JOURNAL LA LIFESCI

VOL. 06 ISSUE 03 (234-251), 2025
DOI: 10.37899/journallalifesci.v6i3.2396

Spatial Conditions of Water Regulating Environmental Services in South Sumatra Province

Neni Triana[1], Ngudiantoro[2], Satria Jaya Priatna[3]

[1]Study Program of Environmental Managenent, Sriwijaya University, Jl. Raya Palembang - Prabumulih Km. 32, North Indralaya, Ogan Ilir, South Sumatera 30662 Indonesia
[2]Faculty of Mathematics and Natural Science, Sriwijaya University, Jl. Raya Palembang - Prabumulih Km. 32, North Indralaya, Ogan Ilir, South Sumatera 30662 Indonesia
[3]Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Jl. Raya Palembang-Prabumulih Km. 32, Indralaya, Ogan Ilir, 30662, South Sumatra, Indonesia

**Corresponding Author: Ngudiantoro*
Email: ngudiantoro@unsri.ac.id

Article Info

Article history:
Received 5 August 2021
Received in revised from 3 September 2021
Accepted 10 September 2021

Keywords:
Spatial
Environmental Services
Environmental Service Performance
Environmental Service Performance of Water Regulation

Abstract

South Sumatra Province has abundant natural resources that support the economy, but uncontrolled development triggers environmental degradation and disaster risks. Sustainable management is needed in accordance with Law No. 32/2009 and PP No. 22/2021. Water regulation environmental services play an important role in maintaining hydrological and ecosystem balance. GIS-based spatial mapping of landscapes, natural vegetation, and land cover is important as a basis for sustainable environmental policies. The research was conducted in South Sumatra Province using secondary data from the Ministry of Environment and Forestry and related agencies. Spatial analysis was carried out based on GIS with an overlay approach to three parameters: land cover (weight 60%), landscape (28%), and natural vegetation (12%). The assessment used the Simple Additive Weighting (SAW) method and produced the Environmental Services Performance Index (IKJLH), which was classified into five categories: very low to very high. The results are visualized in a colored thematic map to show the differences in water regulation performance in each region. The results of the 2023 spatial analysis show that most areas in South Sumatra Province have good water regulation environmental services performance, with a dominance of medium (55%) and high (33%) categories. Ogan Komering Ilir (60.93%), Banyuasin (53.24%), and North Musi Rawas (26.19% very high) are among the best performing areas. In contrast, Palembang City (52.05% low), Empat Lawang, Lahat, and Lubuk Linggau show ecological pressure due to urbanization and land use changes. This condition emphasizes the importance of sustainable environmental management to maintain water regulatory functions in the future.

Introduction

South Sumatra Province is a region with abundant natural resources, ranging from extensive forest cover, peatlands and mangroves, agricultural and plantation potential, to large energy and mineral reserves (Ministry of Environment and Forestry, 2022). This potential has supported economic development, reduced poverty rates, and increased the human development index in the region (Bappeda South Sumatra, 2021). However, development activities that continue to grow without proper environmental management have led to a decline in environmental quality, especially through massive and unsustainable changes in land use (Syahrul et al., 2020). The increase in population and infrastructure development have put great

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

pressure on the sustainability of natural resources (Setiawan & Hadi, 2021). If not controlled, this can exacerbate the vulnerability of the region to disasters such as floods, droughts, erosion, sedimentation, and forest and peatland fires (Wibowo et al., 2019). Therefore, a sustainable development approach is needed that takes into account the carrying capacity and environmental capacity (Peng et al., 2016). National regulations such as Law Number 32 of 2009 and its derivatives, including PP Number 22 of 2021 concerning PPLH, emphasize the importance of controlling the use of natural resources wisely (KLHK, 2021).

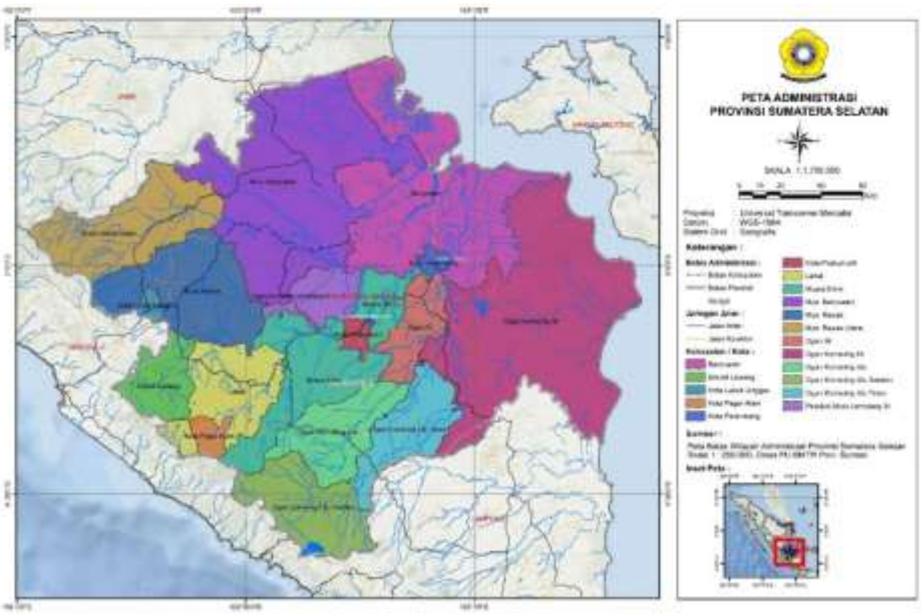
One important aspect in environmental management is environmental services, especially water regulation services that play a role in the hydrological cycle such as water infiltration, aquifer filling, and surface runoff control (Pranowo et al., 2022). These environmental services also support the availability of groundwater and surface water, control erosion, and maintain soil fertility and ecosystem balance (Rochmadi et al., 2019). This function is highly dependent on the biophysical conditions of the area such as lithology, topography, rainfall, vegetation, and land cover types (Handayani et al., 2023). Therefore, spatial mapping is important to assess and visualize the potential and pressure on water regulation environmental services (Ramadhan et al., 2020).

In the context of South Sumatra, a spatial study of water-regulating environmental services is needed as a basis for formulating policies for natural resource management and controlling environmental degradation (Zulfikar & Marzuki, 2022). Assessment of the performance of environmental services as water regulators can be carried out by analyzing three main parameters, namely landscape, natural vegetation, and land cover, using a geographic information system (GIS) approach (Anindita et al., 2021). The results of this study are expected to be able to provide accurate spatial information as material for strategic planning for sustainable development that maintains the ecological function of the region (Sari et al., 2020).

Methods

Research Location

The research was conducted in the South Sumatra Province which is astronomically located at 102° 3’ 52” - 106° 19’ 45” East Longitude and 1° 25’ 13” - 4° 55’ 17” South Latitude.



ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

Figure 1. Research Location Map

Types and Sources of Data

This study uses secondary data obtained from official agencies. The main data includes the 2023 Land Cover Map and the 2021 Landscape Characteristics and Natural Vegetation Type Map at a scale of 1:250,000 sourced from the Ministry of Environment and Forestry through the SIGAP portal (https://sigap.menlhk.go.id). This landscape and natural vegetation map refers to the Decree of the Minister of Environment and Forestry Number SK.1272/MENLHK/SETJEN/PLA.3/12/2021 concerning the Determination of Landscape Characteristics and Natural Vegetation of Indonesian Ecoregions.

Supporting data used include the Regional Administration Map, Road Map, and River Map of South Sumatra Province at a scale of 1:250,000, obtained from the Public Works, Highways and Spatial Planning Office of South Sumatra Province. All data is used as a basis for spatial analysis for mapping the performance of water regulating environmental services in the study area.

Mapping of Water Regulating Environmental Services in South Sumatra Province

Mapping of water regulating environmental services was carried out through GIS-based spatial analysis, with an overlay approach to landscape parameters, natural vegetation types, and land cover. Each parameter was first inventoried, then given a weight and score based on its level of contribution to the environmental service function, referring to the official guidelines of the Ministry of Environment and Forestry (KLHK, 2019; KLHK, 2021).

The initial stage involved an inventory of the typology of the three parameters. The landscape reflects the morphological characteristics of the earth's surface and the interactions between environmental elements such as soil, rocks, water, and flora and fauna that affect the sustainability of the ecosystem (Singh, 2024). Natural vegetation types are defined as plant communities that have not been affected by human activities and represent the original ecosystems of Indonesia (Rochmadi et al., 2019). Land cover describes the results of human activities on the earth's surface and is studied using an official map on a scale of 1:250,000 from the KLHK in 2023 (KLHK, 2023).

Parameter weighting is carried out using the Simple Additive Weighting (SAW) method, based on expert judgment, taking into account the contribution of each parameter to water regulation services (Zhao et al., 2021). The determination of this weight refers to the official document of the Ministry of Environment and Forestry and the Decree of the Minister of Environment and Forestry Number SK.1272/MENLHK/SETJEN/PLA.3/12/2021 concerning ecoregions (MoEF, 2021).

Table 1. Weighting of Landscape Parameters, Natural Vegetation Types and Land Cover for Water Regulation Environmental Services

No.	Parameter	Weight (%)
1	Land Cover	60
2	Natural Landscapes	28
3	Natural Vegetation	12

The next step is to score each parameter typology, on a scale of 1–5. The score is determined based on the level of parameter capability in supporting the environmental service function of water regulation, also referring to the guidelines set by the Ministry of Environment and Forestry (Wang et al., 2020). The results of the multiplication of the weight and score are then

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

added up to obtain the Environmental Service Performance Index (IKJLH). The mathematical model used is as follows:

$$IKJLH = f\{Natural\ Landscape, Natural\ Vegetation, Land\ Cover\}$$
$$= (w_{ba}\ x\ s_{ba}) + (w_{veg}\ x\ s_{veg}) + (w_{pl}\ x\ s_{pl})$$

Description:

w_{ba} : landscape weight

s_{ba} : landscape score

w_{veg} : vegetation weight

s_{veg} : vegetation score

w_{pl} : land cover weight

s_{pl} : land cover score

IKJLH values are classified into five categories, from very low to very high, with intervals value of 0.8 using the Likert scale approach. Visualization of the mapping results is displayed in a thematic spatial map, with different coloring for each index class, making it easier to identify areas with different environmental service performance (Anindita et al., 2021). To facilitate visualization on the map, each category has a different color as follows:

Table 2. Environmental Service Performance Categories

IKJLH	Category	Colour
4,21 – 5,00	Very High	
3,41 - 4,20	High	
2,61 - 3,40	Moderate	
1,81 – 2,60	Low	
1,00 - 1,81	Very Low	

Results and Discussion

Landscape

Based on the Decree of the Minister of Environment and Forestry Number SK. 1272/MENLHK/ SETJEN/PLA.3/12/2021 concerning the Determination of Landscape Characteristics and Natural Vegetation Characteristics of the Indonesian Ecoregion Map Scale 1:250,000, the South Sumatra region consists of 30 (thirty) types of landscape characteristics.

Table 3. Landscape Characteristics in South Sumatra Province

No.	Landform	Area (ha)	Percentage (%)
1	Lake	9,732.044	0.11
2	Fluvial plain with alluvial material	2,064,870.225	23.87
3	Fluvio-marine plain with alluvial material	286,482.104	3.31
4	Fluvio-volcanic plain with alluvial material	24,234.245	0.28
5	Sandy marine plain with alluvial material	988.795	0.01
6	Organic plain with peat material	668,621.677	7.73
7	Undulating-folded structural plain with non-carbonate sedimentary rock material	1,844,826.851	21.32

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

8	Undulating-plutonic structural plain with intrusive igneous rock material	11,235.300	0.13
9	Volcanic plain with pyroclastic material	1,906.861	0.02
10	Undulating volcanic plain with extrusive igneous rock material	253,595.169	2.93
11	Undulating volcanic plain with mixed extrusive igneous and pyroclastic material	21,288.312	0.25
12	Undulating volcanic plain with pyroclastic material	1,914,443.251	22.13
13	River valley with alluvial material	349,711.235	4.04
14	Volcanic cone mountain with mixed extrusive igneous and pyroclastic material	8,776.503	0.10
15	Volcanic cone mountain with pyroclastic material	236,340.178	2.73
16	Upper slope of volcanic cone mountain with mixed extrusive igneous and pyroclastic material	3,944.062	0.05
17	Lower slope of volcanic cone mountain with pyroclastic material	21,178.302	0.24
18	Peak slope of volcanic cone mountain with mixed extrusive igneous and pyroclastic material	17,361.909	0.20
19	Solutional karst mountain with carbonate sedimentary rock material	8,331.113	0.10
20	Folded structural mountain with mixed carbonate and non-carbonate sedimentary rock material	3,729.202	0.04
21	Volcanic mountain with extrusive igneous rock material	252,025.751	2.91
22	Volcanic mountain with mixed extrusive igneous and pyroclastic material	249,254.841	2.88
23	Denudational hill with carbonate sedimentary rock material	2,601.897	0.03
24	Parasitic volcanic cone hill with extrusive igneous rock material	7,022.620	0.08
25	Solutional karst hill with carbonate sedimentary rock material	1,114.151	0.01
26	Folded structural hill with non-carbonate sedimentary rock material	18,368.145	0.21
27	Folded structural hill with mixed carbonate and non-carbonate sedimentary rock material	62,869.205	0.73
28	Volcanic hill with extrusive igneous rock material	207,282.161	2.40
29	Volcanic hill with mixed extrusive igneous and pyroclastic material	67,521.480	0.78
30	Volcanic hill with pyroclastic material	31,977.261	0.37

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

This area shows a diversity of landscapes formed by fluvial, volcanic, structural, and organic processes. These four processes reflect the interaction between geological dynamics and climate factors over a long geological period. Fluvial processes describe the role of water flow in forming landforms such as plains and valleys, while volcanic and structural processes indicate past tectonic and volcanism activities that formed plateaus, mountains, and folded structures (Zhao et al., 2020). The three types of landscapes with the largest coverage are fluvial plains with alluvium material (23.87%), undulating volcanic plains with pyroclastic material (22.13%), and folded structural plains with non-carbonate sedimentary rock material (21.32%). These three types show the dominance of river sedimentation processes as well as volcanic activity and tectonic folding, each of which leaves significant geological traces on current landforms (Putra et al., 2020).

In addition, there are other fairly extensive components such as organic plains with peat material (7.73%). Peatlands are formed from the accumulation of organic matter under anaerobic conditions in tropical wetlands, and have an important role in carbon storage and climate change mitigation (Ribeiro et al., 2021). In addition, river valleys (4.04%) and fluviomarine plains (3.31%) are important indicators of active hydrological and coastal systems. River valleys are formed by vertical erosion of river flows that produce elongated and steep relief, while fluviomarine plains are formed through the interaction between river and sea water, which is important in estuarine and delta systems. Volcanic landscapes are also quite prominent, although the percentage is relatively small, namely between 0.37% and 2.91%. This area includes mountains and hills composed of external igneous rocks such as andesite and basalt, as well as pyroclastic material. Despite its limited coverage, this area is important for the conservation of geological diversity and has the potential for disasters such as landslides and eruptions (Pavlova et al., 2017).

Several other landforms, such as lakes, sandy marine plains, and karst hills, have very small areas (<0.1%), but are still ecologically important. Lakes function as water storage, biodiversity habitats, and microclimate regulators, while sandy marine plains protect the coast from abrasion, and karst areas function as water catchment areas and have high conservation value due to their unique cave ecosystems and geological formations (Taboroši & Kázmér, 2013). Overall, the geomorphological complexity of this area is very high and reflects the importance of a landscape-based approach in spatial planning and natural resource management. The diversity of landforms indicates different vulnerabilities to disasters, as well as potential utilization that must be adjusted to the physical characteristics of the land. Therefore, the integration of geomorphological information into development policies is crucial to realize sustainable development (FAO, 2021).

Natural Vegetation

Based on the Decree of the Minister of Environment and Forestry Number SK.1272/MENLHK/SETJEN/PLA.3/12/2021 concerning the Determination of Landscape Characteristics and Natural Vegetation of Indonesian Ecoregions on a Scale of 1:250,000, South Sumatra Province has 18 types of natural vegetation characteristics.

The most dominant type of natural vegetation is lowland forests (non-dipterocarp) with an area of 3,805,553.40 hectares or around 43.99% of the total provincial area, followed by peat swamp herbaceous vegetation covering an area of 1,972,891.63 hectares (22.80%). Administratively, the most widespread peat swamp forest is in Musi Banyuasin Regency (934,392.81 hectares or 24.55% of the total vegetation), while the most widespread peat swamp herbaceous vegetation is found in Ogan Komering Ilir Regency (86,136.33 hectares or 43.85%).

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

The complete distribution of natural vegetation characteristics per district/city in South Sumatra Province is shown in Table 4 and Table 5.

Table 4. Natural Vegetation Conditions in South Sumatra Province

No.	Natural Vegetation	Area (ha)	Percentage (%)
1	Lowland limestone forest vegetation	17,276.674	0.20
2	Lowland limestone forest vegetation on karst landforms	1,114.151	0.01
3	Mountain limestone forest vegetation on karst landforms	8,331.113	0.10
4	Lowland dipterocarp forest vegetation	800,122.777	9.25
5	Peat swamp forest vegetation	668,621.677	7.73
6	Lowland heath forest (kerangas) vegetation	1,439.277	0.02
7	Lowland forest vegetation (non-dipterocarp)	3,805,553.402	43.99
8	Coastal forest vegetation	988.795	0.01
9	Upper montane forest vegetation	22,625.276	0.26
10	Lower montane forest vegetation	614,577.546	7.10
11	Subalpine forest vegetation	188.555	0.00
12	Riverbank forest vegetation	1,038.228	0.01
13	Mangrove vegetation	286,482.104	3.31
14	Freshwater swamp herbaceous vegetation	65,896.651	0.76
15	Peat swamp herbaceous vegetation	1,972,891.625	22.80
16	Lakeside herbaceous vegetation	9,732.044	0.11
17	Riverside herbaceous vegetation	251,457.949	2.91
18	Brackish riverbank herbaceous vegetation	123,297.006	1.43

The distribution of natural vegetation in this area is dominated by non-dipterocarp lowland forests with an area of 43.99%. Non-dipterocarp lowland forests are a type of tropical lowland forest that is not dominated by the Dipterocarpaceae family, but still has high biodiversity, plays an important role as a carbon sink, microclimate regulator, and habitat for various endemic species (Sakai, 2002). The second largest vegetation type is peat swamp herbaceous vegetation at 22.80%, which generally consists of herbs and shrubs that grow on shallow to deep peatlands. This vegetation plays a role in maintaining peat soil stability, regulating local hydrology, and storing large amounts of carbon (Harenda et al., 2017). Furthermore, there are dipterocarp lowland forests with a coverage of 9.25%, namely lowland tropical forests dominated by trees from the Dipterocarpaceae family. This forest is known to have high productivity and extraordinary diversity of flora and fauna, as well as being a source of economy from non-timber forest products and ecotourism (Masoodi & Sundriyal, 2020).

The three types of vegetation reflect the existence of extensive lowland and swamp ecosystems, which ecologically function in regulating the water cycle, storing carbon, and maintaining biodiversity (Sharma & Naik, 2024). Peat forests also have a significant role, although they only cover 7.73% of the area. This forest is formed on organic soil with high water content, which stores carbon reserves of more than 30% of the world's total soil carbon, so that its destruction can cause the release of large amounts of carbon emissions (Zhou et al., 2020; Vetrita & Cochrane, 2017). Meanwhile, lower mountain forests cover 7.10%, which shows variations in vegetation based on altitude. Lower montane forests usually grow at altitudes between 500–1500 meters and function as a transition zone between lower montane forests and

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

upper montane forests, with high endemicity and an important role in water conservation and slope protection (Saputra et al., 2023).

In coastal and riparian areas, mangrove vegetation (3.31%) and riverbank herbaceous vegetation (2.91%) were found, indicating the important role of watersheds and coastal ecosystems. Mangroves act as natural buffers from sea abrasion, fish spawning grounds, and blue carbon absorbers (Alongi, 2020; Richards & Friess, 2016). Riverbank herbaceous vegetation functions as a natural filter for sediment and pollutants, maintains riverbank stability, and supports semi-aquatic habitats (Pranowo et al., 2021).

Several other types of vegetation, such as karst forests, upper montane forests, and lakeshore vegetation, although very small in area (<1%), still have critical ecological roles. Karst forests, for example, serve as a unique biodiversity refuge and support underground hydrological functions. Upper montane forests function as the main water catchment area and habitat for typical highland flora and fauna. Lakeshore vegetation, although narrow, plays an important role as a transition zone between land and water that supports aquatic ecosystems through water filtration and marginal habitats (Dai et al., 2023; Stone et al., 2024).

Overall, the composition of the natural vegetation in this area reflects the existence of diverse tropical ecosystems, dominated by lowland forests and swamps, and supported by typical vegetation in mountainous areas, coasts, and water bodies. This diversity shows the importance of the landscape as an interconnected ecological unit, and is an important basis for conservation planning and sustainable landscape management, both in terms of biodiversity protection and climate change mitigation (FAO, 2021; Chazdon et al., 2020).

Land Cover in South Sumatra Province

Land cover describes the biophysical conditions of the earth's surface, which can be formed through natural processes or human activities. Land cover due to human activities includes agriculture, plantations, settlements, and mining, while natural land cover includes forests, mangroves, and water bodies.

Based on the 2023 Land Cover Map published by the Ministry of Environment and Forestry, there are 21 land cover classes in South Sumatra Province. The largest type of land cover is mixed dry land agriculture covering an area of 2,389,594.69 hectares (27.62% of the provincial area), followed by plantations covering an area of 2,268,304.95 hectares (26.22%). Significant changes have occurred in the last decade, especially in the increase in plantation area. The spatial representation of land cover in 2023 is shown in Figure 5.

Table 5. Land Cover in South Sumatra Province in 2023

No.	Land Cover in 2023	Area (ha)	Percentage (%)
1	Airport / Port	549.633	0.01
2	Primary Dryland Forest	290,095.832	3.35
3	Secondary Dryland Forest	280,432.491	3.24
4	Primary Mangrove Forest	91,442.333	1.06
5	Secondary Mangrove Forest	70,768.480	0.82
6	Primary Swamp Forest	9,416.261	0.11
7	Secondary Swamp Forest	60,816.865	0.70
8	Plantation Forest	755,884.886	8.74
9	Bare Land	17,864.573	0.21
10	Plantation	2,268,304.947	26.22
11	Settlement	191,253.191	2.21

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

12	Transmigration Settlement	47,033.562	0.54
13	Mining Area	41,873.321	0.48
14	Dryland Agriculture	288,433.200	3.33
15	Mixed Dryland Agriculture	2,389,594.688	27.62
16	Swamp	87,103.047	1.01
17	Rice Field	514,632.277	5.95
18	Shrub	222,519.818	2.57
19	Swamp Shrub	892,683.059	10.32
20	Fish Pond / Aquaculture	60,517.026	0.70
21	Water Body	70,415.361	0.81

Land cover in 2023 shows the dominance of land use for mixed dryland agriculture (27.62%) and plantations (26.22%), reflecting the region's orientation towards the agricultural sector as the backbone of the local economy. Mixed dryland agriculture includes a combination of seasonal food crops and perennial crops without a permanent irrigation system, indicating adaptation to local climate and soil conditions with limited water (Srinivasarao et al., 2021). Meanwhile, plantation expansion—whether oil palm, rubber, or coffee—is a major contributor to land conversion and changes in tropical landscapes, which often result in deforestation, decreased biodiversity, and ecosystem degradation (Austin et al., 2019). Plantation forests account for 8.74%, indicating land rehabilitation programs and forestry intensification, especially through the planting of commercial tree species such as Acacia, Eucalyptus, or Sengon. Although plantations cannot match the complexity of natural forest ecosystems, they still have the potential to provide ecosystem services, including soil protection, water conservation, and carbon sequestration, if managed sustainably (Bauhus et al., 2010; Brockerhoff et al., 2013; Barrios et al., 2018).

Rice fields cover 5.95%, indicating the existence of traditional wet farming and irrigation systems that play an important role in regional food security. However, pressure to convert rice fields to non-agricultural areas, such as settlements and infrastructure, remains a challenge that threatens long-term food productivity (Wen & Zeng, 2024).

Natural forest cover, such as primary (3.35%) and secondary (3.24%) dryland forests, now only accounts for a small proportion of the total area. Primary forests are of great conservation value due to their integrity, high biodiversity, and role in local and global climate regulation. Meanwhile, secondary forests are generally the result of natural regeneration or recovery from human disturbance, and have restorative potential if managed ecologically (Rodríguez-León et al., 2025).

Mangrove forests and swamp forests, both in primary and secondary forms (totaling around 2.69%), play an important role in storing blue carbon, protecting the coast from erosion and storms, and as a habitat for aquatic biota. However, pressure from land conversion for ponds and coastal infrastructure is still high and threatens the function of these ecosystems (Friess et al., 2019; Sahavacharin et al., 2022).

Swamp shrubs (10.32%) represent an ecological transition zone, often formed due to forest degradation, land clearing, or lowering of groundwater levels. This area can be used as an important indicator in monitoring environmental damage and has great potential for ecological-based restoration interventions (Ola et al., 2024).

Other land uses such as settlements, mining, fish ponds, and water bodies account for <3% of the total, reflecting that development pressures are still spatially focused. However, activities

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

in sensitive zones such as coasts, watersheds, and peatlands have significant ecological impacts, both on water quality, biodiversity, and land stability (Ramdani & Hino, 2020).

Overall, this land cover structure shows the dominance of agriculture and plantations as the main drivers of landscape dynamics. Therefore, a sustainable landscape management approach is important to balance economic productivity and environmental conservation. Approaches such as land sharing (integration of conservation and production) or land sparing (expansion of strict conservation areas) can be adaptive strategies in reducing pressure on critical ecosystems (Fischer et al., 2017).

Water Regulatory Environmental Services in 2023

Performance of Water Regulatory Environmental Services per Regency/City

The regency with the largest area of moderate water regulator environmental services performance is Musi Banyuasin Regency, which is around 1,101,471,064 hectares. The area for the category in the regency/city is presented in Figure 2.

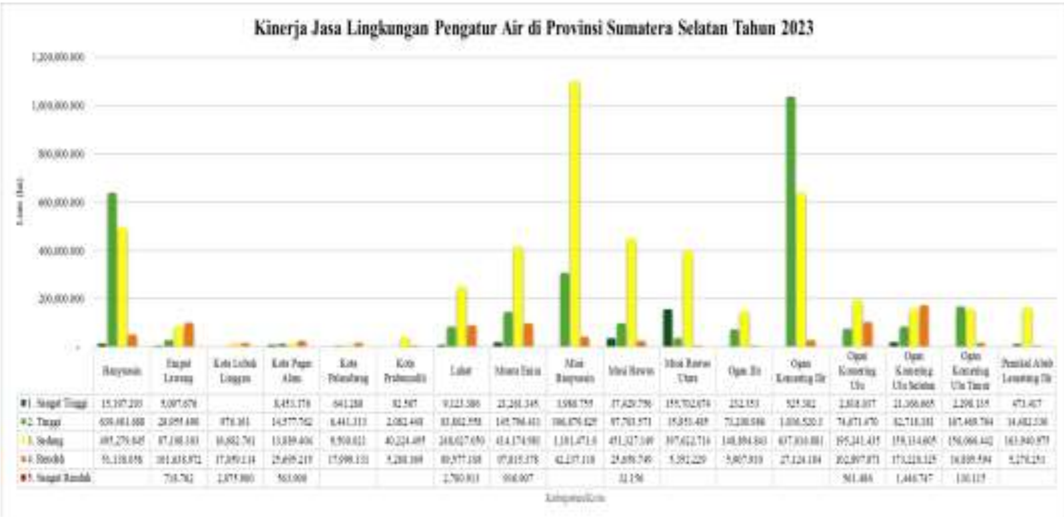


Figure 2. Graph of Water Regulatory Environmental Service Performance in 2023 per Regency/City

Spatial analysis in 2023 shows that most of the regencies/cities in South Sumatra Province have water regulator environmental service performance in the medium and high categories. Musi Banyuasin and Ogan Komering Ilir Regencies have the highest areas in the medium (±1.1 million ha) and high (±1.03 million ha) categories, respectively.

The very high category was only recorded significantly in North Musi Rawas and Musi Rawas Regencies, while cities such as Palembang and Lubuk Linggau are more dominant in the medium and low categories. The low and very low categories reflect pressure on the water regulator function, especially in South Ogan Komering Ulu, Empat Lawang, and Lahat Regencies, although the coverage is still limited. In general, these data show that the water regulator ecosystem function in South Sumatra is still quite good, but environmental management improvements are needed in areas with low performance.

Percentage of Environmental Service Performance for Water Regulation per Regency/City

When compared with the area of each regency/city, the percentage of environmental service performance for water regulation in 2023 can be seen as in Table 4.10. and Figure 4.12. The very high performance category is quite large in the North Musi Rawas Regency area, reaching

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

26.19% of the regency area. The high performance category is still very large in the Ogan Komering Ilir and Banyuasin Regencies, respectively, reaching 60.93% and 53.24% of the area of each regency. The moderate performance category reaches 89.02% of the area of Penukal Abab Lematang Ilir Regency and 84.36% of the area of Prabumulih City. The low performance category reaches 52.05% of the area of Palembang City and the very low performance is still around 5.64% of the city area in Lubuk Linggau City.

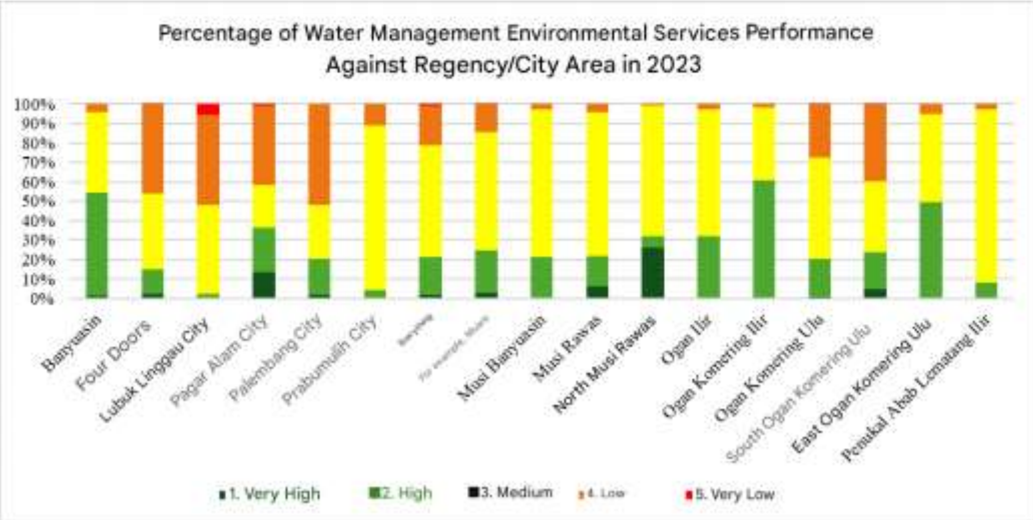


Figure 3. Percentage Graph of Water Regulation Environmental Service Performance in 2023 per Regency/City

Data from 2023 shows that most regencies/cities in South Sumatra Province have water regulation environmental service performance in the medium to high category. Penukal Abab Lematang Ilir (PALI) and Prabumulih Regencies show dominance in the medium category, at 89.02% and 84.36%, respectively. Ogan Komering Ilir (OKI) Regency recorded the highest percentage in the high category at 60.93%, followed by Banyuasin at 53.24%. Meanwhile, the very high category is only significant in North Musi Rawas (26.19%) and Pagar Alam (13.38%). In contrast, the low to very low category is quite high in several areas such as Lubuk Linggau, Empat Lawang, and Pagar Alam, indicating greater ecological pressure on the water regulation function. In general, this province still shows good environmental service potential, but some areas require more attention in land use management and ecosystem conservation to maintain sustainable water regulation functions.

Performance of Water Regulation Environmental Services in South Sumatra

The results of spatial analysis of landscape parameters, natural vegetation and land cover in 2023 describe the condition of the performance of water regulation environmental services in the South Sumatra Province in 2023 which are distributed in spatial form as shown in Figure 4.

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

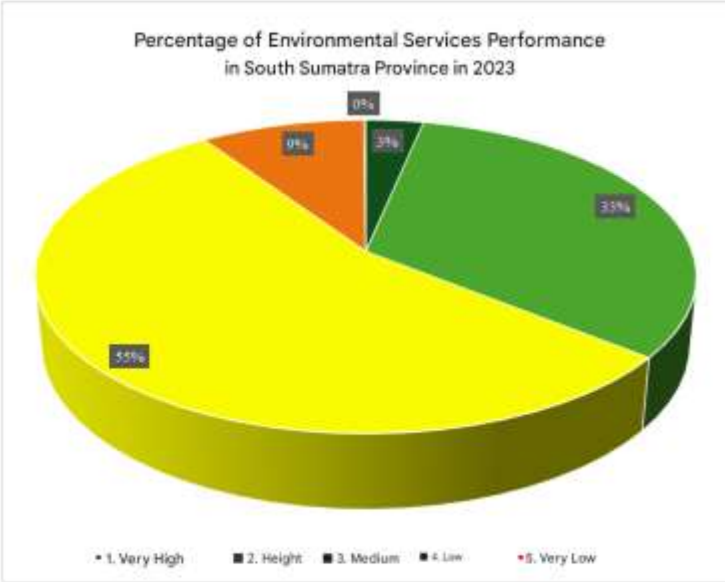


Figure 4. Percentage Graph of Environmental Service Performance of Water Regulation in South Sumatra Province in 2023

The results of the analysis show that the majority of areas are in the moderate category, which is 55%, followed by the high category of 33%. Meanwhile, the low category covers 9% and very high only 3%. There are no areas that fall into the very low category (0%). In general, these data show that most areas in South Sumatra Province have environmental service performance at moderate to high levels. However, there are still a small number of areas with low performance, which require attention and improvement in environmental management in the future.

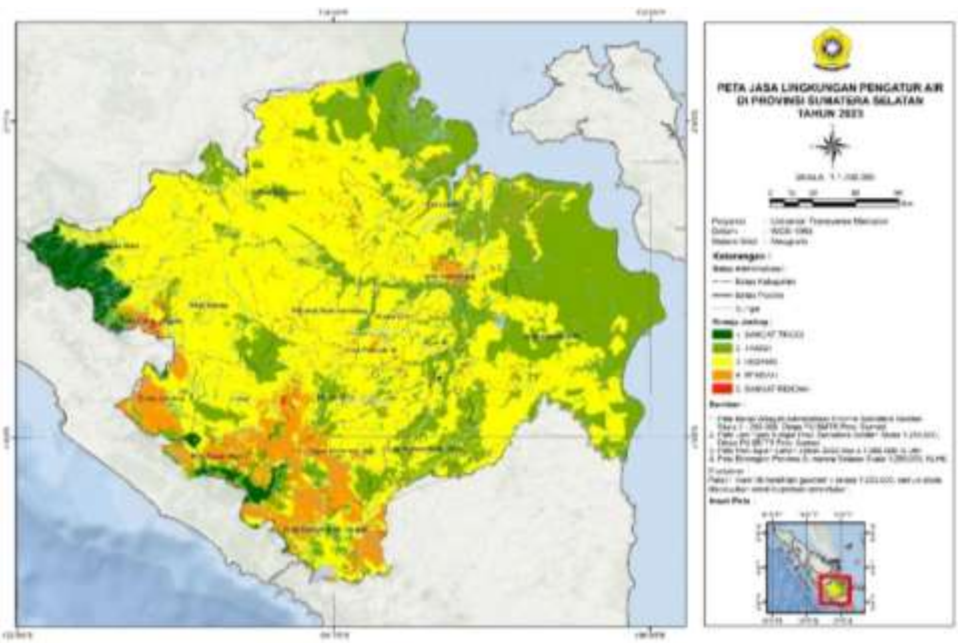


Figure 5. Map of Water Regulating Environmental Services in South Sumatra Province in 2023

Based on the results of the mapping that has been carried out, it can be concluded that basically the South Sumatra Province still has a relatively good performance of water regulating environmental services. This is indicated by the dominance of the "moderate" to "high" categories in most districts/cities, such as Banyuasin, Ogan Komering Ilir, and Muara Enim. In

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

general, the most dominant category of water regulating environmental services in 2023 is the moderate performance category, which reaches around 55% of the area of South Sumatra Province. This performance reflects the ability of the ecosystem to regulate water flow, maintain soil moisture, and prevent flooding and drought—part of the hydrological environmental services that are very important in the life support system (Maes et al., 2019; Yu et al., 2021).

However, there is a tendency that intensive land use activities, such as plantation expansion, mining, and urbanization in several areas, can threaten the sustainability of these environmental service functions. Recent studies have shown that rapid land use change can reduce the capacity of ecosystems to provide important ecosystem services, including water regulation, sediment retention, and nutrient cycling (Zhao et al., 2020).

Therefore, land use in South Sumatra Province needs to be directed in a sustainable and ecosystem-based manner. The landscape management approach must consider the balance between economic development and preservation of ecological functions, by integrating social, ecological, and governance aspects into one unit (De Groot et al., 2010). The principles of landscape approach and spatial planning that take into account the carrying capacity and environmental capacity are very important in preventing long-term ecosystem degradation (Kusters et al., 2018).

Local governments and stakeholders are expected to strengthen spatial regulations, implement incentives for the protection of important ecosystems, and encourage community participation in water and land resource conservation. These efforts are very important to maintain the performance of water regulating environmental services to remain stable and sustainable in the face of development pressures and climate change (de Groot et al., 2020; Sari et al., 2022).

Conclusion

The analysis of the spatial distribution and performance of water-regulating environmental services within the South Sumatra Province is based on the integrating evaluations of the landscape features, natural vegetation, and land cover based on GIS and SAW methodology. The findings indicate that the greater number of regions are placed in moderate (55 %) and high (33 %); performances that are outstanding can be observed in Ogan Komering Ilir, Banyuasin, and North Musi Rawas.

In comparison, Palembang, Empat Lawang and lubuk linggau bear the symptoms of ecological pressures with quick urbanization and land resettlement being the main causative factors. In addition to empirical results, the study confirms the essential ecological importance of landforms and vegetation cover in maintaining hydrological processes including regulation of surface water, mitigation of flood, and filling of the aquifers. Significant spatial disparity of the ecosystem services in the province highlights the importance of aligning the land-use policies to match the environmental capacity and the socio-economic development goals. As such, environmental planning in landscapes and integration of ecological indicators in decision-making in space are still very pertinent.

A number of limitations should also be admitted. Research is based on the secondary sources of data, which, even despite their competence, may fail to reflect recent micro-level changes in land use or the social-institutional factors of affecting the outcome of environmental services. In addition to that, the weighting scheme, based on expertise and official documents, would be more dynamic or participatory to include the local ecological knowledge and the views of stakeholders.

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

But, policy and practice implications are obvious: spatial planning in South Sumatra need to focus on preservation of ecosystem services through protection of well-performing ecological areas and restoration of those degraded and through land-based development planning, especially the extensive agricultural and plantation and urban sprawl activities have to be assessed on their long term implications of confining water regulative services, towards this end a and multi-stakeholder governance necessitates including governmental agencies, civil society, and the local communities, should be adhered to institutionalize sustainable landscape.

Environmental-services research that is looking ahead in the future must, therefore, use enbedded time-based data collections on land-use, and combine such collections with socio-economic data and projections of climate change, so as to gain a more complete picture of the drivers of environmental degradation. The integrated system would increase predictive abilities as well as help develop adaptive management plans considering the current climate change and developmental pressures.

Acknowledgment

The author expresses sincere gratitude to the Environmental and Land Affairs Office for their support and the valuable data and information provided, which have made a significant contribution to the preparation of this article.

References

Alongi, D. M. (2020). Carbon cycling and storage in mangrove forests. *Annual Review of Marine Science, 12*, 195–215.

Anindita, R., Nugroho, S. P., & Rachman, A. (2021). Pemodelan Spasial Jasa Lingkungan Pengatur Air Menggunakan Sistem Informasi Geografis (SIG). *Jurnal Ilmu Lingkungan, 19*(3), 451–462. https://doi.org/10.14710/jil.19.3.451-462

Anindita, R., Wulandari, C., & Sari, D. A. (2021). Analisis Spasial Jasa Lingkungan dalam Pengelolaan Ekosistem Berbasis Bentang Alam. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan, 11*(1), 45–53. https://doi.org/10.29244/jpsl.11.1

Austin, K. G., Schwantes, A., Gu, Y., & Kasibhatla, P. S. (2019). What causes deforestation in Indonesia?. *Environmental Research Letters*, *14*(2), 024007. http://dx.doi.org/10.1088/1748-9326/aaf6db

Bappeda Sumatera Selatan. (2021). *Laporan Indeks Pembangunan Manusia Provinsi Sumatera Selatan Tahun 2021*. Palembang: Bappeda Sumatera Selatan.

Barrios, E., Valencia, V., Jonsson, M., Brauman, A., Hairiah, K., Mortimer, P. E., & Okubo, S. (2018). Contribution of trees to the conservation of biodiversity and ecosystem services in agricultural landscapes. *International Journal of Biodiversity Science, Ecosystem Services & Management*, *14*(1), 1-16. https://doi.org/10.1080/21513732.2017.1399167

Bauhus, J., Pokorny, B., Van der Meer, P. J., Kanowski, P. J., & Kanninen, M. (2010). Ecosystem goods and services–the key for sustainable plantations. In *Ecosystem goods and services from plantation forests* (pp. 205-227). Routledge.

Brockerhoff, E. G., Jactel, H., Parrotta, J. A., & Ferraz, S. F. (2013). Role of eucalypt and other planted forests in biodiversity conservation and the provision of biodiversity-related ecosystem services. *Forest Ecology and Management*, *301*, 43-50. https://doi.org/10.1016/j.foreco.2012.09.018

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

Chazdon, R. L., Lindenmayer, D., Guariguata, M. R., Crouzeilles, R., Benayas, J. M. R., & Chavero, E. L. (2020). Fostering natural forest regeneration on former agricultural land through economic and policy interventions. *Environmental Research Letters*, *15*(4), 043002. http://dx.doi.org/10.1088/1748-9326/ab79e6

Comino, E., Bottero, M., Pomarico, S., & Rosso, M. (2014). Exploring the environmental value of ecosystem services for a river basin through a spatial multicriteria analysis. *Land use policy*, *36*, 381-395. https://doi.org/10.1016/j.landusepol.2013.09.006

Dai, T., Liu, R., Zhou, X., Zhang, J., Song, M., Zou, P., ... & Li, S. (2023). Role of lake aquatic–terrestrial ecotones in the ecological restoration of eutrophic water bodies. *Toxics*, *11*(7), 560. http://dx.doi.org/10.3390/toxics11070560

De Groot, R. S., Alkemade, R., Braat, L., Hein, L., & Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological complexity*, *7*(3), 260-272. http://dx.doi.org/10.1016/j.ecocom.2009.10.006

de Groot, R. S., Palomo, I., & Jacobs, S. (2020). Integrating the multiple values of nature in decision making. *Ecosystem Services, 43*, 101099. https://doi.org/10.1016/j.ecoser.2020.101099

FAO. (2021). *Land Resources Planning Toolbox: Tools for sustainable land management*. Rome: FAO.

FAO. (2021). *The State of the World's Forests 2020: Forests, biodiversity and people*. Rome: FAO.

Fischer, J., Abson, D. J., Butsic, V., Chappell, M. J., Ekroos, J., Hanspach, J., ... & von Wehrden, H. (2014). Land sparing versus land sharing: moving forward. *Conservation Letters*, *7*(3), 149-157.

Friess, D. A., Thompson, B. S., Brown, B., Amir, A. A., Cameron, C., Koldewey, H. J., ... & Sidik, F. (2016). Policy challenges and approaches for the conservation of mangrove forests in Southeast Asia. *Conservation Biology*, *30*(5), 933-949. https://doi.org/10.1111/cobi.12784

Harenda, K. M., Lamentowicz, M., Samson, M., & Chojnicki, B. H. (2017). The role of peatlands and their carbon storage function in the context of climate change. In *Interdisciplinary approaches for sustainable development goals: Economic growth, social inclusion and environmental protection* (pp. 169-187). Cham: Springer International Publishing. http://dx.doi.org/10.1007/978-3-319-71788-3_12

KLHK. (2019). *Pedoman Umum Penilaian Jasa Lingkungan Hidup dalam Pengelolaan Ekoregion*. Jakarta: KLHK.

KLHK. (2021). *Keputusan Menteri Lingkungan Hidup dan Kehutanan Nomor SK.1272/MENLHK/SETJEN/PLA.3/12/2021*. Jakarta: KLHK.

KLHK. (2021). *Peraturan Pemerintah Republik Indonesia Nomor 22 Tahun 2021 tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup*. Jakarta: KLHK.

KLHK. (2023). *Peta Penutupan Lahan Indonesia Tahun 2023*. Jakarta: KLHK. https://sigap.menlhk.go.id

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

Kusters, K., Buck, L., de Graaf, M., Minang, P., & van Oosten, C. (2018). Participatory planning, monitoring and evaluation of multi-stakeholder platforms. *Environmental Management, 62*(1), 170–181. https://doi.org/10.1007/s00267-018-1030-8

Maes, J., Zulian, G., Vallecillo, S., Baró, F., & Paracchini, M. L. (2019). Contributions of ecosystem services to SDGs. *Ecosystem Services, 38*, 100930. https://doi.org/10.1016/j.ecoser.2019.100930

Masoodi, H. U. R., & Sundriyal, R. C. (2020). Richness of non-timber forest products in Himalayan communities—diversity, distribution, use pattern and conservation status. *Journal of ethnobiology and ethnomedicine*, *16*(1), 56. https://ethnobiomed.biomedcentral.com/articles/10.1186/s13002-020-00405-0

Ola, I., Drebenstedt, C., Burgess, R. M., Mensah, M., Hoth, N., & Külls, C. (2024). Remediating oil contamination in the Niger Delta Region of Nigeria: technical options and monitoring strategies. *The Extractive Industries and Society*, *17*, 101405. https://doi.org/10.1016/j.exis.2024.101405

Pavlova, I., Makarigakis, A., Depret, T., & Jomelli, V. (2017). Global overview of the geological hazard exposure and disaster risk awareness at world heritage sites. *Journal of Cultural Heritage*, *28*, 151-157. http://dx.doi.org/10.1016/j.culher.2015.11.001

Peng, J., Du, Y., Liu, Y., & Hu, X. (2016). How to assess urban development potential in mountain areas? An approach of ecological carrying capacity in the view of coupled human and natural systems. *Ecological indicators*, *60*, 1017-1030. http://dx.doi.org/10.1016/j.ecolind.2015.09.008

Pranowo, W. S., Nugroho, S. P., & Lestari, P. (2022). Evaluasi Jasa Pengatur Air dalam Lanskap Ekoregion. *Jurnal Ekologi Tropika, 17*(2), 65–74.

Ramdani, F., & Hino, M. (2020). Drivers of land use change in Indonesia's peatlands. *Environmental Development, 34*, 100504. http://dx.doi.org/10.1088/1742-6596/1175/1/012185

Ribeiro, K., Pacheco, F. S., Ferreira, J. W., de Sousa-Neto, E. R., Hastie, A., Krieger Filho, G. C., ... & Ometto, J. P. (2021). Tropical peatlands and their contribution to the global carbon cycle and climate change. *Global change biology*, *27*(3), 489-505. https://doi.org/10.1111/gcb.15408

Richards, D. R., & Friess, D. A. (2016). Rates and drivers of mangrove deforestation. *PNAS, 113*(2), 344–349. https://doi.org/10.1073/pnas.1510272113

Rochmadi, S., Setiawan, B., & Nugraha, H. (2019). Konservasi Ekosistem Berbasis Vegetasi Alami. *Jurnal Ekologi dan Konservasi, 18*(1), 22–29.

Rodríguez-León, C. H., Sterling, A., Trujillo-Briñez, A., Suárez-Córdoba, Y. D., & Roa-Fuentes, L. L. (2025). Forest attribute dynamics in secondary forests: Insights for advancing ecological restoration and transformative territorial management in the amazon. *Diversity*, *17*(1), 39. https://doi.org/10.3390/d17010039

Sahavacharin, A., Sompongchaiyakul, P., & Thaitakoo, D. (2022). The effects of land-based change on coastal ecosystems. *Landscape and Ecological Engineering*, *18*(3), 351-366. http://dx.doi.org/10.1007/s11355-022-00505-x

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

Sakai, S. (2002). General flowering in lowland mixed dipterocarp forests of South-east Asia. *Biological Journal of the Linnean Society*, *75*(2), 233-247. http://dx.doi.org/10.1046/j.1095-8312.2002.00016.x

Sari, D. R., Yulianda, F., & Fitriani, N. (2022). Penerapan konservasi berbasis masyarakat. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan, 12*(1), 1–12. https://doi.org/10.29244/jpsl.12.1.1-12

Sari, R. N., Kurniawan, A., & Permana, R. (2020). Peran Pemetaan Spasial dalam Pembangunan Berkelanjutan. *Jurnal Kebijakan dan Perencanaan Pembangunan, 14*(2), 73–82.

Setiawan, I., & Hadi, S. (2021). Dampak Urbanisasi terhadap Lingkungan. *Jurnal Pembangunan Wilayah, 15*(2), 89–98.

Sharma, L. K., & Naik, R. (2024). Wetland ecosystems. In *Conservation of saline wetland ecosystems: an initiative towards UN decade of ecological restoration* (pp. 3-32). Singapore: Springer Nature Singapore.

Singh, V. (2024). The environment and its components. In *Textbook of Environment and Ecology* (pp. 1-13). Singapore: Springer Nature Singapore.

Srinivasarao, C., Kundu, S., Rakesh, S., Lakshmi, C. S., Kumar, G. R., Manasa, R., ... & Prasad, J. V. N. S. (2021). Managing soil organic matter under dryland farming systems for climate change adaptation and sustaining agriculture productivity. In *Soil Organic Carbon and Feeding the Future* (pp. 219-251). CRC Press. http://dx.doi.org/10.1201/9781003243090-10

Stone, M. S., Devlin, S. P., Hawes, I., Welch, K. A., Gooseff, M. N., Takacs-Vesbach, C., ... & Doran, P. T. (2024). McMurdo Dry Valley lake edge 'moats': The ecological intersection between terrestrial and aquatic polar desert habitats. *Antarctic Science*, *36*(4), 189-205. http://dx.doi.org/10.1017/S0954102024000087

Syahrul, F., Maulana, R., & Rasyid, M. (2020). Perubahan Penggunaan Lahan dan Dampaknya. *Jurnal Tata Ruang dan Lingkungan, 7*(1), 55–62.

Taboroši, D., & Kázmér, M. (2013). Erosional and depositional textures and structures in coastal karst landscapes. In *Coastal karst landforms* (pp. 15-57). Dordrecht: Springer Netherlands. http://dx.doi.org/10.1007/978-94-007-5016-6_2

Vetrita, Y., & Cochrane, M. A. (2019). Fire frequency and related land-use and land-cover changes in Indonesia's peatlands. *Remote Sensing*, *12*(1), 5. https://doi.org/10.3390/rs12010005

Wang, T., Zhou, Y., Bi, C., Lu, Y., He, G., & Giesy, J. P. (2017). Determination of water environment standards based on water quality criteria in China: Limitations and feasibilities. *Journal of Environmental Sciences*, *57*, 127-136. http://dx.doi.org/10.1016/j.jes.2016.11.010

Wen, H., & Zeng, Z. (2024). Impact of non-agricultural employment on food security in china's old revolutionary base areas. *Agriculture*, *14*(6), 868. https://doi.org/10.3390/agriculture14060868

Wibowo, R. A., Indriatmoko, Y., & Latifah, S. (2019). Kerentanan Wilayah terhadap Bencana. *Jurnal Ilmu Lingkungan, 17*(1), 15–26.

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)

Yu, H., Liu, Y., Zhou, Y., & Wang, J. (2021). Assessing the relationship between ecosystem services and land use change. *Ecological Indicators, 121*, 107207. https://doi.org/10.1016/j.ecolind.2020.107207

Zhao, W., Liu, Y., Wang, C., & Zhang, Y. (2020). Effects of land use change on ecosystem service value. *Ecological Indicators, 108*, 105724. https://doi.org/10.1016/j.ecolind.2019.105724

Zhao, W., Xiao, C., Chai, Y., Feng, X., Liang, X., & Fang, Z. (2021). Application of a new improved weighting method, ESO method combined with fuzzy synthetic method, in water quality evaluation of Chagan Lake. *Water*, *13*(10), 1424. http://dx.doi.org/10.1088/1742-6596/1175/1/012185

ISSN 2721-1304 (Print), ISSN 2721-1207 (online)