e., physical extent and condition of ecosystems), followed by the identification of the flow accounts (i.e., ecosystem services), and culminating in the economic valuation of these services and assets (see Figure 2 Connections between the ecosystem accounts). This sequential framework ensures that the resulting data effectively support provincial-level analysis, planning, and management of natural resources in a standardized and systematic manner.

Figure 2 **Connections between the ecosystem accounts**



Source : Adapted from United Nations *et al.*, (2021)

5.1 Accounting for Ecosystem Extent

The preparation of Ecosystem Extent Accounts under the **SEEA Ecosystem Accounting (SEEA EA) framework** represents a **foundational step** in establishing a structured spatial information system on the ***size** and distribution* of ecosystem assets within the **Ecosystem Accounting Area (EAA)**. These accounts record the extent of each ecosystem type at both the **opening** of the accounting period and the **closing** of the accounting period. The aim is for systematic and continuous monitoring of spatial changes in ecosystems over time.

According to the SEEA EA principles, extent accounting serves as the common starting point for ecosystem accounting. It provides a structured basis for identifying the size, distribution, and temporal changes of ecosystem types within the EAA, and supports the detection of long-term trends through time-series analysis.

Moreover, the spatial datasets generated from the extent account form essential inputs for subsequent SEEA ecosystem accounts, including the ecosystem condition account, ecosystem services account, and monetary asset account. As such, the extent accounts functions as the **foundational spatial dataset** for the entire SEEA EA accounting system.

Scope of the Ecosystem Extent Accounts for Krabi Province: the **Ecosystem Accounting Area (EAA)** is defined to cover the entire province of **Krabi**, including terrestrial ecosystems, forests, wetlands, coastal ecosystems, watersheds, and marine ecosystems. This approach aligns with SEEA EA principles, which require that extent accounts must cover all types of ecosystem assets within the **study area** (as described in Section 2: Define Scope & Boundaries).

Methodology—Ecosystem types were classified according to the **IUCN Global Ecosystem Typology 2.0**, to support subsequent linkages to condition and ecosystem services accounts.

Spatial Data—Data is collected from multiple governmental agencies, as previously described in *Section 2: Define Scope & Boundaries*. All data is processed using GIS following the SEEA principles, which define extent accounts as the output of mapped input data.

Accounting Period—The extent of accounts were compiled for a **five-year accounting period**, consisting of the **Opening Extent (2016)** and **Closing Extent (2020)**. These years correspond to periods for which spatial data were available from relevant agencies, allowing for the gradual analysis of spatial changes at the ecosystem extent.

The Ecosystem Extent Account **results** are presented in **Extent Tables**, showing the areas of each ecosystem type at opening and closing. **Extent Maps** show the spatial extent of ecosystems, and analysis of **changes in the extent** of natural capital stocks within Krabi Province.

Ecosystem Extent Accounts Table

The preparation of **Ecosystem Extent Accounts (EEA**) is important for monitoring and assessing changes in the natural capital of an area. The **Extent Table** is a spatial data presentation format used in the preparation of EEAs to show the size and extent of each ecosystem type at the opening and closing of the accounting period. It also reflects changes in the natural capital stock over the specified period. This information enables analysis of spatial changes in each ecosystem, comparison of expansion or contraction trends among ecosystem types, and supports policy planning for sustainable natural resource management.

Structure of the Extent Table

The structure of the Extent Table consists of **Opening extent**, **Additions**, **Reductions**, **Net change**, and **Closing extent**. Units of area are measured, in **hectares (ha)** or square kilometers (km^2). The rows of the table follow the asset accounting logic: **Opening extent → Changes → Closing extent**. The details are presented on the following page.

The study results show that the study area in **Krabi Province** had ecosystem extent accounts, or a total area of **960,768.00 ha**, at both the Opening (2016) and Closing (2020), as shown in Tables 3 and 4.

Ecosystem type	Classified according to the SEEA ecosystem type reference classification, based on IUCN Global Ecosystem Typology (GET)
Opening extent	The area at the start of the accounting period (ha)
Additions (to extent)	The area increased during the accounting period (ha) 0
Reductions (in extent)	The area decreased during the accounting period (ha)
Net change	The difference = Additions − Reductions (ha), reflecting the net change in natural capital stock
Closing extent	The area at the end of the accounting period, calculated as Opening extent + Net change (ha)

The Ecosystem Extent Accounts Table shows that as of 2020, the ecosystem with the largest area was M2 Pelagic ocean water, covering 457,914.50 ha, followed by T7.3 Plantation, covering 347,438.25 ha, T1.3 Tropical-subtropical montane rainforests, covering 62,592.75 ha, MFT1.2 Intertidal forests and shrublands, covering 39,832.50 ha, and T7.4 Urban and industrial ecosystem, covering 23,015.75 ha, respectively, as shown in Table 5 above.

Mapping Ecosystem Extent

The location, coordinates, and spatial representations (maps) clearly show the geographic distribution, connectivity, and patterns of ecosystem change. These maps provide a clear visualization of the **spatial configuration of ecosystem types within the Ecosystem Accounting Area (EAA)**.

For the **study area in Krabi Province**, ecosystem extent maps for **2016** and **2020** were developed at a scale of **1:550,000**. These maps show significant changes in the spatial distribution of some ecosystem types between the two periods, particularly the extent of **T7.4 Urban and Industrial Ecosystems**, and **F3: Artificial Wetland Ecosystems**, especially **F3.1 Large Reservoirs**, showing an increase. These changes are shown in Figures 3–4.

Ecosystem type change matrix

The **Ecosystem Type Change Matrix** is a structured representation of transitions in ecosystem extent between accounting periods. It enables the identification and quantification of reductions in the area of specific ecosystem types, as well as the corresponding increases in other ecosystem types that replace them (e.g., conversion from forest areas to urban areas). The matrix is a key component of ecosystem extent accounts, supporting the analysis of ecosystem change and providing essential information for assessing temporal trends, informing ecosystem restoration strategies, and guiding evidence-based land-use planning and management.

The calculation was performed using the **Tabulate Area** tool with raster data at a 50-meter pixel resolution to quantify spatial transitions between the 2016 and 2020 accounting periods. The detailed spatial change analysis procedure, including data processing steps in ArcGIS Pro, is provided in **Appendix 3**.

The structure of the matrix is as follows: **rows** represent the original ecosystem types at the beginning of the period (**opening extent**), and **columns** represent the ecosystem types that the areas have changed to (in case of conversion) or remained unchanged. Areas that did not change are recorded along the **diagonal**, while conversions are recorded in cells off the diagonal, intersecting the row of the original type and the column of the new type.

Table 3 Ecosystem Extent Account (Year 2016)

Realms	Terrestrial							Freshwater						Marine				Marine-Freshwater-Terrestrial	Marine-Terrestrial	
Biomes (Unit: Hectare)	T1: Tropical-subtropical forests	T2: Temperate-boreal forests & woodlands	T3: Shrubland & shrubby woodlands	T4: Savanna and grasslands	T7: Intensive land-use			F1: River and streams	F2: Lake Biome	F3: Artificial wetlands biome				M1: Marine shelfs		M2: Pelagic ocean waters	M4: Anthropogenic marine systems	MFT1: Brackish tidal	MT1: Shoreline systems	
Ecosystem Functional Group (EFG)	T1.3 Tropical-subtropical montane rainforests	T2.2 Deciduous temperate forests	T3.1 Seasonally dry tropical shrubland	T4.5 Temperate subhumid grassland	T7.1 Annual Cropland	T7.3 Plantations	T7.4 Urban and industrial ecosystem	F1.1 permanent upland stream	F2.1, F2.2, Small and large freshwater lakes	F3.1 Large Reservoir	F3.3 Rice paddies	F3.4 Fresh water aquafarm	F3.5 Canals/ Ditches, Drains	M1.1 Seagrass meadows	M1.3 Photic coral reefs	M2 Pelagic ocean water (Unable to categorize M2.1 -M2.5)	M4.1 Submerged artificial structures	MFT1.2 Intertidal forests and shrublands	MT1.3 Sandy shorelines	**Total Ecosystem Accounting Area**
Year 2016	63,487.50	11.75	2,489.75	1,392.00	908.75	351,152.75	19,148.75	7,558.50	156.50	984.75	1,310.00	4,395.50	556.75	5,404.50	2,249.00	457,861.00	1,022.75	39,832.50	845.00	**960,768.00**

Remark:

1) The spatial analysis of the extent account for Krabi Province was conducted using the shapefile land use data of the Land Development Department (2016). The shapefile of the provincial maritime boundary data is from the Royal Thai Navy (2019).

2) The area was calculated from the Raster data with a pixel size of 50 meters; therefore, some deviations in area estimation may occur depending on the resolution and accuracy of the original dataset.

3) Dataset M4: Anthropogenic marine biome represents geospatial data from the Department of Marine and Coastal Resources (2013). The area of utilization was estimated by defining a 1-kilometer radius of each anthropogenic point location.

Source: Data processed by TDRI and GISTDA as of 2024.

Table 4 Ecosystem Extent Account (Year 2020)

Realms	Terrestrial							Freshwater						Marine				Marine-Freshwater-Terrestrial	Marine-Terrestrial	
Biomes (Unit: Hectare)	T1: Tropical-subtropical forests	T2: Temperate-boreal forests & woodlands	T3: Shrubland & shrubby woodlands	T4: Savanna and grasslands	T7: Intensive land-use			F1: River and streams	F2: Lake Biome	F3: Artificial wetlands biome				M1: Marine shelfs		M2: Pelagic ocean waters	M4: Anthropogenic marine systems	MFT1: Brackish tidal	MT1: Shoreline systems	
Ecosystem Functional Group (EFG)	T1.3 Tropical-subtropical montane rainforests	T2.2 Deciduous temperate forests	T3.1 Seasonally dry tropical shrubland	T4.5 Temperate subhumid grassland	T7.1 Annual Cropland	T7.3 Plantations	T7.4 Urban and industrial ecosystem	F1.1 permanent upland stream	F2.1, F2.2, Small and large freshwater lakes	F3.1 Large Reservoir	F3.3 Rice paddies	F3.4 Fresh water aquafarm	F3.5 Canals/ Ditches, Drains	M1.1 Seagrass meadows	M1.3 Photic coral reefs	M2 Pelagic ocean water (Unable to categorize M2.1 -M2.5)	M4.1 Submerged artificial structures	MFT1.2 Intertidal forests and shrublands	MT1.3 Sandy shorelines	**Total Ecosystem Accounting Area**
Year 2020 (Unit: Hectare)	62,592.75	0.00	2,781.25	1,686.50	943.00	347,438.25	23,015.75	7,552.75	160.00	1,082.50	1,009.50	4,163.00	1,090.25	5,404.50	2,249.00	457,914.50	1,022.75	39,821.00	840.75	**960,768.00**

Remark:

1) The spatial analysis of the extent account for Krabi Province was conducted using the shapefile land use data of the Land Development Department (2016). The shapefile of the provincial maritime boundary data is from the Royal Thai Navy (2019).

2) The area was calculated from the Raster data with a pixel size of 50 meters; therefore, some deviations in area estimation may occur depending on the resolution and accuracy of the original dataset.

3) Dataset M4: Anthropogenic marine biome represents geospatial data from the Department of Marine and Coastal Resources (2013). The area of utilization was estimated by defining a 1-kilometer radius of each anthropogenic point location.

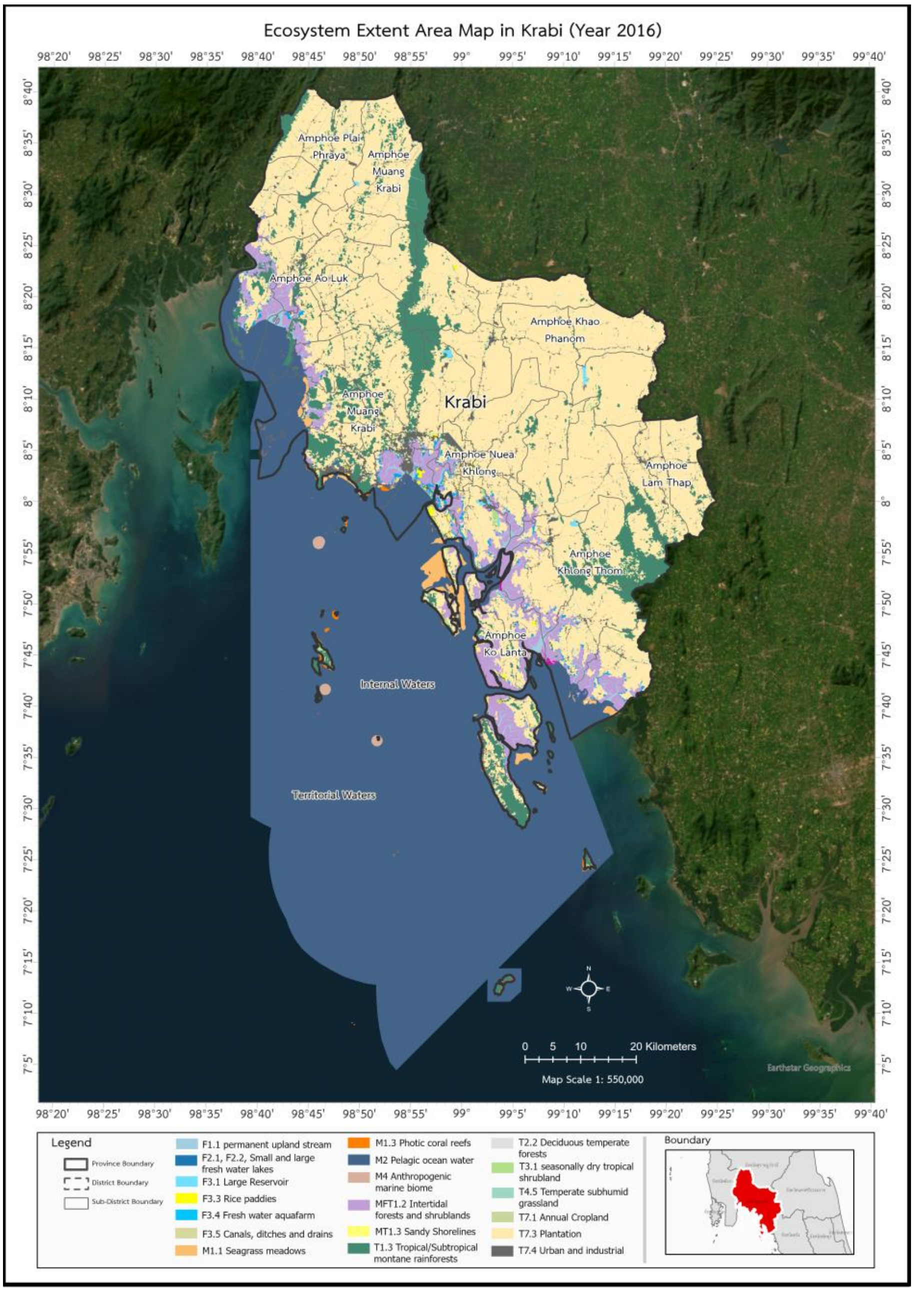
Source: Data processed by TDRI and GISTDA as of 2024.

Table 5 Ecosystem Extent Accounts Table (Unit: Hectare)

Realms	Terrestrial							Freshwater						Marine				Marine-Freshwater-Terrestrial	Marine-Terrestrial	
Biomes	T1: Tropical-subtropical forests	T2: Temperate-boreal forests and woodlands	T3: Shrubland	T4: Grassland	T7: Intensive land use			F1: River and streams	F2: Lake Biome	F3: Artificial wetlands biome				M1: Marine shelf		M2: Pelagic ocean water	M4: Anthropogenic marine biome	MFT: Marine-Freshwater-Terrestrial	MT: Marine-Terrestrial	
Ecosystem Functional Group (EFG)	T1.3 Tropical-subtropical montane rainforests	T2.2 Deciduous temperate forests	T3.1 Seasonally dry tropical shrubland	T4.5 Temperate subhumid grassland	T7.1 Annual Cropland	T7.3 Plantations	T7.4 พื้นที่	F1.1 permanent upland stream	F2.1, F2.2, Small and large freshwater lakes	F3.1 Large Reservoir	F3.3 Rice paddies	F3.4 Fresh water aquafarm	F3.5 Canals/ Ditches, Drains	M1.1 Seagrass meadows	M1.3 Photic coral reefs	M2 Pelagic ocean water (Unable to categorize M2.1 -M2.5)	M4.1 Submerged artificial structures	MFT1.2 Intertidal forests and shrublands	MT1.3 Sandy shorelines	Total Ecosystem Accounting Area
Opening extent (2016)	63,487.50	11.75	2,489.75	1,392.00	908.75	351,152.75	19,148.75	7,558.50	156.50	984.75	1,310.00	4,395.50	556.75	5,404.50	2,249.00	457,861.00	1,022.75	39,832.50	845.00	960,768.00
Additions to extent	648.50	0.00	700.50	483.25	346.00	2,610.50	4,787.50	34.75	10.50	117.00	6.50	102.75	548.25	0.00	0.00	53.50	0.00	440.50	12.00	10,902.00
Reductions to extent	1,543.25	11.75	409.00	188.75	311.75	6,325.00	920.50	40.50	7.00	19.25	307.00	335.25	14.75	0.00	0.00	0.00	0.00	452.00	16.25	10,902.00
Net change in stock	(894.75)	(11.75)	291.50	294.50	34.25	(3,714.50)	3,867.00	(5.75)	3.50	97.75	(300.50)	(232.50)	533.50	0.00	0.00	53.50	0.00	(11.50)	(4.25)	0.00
Closing extent (2020)	62,592.75	0.00	2,781.25	1,686.50	943.00	347,438.25	23,015.75	7,552.75	160.00	1,082.50	1,009.50	4,163.00	1,090.25	5,404.50	2,249.00	457,914.50	1,022.75	39,821.00	840.75	960,768.00
Retained stock	61,944.25	0.00	2,080.75	1,203.25	597.00	344,827.75	18,228.25	7,518.00	149.50	965.50	1,003.00	4,060.25	542.00	5,404.50	2,249.00	457,861.00	1,022.75	39,380.50	828.75	949,866.00

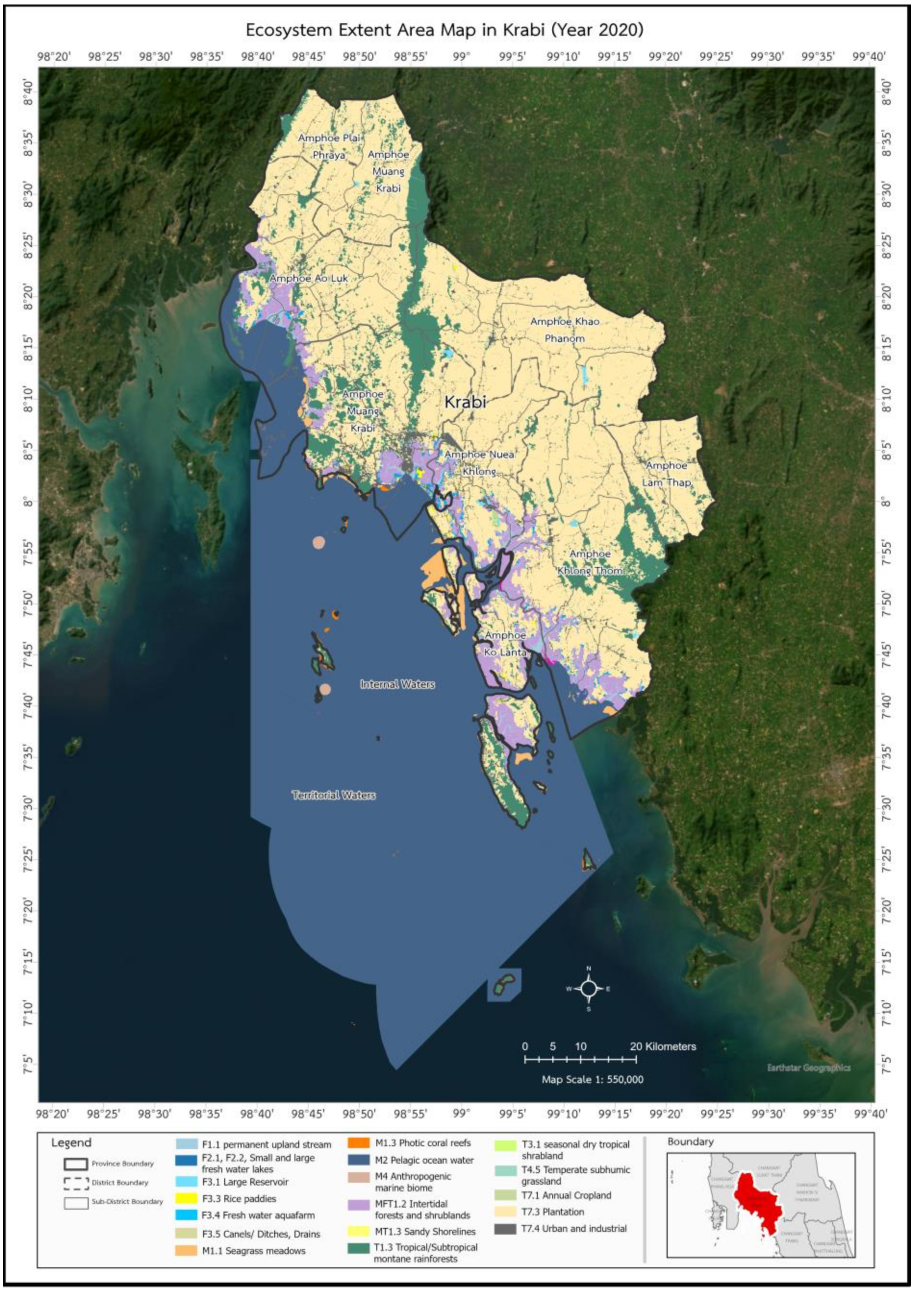
Source: Data processed by TDRI and GISTDA as of 2024.

Figure 3 Ecosystem Extent Map, Krabi Province (2016)



Source: Data processed by TDRI and GISTDA as of 2024.

Figure 4 Ecosystem Extent Map, Krabi Province (2020)



Source: Data processed by TDRI and GISTDA as of 2024.

Key Findings of Ecosystem Changes

The changes in ecosystem types within the **study area in Krabi Province** are presented in the form of a **transpose of a matrix**. The results show that:

- **F3.3 Rice paddies** decreased from approximately 1,310 hectares in 2016 to 1,009.5 hectares in 2020, representing a loss of over 300 hectares.
- **T7.4 Urban and industrial ecosystems** increased from 19,148.75 hectares to 23,015.75 hectares, reflecting continuous urban expansion in the study area.
- **T1.3 Tropical/Subtropical montane rainforests** in **2016** changed to **T7.3 Plantation** (1,238.25 hectares) and T7.4 Urban and industrial ecosystems (245.25 hectares) in 2020.
- **T7.3 Plantation** in **2016** changed to **T7.4 Urban and industrial**, covering **4,012.25 hectares**, and so on.

Full details of the transition matrix are presented in **Table 6.**

Spatial Distribution of Ecosystem Changes

To further identify the spatial distribution of changes, the analysis applied the Intersection technique in ArcGIS Pro to distinguish between changed and unchanged areas. The results were classified into "**changed areas**" and "**unchanged areas**," enabling clear spatial comparison.

The spatial patterns of ecosystem transitions are illustrated through **thematic maps** (Figure 5), where changed areas are highlighted in **red** and unchanged areas in **gray**. These maps provide a clear visualization of the extent and location of ecosystem changes, supporting effective interpretation and decision-making for land-use planning and ecosystem management.

Figure 5 Map of changes in Ecosystem Type between 2016 and 2020

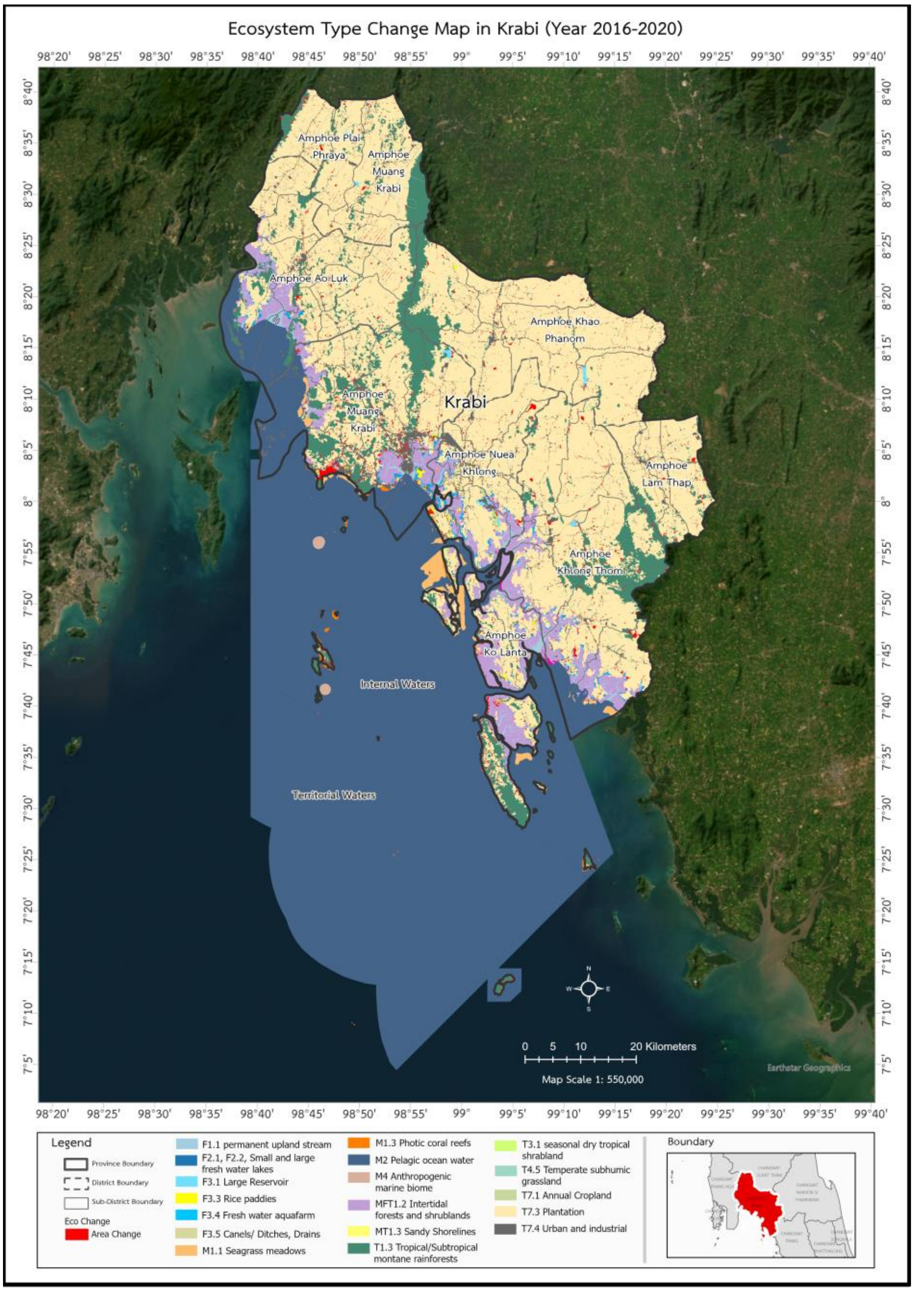


Table 6 Ecosystem type change matrix (Unit: Hectare)

	Realms	Water Sector						Tourism Sector													Total Ecosystem Accounting Area
	Biomes (Unit: Hectare)	Freshwater						Terrestrial							Marine				Marine-Freshwater-Terrestrial	Marine-Terrestrial	
	Physical Asset Accounts	F1.1 Permanent upland streams	F2.1, F2.2, Large and Small permanent freshwater lakes	F3.1 Large reservoirs	F3.3 Rice paddies	F3.4 Freshwater aquafarms	F3.5 Canals, ditches and drains	T1.3 Tropical-subtropical montane rainforests	T2.2 Deciduous temperate forests	T3.1 Seasonally dry tropical shrubland	T4.5 Temperate subhumid grassland	T7.1 Annual Cropland	T7.3 Plantations	T7.4 Urban and industrial ecosystem	M1.1 Seagrass meadows	M1.3 Photic coral reefs	M2 Pelagic ocean water (Unable to categorize M2.1 -M2.5)	M4.1 Submerged artificial structures	MFT1.2 Intertidal forests and shrublands	MT1.3 Sandy shorelines	
	Opening extent (2016)	**7,558.50**	**156.50**	**984.75**	**1,310.00**	**4,395.50**	**556.75**	**63,487.50**	**11.75**	**2,489.75**	**1,392.00**	**908.75**	**351,152.75**	**19,148.75**	**5,404.50**	**2,249.00**	**457,861.00**	**1,022.75**	**39,832.50**	**845.00**	**960,768.00**
	Additions to extent	**34.75**	**10.50**	**117.00**	**6.50**	**102.75**	**548.25**	**648.50**	**0.00**	**700.50**	**483.25**	**346.00**	**2,610.50**	**4,787.50**	**0.00**	**0.00**	**53.50**	**0.00**	**440.50**	**12.00**	**10,902.00**
1	From F1.1 permanent upland stream		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	37.25	0.00	2.00	1.00	40.50
2	From F2.1, F2.2, Small and large fresh water lakes	0.00		3.50	0.00	0.00	3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00
3	From F3.1 Large Reservoir	0.00	0.00		0.00	0.00	8.50	0.00	0.00	6.25	0.00	0.00	0.00	4.50	0.00	0.00	0.00	0.00	0.00	0.00	19.25
4	From F3.3 Rice paddies	0.00	0.00	0.00		7.25	3.75	0.00	0.00	11.75	81.00	5.25	169.00	29.00	0.00	0.00	0.00	0.00	0.00	0.00	307.00
5	From F3.4 Fresh water aquafarm	0.00	0.00	0.00	0.00		2.75	0.00	0.00	1.75	2.25	0.50	280.00	45.50	0.00	0.00	0.00	0.00	2.50	0.00	335.25
6	From F3.5 Canals, ditches and drains	5.00	0.75	0.00	0.00	5.75		0.00	0.00	2.50	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.75
7	From T1.3 Tropical/Subtropical montane rainforests	0.00	0.00	19.75	0.00	0.00	5.00		0.00	18.50	10.75	2.75	1,238.25	245.25	0.00	0.00	0.00	0.00	3.00	0.00	1,543.25
8	From T2.2 Deciduous temperate forests	0.00	0.00	0.00	0.00	0.00	0.75	0.00		0.00	0.00	0.00	2.25	8.75	0.00	0.00	0.00	0.00	0.00	0.00	11.75
9	From T3.1 seasonally dry tropical shrubland	0.00	0.00	1.00	0.00	3.00	28.75	10.75	0.00		40.75	22.25	190.25	101.25	0.00	0.00	0.00	0.00	0.00	11.00	409.00
10	From T4.5 Temperate subhumid grassland	0.00	4.00	0.00	0.00	0.75	26.25	0.00	0.00	42.00		10.25	47.25	58.25	0.00	0.00	0.00	0.00	0.00	0.00	188.75
11	From T7.1 Annual Cropland	0.00	0.00	0.00	0.00	0.00	0.50	13.00	0.00	6.25	5.50		90.50	196.00	0.00	0.00	0.00	0.00	0.00	0.00	311.75
12	From T7.3 Plantation	11.50	5.75	76.75	6.50	55.75	439.75	537.50	0.00	554.50	246.75	277.75		4,012.25	0.00	0.00	0.00	0.00	100.25	0.00	6,325.00
13	From T7.4 Urban and industrial	18.25	0.00	16.00	0.00	5.75	25.75	7.00	0.00	57.00	96.25	27.25	334.50		0.00	0.00	0.00	0.00	332.75	0.00	920.50
14	From M1.1 Seagrass meadows	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
15	From M1.3 Photic coral reefs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
16	From M2 Pelagic ocean water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
17	From M4 Anthropogenic marine biome	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
18	From MFT1.2 Intertidal forests and shrublands	0.00	0.00	0.00	0.00	24.50	3.00	80.25	0.00	0.00	0.00	0.00	257.75	86.50	0.00	0.00	0.00	0.00		0.00	452.00
19	From MT1.3 Sandy Shorelines	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.25	0.00	0.00		16.25
	Reductions to extent	**40.50**	**7.00**	**19.25**	**307.00**	**335.25**	**14.75**	**1,543.25**	**11.75**	**409.00**	**188.75**	**311.75**	**6,325.00**	**920.50**	**0.00**	**0.00**	**0.00**	**0.00**	**452.00**	**16.25**	**10,902.00**
1	To F1.1 permanent upland stream		0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	11.50	18.25	0.00	0.00	0.00	0.00	0.00	0.00	34.75
2	To F2.1, F2.2, Small and large fresh water lakes	0.00		0.00	0.00	0.00	0.75	0.00	0.00	0.00	4.00	0.00	5.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.50
3	To F3.1 Large Reservoir	0.00	3.50		0.00	0.00	0.00	19.75	0.00	1.00	0.00	0.00	76.75	16.00	0.00	0.00	0.00	0.00	0.00	0.00	117.00
4	To F3.3 Rice paddies	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.50
5	To F3.4 Fresh water aquafarm	0.00	0.00	0.00	7.25		5.75	0.00	0.00	3.00	0.75	0.00	55.75	5.75	0.00	0.00	0.00	0.00	24.50	0.00	102.75
6	To F3.5 Canals, ditches and drains	0.00	3.50	8.50	3.75	2.75		5.00	0.75	28.75	26.25	0.50	439.75	25.75	0.00	0.00	0.00	0.00	3.00	0.00	548.25
7	To T1.3 Tropical/Subtropical montane rainforests	0.00	0.00	0.00	0.00	0.00	0.00		0.00	10.75	0.00	13.00	537.50	7.00	0.00	0.00	0.00	0.00	80.25	0.00	648.50
8	To T2.2 Deciduous temperate forests	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	To T3.1 seasonally dry tropical shrubland	0.00	0.00	6.25	11.75	1.75	2.50	18.50	0.00		42.00	6.25	554.50	57.00	0.00	0.00	0.00	0.00	0.00	0.00	700.50
10	To T4.5 Temperate subhumid grassland	0.00	0.00	0.00	81.00	2.25	0.00	10.75	0.00	40.75		5.50	246.75	96.25	0.00	0.00	0.00	0.00	0.00	0.00	483.25
11	To T7.1 Annual Cropland	0.00	0.00	0.00	5.25	0.50	0.00	2.75	0.00	22.25	10.25		277.75	27.25	0.00	0.00	0.00	0.00	0.00	0.00	346.00
12	To T7.3 Plantation	0.00	0.00	0.00	169.00	280.00	0.75	1,238.25	2.25	190.25	47.25	90.50		334.50	0.00	0.00	0.00	0.00	257.75	0.00	2,610.50
13	To T7.4 Urban and industrial	0.25	0.00	4.50	29.00	45.50	0.00	245.25	8.75	101.25	58.25	196.00	4,012.25		0.00	0.00	0.00	0.00	86.50	0.00	4,787.50
14	To M1.1 Seagrass meadows	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
15	To M1.3 Photic coral reefs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
16	To M2 Pelagic ocean water	37.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	16.25	53.50
17	To M4 Anthropogenic marine biome	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
18	To MFT1.2 Intertidal forests and shrublands	2.00	0.00	0.00	0.00	2.50	0.00	3.00	0.00	0.00	0.00	0.00	100.25	332.75	0.00	0.00	0.00	0.00		0.00	440.50
19	To MT1.3 Sandy Shorelines	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		12.00
	Net change in stock	**(5.75)**	**3.50**	**97.75**	**(300.50)**	**(232.50)**	**533.50**	**(894.75)**	**(11.75)**	**291.50**	**294.50**	**34.25**	**(3,714.50)**	**3,867.00**	**0.00**	**0.00**	**53.50**	**0.00**	**(11.50)**	**(4.25)**	**0.00**
	Closing extent (2020)	**7,552.75**	**160.00**	**1,082.50**	**1,009.50**	**4,163.00**	**1,090.25**	**62,592.75**	**0.00**	**2,781.25**	**1,686.50**	**943.00**	**347,438.25**	**23,015.75**	**5,404.50**	**2,249.00**	**457,914.50**	**1,022.75**	**39,821.00**	**840.75**	**960,768.00**
	Retained stock	**7,518.00**	**149.50**	**965.50**	**1,003.00**	**4,060.25**	**542.00**	**61,944.25**	**0.00**	**2,080.75**	**1,203.25**	**597.00**	**344,827.75**	**18,228.25**	**5,404.50**	**2,249.00**	**457,861.00**	**1,022.75**	**39,380.50**	**828.75**	**949,866.00**

5.2 Accounting for Ecosystem Condition

Concept and Principles according to SEEA EA

The preparation of **ecosystem condition accounts** is a key component of the **System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA)** framework. It is designed to measure and monitor the quality and integrity of ecosystems across multiple dimensions: physical, biological, and functional, reflecting changes between the opening and closing periods.

According to SEEA EA, "ecosystem condition" refers to the level of completeness of ecosystem components, structure, and functions. It is fundamental to the ecosystem's ability to persist, remain stable, and continue providing ecosystem services in the long term. Therefore, ecosystem condition accounts assess ecosystem integrity in biophysical terms, without focusing on economic value.

The preparation of ecosystem condition accounts under SEEA EA follows steps:

(1) Defining the study area and ecosystem types

The analysis began by defining the study area in Krabi Province and identifying key ecosystem types important for tourism sector and water management, which are major sectors driving economic activity and the utilization of natural resources, such as freshwater ecosystems, terrestrial ecosystems, and marine and coastal ecosystems, to clarify which ecosystems are covered in the assessment and where they are located.

(2) Selecting ecosystem condition variables

Condition variables are selected according to the **SEEA Ecosystem Condition Typology (SEEA ECT)**, which classifies ecosystem characteristics into 3 main groups (as in Table 6) with the following subclasses:

Group A: Abiotic ecosystem characteristics

This group reflects the status of physical and chemical components that are the foundation for ecosystems and are important conditions for the functioning of biological components.

- **Class A1: Physical state characteristics** – variables describing physical characteristics such as soil structure, and water availability.
- **Class A2: Chemical state characteristics** – variables reflecting the chemical composition of ecosystems, e.g., nutrient levels in soil, water quality, and pollutant concentrations.

Group B: Biotic ecosystem characteristics

This group represents the status of living communities, including composition, structure, and functional processes.

- **Class B1: Compositional state characteristics** – measures the composition and diversity of species in a given area and time, such as abundance of key species.
- **Class B2: Structural state characteristics** – indicates overall biotic structure, such as canopy cover, or vegetation indices (NDVI).
- **Class B3: Functional state characteristics** – reflects ecosystem functions and interactions, such as primary productivity, frequency, and intensity.

Group C: Landscape-level characteristics

This group focuses on spatial patterns at the landscape or seascape level.

- **Class C1: Landscape and seascape characteristics** – metrics describing ecosystem mosaics, landscape diversity, connectivity, fragmentation.

Variables are selected based on their importance for ecosystem integrity, data availability from local and national sources, and consistency with international standards to ensure systematic assessment and monitoring of ecosystem conditions.

(3) Defining Reference Conditions and Reference Levels

Reference standards are set for each variable, specifying upper (best condition) and lower (degraded condition) reference levels to allow comparisons and calculation of condition indices.

(4) Adjusting Variables to Ecosystem Condition Indicators

All variables are adjusted to a standard 0–1 scale to represent ecosystem integrity, where values closer to 1 indicate high completeness and integrity, and values near 0 indicate degradation. This allows meaningful comparison, analysis of trends, and aggregation of multiple variables.

(5) Synthesizing results into ecosystem condition accounts

Accounts show condition indices for opening and closing periods, and where appropriate, indices are aggregated into **weighted condition indices** for each ecosystem type, reflecting overall ecosystem status and trends in the study area.

SEEA Ecosystem Condition Typology (SEEA ECT) classifies ecosystem condition variables into three main groups according to component type and ecosystem functioning (see Table 7).

Ecosystem Condition Accounts in Krabi Province

The Krabi Province ecosystem assessment focuses on supporting the tourism sector and water management, key sectors driving economic activity and natural resource use. The assessment uses data from both local and national agencies, and variables were selected according to **SEEA ECT**, covering all **three groups (A, B, C)** based on data availability and ecosystem relevance, including **freshwater**, **terrestrial**, and **marine/coastal ecosystems**. Variables reflect status, structure, and function. The variable values were then scaled and aggregated into condition indices to assess ecosystem integrity and trends according to international standards.

Table 7 The SEEA Ecosystem Condition Typology Class (SEEA ECT)

ECT groups and classes
Group A: Abiotic ecosystem characteristics
Class A1. Physical state characteristics: physical descriptors of the abiotic components of the ecosystem (e.g. soil structure, water availability)
Class A2. Chemical state characteristics: chemical composition of abiotic ecosystem compartments (e.g. soil nutrient levels, water quality, air pollutant concentrations)
Group B: Biotic ecosystem characteristics
Class B1. Compositional state characteristics: composition/diversity of ecological communities at a given location and time (e.g. presence/abundance of key species, diversity of relevant species groups)
Class B2. Structural state characteristics: aggregate properties (e.g. mass, density) of the whole ecosystem or its main biotic components (e.g. total biomass, canopy coverage, annual maximum normalized difference vegetation index (NDVI))
Class B3. Functional state characteristics: summary statistics (e.g. frequency, intensity) on the biological, chemical and physical interactions between the main ecosystem compartments (e.g. primary productivity, community age, disturbance frequency)
Group C: Landscape-level characteristics
Class C1. Landscape and seascape characteristics: metrics describing mosaics of ecosystem types at coarse (landscape, seascape) spatial scales (e.g. landscape diversity, connectivity, fragmentation)

Source: United Nations et al., (2021)

Freshwater Ecosystem Condition Account

Freshwater ecosystems are crucial for water resource management, public consumption, and supporting economic activities, particularly nature-based tourism. The condition account assesses ecosystem integrity and trends of change in the study area, focusing on evaluating surface water sources and related ecosystems within the framework of SEEA ECT. Variables reflecting the ecosystem's status in both abiotic and biotic dimensions were selected based on suitability and data availability (as shown in Table 8).

Group A: Abiotic characteristics – chemical state indicators include water quality index (WQI) from the Tha Nam Bridge station and the Khlong Yai station. It was found that the water quality index showed a clear improvement trend between 2016 and 2020.

Group B: Biotic characteristics – compositional state uses fish species richness as a representative of biodiversity, while the functional state (Class B3: Functional state) used BOD values as an indirect indicator of the functions of the ecosystem.

The aggregated **freshwater ecosystem condition index** increased from 0.60 in 2016 to **0.86** in 2020, reflecting improved water quality and function of the freshwater ecosystem in the study area.

Terrestrial Ecosystem Condition Account

The terrestrial ecosystems of Krabi Province play a crucial role in biodiversity conservation, maintaining ecosystem balance, and supporting economic activities, particularly ecotourism. The assessment included abiotic, biotic, and landscape characteristics (as shown in Table 9).

Group A: Abiotic characteristics – physical and chemical indicators include Normalized Difference Water Index (NDWI) (vegetation moisture index) and soil organic carbon. NDWI slightly decreased between 2016 and 2020, while soil organic carbon content remained stable; the abiotic characteristics decreased slightly from 0.12 to 0.11, reflecting mild changes in physical and chemical factors in the ecosystem.

Group B: Biotic characteristics – compositional state uses tree species richness and bird species richness as representatives, while the structural state (Class B2: Structural state) and functional state (Class B3: Functional state) use the forest density and Normalized Difference Vegetation Index (NDVI). The biotic condition index remained stable at approximately 0.71, reflecting the health and robustness of the biological ecosystem in the area.

Group C: Landscape characteristics – The forest density in Krabi Province did not change significantly between 2016 and 2020, indicating that the overall landscape characteristics remained relatively stable.

The overall **terrestrial ecosystem condition index** remained stable at approximately **0.82** from 2016 to 2020, reflecting the balance and sustainability of terrestrial ecosystems in the area. Although there were minor changes in some physical indicators, the biological ecosystem remained healthy.

Marine and Coastal Ecosystem Condition Account

Marine and coastal ecosystems are critical for coastal water management, ecosystem balance, and supporting economic activities, particularly marine tourism and coastal resource utilization, such as snorkeling, which directly depend on water quality and ecosystem integrity. The assessment included water quality, ecosystem structure, and coastal landscape characteristics (as shown in Table 10).

Group A: Abiotic characteristics – transparency and marine water quality index (MWQI). Water transparency declined, while MWQI remained relatively stable throughout the same period. The abiotic index decreased from 0.37 in 2016 to 0.20 in 2020, reflecting changes in the physical conditions of the marine ecosystem, particularly water transparency, even though overall water quality did not change significantly.

Group B: Biotic characteristics – compositional state uses fish species richness, coral species richness, and bird species richness; structural state uses the proportion of coral cover at healthy, moderate, and degraded levels. The assessment results show that the proportion of healthy coral tends to increase slightly, while degraded coral tends to decrease. However, considering the overall index of biotic characteristics, it was found to be at approximately 0.03, reflecting the limited state of the biological ecosystem, even though there are signs of structural recovery of the coral reefs.

Table 8 **Freshwater ecosystem condition account**

SEEA Ecosystem Condition Typology Class		Variables		Freshwater (F)										
				Variable values (observed)		Reference level values		Indicator values (rescale)			Indicator weight	Index Values		
		Descriptor	Measurement unit	Opening 2016	Closing 2020	Lower level	Upper level	Opening	Closing	Change in indicator (Closing-Opening)		Opening	Closing	Change
Abiotic characteristics	**A1.Physical state**	Data Not available												
	A2. Chemical state	WQI at Saphan Tha Nam Station	index (0-100)	62.0	73.2	0	100	0.62	0.73	0.11	0.20	0.12	0.15	0.02
		WQI at Khlong Yai Station	index (0-100)	58.0	77.1	0	100	0.58	0.77	0.19	0.20	0.10	0.15	0.06
	Total abiotic							**0.60**	**0.75**	**0.30**	**0.40**	**0.22**	**0.30**	**0.08**
Biotic characteristics	**B1.Compositional state**	Fish species richness[1]		54.00	54.00	0	176	0.31	0.31	0.00	0.20	0.06	0.06	0.00
	B2.Structural state	Data Not available												
	B3.Functional state	BOD at Saphan Tha Nam Station	(mg/l) rescaled 4.0 = 0%, 1.5=100%	80	140	0.00	100.00	0.8	1.40	0.60	0.20	0.16	0.28	0.12
		BOD at Khlong Yai Station	(mg/l) rescaled 4.0 = 0%, 1.5=100%	80	108	0.00	100.00	0.8	1.08	0.28	0.20	0.16	0.22	0.06
	Total biotic							**0.64**	**0.93**	**0.88**	**0.60**	**0.38**	**0.56**	**0.18**
Landscape/waterscape characteristics	**C1.Landscape/waterscape**	Data Not available												
	Total landscape/waterscape	Data Not available												
Total											**1.00**	**0.60**	**0.86**	**0.26**

Remark:

1. A total of 176 freshwater fish species were recorded in the river systems of the western Peninsular Thailand Basin (Vidthayanon, 2017).

Table 9 **Terrestrial ecosystem condition account**

SEEA Ecosystem Condition Typology Class		Variables		Terrestrial (T)										
				Variable values (observed)		Reference level values		Indicator values (rescale)			Indicator weight	Index Values		
		Descriptor	Measurement unit	Opening 2559	Closing 2563	Lower level	Upper level	Opening	Closing	Change in indicator (Closing-Opening)		Opening	Closing	Change
Abiotic characteristics	A1.Physical state	Normalized Difference Water Index (NDWI)	index (-1 to 1)	-0.31	-0.35	-1	1	0.35	0.33	-0.02	0.13	0.04	0.04	0.00
	A2. Chemical state	Soil organic carbon content (2021)	index (0 to 8)	4.66	4.66	0	8	0.58	0.58	0.00	0.13	0.07	0.07	0.00
	Total abiotic							**0.46**	**0.45**	**-0.02**	**0.25**	**0.12**	**0.11**	**0.00**
Biotic characteristics	B1.Compositional state	Tree species richness[1]	Number	423	423	0	100	4.23	4.23	0.00	0.13	0.53	0.53	0.00
		Bird species richness[2]	Number	348	348	0	1083	0.32	0.32	0.00	0.13	0.04	0.04	0.00
	B2.Structural state	Forest cover density[3]	%	6.34	6.34	0	100	0.06	0.06	0.00	0.13	0.01	0.01	0.00
		Crop diversity[4]	Number	10	10	0	27	0.37	0.37	0.00	0.13	0.05	0.05	0.00
	B3.Functional state	Normalized Difference Vegetation Index (NDVI)	index (-1 to 1)	0.36	0.40	-1	1	0.68	0.70	0.02	0.13	0.09	0.09	0.00
	Total biotic							**0.95**	**0.95**	**0.02**	**0.63**	**0.71**	**0.71**	**0.00**
Landscape/waterscape characteristics	C1.Landscape/waterscape	Forest area density	%	0.127	0.126	0	100	0.00	0.00	0.00	0.13	0.00	0.00	0.00
	Total landscape/waterscape							**0.00**	**0.00**	**0.00**	**0.13**	**0.00**	**0.00**	**0.00**
Total											**1.00**	**0.82**	**0.82**	**0.00**

Table 10 **Marine and Coastal ecosystem condition account**

SEEA Ecosystem Condition Typology Class		Variables		Marine (M) + Marine-Freshwater-Terrestrial (MFT) + Marine-Terrestrial (MT)										
				Variable values (observed)		Reference level values		Indicator values (rescale)			Indicator weight	Index Values		
		Descriptor	Measurement unit	Opening 2559	Closing 2563	Lower level	Upper level	Opening	Closing	Change in indicator (Closing-Opening)		Opening	Closing	Change
Abiotic characteristics	A1.Physical state	**Transparency**												
		Noppharat Thara Beach	Meter	0.55	0.40	0.36	0.44	2.38	0.50	-1.88	0.02	0.04	0.01	-0.03
		Ao Nang	Meter	0.65	0.50	0.45	0.55	2.00	0.50	-1.50	0.02	0.04	0.01	-0.03
		Noppharat Thara Beach (Pak Khlong Haeng)	Meter	1.25	1.50	1.35	1.65	-0.33	0.50	0.83	0.02	-0.01	0.01	0.01
		Bilae Beach (Koh Hong)	Meter	0.70	1.00	0.9	1.1	-1.00	0.50	1.50	0.02	-0.02	0.01	0.03
		Ban Saladan (Koh Lanta)	Meter	0.70	0.40	0.36	0.44	4.25	0.50	-3.75	0.02	0.08	0.01	-0.07
		Loh Ba Gao Bay, Koh Phi Phi (Eastern)	Meter	0.65	0.60	0.54	0.66	0.92	0.50	-0.42	0.02	0.02	0.01	-0.01
		Loh Dalum Beach, Koh Phi Phi (Central–Western)	Meter	0.50	0.60	0.35	0.70	0.43	0.71	0.29	0.02	0.01	0.01	0.01
		Loh Dalum Beach, Koh Phi Phi	Meter	1.50	6.00	1.10	6.00	0.08	1.00	0.92	0.02	0.00	0.02	0.02
		Loh Dalum Beach (Phi Phi Cabana), Koh Phi Phi	Meter	0.90	0.80	0.50	0.90	1.00	0.75	-0.25	0.02	0.02	0.01	0.00
		Ton Sai Beach (Ton Sai Village), Koh Phi Phi (Southern) – Point 1	Meter	0.95	1.20	0.80	1.20	0.38	1.00	0.63	0.02	0.01	0.02	0.01
		Ton Sai Beach (Ton Sai Village), Koh Phi Phi (Southern) – Point 2	Meter	8.00	9.50	7.00	11.00	0.25	0.63	0.38	0.02	0.00	0.01	0.01
		Long Beach, Ko Phi Phi (Southeastern)	Meter	1.15	0.60	0.60	1.15	1.00	0.00	-1.00	0.02	0.02	0.00	-0.02
		Maya Bay	Meter	1.10	1.80	1.10	4.00	0.00	0.24	0.24	0.02	0.00	0.00	0.00
		Railay Bay	Meter	0.90	0.80	0.30	0.90	1.00	0.83	-0.17	0.02	0.02	0.01	0.00
		Klong Dao Beach	Meter	0.65	0.40	0.30	0.65	1.00	0.29	-0.71	0.02	0.02	0.01	-0.01
		Baan Klong Nin (Koh Lanta)	Meter	1.10	0.40	0.25	1.10	1.00	0.18	-0.82	0.02	0.02	0.00	-0.01
		Baan Sriraya (Koh Lanta)	Meter	0.65	1.00	0.35	1.10	0.40	0.87	0.47	0.02	0.01	0.02	0.01
		baan bor maung (Bor Maung Bay)	Meter	2.25	1.50	1.35	2.25	1.00	0.17	-0.83	0.02	0.02	0.00	-0.01
		Thale Waek (Separated Sea)	Meter	1.15	0.20	0.20	1.25	0.90	0.00	-0.90	0.02	0.02	0.00	-0.02
		Laem Tong, Koh Phi Phi	Meter	0.55	0.80	0.50	0.85	0.14	0.86	0.71	0.02	0.00	0.02	0.01
		Koh Poda[1]	Meter	7.15	6.00	5.50	7.15	1.00	0.30	-0.70	0.02	0.02	0.01	-0.01
		Koh Kai (Chicken Island) [1]	Meter	7.00	2.70	2.70	7.00	1.00	0.00	-1.00	0.02	0.02	0.00	-0.02
		Loh Samah Bay[1]	Meter	11.50	8.00	3.00	11.50	1.00	0.59	-0.41	0.02	0.02	0.01	-0.01
		Koh Yung (Mosquito Island) [1]	Meter	6.00	1.00	1.00	6.00	1.00	0.00	-1.00	0.02	0.02	0.00	-0.02
	A2. Chemical state	**MWQI**												
		Noppharat Thara Beach	index (0-100)	82.30	81.67	0	100	0.82	0.82	-0.01	0.02	0.01	0.01	0.00
		Ao Nang	index (0-100)	60.40	83.83	0	100	0.60	0.84	0.23	0.02	0.01	0.01	0.00
		Noppharat Thara Beach (Pak Khlong Haeng)	index (0-100)	78.42	84.97	0	100	0.78	0.85	0.07	0.02	0.01	0.02	0.00
		Bilae Beach (Koh Hong)	index (0-100)	88.68	87.65	0	100	0.89	0.88	-0.01	0.02	0.02	0.02	0.00
		Ban Saladan (Koh Lanta)	index (0-100)	60.53	60.76	0	100	0.61	0.61	0.00	0.02	0.01	0.01	0.00
		Loh Ba Gao Bay, Koh Phi Phi (Eastern)	index (0-100)	85.57	89.02	0	100	0.86	0.89	0.03	0.02	0.02	0.02	0.00
		Loh Dalum Beach, Koh Phi Phi (Central–Western)	index (0-100)	78.63	88.12	0	100	0.79	0.88	0.09	0.02	0.01	0.02	0.00
		Loh Dalum Beach, Koh Phi Phi	index (0-100)	81.83	88.74	0	100	0.82	0.89	0.07	0.02	0.01	0.02	0.00

Table 10 **Marine and Coastal ecosystem condition account** *(Continued)*

SEEA Ecosystem Condition Typology Class		Variables		Marine (M) + Marine-Freshwater-Terrestrial (MFT) + Marine-Terrestrial (MT)										
				Variable values (observed)		Reference level values		Indicator values (rescale)			Indicator weight	Index Values		
		Descriptor	Measurement unit	Opening 2559	Closing 2563	Lower level	Upper level	Opening	Closing	Change in indicator (Closing-Opening)		Opening	Closing	Change
Abiotic characteristics *(Continued)*	A2. Chemical state *(Continued)*	Loh Dalum Beach (Phi Phi Cabana), Koh Phi Phi[1]	index (0-100)	88.38	85.70	0	100	0.88	0.86	-0.03	0.02	0.02	0.02	0.00
		Ton Sai Beach (Ton Sai Village), Koh Phi Phi (Southern) – Point 1	index (0-100)	82.14	87.64	0	100	0.82	0.88	0.06	0.02	0.01	0.02	0.00
		Ton Sai Beach (Ton Sai Village), Koh Phi Phi (Southern) – Point 2	index (0-100)	87.51	88.68	0	100	0.88	0.89	0.01	0.02	0.02	0.02	0.00
		Long Beach, Ko Phi Phi (Southeastern)	index (0-100)	86.52	87.24	0	100	0.87	0.87	0.01	0.02	0.02	0.02	0.00
		Maya Bay	index (0-100)	83.48	87.79	0	100	0.83	0.88	0.04	0.02	0.01	0.02	0.00
		Railay Bay	index (0-100)	88.41	85.16	0	100	0.88	0.85	-0.03	0.02	0.02	0.02	0.00
		Klong Dao Beach	index (0-100)	78.70	85.83	0	100	0.79	0.86	0.07	0.02	0.01	0.02	0.00
		Baan Klong Nin (Koh Lanta)	index (0-100)	80.97	86.29	0	100	0.81	0.86	0.05	0.02	0.01	0.02	0.00
		Baan Sriraya (Koh Lanta)	index (0-100)	84.35	87.23	0	100	0.84	0.87	0.03	0.02	0.02	0.02	0.00
		baan bor maung (Bor Maung Bay)	index (0-100)	85.30	83.95	0	100	0.85	0.84	-0.01	0.02	0.02	0.01	0.00
		Thale Waek (Separated Sea)	index (0-100)	89.21	87.79	0	100	0.89	0.88	-0.01	0.02	0.02	0.02	0.00
		Laem Tong, Koh Phi Phi	index (0-100)	84.49	66.73	0	100	0.84	0.67	-0.18	0.02	0.02	0.01	0.00
		Koh Poda[1]	index (0-100)	88.22	88.97	0	100	0.88	0.89	0.01	0.02	0.02	0.02	0.00
		Koh Kai (Chicken Island)	index (0-100)	86.68	89.00	0	100	0.87	0.89	0.02	0.02	0.02	0.02	0.00
		Loh Samah Bay (2017 and 2020)	index (0-100)	87.68	69.76	0	100	0.88	0.70	-0.18	0.02	0.02	0.01	0.00
		Koh Yung (Mosquito Island) (2017 and 2020)	index (0-100)	88.15	90.74	0	100	0.88	0.91	0.03	0.02	0.02	0.02	0.00
Total abiotic											**0.86**	**0.37**	**0.20**	**-0.17**
Biotic characteristics	B1.Compositional state	Fish species richness[1]	no.	57.00	57.00	0	631	0.09	0.09	0.00	0.02	0.00	0.00	0.00
		Coral species richness (2021)[2]	no.	38.00	38.00	0	270	0.14	0.14	0.00	0.02	0.00	0.00	0.00
		Bird species richness[3]	no.	222.00	222.00	0	1083	0.20	0.20	0.00	0.02	0.00	0.00	0.00
	B2.Structural state	coral cover: healthy coral reefs	%	0.95	26.67	0	100	0.01	0.27	0.26	0.02	0.00	0.00	0.00
		coral cover: moderate health coral reefs	%	13.30	40.53	0	100	0.13	0.41	0.27	0.02	0.00	0.01	0.00
		coral cover: damaged coral reefs	%	85.75	32.81	0	100	0.86	0.33	-0.53	0.02	0.02	0.01	-0.01
	B3.Functional state	Data Not available												
	Total biotic										**0.11**	**0.03**	**0.03**	**0.00**
Landscape/seascape characteristics	C1.Landscape/waterscape	Seagrass meadow cover	%	38.00	38.00	0	100	0.38	0.38	0.00	0.02	0.01	0.01	0.00
		Mangrove cover (2014 and 2022)	%	66.23	70.15	0	100	0.66	0.70	0.04	0.02	0.01	0.01	0.00
	Total landscape/waterscape										0.04	**0.02**	**0.02**	**0.00**
Total											**1.00**	**0.42**	**0.25**	**-0.17**

Remark:

1. There are 631 species of fish that inhabit the Krabi River estuary area (Janekarnkij, 2010).

2. Approximately 280 species of coral from 18 families and 71 genera are found in Thailand, with about 270 species in the Andaman Sea and about 240 species in the Gulf of Thailand (Department of Marine and Coastal Resources, 2021).

3. According to data compiled by the Bird Conservation Society of Thailand (BCST), more than 1,082 bird species have been recorded in Thailand (Bird Conservation Society of Thailand, n.d.). Of these, at least 222 species are found within the Krabi River Estuary wetlands (Krabi Provincial Administrative Organization, 2006).

Group C: Landscape characteristics – Indicators for this class include **seagrass meadow cover** and **mangrove forest cover**, which reflect the spatial structure and integrity of coastal ecosystems. The overall index of Landscape/waterscape characteristics showed an increasing trend, especially in mangrove areas, reflecting the stability of the coastal landscape and the restoration of coastal ecosystems in the study area.

The overall **marine and coastal ecosystem condition index** decreased from approximately 0.42 in 2016 to **0.25** in 2020, primarily reflecting changes in the physical components of the ecosystem. Although some biological components and coastal landscape aspects showed stable or improving trends, continuous monitoring of marine and coastal ecosystems is necessary to support sustainable long-term utilization and development.

Policy Observations and Monitoring Needs:

- Freshwater ecosystems show signs of recovery and improving quality.
- Terrestrial ecosystems are balanced and stable, reflecting sustainability.
- Marine and coastal ecosystems are experiencing physical degradation, although some biological components and landscapes are showing recovery; continuous monitoring and management measures are therefore required.
- Monitoring the conditions of all ecosystems is essential to support sustainable use and development.

Accordingly, the Ecosystem condition Accounts of Krabi Province can serve as an important tool for planning natural resource management and supporting sustainable development.

5.3 Accounting for Ecosystem services in physical terms

Ecosystem Services Accounts

Ecosystem services function as the central linking concept in the ecosystem accounting framework, connecting ecosystem assets to the production and consumption activities of businesses, households, and governments. Within this framework, two core aspects define ecosystem services: the supply of services from ecosystems to users, and the contribution of these services to the benefits ultimately enjoyed by society. Each ecosystem asset supplies a bundle of ecosystem services that support economic and other human activities through direct consumption, passive enjoyment, or indirect ecological functions. These services encompass all forms of interaction between ecosystems and people, whether they occur in situ or remotely. In accounting terms, ecosystem services are recorded as flows from ecosystem assets to economic units—entities defined within the national accounts, including firms, households, and government institutions. These flows may involve direct physical transfers, such as the extraction of fish from marine ecosystems, or indirect contributions, such as the provision of flood control, thereby capturing both tangible and regulating services within a consistent accounting structure. A central component is the compilation of Supply and Use Tables, which illustrate the ecosystem services generated by different ecosystem types (supply) and identify the economic sectors or social groups that utilize those services (use). This structure systematically details the economy's dependence on nature and supports policy decisions related to conservation, land-use planning, and the sustainable management of natural resources.

The compilation of ecosystem services flow accounts in physical terms follows the principles and structure of the SEEA Ecosystem Accounting (SEEA EA), in particular the ecosystem services supply and use tables (SUTs). The main steps can be described as follows:

<u>Step 1</u> **Define the ecosystem accounting area and spatial units:** The first step is to delineate the ecosystem accounting area (EAA) and identify the spatial units over which ecosystem services will be measured. This includes delineating ecosystem assets and classifying them into ecosystem types following the SEEA EA ecosystem type reference classification. These spatial units form the basis for attributing the supply of ecosystem services.

<u>Step 2</u> **Classify ecosystem types and identify relevant ecosystem services (IUCN GET 2.0):** Ecosystem types present in Thailand are classified according to the IUCN Global Ecosystem Typology 2.0. In this study, the typology covers 5 realms at Level 1, 13 biomes at Level 2, and 19 ecosystem types at Level 3. For each of these ecosystem types, the physical characteristics of potential ecosystem services are identified and assessed. The research team then screens and selects those ecosystem services that are relevant to the national and provincial context and feasible to quantify, as summarized in Tables 11.

<u>Step 3</u> **Quantify the physical supply of ecosystem services by ecosystem type:** For each selected ecosystem service, suitable physical indicators are defined (for example, tons of biomass harvested, or cubic meters of water regulated), and these are used to estimate the annual flows of that service supplied by each ecosystem type within the EAA. Where possible, spatially explicit data are applied so that the service flows can be linked to specific locations and then aggregated to the corresponding ecosystem types.

<u>Step 5</u> **Attribute ecosystem service flows to users and compile supply and use table:** The physical flows of ecosystem services are then attributed to their users, including economic sectors, households, government units, and, where relevant, other ecosystem assets. These results are organized into (1) Supply table, which records the amount of each service supplied by each ecosystem type, and (2) Use table, which records the amounts used by the different users. For each ecosystem service, total supply equals total use in accordance with the SEEA supply–use accounting identity.

<u>Step 6</u> **Monetary valuation of ecosystem services:** Once the physical flows of ecosystem services have been identified and quantified for each ecosystem type, the research team assesses the monetary value of each type of ecosystem service. The data used for valuation vary according to the nature of each service and are drawn from administrative records maintained by relevant agencies in Krabi Province as well as from existing research studies for the area. The valuation methods is applied depending on the type of ecosystem service, including the use of market prices for related goods and services and benefit transfer, whereby unit values from previous valuation studies are adopted and appropriately adjusted to reflect current prices.

Table 11 Ecosystems and types of economic values for ecosystem services account

Realm	Ecosystem Services		
	Provisioning Services	Regulating and maintenance Services	Cultural Services
Freshwater (F)	**- Biomass provisioning** - Crops - Wild fish and other natural aquatic biomass - Aquaculture **- Water supply** - Natural - Reservoir **- Water use** - Household - Agriculture - Industry - Tourism (hotel) - Ecological Conservation	**- Nursery and protective habitats /Provisioning of habitat**	**Not Available**
Terrestrial (T)	**- Biomass provisioning** - Crops - Wood - Biomass-based energy	**- Carbon sink** - Wood **- Flood control/Water flow regulation** **- Water purification /Water quality regulation** **- Nursery and protective habitats /Provisioning of habitat**	**Not Available**
Marine (M+MFT+MT) = Marine (M) + Marine-Freshwater-Terrestrial (MFT) + Marine-Terrestrial (MT)	**- Biomass provisioning** - Wood - Wild fish and other natural aquatic biomass - Aquaculture - Biomass-based energy	**- Carbon sink** - Seagrass - Mangrove **- Flood control/Water flow regulation** **- Water purification /Water quality regulation** **- Nursery and protective habitats /Provisioning of habitat**	**- Seaview** **- Water, Shore, and Island recreation** **- Coral and Scuba diving**

Source: Synthesized by the TDRI (2025)

Concept and Principles according to SEEA EA

Accounting for ecosystem services in physical terms aims to record the flows of ecosystem services over a defined accounting period using quantitative units such as cubic meters, tons, or counts of use, with measurement typically focused on ecosystem structures, processes, and functions that represent the supply side, though use-based indicators—such as the number of visits to a national park—can also be incorporated. This approach seeks to reconcile the supply and use of ecosystem services across multiple ecosystem assets and user groups, providing as comprehensive coverage as data and resources allow, given that different ecosystem types generate distinct bundles of services. Physical flow accounts support a wide range of analytical and policy applications, including monitoring changes in service supply and use, assessing the significance of particular ecosystems, evaluating trade-offs in spatial planning and land management, and informing the delineation of areas for conservation or other specific land uses, with spatial data playing a central role—especially for regulating and maintenance services—by enabling analysis at finer geographic scales. Information in physical terms also clarifies the relationship between ecosystem services and the System of National Accounts production boundary and provides the empirical basis for subsequent monetary valuation. The compilation of physical ecosystem service flow accounts therefore plays a critical role in identifying and quantifying the actual services provided by ecosystems prior to their economic valuation, enabling systematic tracking of changes in natural resources and assessing the sustainability of ecosystem service provision. It also serves as foundational information that links ecosystem accounting to effective resource planning and spatial management.

Ecosystem Service Accounts in Physical Terms for Krabi Province

For Krabi Province, the compilation of the physical Ecosystem Services Flow Accounts was undertaken for three realm types: Freshwater (F), Terrestrial (T), and Marine (M+MFT+MT). The analysis began by identifying and characterizing the ecosystem services associated with each ecosystem type in physical terms, including both provisioning services, regulating and maintenance services, and cultural services relevant to the provincial context. Subsequently, only those services that were both feasible to quantify with available biophysical and socio-economic data and appropriate to the policy context of Krabi during 2016–2020 were selected for inclusion in the accounts.

The structure of the physical ecosystem services accounts and the classification of service flows follow the System of Environmental-Economic Accounting (SEEA) Central Framework, thereby ensuring consistency with internationally recognized environmental-economic accounting standards. This standardized approach enables comparability across ecosystem types, economic sectors, and geographic scales, while also facilitating integration into broader economic and policy analyses. The detailed physical flow accounts for each ecosystem type and sectoral use are presented in two separate tables: the Supply Table and the Use Table. The Supply Table reports the land area of Krabi Province differentiated by land use categories across ecosystem types, based on data obtained from relevant agencies, as shown in Table 12. The Use Table presents the total physical flows of utilized services, recorded as annual production levels of ecosystem service outputs entering the economy, as shown in Table 13.

Table 12 Ecosystem service supply account in physical terms

Supply Table			Freshwater (F)					Terrestrial (T)					Marine (M) + (MFT) + (MT)				
			2016	2017	2018	2019	2020	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020
Provisioning Services																	
Biomass	Crops (ha)		1,310.00	1,234.88	1,159.75	1,084.63	1,009.50	351,152.75	350,224.13	349,295.50	348,366.88	347,438.25	Not Applicable				
	Wood (ha)		Not Applicable					417,141.75	416,059.38	414,977.00	413,894.63	412,812.25	39,832.50	39,829.63	39,826.75	39,823.88	39,821.00
	Wild fish and other natural aquatic biomass (ha)		9,256.50	9,413.75	9,571.00	9,728.25	9,885.50	Not Applicable					457,861.00	457,874.38	457,887.75	457,901.13	457,914.50
	Aquaculture (ha)		4,395.50	4,337.38	4,279.25	4,221.13	4,163.00	Not Applicable					457,861.00	457,874.38	457,887.75	457,901.13	457,914.50
	Biomass-based energy (ha)		Not Applicable					3.00	3.00	3.00	3.00	3.00	Not Applicable				
Water supply	Surface Water	Natural (ha)	8,271.75	8,404.56	8,537.38	8,670.19	8,803.00	Not Applicable					Not Applicable				
		Reservoir (ha)	984.75	1,009.19	1,033.63	1,058.06	1,082.50	Not Applicable					Not Applicable				
	Groundwater (MCM)		5,704.52	5,518.09	6,593.00	4,859.85	4,862.70	Not Applicable					Not Applicable				
Regulating and maintenance Services																	
Carbon sink	Wood (ha)		Not Applicable					417,141.75	416,059.38	414,977.00	413,894.63	412,812.25	Not Applicable				
	Seagrass (ha)		Not Applicable					Not Applicable					5,404.50	5,404.50	5,404.50	5,404.50	5,404.50
	Mangrove (ha)		Not Applicable					Not Applicable					39,832.50	39,829.63	39,826.75	39,823.88	39,821.00
Forest Benefit: Flood control/Water flow regulation (ha)			Not Applicable					19,148.75	20,115.50	21,082.25	22,049.00	23,015.75	Not Applicable				
Water Resource: Purification/Water quality regulation (ha)			10,566.50	10,648.63	10,730.75	10,812.88	10,895.0	417,141.75	416,059.38	414,977.00	413,894.63	412,812.25	39,832.50	39,829.63	39,826.75	39,823.88	39,821.00
Nursery and protective habitats /Provisioning of habitat (ha)			Not Available					Not Available					39,832.50	39,829.63	39,826.75	39,823.88	39,821.00
Cultural Services																	
Seaview (Rooms)			Not Applicable										18,904	21,647	21,853	22,405	22,405
Water, Shore, and Island recreation (Number of national park)													3	3	3	3	3
Coral and Scuba diving (ha)													2,249	2,249	2,249	2,249	2,249
Migratory bird watching (ha)													21,299	21,299	21,299	21,299	21,299

Source: Data from related organizations with evaluation by TDRI

Table 13 Ecosystem service use account in physical terms

Use Table			Freshwater (F)					Terrestrial (T)					Marine (M) + (MFT) + (MT)				
			2016	2017	2018	2019	2020	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020
Provisioning Services																	
Biomass	Crops	Rice (Tons)	1,729.00	1,309.00	1,403.00	2,517.00	2,626.00	Not Applicable					Not Applicable				
Biomass	Crops	Para Rubber (Tons)	Not Applicable					145,290	146,893	153,980	145,420	133,651	Not Applicable				
Biomass	Crops	Oil palm (Tons)	Not Applicable					2,675,684	3,349,672	3,383,122	3,504,487	3,345,467	Not Applicable				
Biomass	Wood	Acacia Species (Tons)	Not Applicable					0.00	0.00	6,129.85	6,129.85	0.00	Not Applicable				
Biomass	Wood	Mangrove (Tons)	Not Applicable					Not Applicable					3.94	3.96	3.99	4.01	4.02
Biomass	Wild fish and other natural aquatic biomass (Tons)		98.87	171.05	356.50	111.33	200.96	Not Applicable					10,431.00	10,396.00	8,952.00	12,241.00	27,731.41
Biomass	Aquaculture (Tons)		288.78	309.00	549.00	358.00	332.00	Not Applicable					13,286.39	13,203.83	14,078.37	15,039.26	14,632.17
Biomass	Biomass-based energy (Tons)		Not Applicable					306.60	306.60	306.60	306.60	306.60	Not Applicable				
Water use	Service sector (MCM)		6.38	7.94	9.43	10.84	15.36	Not Applicable					Not Applicable				
Water use	Accommodation (MCM)		4.05	5.08	6.85	8.08	4.12	Not Applicable					Not Applicable				
Water use	Household (MCM)		12.02	12.05	11.47	11.41	11.48	Not Applicable					Not Applicable				
Water use	Wastewater Management (MCM)		1.11	1.25	1.29	1.34	1.42	Not Applicable					Not Applicable				
Water use	Other Industries (MCM)		2.78	2.99	3.13	3.53	3.97	Not Applicable					Not Applicable				
Water use	Agriculture (MCM)		4,377.57	4,227.61	4,080.94	13,541.98	5,085.76	Not Applicable					Not Applicable				
Water use	Recirculation from Environment (MCM)		3,554.00	3,445.59	3,329.08	10,890.08	4,126.69	Not Applicable					Not Applicable				
Regulating and maintenance Services																	
Carbon sink	Wood (Million tCO2eq)		Not Applicable					159.61	159.20	158.78	158.37	157.96	Not Applicable				
Carbon sink	Seagrass (Million tCO2eq)		Not Applicable					Not Applicable					1.78	1.78	1.78	1.78	1.78
Carbon sink	Mangrove (Million tCO2eq)		Not Applicable					Not Applicable					3.73	3.73	3.73	3.73	3.73
Forest Benefit: Flood control/Water flow regulation (ha of area protected)			Not Applicable					19,148.75	20,115.50	21,082.25	22,049.00	23,015.75	Not Applicable				
Water Resource: Purification/Water quality regulation (MCM)			14.77	14.89	15.02	15.11	15.14	14.77	14.89	15.02	15.11	15.14	14.77	14.89	15.02	15.11	15.14
Nursery and protective habitats /Provisioning of habitat (ha of area protected)			Not Available					Not Available					39,832.50	39,829.63	39,826.75	39,823.88	39,821.00
Cultural Services																	
Seaview (Rooms)			Not Applicable										12,365	14,601	15,114	15,356	4,091
Water, Shore, and Island recreation	Than Bok Khorani National Park	Thai (person)											38,360	30,344	31,064	25,738	13,405
Water, Shore, and Island recreation	Than Bok Khorani National Park	Foreign (person)											132,508	104,818	107,304	88,906	46,305
Water, Shore, and Island recreation	Mu Koh Lanta National Park	Thai (person)											29,988	21,946	21,966	17,057	7,129
Water, Shore, and Island recreation	Mu Koh Lanta National Park	Foreign (person)											103,589	75,807	75,878	58,919	24,628
Water, Shore, and Island recreation	Hat Noppharat Thara-Mu Ko Phi Phi National Park	Thai (person)											405,457	472,337	346,619	237,546	64,455
Water, Shore, and Island recreation	Hat Noppharat Thara-Mu Ko Phi Phi National Park	Foreign (person)											1,400,588	1,631,613	1,197,339	820,566	222,649
Coral and Scuba diving (ha of area protected)													2,249	2,249	2,249	2,249	2,249
Migratory bird watching (number of persons)													480	480	480	480	480

Source: Data from related organizations with evaluation by TDRI

Freshwater Ecosystem Service Accounts in Physical Terms

Within the freshwater realm of Krabi Province, six biomes were identified in the ecosystem extent account, which formed the basis for the assessment of provisioning services. The analysis focuses on two principal ecosystem services, namely biomass provisioning and water supply. Biomass provisioning services encompass the flows of cultivated biological resources supplied by freshwater ecosystems, which serve both as inputs to economic production and as direct sources of household consumption, particularly in the form of rice and fish products. In this study, biomass provisioning services were further disaggregated into three sub-categories: crops, wild fish and other natural aquatic biomass, and aquaculture. First, crop production within freshwater ecosystems is represented by in-season rice cultivation. In the supply table, this activity is proxied by the area of rice paddies (hectares) according to Ecosystem Extent Account, which serves as the production base. In the use table, the output is recorded as annual rice production (tons), representing the quantity harvested and consumed within the Krabi province, based on data obtained from the Office of Agricultural Economics (OAE). Second, wild fish and other natural aquatic biomass are represented by capturing fisheries in natural freshwater bodies. In the supply table, this activity is proxied by the area of wild aquatic habitats (hectares) across four of the six freshwater biomes —namely permanent upland streams, large and small permanent freshwater lakes, large reservoirs, and canals, ditches and drains —as classified in the Ecosystem Extent Account , which serves as the production base and indicates the spatial extent of ecosystem utilization. In the use table, the output is recorded as annual production levels of wild fish and other aquatic products (tons), representing the harvested biomass entering the economy, based on data obtained from the Department of Fisheries. Lastly, aquaculture is represented by the commercial cultivation of aquatic animals. In the supply table, this activity is proxied by the area of freshwater aquaculture farms (hectares) according to Ecosystem Extent Account, which serves as the production base and indicates the spatial extent of ecosystem utilization. In the use table, the output is recorded as annual production levels of aquaculture (tons), representing the cultivated biomass entering the economy, based on data obtained from the Department of Fisheries.

Water supply services comprise two types: surface water and groundwater. Surface water in this study includes two categories: natural water supply and reservoirs. Natural water supply refers to naturally occurring water bodies that function as storage systems and sources of water for human use. Reservoirs are human-made water bodies, including five reservoirs in Krabi Province—Bang Kam Prat, Huai Nam Khiew, Khlong Ya, Huai Leuk, and Khlong Haeng (Except for Huai Sai Khao Reservoir newly commissioned in 2024). Groundwater is represented by the volume of groundwater in Krabi Province authorized for use, comprising 597 private wells and 201 public wells. In the supply table, natural freshwater sources are represented by the area of natural freshwater bodies (hectares) across four of the six freshwater biomes—namely permanent upland streams, large and small permanent freshwater lakes, and canals, ditches, and drains—as classified in the Ecosystem Extent Account. Reservoirs are represented by the area of large reservoirs (hectares), likewise recorded according to the Ecosystem Extent Account. Groundwater is represented by the volume of water stored within Krabi Province, measured in million cubic meters (MCM), due to the limitation that the spatial extent of groundwater cannot be delineated. In the use table, the output is recorded as annual water utilization across seven purposes: service sector, accommodation, household, wastewater management, other industries, agriculture, and recirculation from the environment. These flows are quantified in MCM, enabling assessment of both the physical availability of water resources and their economic significance across different sectors. All data presented in the use tables are derived from the Water Resource Satellite Account (WRSA), compiled with contributions from multiple agencies involved in water allocation, such as the Provincial Waterworks Authority (Krabi), and the Royal Irrigation Department.

In the regulating and maintenance services, the analysis focuses on water purification and water quality regulation, whereby wetlands act as natural filters. In the supply table, this service is proxied by the area of natural freshwater habitats (hectares) across five of the six freshwater biomes —namely permanent upland streams, large and small permanent freshwater lakes, large reservoirs, rice paddies, and canals, ditches, and drains—as classified in the Ecosystem Extent Account, which serves as the production base and indicates the spatial extent of ecosystem utilization. In the use table, the output is recorded as the annual volume of wastewater discharged into natural water bodies (million cubic meters: MCM). This figure is calculated by multiplying the annual population of Krabi Province during 2016–2020 by the per capita wastewater generation rate of 0.275 cubic meters per person per day, equivalent to 100.375 cubic meters per person per year (Krabi Wastewater Management Authority), and further adjusted by the proportion of wastewater that remains untreated and consequently flows into public freshwater bodies, averaging 94.74%. The resulting product yields the annual discharge volume."

With respect to cultural services, no assessment was undertaken for freshwater ecosystems. Instead, all relevant cultural service information has been recorded under the marine ecosystem accounts, reflecting the concentration of cultural and recreational values associated with coastal and marine environments in Krabi Province.

Terrestrial Ecosystem Service Accounts in Physical Terms

Within the terrestrial realm of Krabi Province, seven biomes were identified in the ecosystem extent account, which formed the basis for the assessment of provisioning services. The analysis focuses specifically on biomass provisioning. Biomass provisioning services encompass the flows of cultivated biological resources supplied by terrestrial ecosystems, which function both as inputs to economic production and as direct sources of household consumption, particularly in the form of agricultural crops, timber, and energy derived from biomass. In this study, biomass provisioning services were further disaggregated into three sub-categories: crops, wood, and biomass-based energy. First, crop production within terrestrial ecosystems is represented by two major crops in Krabi Province, namely para rubber and oil palm. In the supply table, this activity is proxied by the area of plantations (hectares), as classified in the Ecosystem Extent Account, which serves as the production base and indicates the spatial extent of ecosystem utilization. In the use table, crops are represented by the annual production levels of para rubber and oil palm (tons), reflecting the quantity harvested and consumed within Krabi Province, based on data obtained from the Office of Agricultural Economics. Second, wood production within terrestrial ecosystems is represented by forest areas in Krabi Province. In the supply table, this activity is proxied by the area of forests across four of the seven terrestrial biomes—namely tropical-subtropical montane rainforests, deciduous temperate forests, seasonally dry tropical shrubland, and plantations—as classified in the Ecosystem Extent Account, which serves as the production base and indicates the spatial extent of ecosystem utilization. In the use table, wood is represented by the annual production levels of Acacia species during the period 2018–2019 (tons), based on auction sales of Acacia species reported by the Forest Industry Organization (South Region). Lastly, Biomass-based energy in the terrestrial ecosystem is represented by the Khlong Thom Biomass Power Plant, a 30 MW biopower project operated by Thaico Technology Co., Ltd. In the supply table, this activity is proxied by the estimated potential area suitable for the establishment of biomass power plants. In the use table, the output is recorded as biomass fuel (para rubber wood) utilized for electricity generation, amounting to 183,960 kWh per year. This figure is derived from the installed production rate of 30 kW per hour, multiplied by the total hours of operation per year, with the assumption that 70% of the installed capacity is effectively utilized to generate economic value. To produce this volume of electricity, an estimated 306.60 tons of biomass fuel (para rubber wood) are required, based on the assumption that para rubber logs with a moisture content not exceeding 45% can generate approximately 600 kWh per ton. Accordingly, the production of 183,960 kWh necessitates 183,960 ÷ 600 = 306.6 tons of biomass fuel.

In the regulating and maintenance services, the analysis focuses on three principal ecosystem services. First, carbon sequestration from wood is represented in the supply table by the area of forests in Krabi Province across four of the seven terrestrial biomes—namely tropical-subtropical montane rainforests, deciduous temperate forests, seasonally dry tropical shrubland, and plantations—as classified in the Ecosystem Extent Account. In the use table, the output is recorded as the capacity of forests in Krabi Province to absorb carbon dioxide (million tCO_2eq), calculated by multiplying the per-hectare absorption rate of 382.63 tCO_2eq per hectare (based on data from the Department of National Parks, Wildlife and Plant Conservation) by the forest area across the four terrestrial biomes. Second, flood control and water flow regulation are represented through a proxy approach, given the absence of direct data in Thailand on the flood regulation function of forests. The analysis uses the estimated economic value of flood damage in urban areas as a proxy, reflecting the potential reduction in damage if forests provide flood mitigation. Accordingly, both the supply and use tables are represented by the area of urban and industrial ecosystems (hectares of area protected) within terrestrial biomes. Lastly, water purification and water quality regulation emphasize the capacity of forests to purify or treat wastewater. In the supply table, this service is proxied by the area of forests (hectares) in Krabi Province across four of the seven terrestrial biomes—namely tropical-subtropical montane rainforests, deciduous temperate forests, seasonally dry tropical shrubland, and plantations—as classified in the Ecosystem Extent Account. In the use table, the output is recorded as the annual volume of wastewater discharged into natural water bodies (million cubic meters, MCM), calculated using the same methodology applied to freshwater biomes.

With respect to cultural services, no assessment was undertaken for freshwater ecosystems. Instead, all relevant cultural service information has been recorded under the marine ecosystem accounts, reflecting the concentration of cultural and recreational values associated with coastal and marine environments in Krabi Province.

Marine Ecosystem Service Accounts in Physical Terms

Within the marine realm of Krabi Province, six biomes across three realms were identified in the ecosystem extent account, forming the basis for the assessment of provisioning services. The analysis focused specifically on biomass provisioning, which encompasses the flows of cultivated biological resources supplied by marine ecosystems that serve both as inputs to economic production and as direct sources of household consumption, particularly in the form of fish, aquaculture products, and biomass-derived resources. In this study, biomass provisioning services were disaggregated into three sub-categories: wood, wild fish and other natural aquatic biomass, and aquaculture. Wood production within marine ecosystems is represented by mangrove trees within intertidal forests and shrublands. In the supply table, this activity is proxied by the area of these ecosystems (hectares), as classified in the Ecosystem Extent Account, which serves as the production base and indicates the spatial extent of ecosystem utilization. In the use table, the output is recorded as the utilization of mangrove wood for fuel, estimated by dividing the total value of consumption by the market price of mangrove charcoal (50 baht per kilogram), thereby deriving the annual consumption levels. For wild fish and other natural aquatic biomass, the reference is to capture fisheries in natural marine habitats, while aquaculture refers to the commercial cultivation of aquatic organisms. In the supply table, both activities are represented by the area of marine ecosystems (hectares) within pelagic ocean water biomes, as classified in the Ecosystem Extent Account, which serves as the production base and indicates the spatial extent of ecosystem utilization. In the use table, wild fish and other natural aquatic biomass are recorded as the annual production levels of fish and aquatic organisms harvested by local fishers (tons), whereas aquaculture is recorded as the annual production levels of fish and aquatic organisms cultivated in human-made facilities (tons). Data for both categories were obtained from the Department of Fisheries.

In the regulating and maintenance services of the marine ecosystem in Krabi Province, the analysis focused on four principal ecosystem services. First, carbon sequestration from seagrass was represented in the supply table by the area of seagrass in Krabi Province in seagrass meadows biomes, as classified in the Ecosystem Extent Account. In the use table, the output is recorded as the capacity of seagrass in Krabi Province to absorb carbon dioxide (million tCO_2eq), calculated by multiplying the per-hectare absorption rate of 330.00 tCO_2eq per hectare (based on data from the EV Power Energy) by the seagrass area in Krabi provinces. Second, carbon sequestration from mangrove was represented in the supply table by the area of mangrove in Krabi Province in intertidal forests and shrublands biomes, as classified in the Ecosystem Extent Account. In the use table, the output is recorded as the capacity of mangrove in Krabi Province to absorb carbon dioxide (million tCO_2eq), calculated by multiplying the per-hectare absorption rate of 93.75 tCO_2eq per hectare (based on data from the Department of Marine and Coastal Resources) by the mangrove area in Krabi provinces. Third, water purification /water quality regulation emphasizes the capacity of mangroves to purify or treat wastewater. In the supply table, this service is proxied by the area of mangrove forests (hectares) in Krabi Province in intertidal forests and shrublands biomes, as classified in the Ecosystem Extent Account. In the use table, the output is recorded as the annual volume of wastewater discharged into natural water bodies (million cubic meters, MCM), calculated using the same methodology applied to freshwater biomes. Lastly, nursery and protective habitats/ provisioning of habitat highlighted the ecological function of mangroves in providing refuge, nesting habitats, and shelter for wildlife species. Due to data limitations, no per-hectare statistics were available for nursery functions; however, the total mangrove area was assumed to perform this role, and thus both the supply and use tables were represented by the mangrove area in Krabi Province (hectares of area protected).

With respect to cultural services of the marine ecosystem in Krabi Province, the analysis focused on four principal ecosystem services. First, seaview, used as a proxy for the value of Krabi's marine scenery, is represented in the supply table by the total number of hotel rooms available in Krabi Province. In the use table, the output is recorded as the number of rooms actually occupied, calculated by multiplying the total number of rooms by the annual occupancy rate. Both figures are based on data obtained from the Ministry of Tourism and Sports. Second, water, shore, and island recreation, reflecting the recreational value of Krabi's islands, is represented in the supply table by the number of national parks in Krabi Province, comprising three major national parks—Than Bok Khorani National Park, Mu Ko Lanta National Park, and Hat Noppharat Thara–Mu Ko Phi Phi National Park. In the use table, the output is recorded as the number of visitors to these three national parks, disaggregated into Thai and Foreign categories (persons). Third, coral and scuba diving, representing the economic value of diving activities, is proxied by the valuation of coral reefs, as coral ecosystems constitute a primary target of diving activities. Accordingly, in both the supply and use tables, this service is represented by the area of coral reefs in Krabi Province within photic coral reef biomes, as classified in the Ecosystem Extent Account. Lastly, migratory bird watching, a recreational activity that has attracted considerable interest in Krabi Province, has not yet been formally studied in terms of its economic value. Accordingly, in the supply table, this service is proxied by the total area of estuarine habitats in Mueang Krabi District and Nuea Khlong District, which serve as feeding grounds for migratory bird species. In the use table, the output is recorded as the number of visitors participating in birdwatching activities each year, estimated on the basis of the assumption that one trip accommodates four participants, with 20 trips organized per month over a six-month period, yielding a total of 480 participants annually.

5.4 Accounting for Ecosystem services in monetary terms

Concept and Principles according to SEEA EA

Recording ecosystem services in monetary terms constitutes a critical step in linking ecosystem contributions to the economy in a manner that is consistent, comparable, and directly applicable to policy and planning. A monetary ecosystem services account translates measured ecosystem service flows into a common currency using exchange values, thereby enabling users to assess the relative economic significance of different services and to understand how ecosystems underpin production, livelihoods, and public benefits. Expressing values in monetary terms also facilitates communication of the scale and importance of ecosystem contributions to a broader range of stakeholders, particularly decision-makers who rely on economic indicators in policy formulation.

The monetary ecosystem services flow account is typically compiled using a supply–use framework that connects ecosystem assets, as service suppliers, with households, businesses, government, and other users. This structure supports systematic comparisons across ecosystem types, economic sectors, and geographic locations, while also enabling the tracking of changes in value over time. It is important to emphasize, however, that these monetary estimates should not be interpreted as representing the total value of nature. They generally encompass only a subset of ecosystem services and are derived from exchange values rather than broader welfare measures such as consumer surplus. For this reason, monetary accounts are most informative when interpreted in conjunction with physical ecosystem accounts and accompanied by documentation of scope, methodological approaches, and data limitations.

Ecosystem Service Accounts in Monetary Terms for Krabi Province

For Krabi Province, the compilation of the monetary Ecosystem Services Flow Accounts was undertaken across three realm types: Freshwater (F), Terrestrial (T), and Marine (M, MFT, and MT). The analytical process began with the transformation of physical ecosystem service data—including provisioning services, regulating and maintenance services, and cultural services relevant to the provincial context—into monetary values. This conversion provides insights into both the economic value of resources available and the extent to which they have been utilized, thereby offering a more accurate representation of the province's economic indicators.

The structure of the monetary ecosystem services accounts and the classification of service flows follow the System of Environmental-Economic Accounting (SEEA) Central Framework, thereby ensuring consistency with internationally recognized environmental-economic accounting standards. This standardized approach enables comparability across ecosystem types, economic sectors, and geographic scales, while also facilitating integration into broader economic and policy analyses. The detailed monetary flow accounts for each ecosystem type and sectoral use are presented in two separate tables: the Supply Table and the Use Table. The Supply Table reports the unit prices of principal ecosystem services, based on data obtained from relevant agencies, as shown in Table 14. The Use Table presents the total monetary values of utilized, derived by multiplying the quantities recorded in the physical ecosystem service use account by the corresponding unit prices reported in the monetary ecosystem service use account, as shown in Table 15.

Table 14 Ecosystem service supply account in monetary terms

Supply Price of supply			Freshwater (F)					Terrestrial (T)					Marine (M) + (MFT) + (MT)				
			2016	2017	2018	2019	2020	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020
Provisioning Services																	
Biomass	Crops	Rice (THB per ha)	126,031.85	126,031.85	126,031.85	126,031.85	126,031.85	Not Applicable					Not Applicable				
Biomass	Crops	Rubber (THB per ha)	Not Applicable					126,031.85	126,031.85	126,031.85	126,031.85	126,031.85	Not Applicable				
Biomass	Crops	Oil palm (THB per ha)	Not Applicable					126,031.85	126,031.85	126,031.85	126,031.85	126,031.85	Not Applicable				
Biomass	Wood	Acacia Species (THB per Ton)	Not Applicable					0.00	0.00	850.00	850.00	0.00	Not Applicable				
Biomass	Wood	Mangrove (THB per ha)	Not Applicable					Not Applicable					4,941.40	4,969.07	5,004.28	5,030.44	5,045.03
Biomass	Wild fish and other natural aquatic biomass (THB per ha)		120,082.13	120,082.13	120,082.13	120,082.13	120,082.13	Not Applicable					13,037.79	9,859.77	13,519.71	10,702.31	16,274.01
Biomass	Aquaculture (THB per ha)		84,021.23	84,021.23	84,021.23	84,021.23	84,021.23	Not Applicable					52,710.21	57,770.43	53,470.18	51,452.51	52,907.23
Biomass	Biomass-based energy (THB per Ton)		Not Applicable					780.00	780.00	780.00	780.00	780.00	Not Applicable				
Water	Surface water	Natural (THB)	1.49	1.49	1.49	1.49	1.49	Not Applicable					Not Applicable				
Water	Surface water	Reservoir (THB)	1.49	1.49	1.49	1.49	1.49	Not Applicable					Not Applicable				
Water	Groundwater (THB)		1.49	1.49	1.49	1.49	1.49	Not Applicable					Not Applicable				
Regulating and maintenance Services																	
Carbon sink	Wood (THB per tCO2eq)		Not Applicable					6,146.50	6,146.50	6,146.50	6,146.50	6,146.50	Not Applicable				
Carbon sink	Seagrass (THB per tCO2eq)		Not Applicable					Not Applicable					6,146.50	6,146.50	6,146.50	6,146.50	6,146.50
Carbon sink	Mangrove (THB per tCO2eq)		Not Applicable					Not Applicable					6,146.50	6,146.50	6,146.50	6,146.50	6,146.50
Forest Benefit: Flood control/Water flow regulation (THB per ha)			Not Applicable					347.39	3,321.89	1,159.51	23.18	744.92	Not Applicable				
Water Resource: Purification /Water quality regulation (THB per m^3)			15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Nursery and protective habitats /Provisioning of habitat (THB per ha)			Not Available					Not Available					10,158.14	10,215.01	10,287.40	10,341.17	10,371.16
Cultural Services																	
Seaview (THB per Room)			Not Available										1,248.37	1,255.36	1,264.26	1,270.87	1,274.55
Water, Shore, and Island	Than Bok Khorani National Park	Thai (THB per visitor)											60.00	60.00	60.00	60.00	60.00
Water, Shore, and Island	Than Bok Khorani National Park	Foreign (THB per visitor)											300.00	300.00	300.00	300.00	300.00
Water, Shore, and Island	Mu Koh Lanta National Park	Thai (THB per visitor)											40.00	40.00	40.00	40.00	40.00
Water, Shore, and Island	Mu Koh Lanta National Park	Foreign (THB per visitor)											400.00	400.00	400.00	400.00	400.00
Water, Shore, and Island	Hat Noppharat Thara-Mu Ko Phi Phi National Park	Thai (THB per visitor)											40.00	40.00	40.00	40.00	40.00
Water, Shore, and Island	Hat Noppharat Thara-Mu Ko Phi Phi National Park	Foreign (THB per visitor)											400.00	400.00	400.00	400.00	400.00
Coral and Scuba diving (Million THB)													45,763.89	52,122.88	59,365.47	67,614.43	77,009.60
Migratory bird watching (THB/person/visit)													728.00	728.00	728.00	728.00	728.00

Source: Data from related organizations with evaluation by TDRI

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Table 15 Ecosystem service use account in monetary terms

Use			Freshwater (F)					Terrestrial (T)					Marine (M) + (MFT) + (MT)				
			2016	2017	2018	2019	2020	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020
Provisioning Services																	
Biomass	Crops	Rice (Million THB)	165.102	155.634	146.165	136.697	127.229	Not Applicable					Not Applicable				
		Para Rubber (Million THB)	Not Applicable					22,128.22	22,069.70	22,011.18	21,952.66	21,894.14	Not Applicable				
		Oil palm (Million THB)	Not Applicable					22,128.22	22,069.70	22,011.18	21,952.66	21,894.14	Not Applicable				
	Wood (Rai)	Acacia Species (Million THB)	Not Applicable					0.00	0.00	5.21	5.21	0.00	Not Applicable				
		Mangrove (Million THB)	Not Applicable					Not Applicable					196.83	197.92	199.30	200.33	200.90
	Wild fish and other natural aquatic biomass (Million THB)		1,111.54	1,130.42	1,149.31	1,168.19	1,187.07	Not Applicable					5,969.50	4,514.54	6,190.51	4,900.60	7,452.11
	Aquaculture (Million THB)		369.32	364.43	359.55	354.66	349.78	Not Applicable					24,133.95	26,451.60	24,483.34	23,560.16	24,226.99
	Biomass-based energy (Million THB)		Not Applicable					0.24	0.24	0.24	0.24	0.24	Not Applicable				
Water use	Service sector (Million THB)		132.64	165.12	196.05	225.40	319.51	Not Applicable					Not Applicable				
	Accommodation (Million THB)		108.59	136.22	183.89	216.83	110.56	Not Applicable					Not Applicable				
	Household (Million THB)		199.51	200.01	190.36	189.36	190.61	Not Applicable					Not Applicable				
	Wastewater Management (Million THB)		16.71	18.79	19.29	20.17	21.24	Not Applicable					Not Applicable				
	Other Industries (Million THB)		74.61	80.30	83.88	94.68	106.59	Not Applicable					Not Applicable				
	Agriculture (Million THB)		2,188.79	2,113.81	2,040.47	6,770.99	2,542.88	Not Applicable					Not Applicable				
	Recirculation from Environment (Million THB)		1,777.00	1,722.80	1,664.54	5,445.04	2,063.34	Not Applicable					Not Applicable				
Regulating and maintenance Services																	
Carbon sink	Wood (Million THB)		Not Applicable					0.98	0.98	0.98	0.97	0.97	Not Applicable				
	Seagrass (Million THB)		Not Applicable					Not Applicable					356.70	356.70	356.70	356.70	356.70
	Mangrove (Million THB)		Not Applicable					Not Applicable					746.86	746.81	746.75	746.70	746.64
Flood control/Water flow regulation (Million THB)			Not Applicable					6.65	66.82	24.45	0.51	17.14	Not Applicable				
Water purification /Water quality regulation (Million THB)			221.54	223.36	225.25	226.68	227.17	221.54	223.36	225.25	226.68	227.17	221.54	223.36	225.25	226.68	227.17
Nursery and protective habitats /Provisioning of habitat (Million THB)			Not Available					Not Available					404.62	404.60	404.57	404.54	404.51
Cultural Services																	
Seaview (Million THB)			Not Applicable										6.838	8.120	8.465	8.646	2.310
Water, Shore, and Island recreation (Million THB)	Than Bok Khorani National Park	Thai											2.302	1.821	1.864	1.544	0.804
		Foreign											39.752	31.445	32.191	26.672	13.892
	Mu Koh Lanta National Park	Thai											1.200	0.878	0.879	0.682	0.285
		Foreign											41.436	30.323	30.351	23.568	9.851
	Hat Noppharat Thara-Mu Ko Phi Phi National Park	Thai											16.218	18.893	13.865	9.502	2.578
		Foreign											560.235	652.645	478.936	328.226	89.060
Coral and Scuba diving (Million THB)													102.923	117.224	133.513	152.065	173.195
Migratory bird watching (Million THB)													0.349	0.349	0.349	0.349	0.349

Source: Data from related organizations with evaluation by TDRI

Freshwater Ecosystem Service Accounts in Monetary Terms

Within the freshwater ecosystem of Krabi Province, the monetary valuation concentrated on two principal ecosystem services—biomass provisioning and water supply—during 2016–2020. Biomass provisioning was further disaggregated into crops, wild fish and other natural aquatic biomass, and aquaculture, each assessed in both supply and use tables to capture their economic significance. For crops in the freshwater biome, rice cultivated and consumed in Krabi Province (Jasmine Rice 105) is represented in the supply table by a proxy valuation of agricultural land used for rice cultivation. The estimated value of agricultural land for crop production is 300,000 baht per rai, equivalent to 1,875,000 baht per hectare. Applying the formula provided in section 1 of Appendix 4, the appropriate annual rental value is calculated at 126,031.85 baht per hectare. In the use table, the total value of land utilized for rice cultivation is derived by multiplying the annual rental value per hectare by the total area of crops reported in the supply table under the Ecosystem Service Account – Physical. For wild fish and other natural aquatic biomass in the freshwater biome, covering 55 freshwater species, and aquaculture in the freshwater biome, covering 53 freshwater species, both datasets were obtained from the Department of Fisheries. In the supply table, aquaculture is represented by a proxy valuation of aquaculture land use for fish cultivation. The estimated value of aquaculture land for fish production is 200,000 baht per rai, equivalent to 1,250,000 baht per hectare. Applying the formula provided in section 2 of Appendix 4, the appropriate annual rental value is calculated at 84,021.23 baht per hectare. For wild fish and other natural aquatic biomass, the valuation is approximately 1.43 times higher than aquaculture, based on market prices reported by the Office of Agricultural Economics (OAE). Accordingly, the appropriate annual rental value for wild fish and other natural aquatic biomass is estimated at 120,082.13 baht per hectare. The monetary valuation of water services is divided into two components: water supply and water use. In the water supply table, sources are classified into surface water (comprising natural water supply and reservoirs) and groundwater. Both categories are valued as the appropriate fee for water utilization, following the study conducted by the Thailand Development Research Institute (TDRI) on irrigation development and water management. For both types of water, the recommended utilization fee is 1.49 baht per cubic meter. In the water use table, water consumption is valued across seven purposes: service sector, accommodation, household, wastewater management, other industries, agriculture, and recirculation from the environment. Consumption flows are multiplied by sector-specific water prices to derive monetary values, based on differentiated tariffs and regulatory fee structures. Household consumption is valued at 16.6 baht per cubic meter, reflecting the average tariff applied to Type 1 water users by the Krabi Provincial Waterworks Authority. The service sector is assigned a rate of 20.8 baht per cubic meter, corresponding to the average tariff for Type 2 users, while accommodation and other industries are valued at 26.84 baht per cubic meter, consistent with the average tariff for Type 3 users. Wastewater treatment services are priced at 15 baht per cubic meter, in line with the 20-Year Community Wastewater Management Plan (2018–2037). Finally, water use for agriculture and recirculation from the environment is valued at 0.5 baht per cubic meter, in accordance with the irrigation fee schedule established by the 2021 Ministerial Regulation issued by the Royal Irrigation Department.

In terms of regulating and maintenance services, the analysis focused on water purification and water quality regulation in freshwater ecosystems, assessed through a proxy approach based on management costs. This method illustrates that, with an effective wastewater treatment system, no untreated effluent would be discharged into public freshwater bodies, thereby avoiding the economic losses associated with the degradation of these natural assets. In the supply table, this service is represented by the average wastewater treatment fee charged under the 20-Year Community Wastewater Management Plan (2018–2037) of the Wastewater Management Authority. In the use table, the total value of treated wastewater is calculated by multiplying the average wastewater treatment fee by the annual volume of wastewater discharged into natural water bodies, as reported in the use table under Ecosystem Service Account – Physical.

With respect to cultural services, no assessment was undertaken for freshwater ecosystems; instead, all relevant cultural service information was recorded under the marine ecosystem accounts, reflecting the concentration of cultural and recreational values associated with coastal and marine environments in Krabi Province."

Terrestrial Ecosystem Service Accounts in Monetary Terms

Within the terrestrial ecosystem of Krabi Province, the monetary valuation concentrated on biomass provisioning, which was disaggregated into three sub-categories—crops, wood, and biomass-based energy—each assessed in both supply and use tables for the period 2016–2020. For crops in terrestrial biomes, rubber and oil palm cultivated and consumed in Krabi Province are represented in the supply table by a proxy valuation of agricultural land use for rubber and oil palm cultivation, applying the same method used for rice in the freshwater biome. Accordingly, the appropriate annual rental value is calculated at 126,031.85 baht per hectare. In the use table, the total value of land utilized for rubber and oil palm cultivation is derived by multiplying the annual rental value per hectare by the total area of crops reported in the supply table under the Ecosystem Service Account – Physical. For use table reporting, the total monetary value is divided equally into two components, with one half attributed to rubber cultivation and the other half to oil palm cultivation. For wood in terrestrial biomes, the supply table is represented by the unit price of Acacia species sold during 2018–2019, reported at 850 baht per ton by the South Forest Industry Organization. In the use table, the total value of Acacia wood in Krabi Province is calculated by multiplying the unit price of Acacia species by the volume of Acacia wood sold, as recorded in the use table under Ecosystem Service Account – Physical. For biomass-based energy in the terrestrial biomes, the Khlong Thom Biomass Power Plant is used as the representative case. In the supply table, this service is proxied by the price of biomass fuel used for electricity generation, based on the purchase price of para rubber logs with a moisture content not exceeding 45 percent, reported at 780 baht per ton (ACE, 2021). In the use table, the total value of electricity generated by biomass power plants is calculated by multiplying the volume of biomass fuel consumed, as recorded in the use table under Ecosystem Service Account – Physical, by the unit price of biomass fuel. This measure reflects the monetary value of electricity produced through biomass utilization.

In terms of regulating and maintenance services, the analysis focuses on three principal ecosystem services. First, carbon sequestration from wood is represented in the supply table by the price of the social cost of carbon (SCC), set at USD 190 per ton of carbon dioxide equivalent, or 6,146.50 baht per ton of carbon dioxide equivalent, as announced by the U.S. Environmental Protection Agency (EPA). In the use table, the total value of carbon sequestration from wood is calculated by multiplying the volume of carbon dioxide absorbed, as recorded in the Ecosystem Service Account – Physical use table, by the SCC unit price. Second, flood control and water flow regulation highlight the role of forests in mitigating rainfall extremes and reducing the risks of floods, droughts, and landslides. This valuation method illustrates the potential economic burden that could be avoided if such problems did not occur, thereby reflecting the value of the ecosystem service. In the supply table, the service is represented by the value per hectare for flood management in Krabi Province, calculated by dividing the total economic damage costs (as reported in the use table) by the area recorded in the Ecosystem Service Account – Physical use table. In the use table, the total value is recorded as the cost of flood management within the province, based on statistical data on flood events during 2016–2020, as documented in the Krabi Provincial Disaster Prevention and Mitigation Plan (2021–2027, First Revision). The valuation varies depending on the occurrence and severity of flood events. Lastly, water purification and water quality regulation were assessed using the same proxy approach applied to freshwater ecosystems. In the supply table, this service was represented by the average wastewater treatment fee charged by the Krabi Wastewater Management Authority at 15 baht per cubic meter. In the use table, the total value of treated wastewater is calculated by multiplying the average wastewater treatment fee by the annual volume of wastewater discharged into natural forest bodies, as reported in the use table under Ecosystem Service Account – Physical

With respect to cultural services, no assessment was undertaken for terrestrial ecosystems; instead, all relevant cultural service information has been recorded under the marine ecosystem accounts, reflecting the concentration of cultural and recreational values associated with coastal and marine environments in Krabi Province.

Marine Ecosystem Service Accounts in Monetary Terms

Within the marine ecosystem of Krabi Province, the monetary valuation concentrated on biomass provisioning, which was disaggregated into three sub-categories: wood, wild fish and other natural aquatic biomass, and aquaculture. For wood in marine biomes, mangrove resources are represented in the supply table through estimated present values of production functions related to timber and fuelwood collection, drawing on valuation studies such as Valuing Mangrove Conservation in Southern Thailand (Sathirathai and Barbier, 2001) and The Economic Value of Laem Phak Bia Mangrove Ecosystem Services in Phetchaburi Province, Thailand (Sitthinan Wiwatthanapornchai et al., 2014). In the use table, the total monetary value of mangrove production functions is calculated by multiplying the total mangrove area in Krabi Province, as recorded in the supply table under Ecosystem Service Account – Physical by the projected unit values derived from these studies. For wild fish and other natural aquatic biomass in the marine biome, covering 53 marine species, and aquaculture in the freshwater biome, also covering 53 species, both datasets were obtained from the Department of Fisheries. In the supply table, both outputs are represented by a proxy valuation, calculated by applying 30 percent of the market price of fish production—covering both capture fisheries and aquaculture—based on data from the Office of Agricultural Economics (OAE). This adjustment was made to isolate the value added of fish production, excluding other cost components such as labor and fuel for fishing vessels. In the use table, the total value of fish production is calculated by multiplying the area of each type of fishery (natural capture and aquaculture) by the adjusted market price (weighted at 30 percent), as reported in the supply table.

In terms of regulating and maintenance services, four principal ecosystem services were considered. First, carbon sequestration from seagrass is represented in the supply table by the social cost of carbon (SCC), valued at 6,146.50 baht per ton of carbon dioxide equivalent, consistent with the valuation applied in freshwater biomes. In the use table, the total value of carbon sequestration from seagrass is calculated by multiplying the volume of carbon dioxide absorbed, as recorded in the Ecosystem Service Account – Physical use table, by the SCC unit price. Second, carbon sequestration from mangroves is represented in the supply table by the same SCC valuation of 6,146.50 baht per ton of carbon dioxide equivalent. In the use table, the total value of carbon sequestration from mangroves is calculated by multiplying the recorded volume of carbon dioxide absorbed by the SCC unit price. Third, water purification and water quality regulation are assessed using the same proxy approach applied to freshwater ecosystems. In the supply table, this service is represented by the average wastewater treatment fee charged by the Krabi Wastewater Management Authority, set at 15 baht per cubic meter. In the use table, the total value of treated wastewater is calculated by multiplying the average wastewater treatment fee by the annual volume of wastewater discharged into marine bodies, as reported in the Ecosystem Service Account – Physical use table. Lastly, nursery and protective habitats are represented in the supply table through estimated present values of production functions related to nursery and protective habitats, drawing on valuation studies such as *Valuing Mangrove Conservation in Southern Thailand* (Sathirathai and Barbier, 2001) and *The Economic Value of Laem Phak Bia Mangrove Ecosystem Services in Phetchaburi Province, Thailand* (Sitthinan Wiwatthanapornchai et al., 2014). In the use table, the total monetary value of mangrove production functions is calculated by multiplying the total mangrove area in Krabi Province, as recorded in the Ecosystem Service Account – Physical supply table, by the projected unit values derived from these studies.

With respect to cultural services, four principal ecosystem services were considered. First, seaview is represented in the supply table by the marginal average hotel price differential between garden-view and sea-view rooms in Krabi Province, estimated at approximately 13.21 percent. This figure was derived using hedonic pricing methods based on characteristics data from 176 hotels (calculation method presented in section 3 of Appendix 4), thereby reflecting econometric evidence that rooms with sea views command a price premium. The marginal value was subsequently converted to present value for consistency with the accounting framework. In the use table, the total marginal value is calculated by multiplying the marginal price of seaview (as reported in the supply table) by the number of rooms actually occupied, adjusted by the proportion of hotel rooms with sea views in Krabi Province. This proportion was estimated at 44.30 percent, based on the same dataset of 176 hotels. Second, water, shore, and island recreation is represented in the supply table by the entrance fees charged at the three major national parks in Krabi Province. In the use table, the total monetary value is calculated by multiplying the number of visitors to these national parks by the entrance fee (as reported in the supply table). Third, coral and scuba diving is valued by adjusting the national market value of diving activities to reflect only Krabi Province, using the number of PADI-registered dive shops as a proxy. Out of a total of 170 dive shops nationwide, 28 are located in Krabi. To isolate the value added attributable to coral ecosystems, the valuation applies a weighting factor of 25 percent, based on the assumption that coral reefs constitute the primary target of diving activities. In the supply table, the service is represented by the average value of coral per hectare, calculated by dividing the total coral value (as reported in the use table) by the coral reef area recorded in the Ecosystem Service Account – Physical supply table. In the use table, the total value of coral is represented by 25 percent of the weighted market value of diving activities in Krabi Province. Lastly, migratory bird watching is represented in the supply table by the estimated profit per visitor per trip, calculated at 728 baht. This figure was derived from a trip price of 1,800 baht, net of operating costs of 1,072 baht. In the use table, the total value is calculated by multiplying the estimated number of visitors, as recorded in the Ecosystem Service Account – Physical supply table, by the profit of 728 baht per person per trip reported in the supply table.

5.5 Accounting for Ecosystem asset in monetary terms

Concept and Principles according to SEEA EA

The monetary ecosystem asset account constitutes a critical element of the ecosystem accounting framework, as it enables the recording of ecosystem asset values in monetary terms. Within this framework, ecosystem assets are valued using the net present value (NPV) of the ecosystem services expected to be supplied by those assets over time, with 2020 adopted as the base year for calculation. Valuation follows the exchange value principles established in environmental-economic accounting. It is important to emphasize that these estimates do not represent a comprehensive or universal measure of the value of nature; rather, they reflect the exchange value of the specific ecosystem services captured within the ecosystem service flow accounts. This distinction is essential, since the monetary valuation of ecosystem assets is designed to support accounting and policy analysis, not to reduce the broader ecological significance to a single monetary figure

Beyond recording asset values at a given point in time, the monetary ecosystem asset account also captures changes in the value of ecosystem assets across an accounting period. These changes may arise from ecosystem enhancement, ecosystem degradation, ecosystem conversion, and other changes in asset volume associated with price changes. In this sense, the account does not merely provide a static valuation of ecosystems, but also offers a dynamic framework for understanding how ecological and economic factors interact to alter the value of ecosystem assets over time. Such information is especially useful for tracing how changes in ecosystem condition and extent are linked to broader socioeconomic drivers, including shifts in economic activity, and land-use change.

The value of ecosystem assets in monetary terms can contribute significantly to policy discussion and decision-making. It enables comparison across different ecosystem types and asset classes, and it allows ecosystem assets to be considered alongside produced and financial assets in broader assessments of national wealth and sustainability. In this respect, monetary ecosystem asset accounts can support wealth accounting and provide a basis for examining whether current patterns of ecosystem use are consistent with long-term sustainability. When combined with physical information on ecosystem extent, condition, and ecosystem service flows, monetary valuations can also help assess the sustainability of ecosystem service provision and support project planning, monitoring, and evaluation by highlighting the implications of changes in future service flows.

At the same time, monetary measures alone are insufficient for analyzing non-marginal ecological change or sustainability issues related to ecological thresholds, resilience, and planetary boundaries. For this reason, the ecosystem accounting framework is particularly valuable because it integrates monetary information with physical data on ecosystem extent, condition, and service capacity. This integrated structure provides a clearer line of sight between biophysical change and economic valuation, thereby strengthening the analytical usefulness of ecosystem accounts. It also underscores the need to distinguish carefully between changes in value driven by prices and those driven by changes in the volume or condition of ecosystem assets and services.

Ecosystem Asset Accounts for Krabi Province

For Krabi Province, the compilation of ecosystem assets in monetary terms was undertaken for three realm types: Freshwater (F), Terrestrial (T), and Marine (M+MFT+MT). The analytical process began with the calculation of the total annual value of ecosystem services utilized or consumed during the study period 2016–2020 for each realm, based on data from the accounting of ecosystem services in monetary terms. These annual values were then aggregated and converted into Net Present Value (NPV). Subsequently, changes in ecosystem asset values were classified into ecosystem enhancement and ecosystem degradation. In addition, ecosystem conversions were analyzed through the valuation of land use changes in Krabi Province, drawing on data from both the accounting of ecosystem extent and the accounting of ecosystem services in monetary terms.

The structure of these accounts and the classification of ecosystem assets in monetary terms in Krabi Province follow the System of Environmental-Economic Accounting (SEEA) Central Framework, thereby ensuring consistency with internationally recognized environmental-economic accounting standards. This standardized approach enables comparability across ecosystem types, economic sectors, and geographic scales, while also facilitating integration into broader economic and policy analyses. The detailed monetary ecosystem asset accounts record changes in the value of ecosystem assets over an accounting period, including changes due to ecosystem degradation, ecosystem enhancement, and ecosystem conversions, as presented in Table 16.

Table 16 Monetary ecosystem asset account (NPV)

Unit: Million THB

	Freshwater (F)	Terrestrial (T)	Marine (M+MFT+MT)	Total
Opening value (2016) (MB)	**7,017.10**	**49,040.76**	**72,330.85**	**128,388.71**
Ecosystem enhancement	8,663.66	-	1,236.04	9,899.70
Ecosystem degradation	(8,434.77)	(5,006.96)	(6,854.48)	(20,296.21)
Ecosystem conversions				
Additions	470.00	1,016.69	68.98	1,555.67
Reductions	(414.95)	(1,030.89)	(63.84)	(1,509.68)
Net change in value	283.93	(5,021.16)	(5,613.29)	(10,350.52)
Closing value (2020) (MB)	**7,301.02**	**44,019.61**	**66,717.56**	**118,038.19**

Freshwater Ecosystem Asset Accounts

Within the freshwater realm of Krabi Province, particular emphasis was placed on the valuation of both Provisioning Services and Regulating and Maintenance Services. For Provisioning Services, the assessment was divided into two main categories. First, biomass provisioning services were calculated for three principal products: rice, wild fish and other natural aquatic biomass, and aquaculture. These represent the value of biomass consumed within Krabi Province. Second, water use was evaluated across seven distinct purposes, namely: the service sector, accommodation, households, wastewater management, other industries, agriculture, and environmental recirculation. Each of these categories was quantified to reflect the economic value of water utilized and consumed within the province.

In addition to provisioning services, the freshwater realm plays a critical role in Regulating and Maintenance Services, particularly in water purification and water quality regulation. These functions were assessed in monetary terms to capture the value of the ecosystem's contribution to maintaining water quality and ensuring the sustainability of freshwater resources.

The compilation of ecosystem assets in monetary terms further demonstrates the dynamic changes in ecosystem value between 2016 and 2020. Enhancements, degradations, and conversions were systematically recorded, resulting in a net change of 283.93 million baht. Consequently, the closing value of freshwater ecosystem assets in 2020 was estimated at 7,301.02 million baht, compared to an opening value of 7,017.10 million baht in 2016. This structured accounting framework ensures that the freshwater ecosystem accounts comprehensively reflect both the direct material benefits derived from biomass and water use, as well as the essential regulating functions that underpin long-term ecological and economic resilience.

Terrestrial Ecosystem Asset Accounts

Within the terrestrial realm of Krabi Province, particular emphasis was placed on the valuation of both Provisioning Services and Regulating and Maintenance Services. For Provisioning Services, the assessment primarily focused on biomass provisioning services, represented by four key products: rubber, oil palm, Acacia species, and biomass power generation. These products reflect the tangible material benefits derived from terrestrial ecosystems and their contribution to local consumption and production activities.

In addition to provisioning services, the terrestrial realm plays a vital role in delivering Regulating and Maintenance Services. Three principal ecosystem functions were considered: (i) carbon sequestration by forest ecosystems, which contributes to climate regulation and mitigation of greenhouse gas emissions; (ii) flood control and water flow regulation, which reduce risks associated with hydrological extremes and safeguard human settlements and economic activities; and (iii) water purification and water quality regulation, which maintain the integrity of terrestrial resources and support long-term ecological sustainability.

The compilation of ecosystem assets in monetary terms further demonstrates the dynamic changes in terrestrial ecosystem value between 2016 and 2020. Ecosystem degradation was recorded at 5,006.96 million baht, while conversions included additions of 1,016.69 million baht and reductions of 1,030.89 million baht. These changes resulted in a net decline of 5,021.16 million baht. Consequently, the closing value of terrestrial ecosystem assets in 2020 was estimated at 44,019.61 million baht, compared to an opening value of 49,040.76 million baht in 2016. This structured accounting framework ensures that terrestrial ecosystem accounts comprehensively capture both the direct economic values of biomass production and energy generation, as well as the critical regulating functions that underpin resilience, climate stability, and sustainable resource management in Krabi Province.

Marine Ecosystem Asset Accounts

Services, Regulating and Maintenance Services, and Cultural Services. For Provisioning Services, the assessment primarily focused on biomass provisioning services, represented by three key products: charcoal derived from mangrove wood, wild fish and other natural aquatic biomass, and aquaculture. These products reflect the direct material benefits generated by marine ecosystems and their contribution to local consumption and economic activities.

In addition to provisioning services, the marine realm delivers critical Regulating and Maintenance Services. Four principal ecosystem functions were considered: (i) carbon sequestration by seagrass meadows, which play a vital role in mitigating greenhouse gas emissions; (ii) carbon sequestration by mangrove forests, which contribute significantly to climate regulation and coastal resilience; (iii) water purification and water quality regulation, which safeguard the integrity of marine and coastal resources; and (iv) nursery and protective habitats, which provide essential breeding and sheltering grounds for aquatic species and thereby sustain biodiversity and fisheries productivity.

Cultural Services also constitute an important source of value within the marine realm of Krabi Province, particularly through tourism activities that generate substantial economic benefits. The assessment identified four major components: (i) seaview, serving as a proxy for the aesthetic and scenic value of Krabi's coastal landscapes; (ii) water, shore, and island recreation, serving as a proxy for the value of one-day island trips and related recreational activities; (iii) coral reef tourism and scuba diving, which highlight the recreational and biodiversity value of marine ecosystems; and (iv) migratory bird watching, which reflects the cultural and ecological significance of avian biodiversity in coastal habitats.

The compilation of ecosystem assets in monetary terms further demonstrates the dynamic changes in marine ecosystem value between 2016 and 2020. Ecosystem enhancement was recorded at 1,236.04 million baht, while degradation amounted to 6,854.48 million baht. Conversions included additions of 68.98 million baht and reductions of 63.84 million baht. These changes resulted in a net decline of 5,613.29 million baht. Consequently, the closing value of marine ecosystem assets in 2020 was estimated at 66,717.56 million baht, compared to an opening value of 72,330.85 million baht in 2016. This structured accounting framework ensures that marine ecosystem accounts comprehensively capture the diverse contributions of marine ecosystems, encompassing direct material benefits, regulating functions essential for ecological stability, and cultural services that underpin Krabi's tourism economy and long-term sustainable development.

Monetary ecosystem asset account summary

The ecosystem asset accounts of Krabi Province reveal both the diversity of services provided by freshwater, terrestrial, and marine realms and the dynamic changes in their monetary values between 2016 and 2020. In the freshwater realm, provisioning services were quantified through biomass production—rice, wild fish, and aquaculture—and water use across seven categories, while regulating services were captured through water purification and quality regulation. These functions contributed to a modest net increase of 283.93 million baht, raising the closing value of freshwater ecosystem assets to 7,301.02 million baht in 2020 from 7,017.10 million baht in 2016. By contrast, terrestrial ecosystems, which provide biomass from rubber, oil palm, Acacia species, and biomass power generation, alongside regulating services such as carbon sequestration, flood control, and water purification, experienced a net decline. Degradation and conversions together reduced the value by 5,021.16 million baht, resulting in a closing value of 44,019.61 million baht in 2020 compared to 49,040.76 million baht in 2016. Marine ecosystems, which encompass provisioning services such as mangrove wood, wild fish, and aquaculture, regulating services including carbon sequestration, water purification, and nursery habitats, and cultural services such as seaview, coastal recreation, coral reef tourism, and birdwatching, also recorded a significant decline. Despite enhancements of 1,236.04 million baht, degradation and conversions led to a net decrease of 5,613.29 million baht, lowering the closing value to 66,717.56 million baht in 2020 from 72,330.85 million baht in 2016. Taken together, the three ecosystem realms demonstrate that while freshwater assets showed resilience and modest growth, terrestrial and marine assets faced substantial losses, leading to an overall decline in Krabi's ecosystem asset value from 128,388.71 million baht in 2016 to 118,038.19 million baht in 2020. This outcome underscores both the importance of provisioning, regulating, and cultural services to the province's economy and the urgent need for policies that strengthen ecological resilience and sustainable resource management.

6. Data Gaps

Analysis of data gaps and approaches to efficiently collecting or acquiring additional data, such as using modeling or analysis of existing data, identified the following key issues:

- Accounting Period and the Use of Existing Data

Generally, Ecosystem Extent Accounts are compiled using an annual accounting period to align with environmental-economic accounting frameworks. However, in cases where data is collected irregularly or incomplete for every year, a multi-year accounting interval may be more suitable, especially for land use maps that are compiled only for specific periods. The data period should be clearly specified to maintain temporal consistency.

- Inconsistent Availability of Spatial Data

The compilation of ecosystem accounts requires accurate, consistent, and standardized spatial and Geographic Information System (GIS) data, including both shapefile and raster datasets with appropriate spatial resolution. These data are necessary to support analyses and generate outputs in both tabular and spatial map formats with clearly defined geographic coordinates. However, spatial datasets obtained from different agencies often vary in data formats, spatial resolution, and temporal resolution. Therefore, data standardization and harmonization are necessary before integrating datasets for analysis.

- Spatial Alignment and Coordinate Reference Systems

The integration of multiple spatial datasets, such as land cover maps, remote sensing data, and shapefiles, requires all datasets to use a consistent Coordinate Reference System and has spatial alignment. In addition, ecosystem classes should be mutually exclusive within each spatial unit to avoid overlapping classifications, which may lead to inaccuracies in area calculations and ecosystem change analysis.

- Linking with Other Accounts

Extent Accounts serve as the spatial baseline for the development of other ecosystem accounts, including Ecosystem Condition Accounts, Ecosystem Services Accounts, and Monetary Ecosystem Accounts. Therefore, the data structure should be designed to be interconnected and usable to support continuous and systematic analysis.

- Limitations in Spatial Analysis

Accounting entries cannot clearly separate Additions and Reductions into managed ecosystems and unmanaged ecosystems due to insufficient detailed spatial information on land management and land use practices. As a result, the analysis of drivers of ecosystem change remains limited in some areas and time periods.

7. Conclusions

In conclusion, this research project successfully constructed a natural capital account for Krabi province using the United Nations System of Environmental-Economic Accounting (UN-SEEA) framework. Focusing on the tourism and water resources sectors, the study evaluated Krabi's inland and ocean territories by mapping them across major terrestrial, freshwater, and marine ecosystems. While the local environment spans diverse ecological boundaries, data constraints required marine-related categories to be consolidated into a single marine account. By developing extent, condition, services, and asset accounts over a five-year period (2016-2020), this project provides a rigorous, empirically grounded assessment of the structural and economic shifts within Krabi's environment.

The structural trends captured in the extent accounts reveal a landscape undergoing noticeable transformation due to human development and natural shifts. Terrestrial ecosystems faced considerable pressure, characterized by a steady conversion of natural and agricultural land into urban and industrial areas, leading to a net loss of tropical and subtropical rainforests. The freshwater ecosystem witnessed internal reallocations, with traditional rice paddies and aquafarms being converted into crop plantations, balanced against an expansion of artificial water channels and drains. Meanwhile, the marine ecosystem remained relatively stable in total area, experiencing minor reconfigurations such as shoreline adjustments driven by beach erosion.

Beyond spatial changes, the condition accounts offer a nuanced perspective on the qualitative health of Krabi's natural assets. The findings point to a divergent trajectory between inland and coastal waters. On one hand, freshwater quality exhibited a upward trend, reflected by a marked improvement in the environmental index derived from Water Quality Index (WQI) and Biochemical Oxygen Demand (BOD) metrics. Conversely, the marine water quality index suffered a severe deterioration over the same period. This decline in coastal water health serves as a critical warning sign, providing undeniable evidence that the marine ecosystem is under profound stress and requires immediate policy interventions to halt degradation.

These structural and qualitative changes directly influenced the flow of ecosystem services and their economic contributions. In the terrestrial sector, a contraction in rubber and palm oil plantation areas led to a monetary decline for these commercial crops, while falling rice outputs diminished the economic contributions of freshwater ecosystems. Concurrently, the marine sector faced volatility, with fish landings and market prices experiencing heavy fluctuations. Compounding these systemic ecological pressures, the COVID-19 pandemic severely disrupted the tourism sector, evidenced by a catastrophic drop in visitor numbers across the province's premier marine national parks and a drop in accommodation-sector water consumption.

Ultimately, aggregating these economic flows allowed the project to formulate the monetary asset account for Krabi’s natural capital. Taken as a whole, the total asset value of Krabi's natural capital experienced a noticeable contraction over the five-year period. This downward trend was heavily driven by asset depreciation in the terrestrial ecosystem from reduced plantation areas, alongside a decline in marine ecosystem value accelerated by volatile fisheries and the collapse of tourism.

In summary, the SEEA results generate an empirical justification for proactive governance. The systematic decline in Krabi's natural capital highlights an urgent need for the government to design policy interventions aimed at improving agricultural productivity and rehabilitating the condition of the marine ecosystem.

Appendix 1

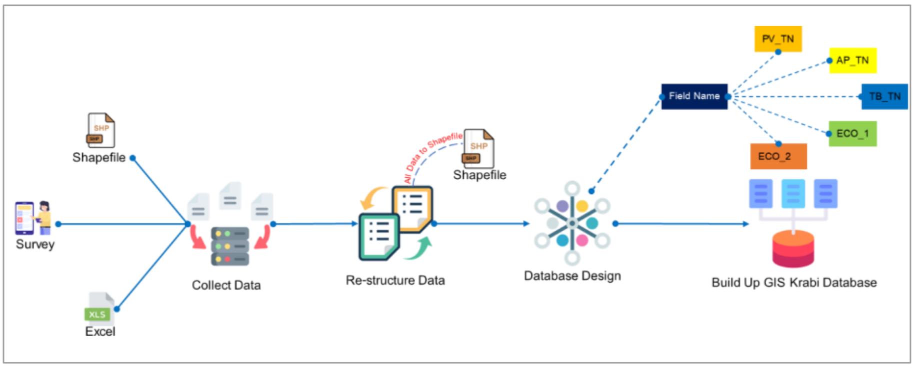
Geospatial Database Development and Spatial Analysis for Krabi Province

The development of the geospatial database for Krabi Province under the "Integration of Natural Capital Accounting in Public and Private Sector Policy and Decision-making for Sustainable Landscapes" project, aims to create a reliable database that can be used for effective policy analysis and decision-making. This process requires integrating data from various sources, including statistics, surveys, and geospatial data from directly responsible agencies, to ensure that the data is accurate and academically acceptable.

1. Conceptual Framework for Krabi Province Geospatial Database Preparation

This study designed a conceptual framework for the Krabi Province geospatial database, enabling users to understand the data's structure and origin, including varying storage formats, types, map scales, and geographic coordinate systems from different agencies. The process includes Data Collection, Data Restructuring, Database Design, and Building Up the GIS Krabi Database, as shown in Figure A1.1.

Figure A1.1 Conceptual Framework for the Krabi Province Geospatial Database Development



Source: Conducted by author

1) Data Collection

The development of the Krabi Province geo-informatics database under this project began with coordination and requesting data from relevant agencies, including the Geo-Informatics and Space Technology Development Agency (Public Organization) (GISTDA) and other relevant government agencies. The Thailand Development Research Institute (TDRI) has requested data from the responsible agencies directly to compile reliable and academically accepted data. All collected data will be categorized by type, such as geo-informatics data (Shapefile), spreadsheet data (Excel), survey data, and other types of data for ease of management and analysis.

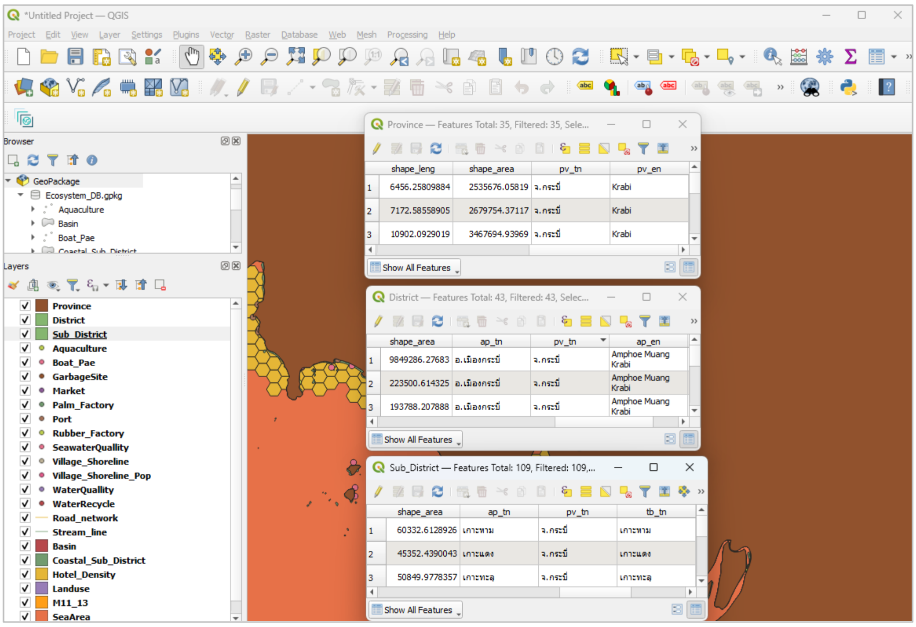
2) Data Restructuring

Collected data, often with varying formats and coordinate systems, is transformed into a Shapefile (.shp) format compatible with QGIS. Coordinates are adjusted to EPSG:4326 – WGS 84, the project's standard.

3) Database Design

Database design is crucial for managing diverse and redundant data efficiently. It involves defining relationships between data tables using shared fields (e.g., "PV_TN" for Thai province names) to integrate data from multiple sources accurately, as shown in Figure A1.2.

Figure A1.2 Example of combining data tables for province, district, and sub-district boundaries that have matching Field Names



Source: Conducted by author

4) Build Up GIS Krabi Database

All data is consolidated into a single GeoPackage (.gpkg) database, an open-format standard by the Open Geospatial Consortium (OGC), enabling efficient data exchange across GIS systems. GeoPackage stores raster imagery, attribute data, and vector spatial data (e.g., administrative boundaries, waterways) in one lightweight file, simplifying management without licensing restrictions, as shown in Figure A1.3.

Figure A1.3 Example of GeoPackage data storage

Source: Chaipat (2019)

A GeoPackage (.gpkg) database can be used with the QGIS program in both online and offline modes. It can also contain multiple GIS layers and tables within a single database without consuming significant processing resources, making it lightweight. This makes it convenient for system development and data management. Most importantly, it has no usage limitations related to copyrights.

2 List and Types of Data

The primary data source for the Krabi Province geospatial database is GISTDA, in collaboration with TDRI and the project. It includes 17 Shapefile (.shp) geospatial data items. Additionally, TDRI obtained 20 related data items from government agencies and 12 Excel table data items (.xls) that were restructured into Shapefile (.shp) geospatial data, as shown in Table A1.1.

Table A1.1 List and Types of Data Collected from Agencies

No.	Data Name	Type	Kind	Extension	Year	Agency
1	Village Location	Shapefile	Point	.shp	2566	GISTDA
2	Sub-district Boundary	Shapefile	Polygon	.shp	2566	GISTDA
3	District Boundary	Shapefile	Polygon	.shp	2566	GISTDA
4	Province Boundary	Shapefile	Polygon	.shp	2566	GISTDA
5	Municipality Boundary	Shapefile	Polygon	.shp	2566	GISTDA
6	Annual Rice Cultivation Area	Shapefile	Polygon	.shp	2566/2567	GISTDA

Table A1.1 List and Types of Data Collected from Agencies *(Continued)*

No.	Data Name	Type	Kind	Extension	Year	Agency
7	Rubber Plantation Area	Shapefile	Polygon	.shp	2566	GISTDA
8	Recurrent Flood Area	Shapefile	Polygon	.shp	2566	GISTDA
9	Water Sources	Shapefile	Polygon	.shp	2566	GISTDA
10	Waterways	Shapefile	Polygon	.shp	2566	GISTDA
11	Waterways	Shapefile	Line	.shp	2566	GISTDA
12	Beachfront Line	Shapefile	Polygon	.shp	2565	GISTDA
13	Mangrove Forest Area	Shapefile	Polygon	.shp	2565	GISTDA
14	Important Places (Old)	Shapefile	Point	.shp	2550	GISTDA
15	Important Places (Updated)	Shapefile	Point	.shp	2563	GISTDA
16	Transportation Routes	Shapefile	Line	.shp	2563	GISTDA
17	Hotel Density	Shapefile	Point	.shp	2566	GISTDA
18	Aquaculture Farms	Excel	Table	.xls	2566	Environment and Pollution Control Office 15
19	Waste Disposal Service Area	Excel	Table	.xls	2566	Environment and Pollution Control Office 15
20	Waste Disposal Sites	Excel	Table	.xls	2566	Environment and Pollution Control Office 15
21	Wastewater Treatment Plants	Excel	Table	.xls	2566	Environment and Pollution Control Office 15
22	Fresh Markets	Excel	Table	.xls	2567	Environment and Pollution Control Office 15
23	Fish Landing Sites	Excel	Table	.xls	2566	Environment and Pollution Control Office 15
24	Palm Oil Industrial Plants	Excel	Table	.xls	2566	Environment and Pollution Control Office 15
25	Rubber Industrial Plants	Excel	Table	.xls	2566	Environment and Pollution Control Office 15
26	Ports	Excel	Table	.xls	2566	Environment and Pollution Control Office 15
27	Coastal Sub-districts	Shapefile	Polygon	.shp	2563	Department of Marine and Coastal Resources
28	Land Use	Shapefile	Polygon	.shp	2550-2563	Department of Land Development
29	Sub-district Boundary	Shapefile	Polygon	.shp	2550-2563	Department of Land Development
30	District Boundary	Shapefile	Polygon	.shp	2550-2563	Department of Land Development
31	Province Boundary	Shapefile	Polygon	.shp	2550-2563	Department of Land Development

Table A1.1 List and Types of Data Collected from Agencies *(Continued)*

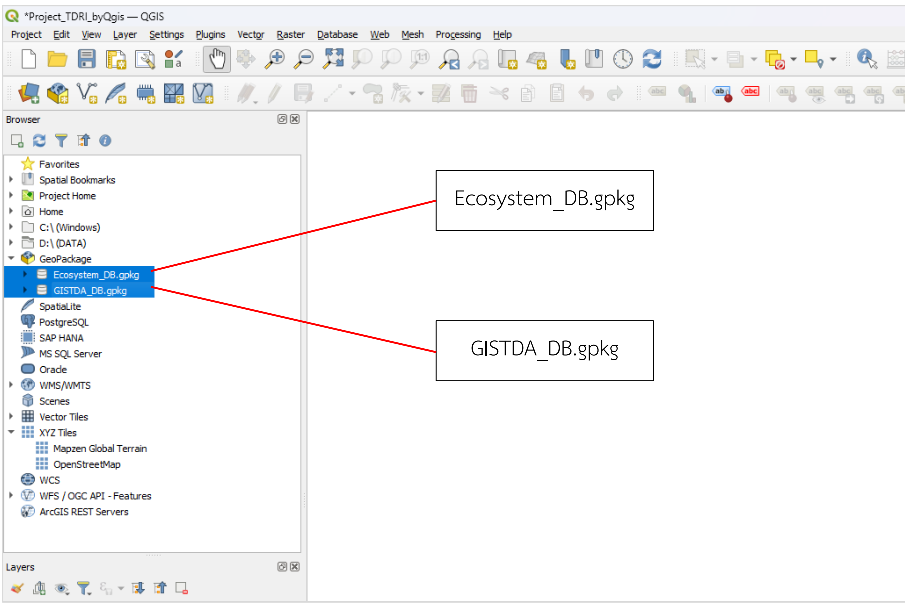
No.	Data Name	Type	Kind	Extension	Year	Agency
32	Maritime Territory	Shapefile	Polygon	.shp	2562	Royal Thai Navy
33	Coastal Villages	Shapefile	Point	.shp	2566	Department of Marine and Coastal Resources
34	Coastal Villages	Excel	Table	.xls	2566	Department of Marine and Coastal Resources
35	Seawater Quality Monitoring Stations	Excel	Table	.xls	2566	Pollution Control Department
36	Water Quality Monitoring Stations	Excel	Table	.xls	2566	Environment and Pollution Control Office 15
37	Population	Excel	Table	.xls	2566	Department of Land Development
38	Coastal Population Density	Shapefile	Point	.shp	2566	Data updated to Shapefile (.shp) by GISTDA
39	Seawater Quality Monitoring Stations	Shapefile	Point	.shp	2566	Data updated to Shapefile (.shp) by GISTDA
40	Water Quality Monitoring Stations	Shapefile	Point	.shp	2566	Data updated to Shapefile (.shp) by GISTDA
41	Aquaculture Farms	Shapefile	Point	.shp	2566	Data updated to Shapefile (.shp) by GISTDA
42	Waste Disposal Service Area	Shapefile	Point	.shp	2566	Data updated to Shapefile (.shp) by GISTDA
43	Waste Disposal Sites	Shapefile	Point	.shp	2566	Data updated to Shapefile (.shp) by GISTDA
44	Wastewater Treatment Plants	Shapefile	Point	.shp	2566	Data updated to Shapefile (.shp) by GISTDA
45	Fresh Markets	Shapefile	Point	.shp	2566	Data updated to Shapefile (.shp) by GISTDA
46	Fish Landing Sites	Shapefile	Point	.shp	2566	Data updated to Shapefile (.shp) by GISTDA
47	Palm Oil Industrial Plants	Shapefile	Point	.shp	2566	Data updated to Shapefile (.shp) by GISTDA
48	Rubber Industrial Plants	Shapefile	Point	.shp	2566	Data updated to Shapefile (.shp) by GISTDA
49	Ports	Shapefile	Point	.shp	2566	Data updated to Shapefile (.shp) by GISTDA

Source: Conducted by author

3 Krabi Province Geospatial Database

This study designed a basic geospatial data storage structure for Krabi Province under the "Integration of Natural Capital Accounting in Public and Private Sector Policy and Decision-making for Sustainable Landscapes" project. The data is stored in the GeoPackage (.gpkg) format, which is a standard database format compatible with QGIS. The data is divided into two main databases: 1) GISTDA_DB.gpkg and 2) Ecosystem_DB.gpkg (as shown in Figure A1.4).

Figure A1.4 Databases under the Natural Capital Accounting Project



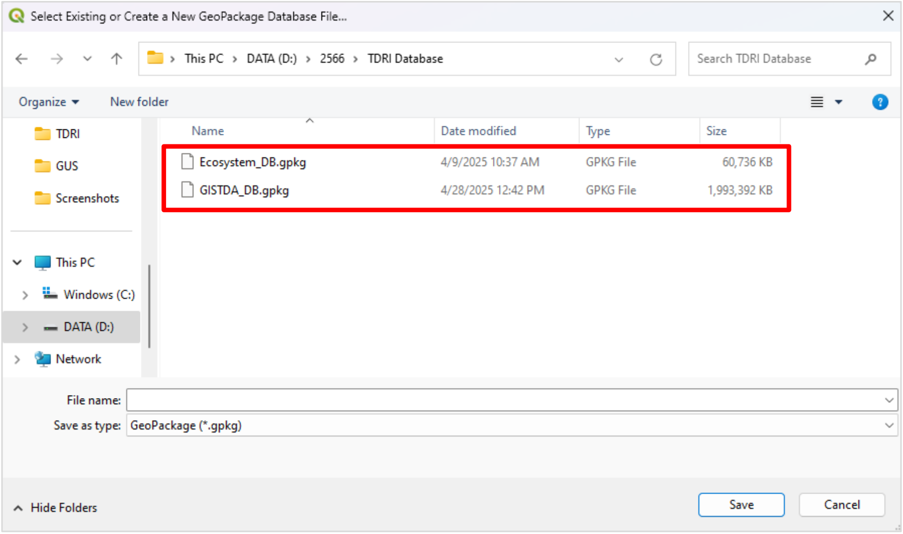
Source: Conducted by author

1) GISTDA_DB.gpkg

The database named GISTDA_DB.gpkg is used to store basic geo-informatics data of Krabi Province from the Geo-Informatics and Space Technology Development Agency (Public Organization) or GISTDA only. There are 17 data layers in total as shown in Figure A1.5 and Table A1.2

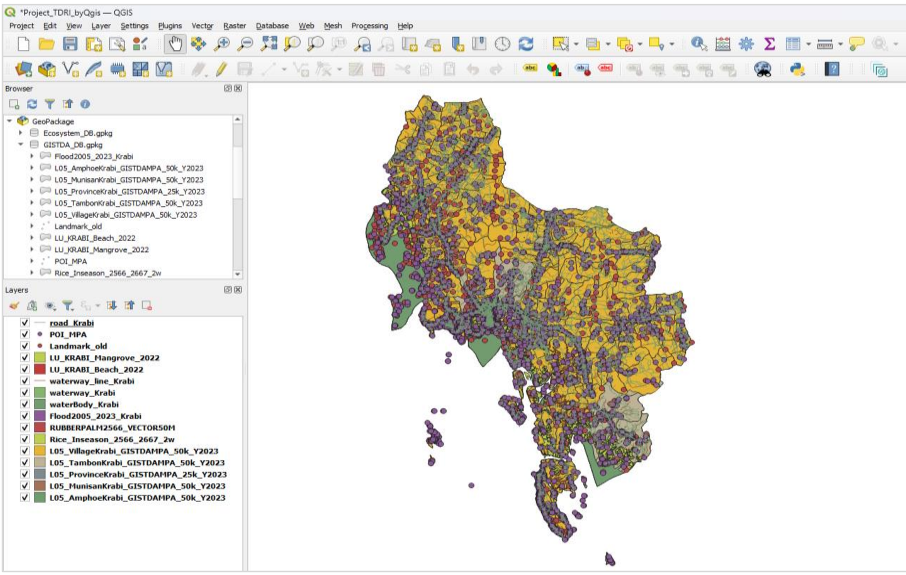
The author imported both GeoPackage databases into QGIS by connecting the database through the "Database" menu and selecting "GeoPackage" to activate the data (as shown in Figure A1.6). This process allows for convenient and efficient access and analysis of the data.

Figure A1.5 Example of importing a GeoPackage database with QGIS



Source: Conducted by author

Figure A1.6 List of data layers from GISTDA under the Geopackage database (GISTDA_DB.gpkg)



Source: Conducted by author

Table A1.2 List of data layers from GISTDA under the GISTDA_DB.gpkg database

No.	Data Group	Data Name	Data Layer Name	Type	Geometry Type	Extension	Year
1	Administration	Village Location	L05_VillageKrabi_GISTDAMPA_50k_Y2023	Shapefile	Point	.shp	2023
2	Administration	Tambon Boundary	L05_TambonKrabi_GISTDAMPA_50k_Y2023	Shapefile	Polygon	.shp	2023
3	Administration	Amphoe Boundary	L05_AmphoeKrabi_GISTDAMPA_50k_Y2023	Shapefile	Polygon	.shp	2023
4	Administration	Province Boundary	L05_ProvinceKrabi_GISTDAMPA_25k_Y2023	Shapefile	Polygon	.shp	2023
5	Administration	Municipality Boundary	L05_MunisanKrabi_GISTDAMPA_50k_Y2023	Shapefile	Polygon	.shp	2023
6	Agriculture	Annual Rice Cultivation Area	Rice_Inseason_2566_2667_2w	Shapefile	Polygon	.shp	2023/2024
7	Agriculture	Rubber Plantation Area	RUBBERPALM2566_VECTOR50M	Shapefile	Polygon	.shp	2023
8	Flood Data	Recurring Flood Area	Flood2005_2023_Krabi	Shapefile	Polygon	.shp	2023
9	Water Resources	Water Body	waterBody_Krabi	Shapefile	Polygon	.shp	2023
10	Water Resources	Waterway (Polygon)	waterway_Krabi	Shapefile	Polygon	.shp	2023
11	Water Resources	Waterway (Line)	waterway_line_Krabi	Shapefile	Line	.shp	2023
12	Marine Data	Beach	LU_KRABI_Beach_2022	Shapefile	Polygon	.shp	2022
13	Marine Data	Mangrove Forest Area	LU_KRABI_Mangrove_2022	Shapefile	Polygon	.shp	2022
14	Important Locations	Important Locations (Old)	Landmark_old	Shapefile	Point	.shp	2007
15	Important Locations	Important Locations (Updated)	POI_MPA	Shapefile	Point	.shp	2020
16	Transportation	Transportation Routes	road_Krabi	Shapefile	Line	.shp	2020
17	Important Locations	Hotel Density	Hotel_Density	Shapefile	Point	.shp	2023

Source: Conducted by author

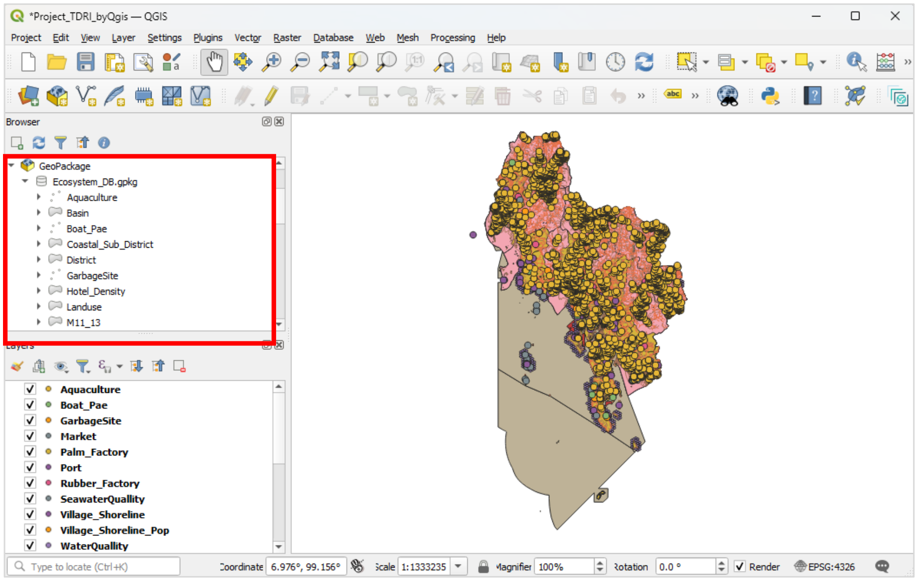
2) Ecosystem_DB.gpkg

This database is used to store specific foundational geospatial data from relevant government agencies, including the Office of Environmental and Pollution Control Region 15, the Pollution Control Department, the Department of Marine and Coastal Resources, the Land Development Department, and the Royal Thai Navy. All data was updated to the Shapefile (.shp) format and includes a total of 20 data layers, as shown in Table A1.3 and Figure A1.7.

Using the GeoPackage (.gpkg) database with QGIS is an effective approach for managing and analyzing geospatial data, particularly for the Natural Capital Accounting for Policy Decision-Making for Sustainable Development project in Krabi Province. Two GeoPackage databases, GISTDA_DB.gpkg and Ecosystem_DB.gpkg, were imported for data analysis and display, as shown in Figures A1.5–A1.8.

Therefore, using both GeoPackage (.gpkg) databases, GISTDA_DB.gpkg and Ecosystem_DB.gpkg, with QGIS under the Natural Capital Accounting for Policy Decision-Making for Sustainable Development project is an effective approach for managing and analyzing geospatial data to support natural capital accounting and policy decision-making for sustainable development in Krabi Province.

Figure A1.7 List of data layers from government agencies under the GeoPackage database (Ecosystem_DB.gpkg)



Source: Conducted by author

Table A1.3 List of data layers from agencies under the Ecosystem_DB.gpkg database

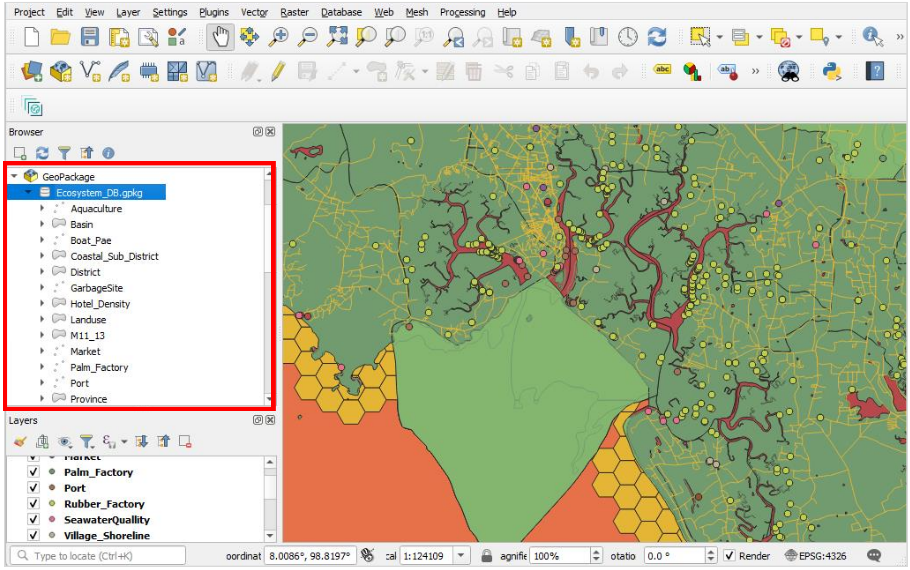
No.	Data Group	Data Name	Data Layer Name	Type	Geometry Type	Extension	Year	Agency
1	Agriculture	Aquaculture Sources	Aquaculture	Excel	Table	.xls	2023	Environmental and Pollution Control Office 15
2	POI	Waste Disposal Service Area	GarbageSite_ Services	Excel	Table	.xls	2023	Environmental and Pollution Control Office 15
3	POI	Waste Disposal Sites	GarbageSite	Excel	Table	.xls	2023	Environmental and Pollution Control Office 15
4	POI	Wastewater Treatment Plants	WaterRecycle	Excel	Table	.xls	2023	Environmental and Pollution Control Office 15
5	POI	Fresh Markets	Market	Excel	Table	.xls	2024	Environmental and Pollution Control Office 15
6	POI	Fish Piers	Boat_Pae	Excel	Table	.xls	2023	Environmental and Pollution Control Office 15
7	POI	Palm Industry Factories	Palm_Factory	Excel	Table	.xls	2023	Environmental and Pollution Control Office 15
8	POI	Rubber Industry Factories	Rubber_Factory	Excel	Table	.xls	2023	Environmental and Pollution Control Office 15
9	POI	Ports	Port	Excel	Table	.xls	2023	Environmental and Pollution Control Office 15
10	Administration	Coastal Sub-districts	Coastal_Sub_	Shapefile	Polygon	.shp	2020	Department of Marine and Coastal Resources

Table A1.3 List of data layers from agencies under the Ecosystem_DB.gpkg database *(Continued)*

No.	Data Group	Data Name	Data Layer Name	Type	Geometry Type	Extension	Year	Agency
11	Land Use	Land Use	Landuse	Shapefile	Polygon	.shp	2007-2020	Department of Land Development
12	Administration	Sub-district Boundary	Sub_District	Shapefile	Polygon	.shp	2007-2020	Department of Land Development
13	Administration	District Boundary	District	Shapefile	Polygon	.shp	2007-2020	Department of Land Development
14	Administration	Province Boundary	Province	Shapefile	Polygon	.shp	2007-2020	Department of Land Development
15	Administration	Maritime Boundary	SeaArea	Shapefile	Polygon	.shp	2019	Royal Thai Navy
16	POI	Coastal Villages	Village_Shoreline	Shapefile	Point	.shp	2023	Department of Marine and Coastal Resources
17	POI	Coastal Villages	Village_Shoreline	Excel	Table	.xls	2023	Department of Marine and Coastal Resources
18	POI	Seawater Quality Monitoring Stations	SeawaterQuallity	Excel	Table	.xls	2023	Pollution Control Department
19	POI	Water Quality Monitoring Stations	WaterQuallity	Excel	Table	.xls	2023	Environmental and Pollution Control Office 15
20	POI	Population Count	Village_Shoreline_Pop	Excel	Table	.xls	2023	Department of Land Development

Source: Conducted by author

Figure A1.8 Example of connecting to the Ecosystem_DB.gpkg database with QGIS



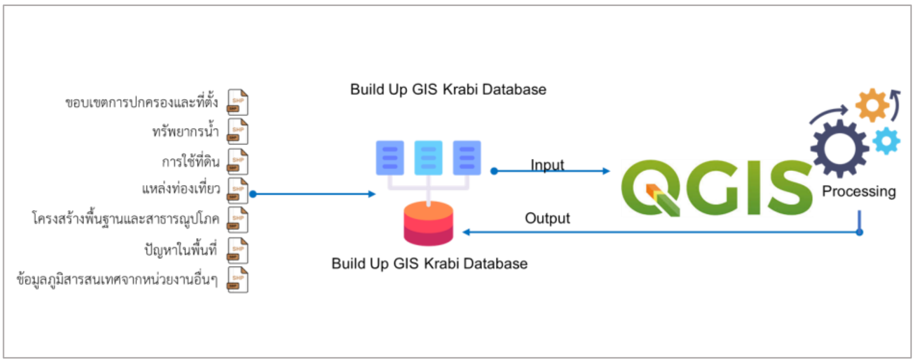
Source: Conducted by author

4. Spatial Data Analysis

Spatial Data Analysis is the process of examining patterns, relationships, and trends hidden within data that has a geographical nature. This data is referenced to locations on the Earth's surface. The analysis process uses statistical, mathematical, and visualization tools to understand phenomena occurring in a specific area and to support data-driven decisions.

A key difference between spatial analysis and general data analysis is the emphasis on spatial components such as location, shape, size, distribution, proximity, and the spatial relationships of the data. Therefore, the design and structuring of the Krabi Province geospatial database (Build Up GIS Krabi Database) under this project is a crucial step for effective spatial analysis, serving as both input and output for the QGIS program, as shown in Figure A1.9.

Figure A1.9 The connection between the basic geospatial database and the QGIS program



Source: Conducted by author

4.1 Spatial Database Design and Management

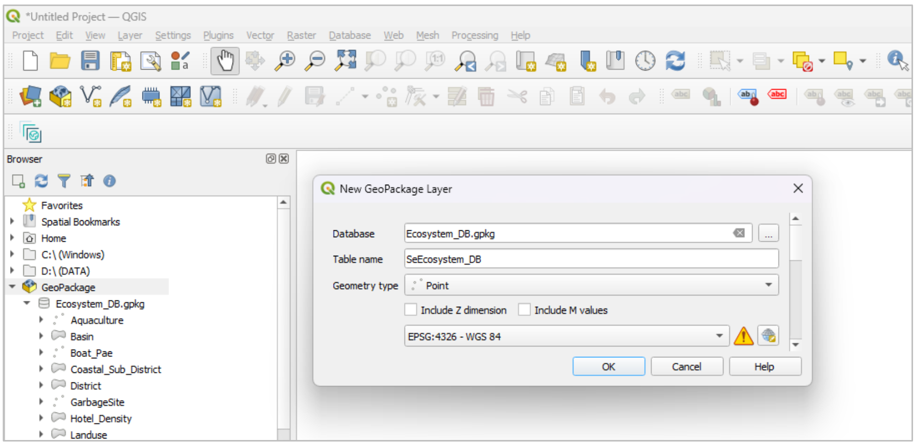
Spatial data analysis requires a suitable data structure to support efficient storage, visualization, and geospatial processing. A Spatial Database is therefore the core of this process, with steps ranging from creating the database to formatting the data, structuring data tables, and linking data from different sources to ensure they can be used together effectively.

Storing geospatial data in a standardized database is essential. This project uses the GeoPackage (.gpkg) file format, as mentioned in section 1. The key features of GeoPackage are:

- Supports storing multiple geospatial layers simultaneously.
- Supports a standard Coordinate Reference System.
- Efficiently works with QGIS and other GIS software.
- Easy to manage, edit, and share data in the same format.

The geographic coordinate system for the GeoPackage (.gpkg) database was set to EPSG:4326 – WGS84, as shown in Figure A1.10. This widely used coordinate system uses latitude and longitude degrees and is suitable for data collection before spatial analysis.

Figure A1.10 Specifying the coordinate values of the Geo Package database



Source: Conducted by author

Improving Data for Geospatial (GIS) Format

Data used for spatial analysis comes in various formats and origins. Some data, such as Excel tables or data without coordinate values, is not in a direct geospatial format. It is necessary to improve and convert this data so it can be imported into a GIS system.

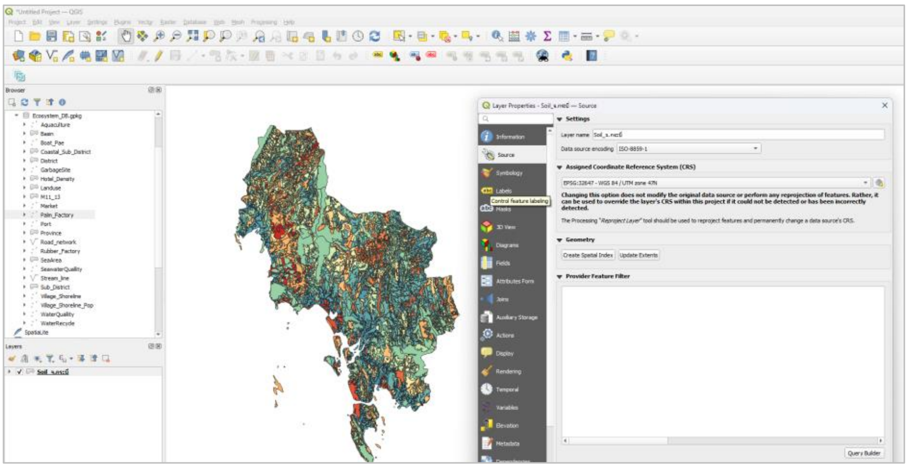
Data Reprojection

One of the most common issues in GIS is the inconsistency of coordinate systems, as different agencies may use different systems (e.g., various UTM Zones, Indian 1975, or even no coordinate system at all). Data reprojection in QGIS is a simple and fast process using the "Reproject Layer" tool or by saving a new layer and specifying the coordinate system as EPSG:4326 – WGS84, as shown in Figure A11. Ensuring all data uses the same EPSG:4326 – WGS84 coordinate system helps the data display correctly on a GIS map and allows for analysis without positional errors.

Converting Excel Table Data to GIS Format

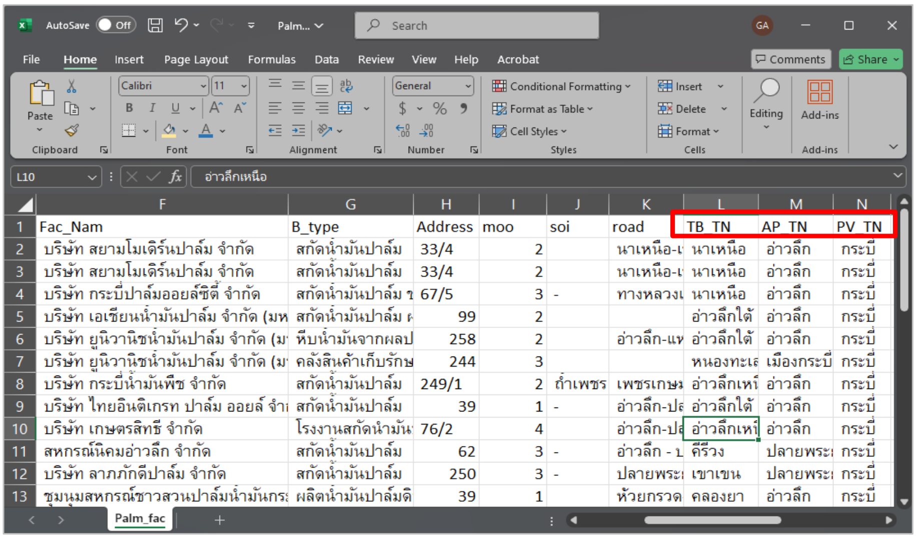
Data from Excel files (.xls or .xlsx) stored in tables, such as water quality data and pollution source data from industrial plants, often lack direct coordinate values. However, existing fields like sub-district name (TB_TN), district name (AP_TN), province name (PV_TN), or coordinate codes hidden in some columns can be used to link this data to other map data that already has coordinates (as shown in Figure A1.12). This is done by using the "Join Field" function with a layer that has coordinates, such as a sub-district or district boundary layer, using a matching column as the link.

Figure A1.11 Specifying the coordinate values of the Geo Package database



Source: Conducted by author

Figure A1.12 Example of data from an Excel table file with Field Names (TB_TN), (AP_TN), (PV_TN)

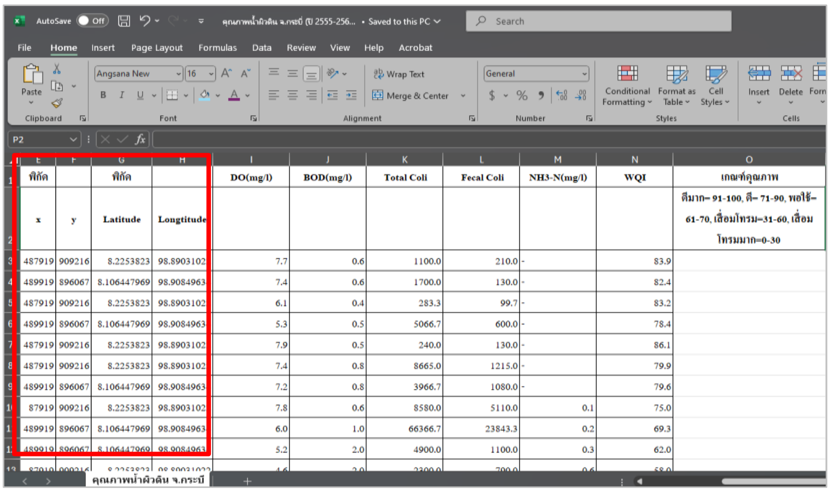


	F	G	H	I	J	K	L	M	N
1	Fac_Nam	B_type	Address	moo	soi	road	TB_TN	AP_TN	PV_TN
2	บริษัท สยามโมเดิร์นปาล์ม จำกัด	สกัดน้ำมันปาล์ม	33/4	2		นาเหนือ-เ	นาเหนือ	อ่าวลึก	กระบี่
3	บริษัท สยามโมเดิร์นปาล์ม จำกัด	สกัดน้ำมันปาล์ม	33/4	2		นาเหนือ-เ	นาเหนือ	อ่าวลึก	กระบี่
4	บริษัท กระบี่ปาล์มออยล์ซิตี้ จำกัด	สกัดน้ำมันปาล์ม ข	67/5	3	-	ทางหลวงเ	นาเหนือ	อ่าวลึก	กระบี่
5	บริษัท เอเชียนน้ำมันปาล์ม จำกัด (มห	สกัดน้ำมันปาล์ม ผ	99	2			อ่าวลึกใต้	อ่าวลึก	กระบี่
6	บริษัท ยูนิวานิชน้ำมันปาล์ม จำกัด (ม	หีบน้ำมันจากผลป	258	2		อ่าวลึก-แห	อ่าวลึกใต้	อ่าวลึก	กระบี่
7	บริษัท ยูนิวานิชน้ำมันปาล์ม จำกัด (ม	คลังสินค้าเก็บรักษ	244	3			หนองทะเล	เมืองกระบี่	กระบี่
8	บริษัท กระบี่น้ำมันพืช จำกัด	สกัดน้ำมันปาล์ม	249/1	2	ถ้ำเพชร	เพชรเกษม	อ่าวลึกเหน	อ่าวลึก	กระบี่
9	บริษัท ไทยอินติเกรท ปาล์ม ออยล์ จำ	สกัดน้ำมันปาล์ม	39	1	-	อ่าวลึก-ปล	อ่าวลึกใต้	อ่าวลึก	กระบี่
10	บริษัท เกษตรสิทธี จำกัด	โรงงานสกัดน้ำมัน	76/2	4		อ่าวลึก-ปล	อ่าวลึกเหน	อ่าวลึก	กระบี่
11	สหกรณ์นิคมอ่าวลึก จำกัด	สกัดน้ำมันปาล์ม	62	3	-	อ่าวลึก - บ	คีรีวง	ปลายพระย	กระบี่
12	บริษัท ลาภภักดีปาล์ม จำกัด	สกัดน้ำมันปาล์ม	250	3	-	ปลายพระย	เขาเขน	ปลายพระย	กระบี่
13	ชุมนุมสหกรณ์ชาวสวนปาล์มน้ำมันกระ	ผลิตน้ำมันปาล์มดิ	39	1		ห้วยกรวด	คลองยา	อ่าวลึก	กระบี่

Source: Conducted by author

In cases where the Excel file already contains latitude and longitude values (as shown in Figure A1.13), it can be imported into QGIS to be converted into a GIS layer using the "Add Delimited Text Layer" function. This function automatically converts the table data into point data that can be displayed on a map.

Figure A1.13 Example of data from an Excel table file with coordinate values



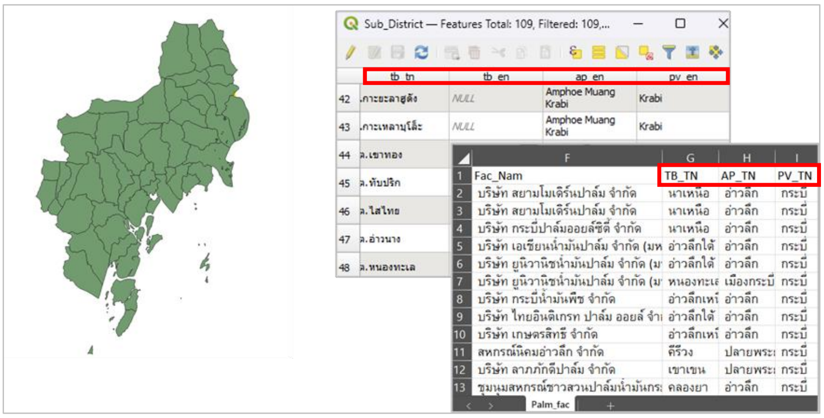
พิกัด x	y	พิกัด Latitude	Longtitude	DO(mg/l)	BOD(mg/l)	Total Coli	Fecal Coli	NH3-N(mg/l)	WQI	เกณฑ์คุณภาพ ดีมาก= 91-100, ดี= 71-90, พอใช้= 61-70, เสื่อมโทรม=31-60, เสื่อมโทรมมาก=0-30
487919	909216	8.2253823	98.8903102	7.7	0.6	1100.0	210.0	-	83.9	
489919	896067	8.106447969	98.9084963	7.4	0.6	1700.0	130.0	-	82.4	
487919	909216	8.2253823	98.8903102	6.1	0.4	283.3	99.7	-	83.2	
489919	896067	8.106447969	98.9084963	5.3	0.5	5066.7	600.0	-	78.4	
487919	909216	8.2253823	98.8903102	7.9	0.5	240.0	130.0	-	86.1	
487919	909216	8.2253823	98.8903102	7.4	0.8	8665.0	1215.0	-	79.9	
489919	896067	8.106447969	98.9084963	7.2	0.8	3966.7	1080.0	-	79.6	
87919	909216	8.2253823	98.8903102	7.8	0.6	8580.0	5110.0	0.1	75.0	
489919	896067	8.106447969	98.9084963	6.0	1.0	66366.7	23843.3	0.2	69.3	
489919	896067	8.106447969	98.9084963	5.2	2.0	4900.0	1100.0	0.3	62.0	

Source: Conducted by author

Linking Table Data via Field Name (Join Table)

Joining tables is a critical process for linking tabular data without geographic coordinates to spatial data that has coordinates. This is done using matching field names, such as the sub-district name (TB_TN), which connects sub-districts from different datasets. If the field names do not match, they can be changed to match before the join. Once the join is successful, the data from the Excel table is appended to the attribute table of the target GIS layer and can be displayed on the map immediately. An example is displaying the location of rubber processing factories on a map of sub-district boundaries in Krabi Province by joining tables based on the matching TB_TN field names (as shown in Figure A1.14).

Figure A1.14 Example of linking table data using a matching Field Name, TB_TN



Source: Conducted by author

Creating the Study Area Boundary Data

Defining the geospatial study area for Krabi Province involved two main steps: data preparation and data processing. The details are as follows

Geospatial Data Preparation

Geospatial data for Krabi Province was collected from the responsible agencies and was in the Shapefile (.shp) format:

- Maritime Territory Data: From the Royal Thai Navy, Ministry of Defense. This is vector data in line format showing marine administrative boundaries with a shared usage agreement.
- Land Use Data: From the Department of Land Development. This is vector data in polygon format showing land use types, such as Urban and Built-up Land (U), Agricultural Land (A), Forest Land (F), and Water (W).
- Administrative Boundary Data: From the Department of Provincial Administration. This is vector data in polygon format showing the boundaries of provinces, districts, and sub-districts.

Data Processing with QGIS

Geospatial data processing was conducted using QGIS, an open-source software that provides a comprehensive suite of tools for geospatial analysis. The steps are as follows:

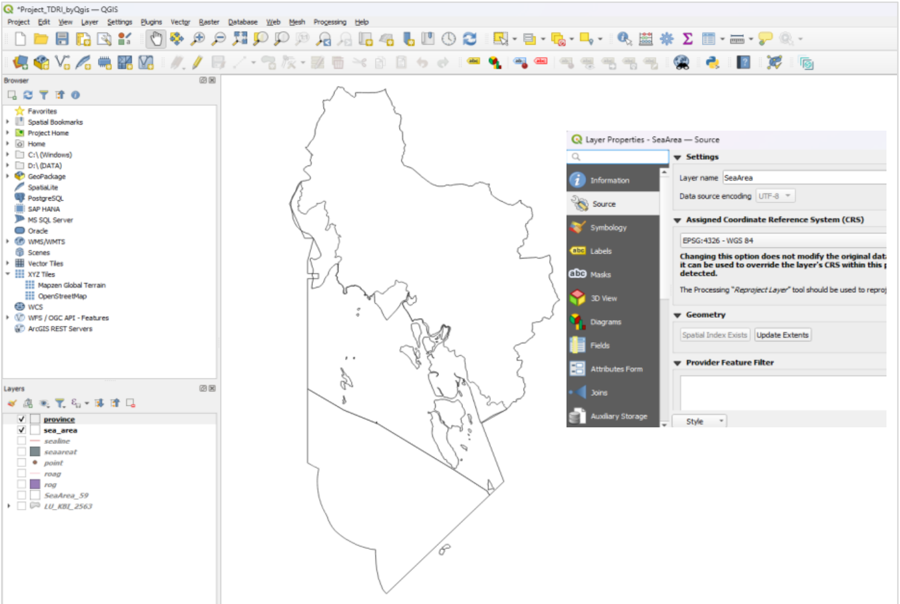
1) **Checking the Geographic Coordinate System:** The geographic coordinate system of all data was checked using the "Reproject Layer" tool to ensure all data was in the EPSG:4326 – WGS84 system so it could be used together (as shown in Figure A15).

2) **Union:** The Union tool was used to combine different datasets—administrative boundaries, land use data, and maritime territory data (as shown in Figure A16)—to create a single study area covering all of Krabi Province for the project.

3) **Dissolve**: The Dissolve tool was used to reduce data redundancy. For example, after combining the land use data and maritime territory data, there were overlapping marine areas. The Dissolve command was used to merge these into a single "Ocean" group within the study area (as shown in Figure A17).

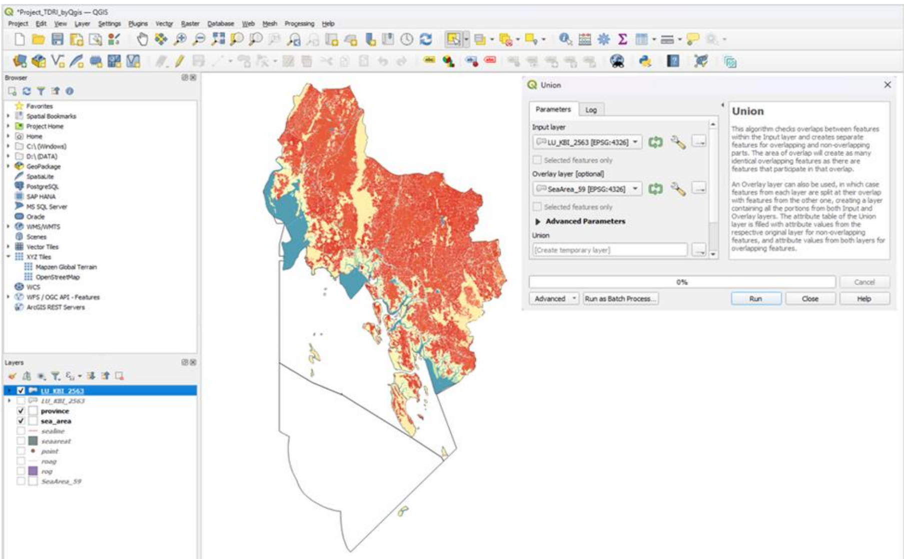
4) **Adding Specific Areas to the Krabi Province Study Area:** The preparation of the study area data in Krabi Province used basic information from the Land Development Department's land use data, which classified the use in each area but did not cover the entire study area of Krabi Province, such as seawater areas, seagrass, coral reefs, etc. Therefore, to ensure that the study results are complete and comprehensive in Krabi Province, this study has conducted additional data on the area's boundaries as follows:

Figure A1.15 Example of setting the geographic coordinate system to EPSG:4326 – WGS 84



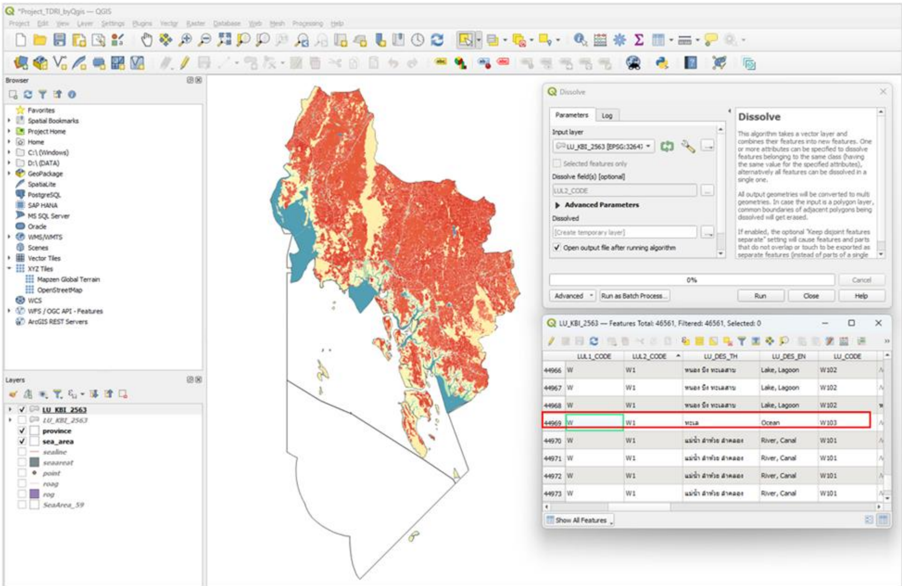
Source: Conducted by author

Figure A1.16 Example of combining all Krabi Province area data sets into one area using the Union command



Source: Conducted by author

Figure A1.17 Example of reducing redundancy of ocean area data in Krabi Province using the Dissolve command



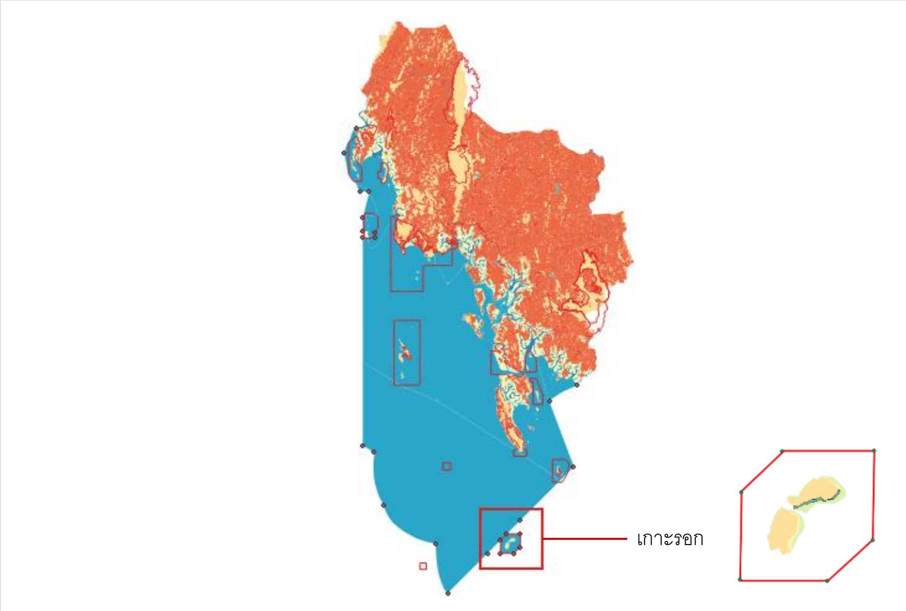
Source: Conducted by author

- ***Adding the Ko Rok Area***

Koh Rok is located in Krabi Province under the care of Mu Ko Lanta National Park in Krabi Province. It consists of two main islands, Koh Rok Nai and Koh Rok Nok, separated by a distance of about 100 meters. Koh Rok Nai is home to the National Park Protection Unit Lanta 1 (Koh Rok). It is famous for its beautiful snorkeling spots, with fine white sand and crystal-clear waters, making it perfect for relaxation. There are also nature trails for visitors to explore the island's natural beauty. Koh Rok Nok is the site of the Siam Boundary Marker, the maritime border between Thailand and Myanmar. This island features long stretches of sandy beaches, ideal for relaxation and swimming. It is also known for its excellent snorkeling spots and vibrant coral reefs, making it suitable for scuba diving.

Therefore, this study has been carried out to extend the area of Koh Rok (Koh Rok Nok - Koh Rok Nai), in Mu Ko Lanta National Park, Krabi Province, by drawing additional boundaries with the word Digitize to define the maritime boundary of Koh Rok (Koh Rok Nok - Koh Rok Nai) as part of the study area of Krabi Province (as shown in Figure A18), referring to the boundary location from the national park, Department of National Parks, Wildlife and Plant Conservation.

Figure A1.18 Example of adding the Ko Rok area boundary with the Digitize command



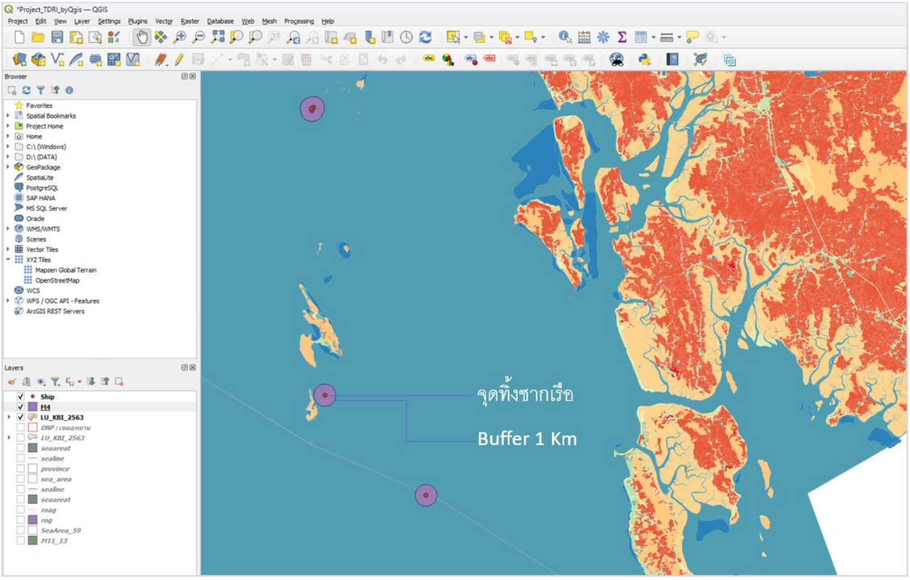
Source: Conducted by author

- ***Adding Shipwreck Locations***

The Department of Marine and Coastal Resources, in collaboration with the Department of National Parks, Wildlife and Plant Conservation, and the Royal Thai Navy, has placed decommissioned warships, namely the Golam, Rawi, and Talibong, on the east side of Koh Yawasam, Ao Nang Subdistrict, Mueang District, Krabi Province, at latitude 7°56.897' degrees north, longitude 89°46.815' degrees east (as of April 2013), approximately 300 meters from the island, south of Ao Nang, approximately 12 kilometers from shore. The average water depth to the bottom is 20 meters, the depth at the mast is 15 meters. The ship Kled Kaew on HTMS Pattani is located in the sea in front of Viking Cave, on the east side in front of Viking Cave, in the area of Koh Phi Phi Leh. Krabi Province, latitude (north) 7° 41.732" N, longitude (east) 98° 46.626" E (as of March 2014), approximately 800 meters from shore, with an average water depth of 25 meters. All boat landings are intended to serve as an underwater learning park and artificial reefs under the Underwater Learning Project, and to develop into an important diving site in the future (Department of Marine and Coastal Resources, 2015).

However, the boat landing site for the underwater learning park falls under the Krabi study area's Ecosystem Type: Anthropogenic marine biome (M4) - Submerged artificial structures (M4.1). Therefore, this study generated geographic coordinates of the boat landing site for the underwater learning park using the Create Point command and estimated the marine utilization area of the boat landing site using the Buffer Radius command, creating a 1-kilometer buffer zone around the boat landing site, as shown in Figure A19).

Figure A1.19 Example of adding shipwreck locations with the Create Point and Buffer Radius commands

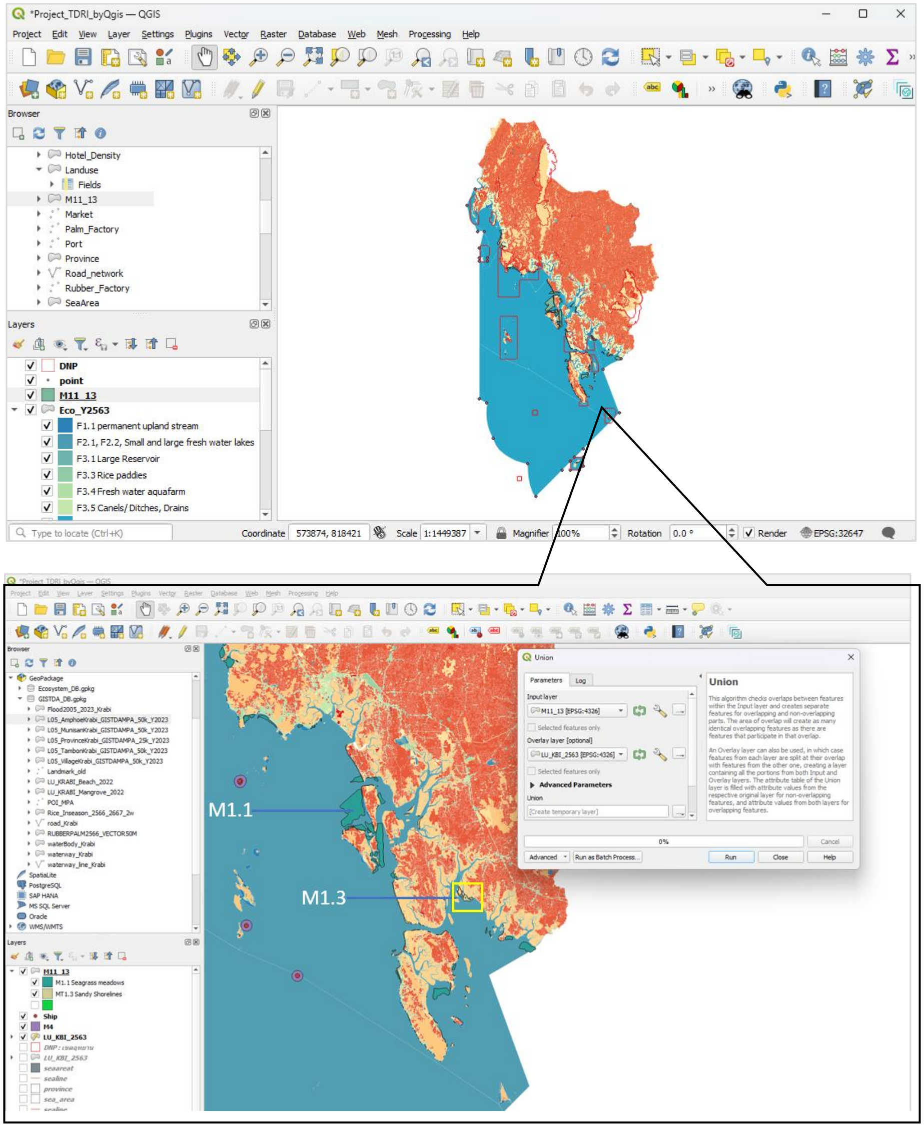


Source: Conducted by author

- ***Adding Seagrass and Coral Reef Areas***

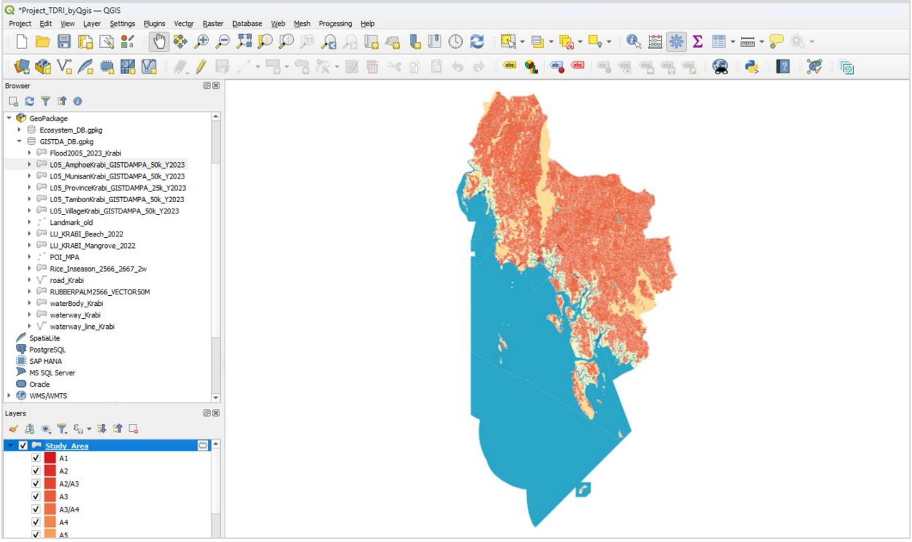
The boundaries of seagrass beds and coral reefs are categorized under Ecosystem Types Seagrass meadows (M1.1) and Photic coral reefs (M1.3), respectively. Data for these areas was collected from the Department of Marine and Coastal Resources and combined with the study area using the "Union" command (as shown in Figure A20). This unified dataset for the study area now includes land use, administrative boundaries, maritime territory, the Ko Rok area, and the shipwreck locations (as shown in Figure A21)

Figure A1.20 Example of adding seagrass and coral reef boundaries with the Union command



Source: Conducted by author

Figure A1.21 Krabi Province study area data



Source: Conducted by author

Appendix 2

Identifying Ecosystem Types in the Study Area

The identification of ecosystem types in the study area aims to enable accurate analysis of ecosystem extent accounts in accordance with the framework for developing ecosystem accounts based on the principles of the United Nations System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA). This requires reclassifying land use data in Krabi Province. This classification is based on the IUCN Global Ecosystem Typology 2.0, which aims to systematically analyze changes in ecosystem areas.

The ecosystems in the Krabi study area are classified according to the IUCN Global Ecosystem Typology 2.0 (Keith, D. A., et al., 2020). These include Level 1 (5 Realms), Level 2 (13 Biomes), and Level 3 (19 Ecosystem Functional Groups: EFGs). Details are provided in Table A2.1.

Table A2.1 Types of Ecosystems in Krabi Province Classified According to IUCN Global Ecosystem Typology 2.0

Level 1: 5 Realms	Level 2: 13 Biomes	Level 3: 19 Ecosystem Functional Groups (EFGs)
Terrestrial	T1: Tropical-subtropical forests	T1.3 Tropical-subtropical montane rainforests
	T2: Temperate-boreal forests & woodlands	T2.2 Deciduous temperate forests
	T3: Shrubland & shrubby woodlands	T3.1 Seasonally dry tropical shrubland
	T4: Savanna and grasslands	T4.5 Temperate subhumid grassland
	T7: Intensive land-use	T7.1 Annual Cropland
		T7.3 Plantations
		T7.4 Urban and industrial ecosystem
Freshwater	F1: River and streams	F1.1 Permanent upland streams
	F2: Lakes	F2.1, F2.2, Large and Small permanent freshwater lakes
	F3: Artificial fresh waters	F3.1 Large reservoirs
		F3.3 Rice paddies
		F3.4 Freshwater aquafarms
		F3.5 Canals, ditches and drains
Marine	M1: Marine shelfs	M1.1 Seagrass meadows
		M1.3 Photic coral reefs
	M2: Pelagic ocean waters	M2 Pelagic ocean water (Unable to categorize M2.1-M2.5)
	M4: Anthropogenic marine systems	M4.1 Submerged artificial structures
Marine-Freshwater-Terrestrial	MFT1: Brackish tidal	MFT1.2 Intertidal forests and shrublands
Marine-Terrestrial	MT1: Shoreline systems	MT1.3 Sandy shorelines

Source: Analysis by TDRI as of 2024

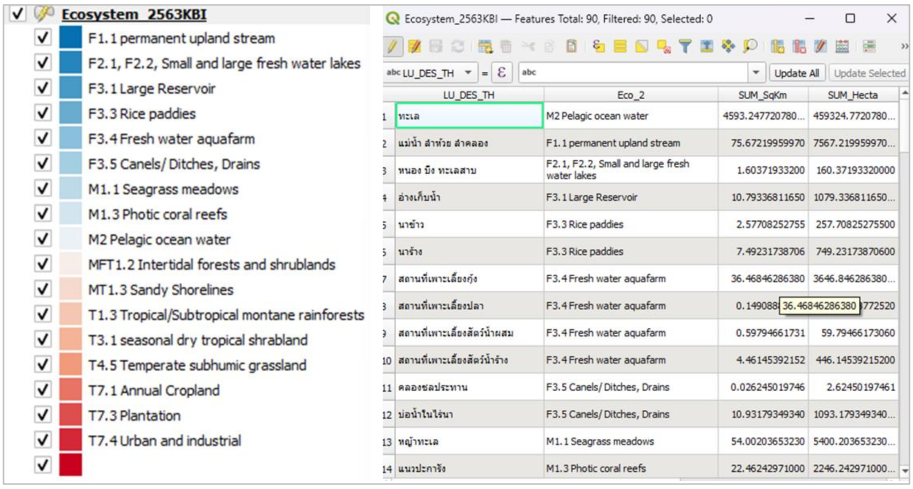
Guidelines for identifying areas by ecosystem type

Land use data from the Department of Land Development for 2016 and 2020 will be adjusted to reflect ecosystem type, such as:

- Land use data classified as "marine area" is reclassified as Pelagic Ocean Water (M2).
- "Seagrass area" is reclassified as Seagrass Meadows (M1.1).
- "Coral reef area" is reclassified as Photic Coral Reefs (M1.3).
- "Tropical forest area" is reclassified as Tropical-subtropical montane rainforests (T1.3).

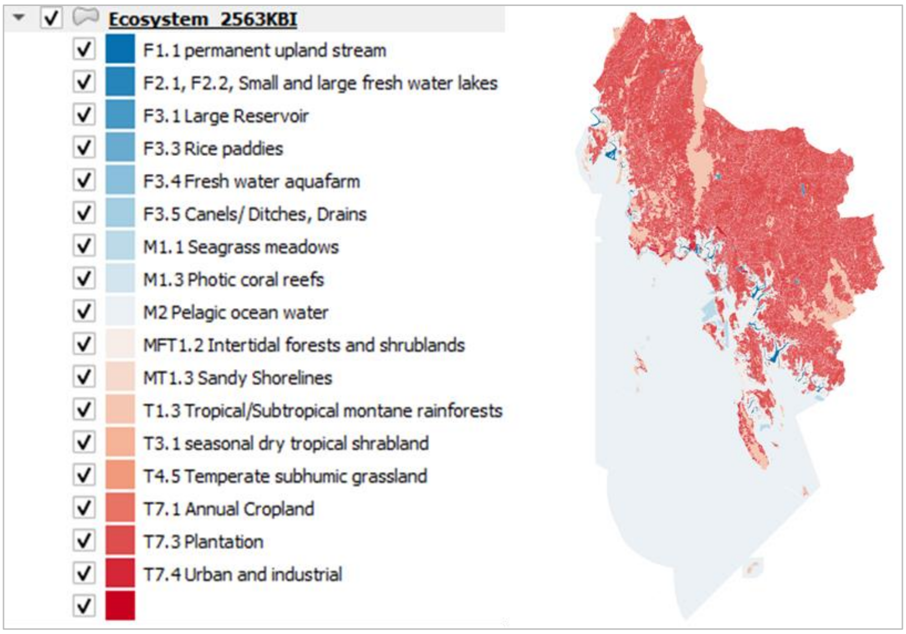
The identification of areas by ecosystem type was carried out through the QGIS program using the Filter, Select by Attribute and Field Calculator tools to assign ecosystem type values to each land use plot (as shown in Figure A2.1). The data obtained from the identification of areas by ecosystem type was presented in map form to show the Ecosystem Type of the study area in Krabi Province (as shown in Figure A2.2).

Figure A2.1 Example of identifying land use areas by ecosystem type



Source: Conducted by author

Figure A2.2 Example of identifying the Krabi Province study area by ecosystem type



Source: Conducted by author

Appendix 3

Spatial Change Analysis

Spatial change analysis of the Krabi Province study area is a crucial step in understanding land use and ecosystem area changes between 2016 and 2020. This study utilized ArcGIS Pro to perform the analysis. The Tabulate Area tool was applied to raster data with a spatial resolution of 50 meters to quantify transitions between ecosystem types across accounting periods.

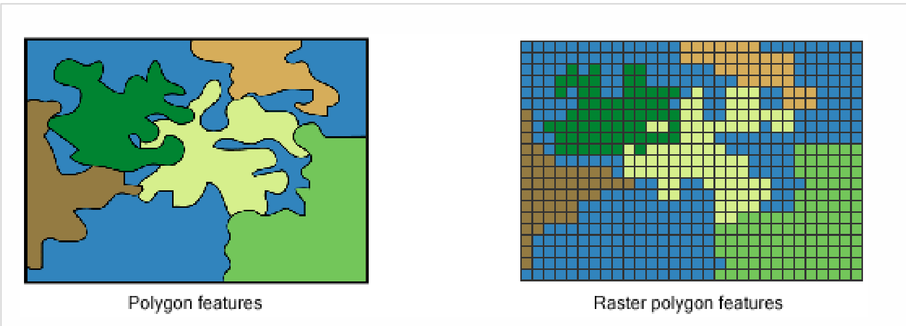
1. Data Preparation and Raster Conversion

Spatial data in vector format (Shapefile: .shp) were converted into raster format (.tif) using the Feature to Raster (Conversion) tool in ArcGIS Pro (Figure A3.1). This step is essential for enabling pixel-based spatial analysis.

During the conversion process, a pixel size of 50 meters was defined (Figure A3.2) to standardize spatial resolution and reduce the complexity of vector data. Each raster cell was assigned an ecosystem type value based on the corresponding polygon attributes. As a result, areas within the same ecosystem type were represented by uniform pixel values (Figure A3.3).

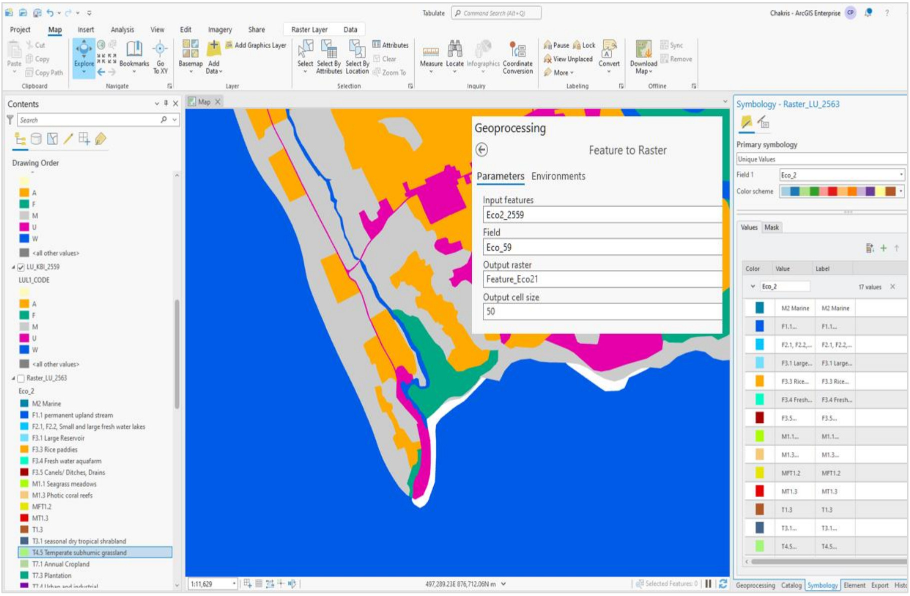
This rasterization process ensures compatibility with the Tabulate Area tool and supports accurate spatial analysis of ecosystem changes over time.

Figure A3.1 Example of converting data from Vector to Raster



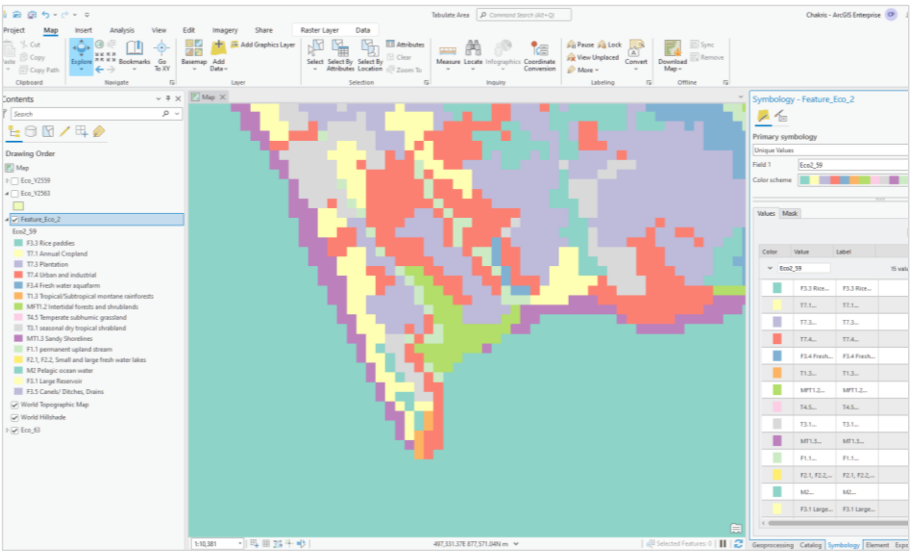
Source: Esri (2021)

Figure A3.2 Example of converting data from Vector to Raster using the Feature to Raster tool



Source: Conducted by author

Figure A3.3 Example of converting Krabi Province study area data from Vector to Raster



Source: Conducted by author

2. Spatial Change Analysis Using Tabulate Area

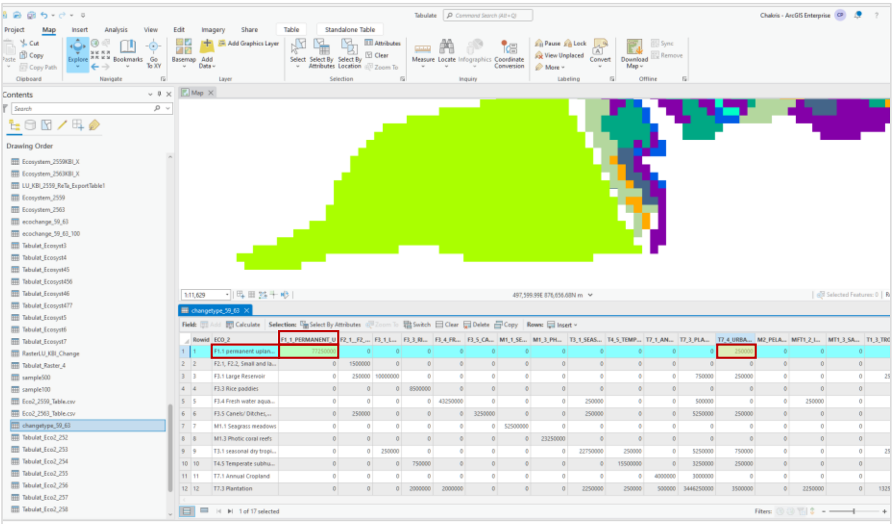
The analysis of ecosystem changes between 2016 and 2020 was conducted using the Tabulate Area tool in ArcGIS Pro. This tool calculates the area of transitions between ecosystem types across different time periods.

Analysis Steps:

1) **Overlaying Two Time Periods:** Raster data from 2016 and 2020 were overlaid with the same coordinate system.

2) **Tabulate Area Processing:** ArcGIS Pro calculates the areas that are the same and those that have changed according to their Ecosystem Type. The output is presented as a matrix table, which serves as the basis for ecosystem change analysis (Figure A3.4).

Figure A3.4 Example of displaying the results of area changes in the Krabi study area



Source: Conducted by author

3. Identification of Changed and Unchanged Areas

To further distinguish spatial patterns of change, the Intersection technique in ArcGIS Pro was applied to overlay ecosystem maps from different years.

This process enabled classification of the study area into:

- **Changed areas** (areas where ecosystem types were converted)
- **Unchanged areas** (areas where ecosystem types remained stable)

The workflow includes data preparation, raster classification, spatial overlay, and extraction of transition statistics. These outputs support the interpretation of spatial patterns presented in the main analysis.

Appendix 4

Pricing Calculation formula

1) Valuation Procedure for Agricultural Land in Krabi Province

The calculation of the appropriate annual rental value of agricultural land was conducted using a present value approach over a 20-year horizon, applying a discount rate of 3 percent. The estimated market value of agricultural land was set at 1,875,000 baht per hectare (equivalent to 300,000 baht per rai). The present value of land (PV) represents the total value of future rental income streams, while the annual rental value (R) is derived using the annuity formula:

$$\text{PV} = \frac{PMT}{(1+r)^1} + \frac{PMT}{(1+r)^2} + \cdots + \frac{PMT}{(1+r)^n}$$

$$\text{PV} = \text{PMT}\left(\frac{1-(1+r)^{-n}}{r}\right)$$

$$\text{PMT} = \frac{PV\ \times r}{1-(1+r)^{-n}}$$

$$\text{PMT} = \text{R} = \frac{PV\ \times r}{1-(1+r)^{-n}}$$

- PV= Present value of land (1,875,000 baht per hectare)
- R= Annual rental value (baht per hectare per year)
- r= Discount rate (0.03)
- n= Number of years (20)

Substituting the values:

$$\text{R} = \frac{1{,}875{,}000\ \times 0.03}{1-(1+0.03)^{-20}}$$

$$\text{R} = \frac{56{,}250}{0.44632}$$

$$\text{R} = 126{,}031.85$$

*The appropriate annual rental value of agricultural land for crop cultivation in Krabi Province is **126,031.85 baht per hectare per year**.*

2) Valuation Procedure for Aquaculture Land in Krabi Province

The appropriate annual rental value of aquaculture land was calculated using the present value of an annuity formula over a 20-year horizon, applying a discount rate of 3 percent. The estimated market value of aquaculture land was set at 1,250,000 baht per hectare (equivalent to 200,000 baht per rai). The present value (PV) represents the total value of future rental income streams, while the annual rental value (R) is derived as follows:

$$\mathrm{R} = \frac{PV \times r}{1-(1+r)^{-n}}$$

$$\mathrm{R} = \frac{1{,}250{,}000 \times 0.03}{1-(1+0.03)^{-20}}$$

$$\mathrm{R} = \frac{37{,}500}{0.44632}$$

$$\mathrm{R} = 84{,}021.23$$

*The appropriate annual rental value of aquaculture land in Krabi Province is **84,021.23 baht per hectare per year**.*

3) Hedonic Pricing Analysis for Seaview Hotel Rooms

The hedonic pricing regression model was specified in log-linear form, with the natural logarithm of hotel accommodation price ($\ln p$) regressed against a set of explanatory variables representing room characteristics. The estimated equation is:

$$In\_p = \beta_0 + \beta_1 Sview + \beta_2 sqm + \beta_3 star + \beta_4 break + \beta_5 Dex + \beta_6 Suit + \beta_7 Fam + \beta_8 Pool + \varepsilon_i$$

- **p** = Hotel accommodation price
- **Sview** = Dummy variable indicating beachfront accommodation.

  (1 = Seaview room, 0 = non-Seaview room)
- **sqm** = Room size (Unit: sqm.)
- **star** = Hotel star rating (Scale 1-5)
- **break** = Breakfast (1 = Have breakfast, 0 =Don't have breakfast)
- **Dex** = Deluxe room (1 = Deluxe room, 0 = other)
- **Suit** = Suite room (1 = Suite room, 0 = other)
- **Fam** = Family room (1 = Family room, 0 = other)
- **Pool** = Pool villa room (1 = Pool villa room, 0 = other)

Insert the estimated coefficients

$$In\_p = 7.861 + 0.124Sview + 0.004sqm + 0.545star + 0.387break + 0.210Dex + 0.228Suit + 0.545Fam + 0.453Pool$$

The coefficient of interest, $\beta_1 = 0.124$, corresponds to the dummy variable *Sview*, which indicates whether a room has a sea view. Because the dependent variable is expressed in logarithmic form, the coefficient must be transformed to interpret its effect in percentage terms. The transformation is given by:

$$e^{\beta_1} - 1 = e^{0.124} - 1$$

$$= 1.1321 - 1 = 0.1321$$

This result implies that, ceteris paribus, the presence of a sea view increases the hotel room price by **approximately 13.21 percent** relative to rooms without a sea view.

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