

Analysis of Ecosystem Services Performance in Peri-urban Areas of Sleman Regency for Sustainability Development

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Abstract. The peri-urban area becomes dynamic due to physical, economic, and social development. Sleman Region has a few peri-urban areas which are adjacent to Yogyakarta City. They are Mlati Subdistrict and Depok Subdistrict. The development of the peri-urban area leads to land use conversion. Unplanned land conversion affects ecosystem services. Therefore, an analysis of ecosystem services performance (provider, regulation, cultural, and biodiversity services) is needed. This study aimed to construct an ecosystem services map and to analyze ecosystem services performance. Ecosystem services analysis was carried out to support the preparation of development programs and policies based on sustainable development principles. Ecosystem services value obtained by ecosystem services maps construction based on ecoregion score data from D3TLH DLHK Yogyakarta Province (2021) and land use score (2020). The value of ecosystem services was represented by ordinal classified data as five classes, from Very Low to Very High. The results show that ecosystem services in peri-urban areas in Sleman Regency varied. Food and clean water provisioning services were categorized as Low, as water and flood management services. Cultural shelter and living space services were categorized as Very High, while biodiversity support services were classified as Very Low.

1 Introduction

Peri-urban is an area characterized by the end of rural characteristics and the emergence of urban environment characteristics [1]. It refers to the area around the urban center [2]. Peri-urban areas result from increased population growth and rapid urban migration that extends into rural areas. These areas are dynamic and ever-changing, leading to new forms of socio-economic interaction and significantly impacting environmental change [3]. The

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urbanized nature of peri-urban areas has led to uncontrolled development activities that have triggered various environmental problems.

The transformation of peri-urban areas that experience dynamic land use change is influenced by the character of the city center, road access, and government policies [4]. The rapid population growth rate and movement in peri-urban areas increase the demand for land supply to meet their needs. The demand for land supply will result in land use changes in peri-urban areas. Human activities in converting this land can cause disturbances in environmental balance because when the land has changed function, it will be difficult to change back to its original function [5]. This land conversion activity indirectly changes the ecosystem in the area.

Ecosystem service is the benefit of transforming resources and the environment into something useful for humankind [6]. Based on The Millenium Ecosystem Assessment framework, there are four categories of ecosystem services: provisioning services, regulating services, supporting services, and cultural services. Provisioning services include food, genetic resources, nutrients, and fresh water. Cultural services can be defined as education, recreation, and aesthetic values. Supporting services include primary production, oxygen production, and water cycling. Regulating services of the ecosystem can be climate regulation, water purification, and erosion regulation [7].

Many ecosystem services have been analyzed, including research on ecosystem services in Karimunjawa Island, Pekalongan City, and Semarang Regency. Based on the study results, most areas on Karimunjawa Island are included in the high class [8]. This ecosystem service assessment shows that most areas of Karimunjawa Island can still support and provide clean water, and the government needs to implement policies to maintain this function. Observations of ecosystem services in Pekalongan City show that most areas of Pekalongan City have low food provisioning services [9]. Food provisioning services in Semarang Regency are 27.96 high, 25.05 very high. Water provisioning services are 33% high and 13.30% very high [10].

The implementation of ecosystem service analysis of an area is beneficial for public policy making [11]. This research aimed to map various ecosystem services in the peri-urban area of Sleman Regency and analyze the performance of these ecosystem services. Combining ecosystem service analysis with mapping will show a complete ecosystem service performance analysis with variations in its spatial distribution. Mapping and analyzing ecosystem services can guide policymakers to develop and implement more targeted programs [12].

Valuation of ecosystem services can benefit humans, especially in supporting sustainable development. Information on the potential of various ecosystems, both in the form of goods and services, can guide local governments in planning sustainable policies. Understanding ecosystem services can also support information related to threats and risks in utilizing ecosystems in a region. Therefore, an integrated assessment of the potential of ecosystem services is critical, considering the positive and negative impacts of activities in peri-urban areas vary.

The study sites are peri-urban areas of Sleman Regency, namely Kapanewon Mlati and Depok (see Figure 1A). These two subdistricts were selected because they are administratively adjacent to Yogyakarta. In addition, there are many economic and educational centers in these locations. This condition causes land conversion from vegetated lands to built-up lands. This land change is characteristic of peri-urban areas [13]. Kapanewon Mlati consists of 5 villages with an area of 2840.33 ha. In comparison, Kapanewon Depok consists of 3 villages with an area of 3213.15 ha.

The types of land use in the peri-urban area of Sleman Regency in 2020 consist of open land, buildings, forests, waters, plantations, agriculture, and transportation (see Figure 1B). The extent of land use varies in each urban village, as presented in Table 1. Open land is the dominant land in the peri-urban area of Sleman Regency, with details of land use in the form of parking areas, vacant land, runways, sports fields, yards, and parks. These various types of open land can potentially experience land use change in the peri-urban area. Each land use type has a role and value in analyzing ecosystem services [14], including provisioning, regulating, cultural, and biodiversity services.

2 Methods

Each group of ecosystem services contributes to and sustains various elements of human and economic welfare. The Provisioning Services, Regulatory Services, and Cultural Services groups are believed to directly affect human welfare, while the Supporting Services group indirectly affects human welfare [15]. The selection of ecosystem services is also adjusted to the characteristics of the area and the problems that occur in the Peri-urban Area of Sleman Regency, namely as follows:

1. Food Providing Ecosystem Services
2. Ecosystem Services Providing Clean Water
3. Ecosystem Services for Flood and Water Management
4. Climate Regulation Ecosystem Services
5. Cultural Ecosystem Services Shelter and Living Space
6. Ecosystem Services Biodiversity Support Function

Table 1. Land Use in a Peri-urban Area of the Sleman Regency

No	Subdistrict/ Village	Land Use Area (ha)							Total
		Open Area	Buildi ng	Fore st	Wate r	Plantati on	Agricultu re	Trans- portati on	
1	Depok								
	Caturtunggal	486.25	408.94	2.35	14.92		48.25	76.80	1037.52
	Condongcatur	422.25	295.48		13.75		76.08	50.97	858.53
	Maguwoharjo	660.31	274.40		66.36		232.71	83.33	1317.11
		1568.81	978.82	2.35	95.03	0.00	357.04	211.09	3213.15
2	Mlati								
	Sendangadi	242.68	128.48		15.59	0.84	117.27	28.90	533.76
	Sinduadi	339.10	229.27	1.35	19.39		91.93	51.84	732.89
	Sumberadi	261.00	84.08		17.55	6.78	216.96	13.04	599.41
	Tirtoadi	184.18	57.26		10.16	2.99	226.79	13.06	494.43
	Tlogoadi	172.21	69.59		10.43	12.57	201.23	13.82	479.84
		1199.16	568.68	1.35	73.12	23.19	854.18	120.65	2840.33

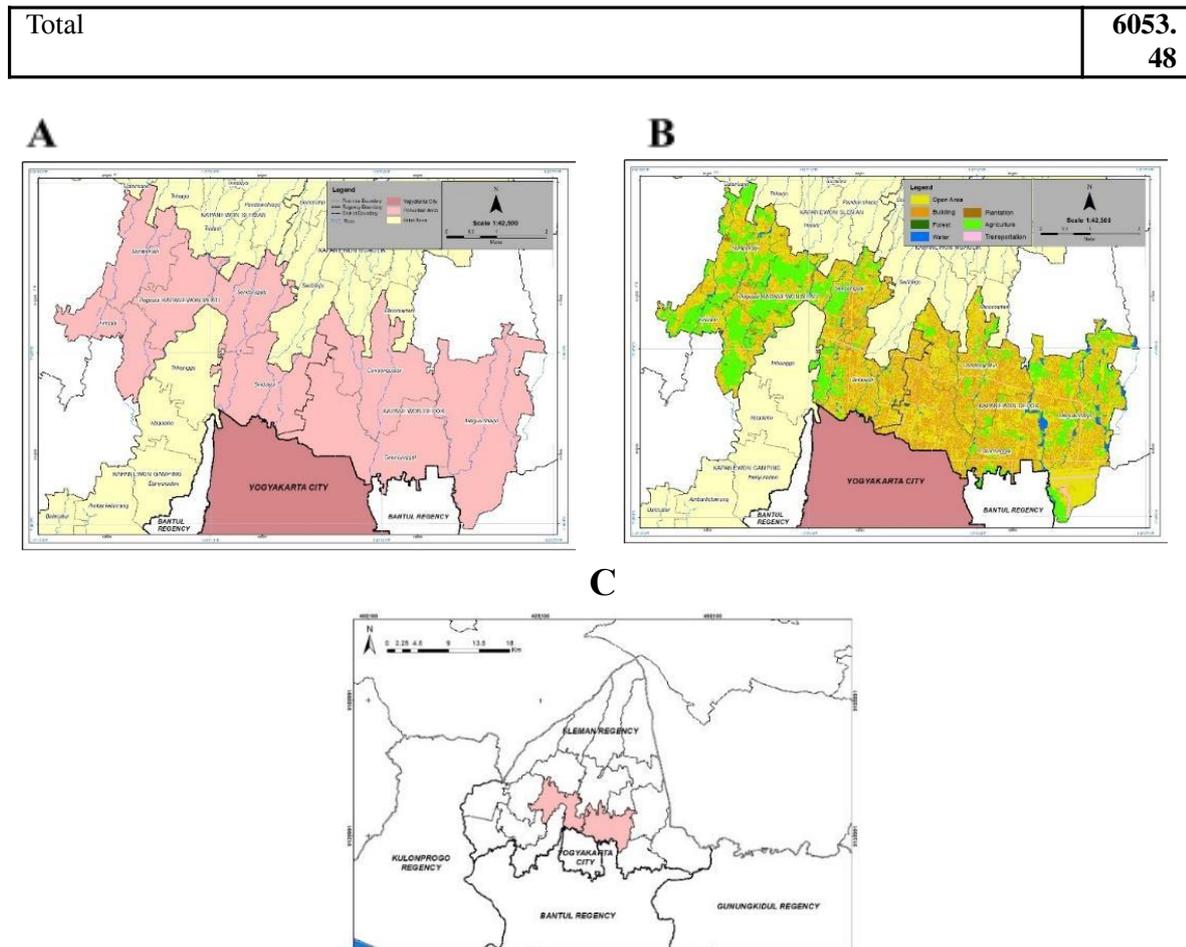


Fig. 1. A) Study location; B) Land use map; C) Inset map shows the study area

Stages and methods of data processing carried out in this study included identification of ecosystem services from land use, valuation and weighting of ecosystem services based on the expert judgment of ecoregion and land use data, spatial analysis, and calculation of ecosystem services index (IJE), classification of ecosystem service classes, and spatial visualization. The assessment and weighting of ecosystem services are done through expert judgment for land use and ecoregions. This study's ecosystem service score was based on data from D3TLH (Environmental Support Capacity) DLHK (Department of Environment Forestry) DIY Province in 2021. The data used in this research is the Ecoregion Map of Yogyakarta Province at a scale of 1:100,000 (2013) sourced from the Ministry of Environment and Forestry (KLHK) and the Sleman Regency Peri-urban Area Land Use Map at a scale of 1:10,000 (2020) sourced from the Sleman Regency Land and Spatial Planning Office.

Spatial data processing through an overlay (intersect) procedure between land cover and ecoregion data to produce a new spatial element from the intersection of the two spatial data. Next, overlay the new spatial elements with the weighted IJE values from the previous stage by entering the IJE values of land cover and ecoregion into the attribute table. The calculation of land cover and ecoregion values to generate IJE was done using Equation 1 below:

$$IJE = \sqrt{(IJE_{eco} \times IJE_{luc}) / (\max(\sqrt{(IJE_{eco} \times IJE_{luc})}))}$$

(1)

With:

- IJE = Ecosystem Services Index
- IJEeco = Ecosystem Services Index for Ecoregion
- IJEIulc = Ecosystem Services Index for Land Use Land Cover
- Max = maximum value from the calculation of the product and root of the ecosystem services index values for land cover and ecoregion.

An ecosystem services map is a visual representation that shows variations in the spatial distribution of the value of ecosystem services within an ecoregion. The value of ecosystem services was represented in ordinal classification data of 5 classes, ranging from Very High, High, Medium, Low, and Very Low. Details of the interval values for each class are shown in Table 2.

Table 2. Class Interval Value in Determining Ecosystem Services

Classification	Interval	Class Description	Color
Class I	0 – 0,1328	Very Low	Red
Class II	0,1328 – 0,2204	Low	Orange
Class III	0,2204 – 0,3659	Intermediate	Yellow
Class IV	0,3659 – 0,6075	High	Light Green
Class V	0,6075 – 0,9880	Very High	Dark Green

The preparation of the ecosystem service-based environmental carrying capacity map for the Peri-Urban Area of Sleman Regency is based on the ecoregion score (Table 3) and land use score data (Table 4) of D3TLH DLHK DIY Province in 2021 at a scale of 1:50,000 which was then converted to a scale of 1:10,000 based on the scale used in the preparation of the Central Sleman Detailed Spatial Plan. This conversion was carried out by substituting more detailed land use, namely the 2020 land use map obtained from the Sleman Regency Spatial Planning and Land Office, as input from the ecosystem service performance analysis without changing the index obtained from the previous expert assessment.

Table 3. Ecoregion score for each type of ecosystem service

Ecoregion	Score P1	Score P2	Score R1	Score R2	Score C1	Score D1
Fluviovolcanic plain with alluvium material	1.398	2.378	2.14 6	1.70 2	4.181	0.843
Undulating volcanic plains made of outer igneous rocks	1.698	1.479	1.77 7	2.32 6	2.605	2.870

Table 4. Land use score for each type of ecosystem service

Land Use	Score P1	Score P2	Score R1	Score R2	Score C1	Score D1
Industrial, Trade and Office Buildings	0.210	0.316	0.199	0.683	1.14 1	0.14 0
Other Non-residential Buildings	0.172	0.316	0.185	0.413	1.18 0	0.13 2
City Settlement Building	0.152	0.152	0.152	0.152	2.40 6	0.15 2
Garden	1.358	1.110	1.427	1.184	2.34 8	0.73 6
Freshwater Fishpond	1.691	0.192	0.345	0.364	0.85 9	1.80 4

Field with Palawija	2.065	0.463	0.424	0.494	2.49 3	0.56 1
Other Open Land	0.304	0.353	0.467	0.380	2.39 1	0.12 5
Rice Fields with Rice Interspersed with Other Crops	2.729	1.792	0.916	0.671	1.76 9	0.38 1
Shrubs	0.450	1.055	0.523	1.250	1.57 0	0.13 9
River	1.217	2.909	1.913	0.604	0.66 4	0.18 9
Other Dryland Annual Crops	1.887	0.192	0.523	0.508	0.97 3	0.43 8
Multi-Purpose Reservoir	2.024	3.742	1.421	1.264	0.65 4	1.80 4

Caption Table 2 and Table 3:

P1: Food-Providing Ecosystem Services

P2: Ecosystem Services Providing Clean Water

R1: Ecosystem Services for Flood and Water Management

R2: Climate Regulation Ecosystem Services

C1: Cultural Ecosystem Services Shelter and Living Space

D1: Ecosystem Services with Biodiversity Support Function

3 Result and discussion

Food Provision Ecosystem Services

Ecosystems provide the benefits of providing food, which is everything that comes from biological sources, and water, both processed and unprocessed, which is intended as food or drink for human consumption. Food provision by ecosystems can come from agricultural and plantation products, livestock, marine products, and forest food. Generally, food provisioning services in Depok and Melati Subdistrict are dominated by low-category ecosystem services (see Table 5).

Table 5. Area of Food Provision Ecosystem Services in Peri-urban Areas of Sleman Regency

Subdistrict/ Village	Class				Total (ha)
	Low	Intermediate	High	Very High	
Depok	2569.12	62.00	446.95	135.08	3213.15
Caturtunggal	954.70	12.92	68.01		1035.63
Condongcatur	705.06	7.96	114.63	30.88	858.53
Maguwoharjo	909.36	41.12	264.32	104.20	1319.00
Mlati	1513.91	58.18	1180.15	88.08	2840.33
Sendangadi	317.50	15.03	190.21	10.73	533.47
Sinduadi	582.17	16.74	134.56		733.47
Sumberadi	234.30	9.53	278.00	77.35	599.19
Tirtoadi	177.83	7.41	309.18		494.43
Tlogoadi	202.10	9.47	268.20		479.77
Total (ha)	4083.03	120.18	1627.10	223.17	6053.48

The low category of food ecosystem services is influenced by land use, mainly in the form of settlements, so it cannot be utilized for agricultural activities. The large number of

settlements that dominate this area is due to the development of trade and service provision, making it a peri-urban area. Interestingly, in the western part of Melati Subdistrict, there are still many agricultural and plantation lands that are productive in producing food products, as seen in the map in **Figure 2**. This condition makes the area classified as a high food-providing ecosystem service class.

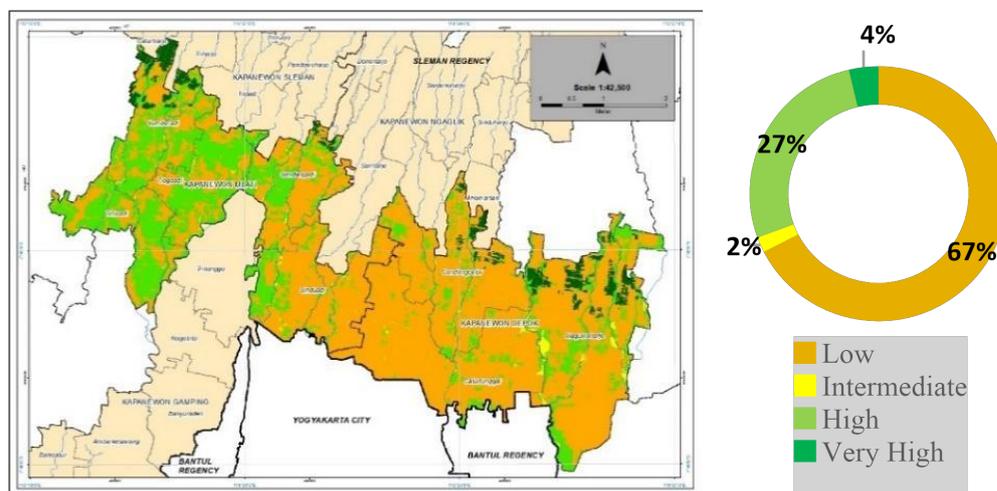


Fig. 2. Map and Diagram of Food Provision Ecosystem Services

Clean Water Supply Ecosystem Services

The availability of clean water is essential to support human needs, including for domestic, agricultural, industrial, and service purposes. Ecosystems provide the benefits of providing clean water from both surface water and groundwater. The provision of clean water services is strongly influenced by rainfall conditions and layers of soil and rock that can store water (aquifers). In addition, other factors such as landscape, vegetation, and land cover also influence the provision of water services.

Table 6. Area of Clean Water Supply Ecosystem Services in Peri-urban Areas of Sleman Regency

Subdistrict/ Village	Class					Total (ha)
	Very Low	Low	Intermediate	High	Very High	
Depok Subdistrict	190.80	2401.98	108.21	249.6	262.54	3213.1
Caturtunggal	0.26	954.44	0.61	18.99	61.33	1035.63
Condongcatur	87.33	620.30	38.54	66.36	45.99	858.53
Maguwoharjo	103.21	827.23	69.06	164.28	155.22	1319.00
Mlati Subdistrict	35.82	1476.14	62.97	433.1	832.23	2840.3
Sendangadi	5.25	312.25	6.01	87.82	122.13	533.47
Sinduadi		582.17		42.63	108.67	733.47
Sumberadi	29.61	203.36	54.85	154.41	156.95	599.19

Tirloadi		177.27	0.37	82.96	233.83	494.43
Tlogoadi	0.96	201.08	1.74	65.35	210.65	479.77
Total (ha)	226.62	3878.12	171.18	682.80	1094.77	6053.48

Generally, Depok and Mlati Subdistrict water supply services are low (see **Table 6** and **Figure 3**). The geological condition of the area, composed of young volcanic deposits, makes the aquifer productivity in the area relatively high. However, because most of the land in the Depok Subdistrict and Melati Subdistrict is used for residential buildings, industry, trade, offices, and others, it is difficult for water to be absorbed back into the soil. This condition results in a low supply of clean water in the area.

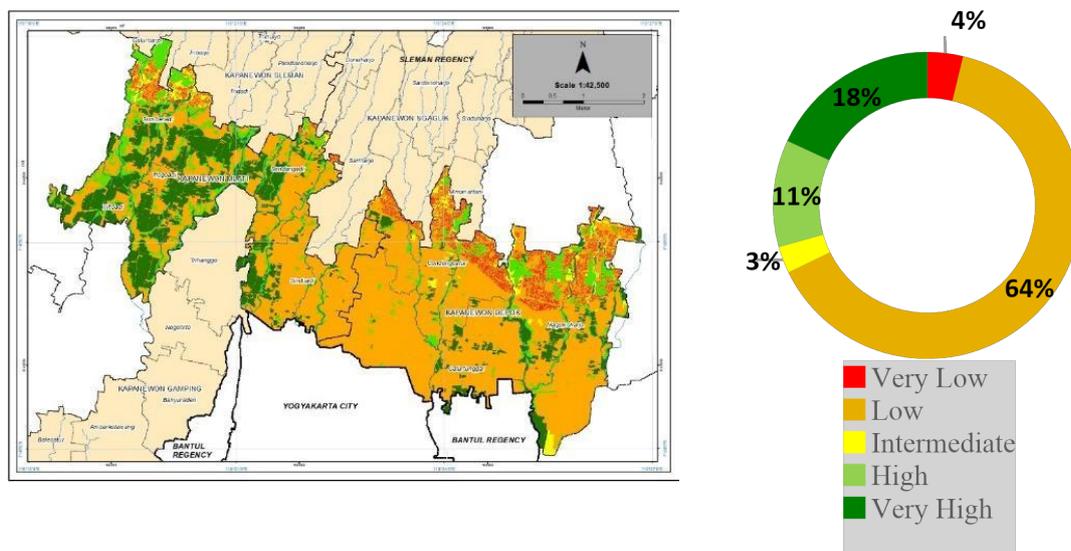


Fig. 3. Map and Diagram of Clean Water Supply Ecosystem Services

Climate Regulation Ecosystem Services

Climate regulation depends on biotic factors, mainly vegetation, position, and physiography (elevation and landform) [16]. Areas with dense vegetation located at a highland will have better climate regulation ecosystem services. The effect of good climate regulation ecosystem services will be directly helpful in reducing carbon dioxide emissions and global warming.

Table 7. Area of Climate Regulation Ecosystem Services in Peri-urban Areas of Sleman Regency

Subdistrict/ Village	Class				Total (ha)
	Very Low	Low	Intermediate	High	
Depok	798.98	1378.09	608.74	427.34	3213.15
Caturtunggal	302.76	470.10	186.23	76.54	1035.63
Condongcatur	264.73	357.71	134.98	101.10	858.53
Maguwoharjo	231.50	550.28	287.53	249.69	1319.00
Mlati	449.41	814.90	375.73	1200.28	2840.33
Sendangadi	96.46	160.12	83.03	193.85	533.47
Sinduadi	164.86	297.36	131.03	140.23	733.47
Sumberadi	74.45	135.62	109.06	280.06	599.19
Tirloadi	54.02	104.21	24.10	312.10	494.43
Tlogoadi	59.63	117.59	28.51	274.05	479.77

Total (ha)	1248.40	2192.99	984.47	1627.62	6053.48
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Classifications of climate regulation ecosystem services in Peri-urban areas of Sleman Regency are shown in **Table 7** and **Figure 4**. Based on **Table 7**, climate regulation service from most areas in the Depok Sub-district is classified as Low Class. The climate regulation ecosystem services that Mlati Subdistrict can provide are mostly High. This condition is influenced by land use characteristics dominated by built-up land and moderately vegetated land such as yards and mixed farmland.

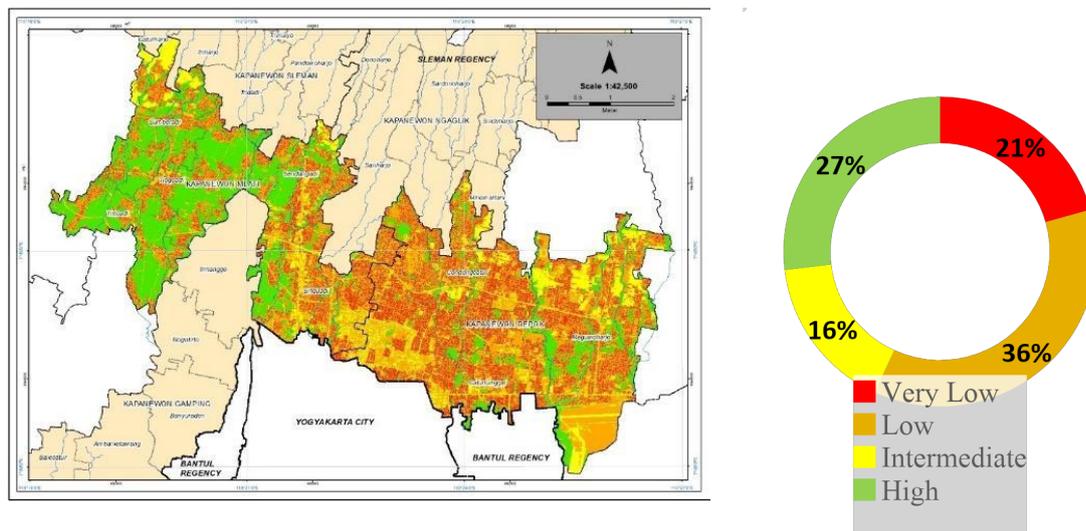


Fig. 4. Map and Diagram of Climate Regulation Ecosystem Services

Regulation of Water and Flood Management

Sleman Regency ecosystem service related to water and flood management regulation is shown in **Table 8** dan **Figure 5**. Based on the table and figure, most of the area has a Low ability to regulate water and flood management service. The area is up to 2.492,02 ha (41 %). The Low support is caused by land uses around the peri-urban area of Sleman Regency, dominated by industrial, trading areas, office, housing, and other built-up areas.

Table 8. Area of Climate Regulation of Water and Flood Management in Peri-urban Areas of Sleman Regency

Subdistrict/ Village	Class				Total (ha)
	Very Low	Low	Intermediate	Very High	
Depok	939.75	1629.37	52.74	591.29	3213.15
Caturtunggal	484.04	470.66	0.30	80.63	1035.63
Condongcatur	240.87	464.19	12.27	141.19	858.53
Maguwoharjo	214.84	694.52	40.17	369.46	1319.00
Mlati	649.10	862.65	2.92	1325.65	2840.33
Sendangadi	148.03	169.47		215.96	533.47
Sinduadi	284.81	297.36		151.30	733.47
Sumberadi	59.94	172.82	1.93	364.49	599.19
Tirtoadi	73.06	104.21	0.93	316.23	494.43
Tlogoadi	83.26	118.79	0.06	277.67	479.77
Total (ha)	1588.86	2492.02	55.67	1916.94	6053.48

Domination of built-up areas reduces water catchment area [17]. The vast built-up area increases runoff potency and decreases water recharge into the soil. Therefore, the capability of ecosystem service of this peri-urban area on the regulation of water and flood management becomes low. Similar research was also conducted on mangrove ecosystems in the coastal areas of Pekalongan, where the regulatory services of mangrove ecosystems protect settlements from the threat of inundation flooding [18].

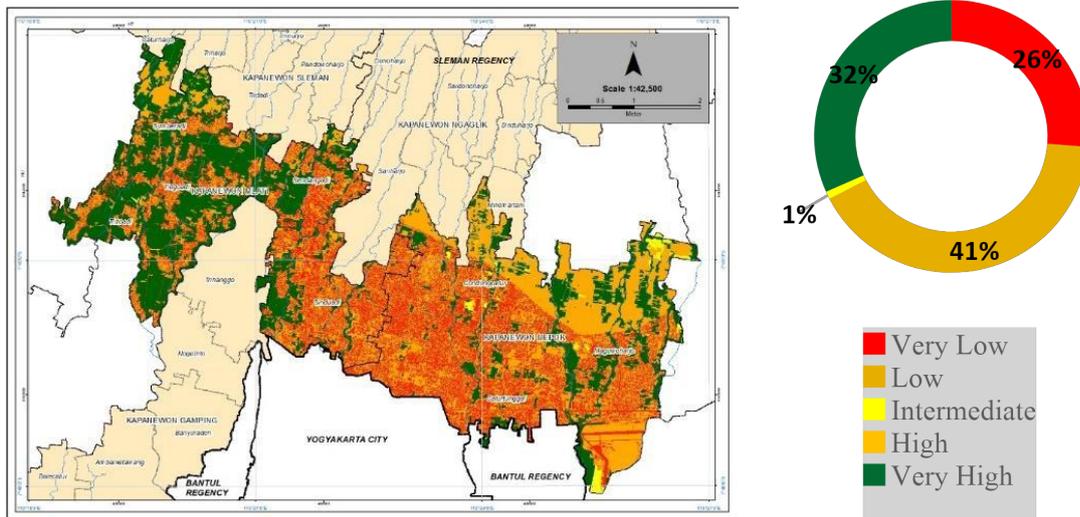


Fig. 5. Map and Diagram of Regulation of Water and Flood Management

Cultural Services

Cultural Ecosystem Services of Shelter and Space

Ecosystems provide positive benefits for humans, especially space to live and prosper. This living space is supported by high land capability and suitability, thus supporting life socially, economically, and culturally. Ecosystem services as a place to live and social living space are strongly influenced by physical and geographical environmental conditions and more significant regional development opportunities.

Table 9. Area of Cultural Ecosystem Services in Peri-urban Areas of Sleman Regency

Subdistrict/ Village	Class				Total (ha)
	Low	Intermediate	High	Very High	
Depok	30.16	427.94	744.66	2010.39	3213.15
Caturtunggal	0.14	61.49	182.11	791.89	1035.63
Condongcatur	5.10	90.92	210.43	552.07	858.53
Maguwoharjo	24.92	275.54	352.12	666.43	1319.00
Mlati	8.77	923.47	366.52	1541.56	2840.33
Sendangadi	0.57	136.40	73.17	323.33	533.47
Sinduadi		108.67	119.95	504.85	733.47
Sumberadi	8.20	233.69	126.05	231.24	599.19
Tirloadi		233.83	19.61	240.99	494.43
Tlogoadi		210.87	27.74	241.16	479.77
Total (ha)	38.93	1351.42	1111.18	3551.96	6053.48

The calculation of cultural ecosystem services for residence and living space in the Peri-urban area of Sleman Regency, specifically Depok Subdistrict and Melati Subdistrict, in **Table 9** shows that 3551.96 ha of the total area of 6053.48 ha or 59% of the total area (**Figure 6**) is used for settlements, educational facilities, health, and trade industries. The land's morphology, primarily plains, facilitates mobility, so it is very supportive in providing settlements and other public facility buildings.

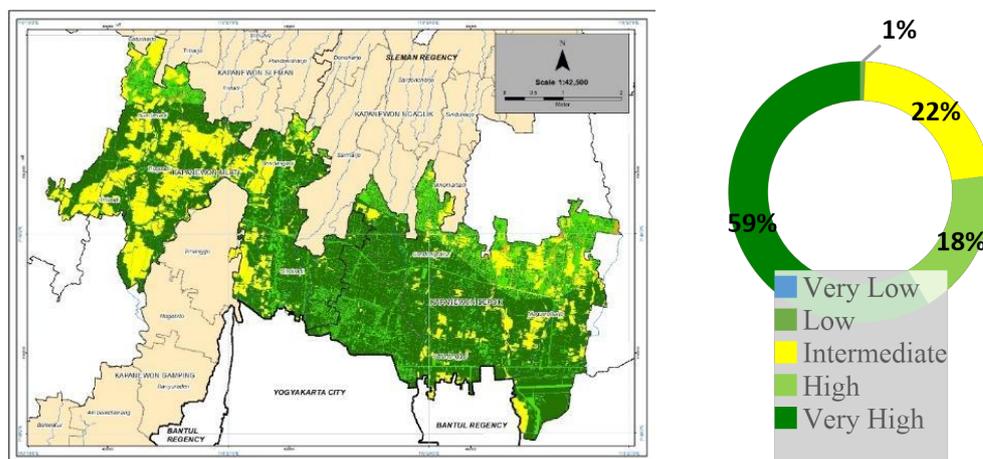


Fig. 6. Map and Diagram of Cultural Ecosystem Services of Shelter and Space

1.1.1 Biodiversity Services

Ecosystem Services Supporting Biodiversity

Supporting Biodiversity services encompass land-contented biodiversity and land-formed biodiversity. The service is a start for the emergence of various ecosystem services that the area can fulfill. The performance of supporting biodiversity shows the capability of an area or an ecosystem to support the sustainability of an ecosystem, both related to protester form and soil maintenance or sustainability of vegetation and organisms in the ecosystem. Most of the capability of the areas in peri-urban at Sleman area on ecosystem services supporting biodiversity is Very Low (**Table 10** and **Figure 7**), both the Depok sub-district and Mlati sub-district. The areas with Very Low support for biodiversity have low vegetated land use.

Table 10. Area of Ecosystem Services Supporting Biodiversity in Peri-urban Areas of Sleman Regency

Subdistrict/ Village	Class				Total (ha)
	Very Low	Low	Intermediate	High	
Depok	2069.52	310.32	595.46	237.85	3213.15
Caturtunggal	966.81	0.25	68.25	0.31	1035.63
Condongcatur	490.99	115.55	189.69	62.30	858.53
Maguwoharjo	611.72	194.52	337.52	175.24	1319.00
Mlati	1458.11	66.04	1165.47	150.70	2840.33
Sendangadi	312.83	10.34	193.55	16.75	533.47
Sinduadi	598.91		134.56		733.47
Sumberadi	152.09	54.35	260.53	132.22	599.19
Tirloadi	185.24		309.18		494.43
Tlogoadi	209.04	1.35	267.65	1.74	479.77
Total (ha)	5124.63	1981.04	4376.48	4433.93	15916.09

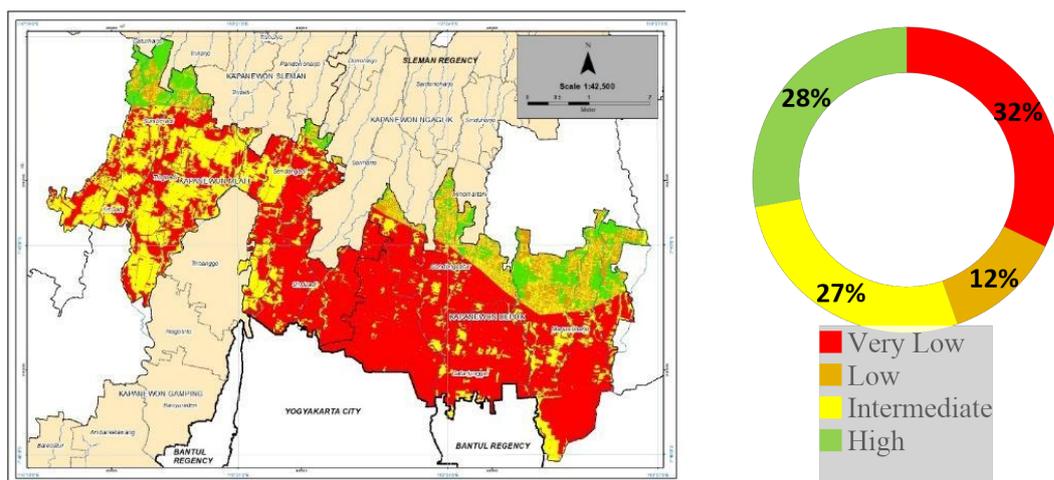


Fig. 7. Diagram of Ecosystem Services Supporting Biodiversity

Spatially, the valuation of ecosystem services in peri-urban areas depends on the identified land use types. Each land use type contributes a specific value to each type of ecosystem service. The type of land use in the form of irrigated rice fields will have a high score on food provisioning ecosystem services, while the cultural ecosystem services for residents will have a low score. The determination of this score comes from expert discussions, the results of which are listed in the Ecosystem Services-Based Environmental Support and Capacity document. The detailing of land use aims to provide more detailed information on the ecosystem services assessment. Ecosystem service performance assessment can support policymakers in developing appropriate, targeted, and sustainable plans, programs, and policies [19].

Peri-urban areas are identical to urbanization processes that can change the role of ecosystem services for human life; land use changes can reduce the value of ecosystem services providing, regulating, and biodiversity [20]. Ecosystem services that provide food and clean water show a similar pattern, with the dominance of low ecosystem service performance values. Depok Sub-district, with the dominance of built-up areas, in the form of settlements, education, hospitals, trade, and services, does not support the provision of food and clean water sources. Whereas in Mlati Sub-district, many rice fields still function as a source of high food and clean water supply. Ecosystem services that regulate climate, water management, and flooding also depend on the character of the type of land use. Depok sub-district, dominated by built-up areas, has low to very low regulating services. Whereas the Mlati sub-district still has vegetated areas so high regulating services.

An interesting pattern is found in the cultural services of residence and living space, with a very high ecosystem service value. This follows the character of peri-urban areas where there is a lot of land conversion, from vegetated to built-up land. In contrast, ecosystem services supporting biodiversity have a very low value due to the lack of vegetated land as a natural habitat for various plants and animals. Research conducted [21] in the peri-urban Chatra Wetland area shows that biodiversity ecosystem services are also in the Low category, so attention and efforts are needed to restore ecological conditions in the peri-urban area, considering that this area is prone to land conversion.

4 Conclusion

The performance analysis of ecosystem services in the Sleman district's peri-urban area varies in the Very Low to Very High categories. These category values indicate that evaluation and regulation are needed to utilize ecosystems in peri-urban areas. The condition of the peri-urban area has an impact on very low biodiversity support services. Peri-urban areas with the dominant land use in built-up land make cultural services a very high category. The characteristics of cities in peri-urban areas make climate regulation, water management, and flooding services low due to the emergence of urban heat islands and limited water catchment areas. Likewise, ecosystem services that provide food and clean water in the peri-urban area of Sleman Regency are categorized as low. This is influenced by the high phenomenon of land conversion from vegetated land to built-up land in the peri-urban area of Sleman Regency. This research can be further developed by adjusting the field conditions and predicting land use change.

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