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Assessment of Food Supply Ecosystem Services and Water Supply Ecosystem Services to Optimise Sustainable Land Use Planning in Samin Watershed, Central Java, Indonesia

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ABSTRACT

This research aims to analyze ecosystem services providing food and water as a basis for sustainable land use planning in the Samin watershed. This type of research is a descriptive survey. This research describes spatially the ecosystem services of providing food and water in the research area, which is processed using a Geographic Information System (GIS) with output in the form of an ecosystem services map. The research results show that the Samin watershed Ecoregion is mostly (54%) in the form of Fluvio-volcanic Plain Pyroclastic material and the land cover is dominated by irrigated rice fields (43.69%) influencing the high level of food supply ecosystem services in the Samin watershed, so that the majority (59%) provision of ecosystem services including food is very high. Most of the Samin watershed water supply ecosystem services (72%) are in the high category, influenced by ecoregional conditions and land cover of the Samin watershed. The land cover of the Samin watershed is mostly (72.96%) in the form of land cover which functions for water absorption, and the density of the land cover is mostly (49.721%) including very high density. The research results can be used as a reference for the government in determining policies towards sustainable land use.

1. INTRODUCTION

Ecosystems provide potential that can be utilized to improve the quality of life of humans and other living things. The benefits directly and indirectly obtained by humans from ecosystems to meet their needs are called ecosystem services [1]. Ecological processes in ecosystems will produce benefits through ecosystem services that contribute to the quality and well-being of human life [2]. Humans can utilize ecosystem services to meet their needs, including ecosystem services provision, regulatory ecosystem services, supporting ecosystem services, and cultural ecosystem services [3, 4]. One strategy that can be used for environmental management is to increase public understanding of the importance of environmental ecosystem services [5].

The negative pressure of regional development on ecosystems exceeding the carrying capacity of ecosystems can result in an imbalance between supply and demand for ecosystem services [6]. Ecosystem services can represent the condition of the environment's carrying capacity and carrying capacity. The ecosystem services approach measures environmental carrying capacity [7]. The higher the ecosystem services, the better the environment's carrying capacity and accommodating Capacity. This is because ecosystem services contribute to ecosystems' overall health and productivity, allowing more fantastic population support without destroying habitats [3]. As human population and economic activity increase, so does the demand for ecosystem services, potentially exceeding the environment's carrying capacity. This can lead to ecosystem degradation, which can reduce the provision of ecosystem services and threaten human well-being [8]. Conversely, ecosystem conservation and restoration can help maintain or even increase the carrying capacity of ecosystems and provide ecosystem services [9].

Over the past 100 years, climate change [10], environmental pollution [11, 12], ecological damage [13, 14], and land-use change [15] have had enormous impacts on ecosystem function and consequently led to a significant reduction in ecosystem services, impacting human survival [16, 17]. Human activities that do not pay attention to the environment and do not apply the principles of sustainable development cause serious environmental damage. Severe damage caused in some ecosystems causes ecosystems to become irreversible and their carrying capacity to be exceeded. Therefore, researchers' attention to the function of ecosystem services is increasing [4].

Food and water supply ecoregion conditions and good land cover influence the quality of ecosystem services. The quality of land cover and ecoregion conditions will affect the quality of ecosystem services [18]. The availability, needs and quality of ecosystem services are, among others, influenced by changes in land use and land cover. Increasing population and urbanization in urban areas will decrease the quality of ecosystem services. The quality of freshwater ecosystem services is also affected by changes in land use and land cover [19].

Land use planning that uses the basis of ecosystem services can optimize planning results to realize sustainable land use.

Policymakers should pay attention to carrying capacity [20] and changes in ecosystem services in policy formulation and planning [6, 21, 22]. However, regional characteristics, such as watersheds and ecoregions, must be considered in assessing carrying capacity and ecosystem services in sustainable land use planning [23]. Watersheds play an essential role in Ecosystem Services. One of the main impacts of watershed problems on ecosystem services is a decrease in water quality. Pollution from agricultural runoff, industrial waste, and other sources can degrade water quality, making it less suitable for drinking, irrigation, and other uses. This can lead to decreased provision of services, such as water supply and storage, that are essential for human well-being and economic development [13, 24].

Samin watershed is one of the sub-watersheds of the Bengawan Solo River in Java, Indonesia. Samin watershed is one of 282 watersheds in Indonesia in critical condition [25]. Currently, the sustainability of forest resources in the upper reaches of the Samin watershed is threatened due to human exploitation of the forest. Land use in the Samin watershed has undergone significant changes, with increased settlement area and reduced forest area [26-28]. Very high population pressure on land causes complex problems in the Samin watershed, which has an impact on decreasing the watershed's carrying capacity function and resulting in environmental problems such as floods, droughts, landslides, and critical land [29]. Flood events have been recorded in recent years, namely in 2013, 2014, 2015 and 2016. The complexity and complexity of the relationship between abiotic-biotic and cultural components in the ecosystem in the Samin watershed is caused by the watershed's multipurpose and multiple conflicts of demand or needs [30]. The natural ecosystem in the Samin watershed overlaps with artificial ecosystems / social ecosystems, so many consequences arise due to the interrelationship between natural ecosystems and social ecosystems in the Samin watershed. In order to prepare regional spatial planning, considering that the Samin watershed is part of the upstream Bengawan Solo watershed, which has an essential function as a water catchment area, it is necessary to analyze the carrying capacity of the environment so that land use in the Samin watershed is following its carrying capacity. Ecosystem services can represent the condition of the carrying capacity of the environment. The results of the environmental carrying capacity analysis based on the analysis of ecosystem services will be used as a basis and direction for land use of the Samin watershed so as not to cause environmental problems, which in turn will affect the balance of the ecosystem, especially in the upstream Bengawan Solo watershed. Evaluation of ecosystem services assessments is urgently needed to support better ecosystem management and reduce the increasing scarcity of ecosystem services over time [31].

The Samin watershed problem is a watershed problem around the world. Efforts to solve these problems are through ecosystem service analysis. Ecosystem Services Analysis has never been carried out in the Samin watershed. The approach used in the analysis of ecological services in other studies does not consider the integration and interaction between approaches, such as the research of Anjinho et al. [32], which examined the impact of land-use change on aquatic ecosystem services. Furthermore, Varyvoda and Taren [33] research analyzes food supply ecosystem services. Analysis that only focuses on one approach may not be able to answer very complex watershed problems. So this research seeks to combine ecoregion analysis, land cover, water and food supply ecosystem services to solve the very complex problems of the Samin watershed. Similar efforts can be made in other watersheds worldwide to reduce degradation, improve environmental quality and comfort, and preserve ecological values and biodiversity [34-36].

The objectives of this study are to (1) analyze the ecoregion and land cover in the Samin watershed, (2) analyze the ecosystem services for the supply of water in the Samin watershed, (3) analyze the services of the food supply ecosystem of the Samin watershed, and (4) analyze the land use planning based on the services of the water and food supply ecosystem.

2. METHODS

The location of the study is the Samin watershed, which is part of the Karanganyar Regency and Sukoharjo Regency, Central Java Province, Indonesia. The study site is astronomically located at 7° 33′ 57" S - 7° 42′ 54" S and 110° 52′ 27" E - 111° 11′ 27" E. The Samin watershed is part of the upstream Bengawan Solo watershed, which has an essential function as a water catchment area, so it is necessary to analyze ecosystem services so that land planning in the Samin watershed follows its Carrying Capacity.

This type of research is a descriptive survey, collecting a large amount of qualitative and quantitative data simultaneously. Research results are analyzed descriptively using a spatial approach, which is an approach to understanding specific symptoms on the earth's surface that pays attention to the position of space in the analysis [37]. This study spatially described ecosystem services for food and water supply in the research area, whose treatment was using a Geographic Information System (GIS) with output as a map of ecosystem services.

The study population is the entire ecoregion, and a saturated sampling technique covers land cover in the Samin watershed. The research was conducted through three stages, namely, pre-field stage, field stage, and post-field stage. The primary data for ecosystem services assessment are ecoregion, land cover and land cover density.

2.1 Analysis of ecoregion and land cover in the Samin watershed

Ecoregion analysis is carried out through overlays of geological maps and landform maps. The Geological Map of the Samin watershed is sourced from the Systematic Geological Map of Indonesia Ponorogo, Surakarta and Giritontro Sheets on a Scale of 1:100,000. Meanwhile, the Land Formation Map is sourced from SIDIGI (Results Dissemination Information System and Geospatial Information) P3E Java.

Land cover analysis is carried out through the following stages: (a). Digital interpretation of Landsat 8 imagery and land cover classification using Supervised Classification, (b). An image accuracy test using a matrix table of image interpretation accuracy tests aims to test the accuracy of image interpretation results and field data verification (c). Land cover data verification is conducted by conducting a field survey at a location determined as a sample (d). Match the data from image classification to data verification, then reinterpreting, and (e). Analyze land cover.

2.2 Land cover density analysis

Land cover density analysis is carried out as a basis for ecosystem service analysis. The stages in the land cover density analysis are as follows:

a) Vegetation transformation analysis using NDVI (*Normalized Difference Vegetation Index*) land cover from Landsat 8 imagery, with the formula:

$$NDVI=\frac{(NIR-VIS)}{(NIR+VIS)}$$

Description:
NDVI=Vegetation index value
NIR=Near-infrared radiation value
VIS=The radiation value of red waves appears

b) Classification of vegetation index values obtained from NDVI transformation (the closer to number 1, the higher the density).

c) The land cover density from NDVI analysis was matched to the land cover density in the field and reinterpreted.

d) Analyzing land cover density.

2.3 Ecosystem services analysis

Determination of environmental ecosystem services is carried out by:

1. Establish ecosystem services proxies through look-up tables for each land cover class.
2. Develop ecosystem service proxies through expert judgment that assesses the ecosystem service potential of each land cover class.
3. Establish ecosystem service proxies by identifying relationships between ecosystem processes and services produced.
4. Extrapolate ecosystem services data collected through primary surveys and mapped through cartographic processes.

Experts assess ecosystem services by filling out a questionnaire prepared to assess each ecosystem service's weight from each type of ecoregion and land cover. The distributed questionnaire contained a table that illustrated the comparison of the scale of ecosystem service assessment for each land cover class and type of ecoregion. The questions are based on theory and knowledge, observations, and expert experiences on factual conditions. Mapping ecosystem services with a land-use-based proxy approach that uses expert judgment from multiple disciplines can produce a comprehensive assessment. Expert assessments qualitatively and quantitatively can be considered as data so that they can be used as weights on various land classes.

Using the reference to the Guidelines for the Preparation of Carrying Capacity and Environmental Carrying Capacity by the Ministry of Environment and Forestry of the Republic of Indonesia, the determination of environmental ecosystem services is weighted 28% for landscapes (ecoregions), 12% for natural vegetation types (vegetation density), and 60% for land cover. After obtaining the score and weight, the environmental service performance index was calculated using the Simple Additive Weight method.

2.4 Land use planning

Land use planning is carried out by making zoning based on the part of the watershed. Each zoning is tabulated by entering parameters such as water carrying capacity, land balance carrying capacity, food supply ecosystem services, and water supply ecosystem services. The results of the tabulation are used as a reference in the preparation of land use directives.

3. RESULT AND DISCUSSION

3.1 Ecoregion and land cover of Samin watershed

The ecoregion is a geographical area with general characteristics of landforms, soil, water sources, climate, animals and vegetation throughout the earth's biosphere. The division of ecoregions in the Samin watershed is presented in Table 1.

Based on Table 1, the Samin watershed has a diverse ecoregion. Based on the type and characteristics of landforms, the subdivision of the Samin watershed ecoregion with an area of 32,378.88 ha is divided into six ecoregions spread across two districts and 12 sub-districts, as presented in Figure 1.

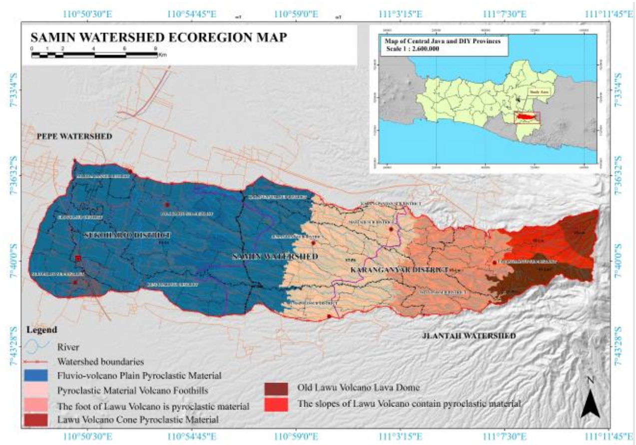

Figure 1. Samin watershed ecoregion map

Table 1. Ecoregion division in Samin watershed

No.	Ecoregion	Code	Watershed Slopes	Area (ha)
1	Fluvio-volcanic plains pyroclastic material	F2-Fv	Downstream Watershed	13460,98
2	Fluvio-volcanic plains pyroclastic material	F2-Fv	Central Watershed	4136,12
3	Plateau of the Foot of the Volcano Pyroclastic Material	V7-Pk	Upstream Watershed	1925,92
4	Plateau of the Foot of the Volcano Pyroclastic Material	V7-Pk	Central Watershed	4797,22
5	the Foot of the Volcano Pyroclastic Material	V6-Lw	Upstream Watershed	4881,91
6	Lawu Volcano Cone Pyroclastic Material	V3-Lw	Upstream Watershed	707,06
7	Old Lawu Vulcano Lava Dome	V1-LwT	Upstream Watershed	1237,66
8	The Slope of Lawu Volcano contain Pyroclastic Material	V5-Lw	Upstream Watershed	1232,02
	Total Area			32378,88

Ecosystem services can be determined by endogenous factors and the dynamics of exogenous factors, which are reflected by two components, namely ecoregion conditions and land cover (land cover/land use) as estimators or proxies [20]. Ecoregion maps contain information about landscape characteristics in the form of geomorphology and morphogenesis that can describe the boundaries of these characteristics so that differences can be seen. Ecoregion maps can indicate ecosystem functions that may be dominant in a particular ecoregion because each type of ecoregion forms and has ecosystems and ecosystem functions according to their respective characteristics. Ecoregion maps and land cover maps are combined to provide more detailed information for ecosystem services assessments than information based on land cover data alone. The assessment of ecosystem services based solely on land cover is considered to have several shortcomings. Therefore, ecoregion data is used as variables or additional data in addition to land cover data to determine the relationship between ecosystem processes and services and produce maps of ecosystem services. The condition of the Samin watershed ecoregion is mostly (54%) in the form of Fluvio-volcanic Plains Pyroclastic Material (F2-Fv), affecting the high service of food supply ecosystems in the Samin watershed. Ecoregion F2-Fv is originally a volcanic landform process in volcanic plains through volcanic activity originating from tuff deposits. This region has a slope to undulating topography, and material deposits from Mount Lawu, which have high fertility, allow for the development of agricultural land as food producers.

Land cover is a biophysical cover on the earth's surface that can be observed due to human regulation, activities, and treatment carried out on certain types of land cover to carry out production, change, or maintenance activities on land cover [38]. Samin watershed has a lowland morphology with land cover including buildings, settlements, secondary highland forests, grasslands, irrigated rice fields, rainfed fields, dry land, plantations, and pine forests. Land cover information was obtained based on the results of the interpretation of Landsat 8 imagery coverage of the Samin watershed in 2021. The area of the land cover of the Samin watershed can be presented in Table 2. The spatial distribution of land cover of the Samin watershed is presented in Figure 2.

The most oversized land cover in the Samin watershed is irrigation rice fields, with an area of 14,158.48 Ha (43.69%); next is land cover in the form of settlements, with an area of 8,650.03 Ha (26.69%). The narrowest land cover is rainfed rice fields with an area of 9.5 Ha (0.03%).

Table 2. Samin watershed land cover in 2021

No.	Land Cover	Area (ha)	Percentage (%)
1.	Building	112.60	0.35
2.	Secondary Upland Forest	427.13	1.32
3.	Pine Forests	1520.21	4.69
4.	Empty Land	42.82	0.13
5.	Grass Land	94.67	0.29
6.	Plantation	1775.34	5.48
7.	Settlement	8650.03	26.69
8.	Irrigation rice fields	14158.48	43.69
9.	rainfed rice fields	9.51	0.03
10.	Shrubs Land	1323.06	4.08
11.	River/ Water bodies	88.28	0.27
12.	Dry Land	4205.40	12.98
Total		32407.53	100

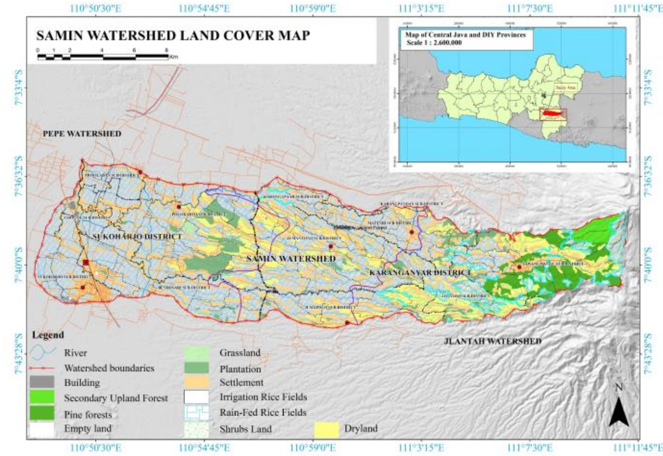

Figure 2. Samin watershed land cover map

3.2 Food supply ecosystem services

Food supply ecosystem services provide the benefits of providing food, namely everything that comes from biological sources (plants and animals) and water (fish), both processed and unprocessed, which is intended as food or beverages for human consumption. Ecosystem services for providing food are grouped into food obtained directly from nature (for example, caught fish products, wild food plants, and forest products that can be used as food) and food obtained from human cultivation that relies on environmental support (for example, agricultural products).

The study area mostly has very high food supply ecosystem services, with 19,082.30 Ha (59%) and moderate food supply ecosystem services, with 10,592.21 Ha (33%). Based on its spatial distribution, the downstream watershed of 8,845.99 Ha (66%) has very high food supply ecosystem services, and 4,030.17 Ha (30%) areas have moderate food supply ecosystem services. In the central watershed, 6034.49 Ha (68%) of the area is included in the high food supply ecosystem services category. In contrast, the upstream watershed, which includes very high food supply ecosystem services, covers an area of 4,201.82 (42%). Samin watershed food supply ecosystem services are presented in Table 3 and Figure 3.

Land cover conditions affect the high ecosystem services and food supply in the Samin watershed. The land cover density in the Samin watershed is mostly (49.721%) including very good density, and 29.219% of the area has a good land cover density. The large land cover in the form of irrigated rice fields in the Samin watershed (14,158.48 Ha or 43.69%) and moor (4,205.40 Ha) affects the high level of food supply ecosystem services in the Samin watershed. Irrigated rice fields are the dominant land cover in the downstream Samin watershed. Land cover conditions affecting ecosystem services for food supply in the Samin watershed align with research [1, 39], which states that land use and land cover affect ecosystem services. Changes in land cover, such as deforestation, urbanization, and agricultural expansion, can significantly impact ecosystem services and food security [33, 40, 41]. Experts on land functions, from production land to organizational land and tourism, often occur in the Samin watershed, which can potentially reduce the value of ecosystem services providing food.

Table 3. Samin watershed food supply ecosystem services in 2021

No.	Watershed Section	Sub-District	Area of Ecosystem Services (Ha)					
			Very Low	Low	Moderate	High	Very High	Total
1	Downstream	Bendosari	0.00	1.66	933.70	22.67	2148.55	3106.58
		Grogol	0.00	48.09	219.45	14.10	487.76	769.40
		Jumantono	0.00	2.26	154.46	94.46	330.58	581.75
		Mojolaban	0.00	1.22	164.76	7.69	632.24	805.92
		Polokarto	0.00	6.51	1897.74	359.76	3967.25	6231.25
		Sukoharjo	0.00	25.84	660.05	0.58	1279.61	1966.08
		Total	0.00	85.57	4030.17	499.25	8845.99	13460.98
2	Central	Bendosari	0.00	0.00	117.82	8.90	301.93	428.65
		Jumantono	0.00	0.00	1303.51	79.11	2951.01	4333.63
		Jumapolo	0.00	0.00	458.32	3.38	892.53	1354.23
		Karanganyar	0.00	0.00	239.42	0.72	485.45	725.58
		Karangpandan	0.00	0.00	7.88	0.00	37.47	45.35
		Matesih	0.00	0.00	491.60	0.00	954.65	1446.24
		Polokarto	0.00	0.05	149.58	38.58	411.45	599.65
		Total	0.00	0.05	2768.12	130.69	6034.49	8933.34
3	Upstream	Jatiyoso	0.00	15.39	395.18	412.72	810.06	1633.35
		Jumantono	0.00	0.00	243.52	0.02	524.31	767.85
		Jumapolo	0.00	0.00	342.50	68.78	835.52	1246.80
		Karangpandan	0.00	0.00	2.29	1.73	9.09	13.12
		Matesih	0.00	0.00	355.23	22.27	757.51	1135.01
		Tawangmangu	0.00	61.40	2455.21	1406.51	1265.32	5188.43
		Total	0.00	76.78	3793.92	1912.03	4201.82	9984.56
Total Samin watershed			0,00	162,40	10592.21	2541.97	19082.30	32378.88

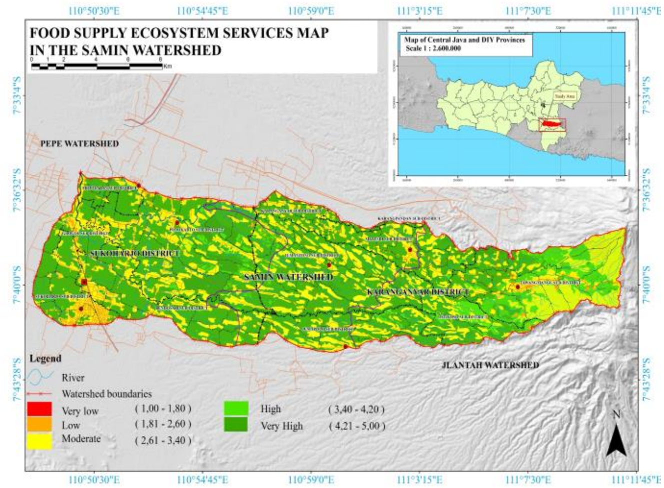

Figure 3. Samin watershed food supply ecosystem services map

3.3 Water supply ecosystem services

Water supply ecosystem services describe the availability of clean water from both surface and groundwater (including its storage capacity) and rainwater that can be used for domestic, agricultural, industrial, and service purposes. The concept of water provider ecosystem services is the level at which an ecosystem can ensure the availability of water that can support the life of creatures on earth sourced from surface water, groundwater, and rainwater that can be used for domestic, agricultural, industrial and service purposes. The provision of clean water services by ecosystems can be influenced by rainfall conditions, slopes, soil layers, and rock structures that can store water (aquifers), as well as land cover conditions that affect groundwater storage systems. Samin watershed water supply ecosystem services are presented in Figure 4.

Water supply ecosystem services are water availability for use, that is, the maximum amount of water that can be extracted sustainably. The provision of water services is strongly influenced by rainfall conditions and soil or rock layers (aquifers) storing water, as well as factors that can affect groundwater storage systems such as land cover. In the hydrological cycle, water supply ecosystem services are water extraction through groundwater utilization, water absorption by plant roots, and surface water availability. Water is an essential natural resource for the survival of humans and other living things and must be maintained to ensure its sustainability. The need for water availability is the only environmental service that can be felt equally throughout Indonesia. In addition, water plays an essential role in the sustainability of other environmental services. One example is food supply services, which show that water availability is closely related to the growth and yield of food crops and affects the productivity of livestock and fisheries because all living things need water.

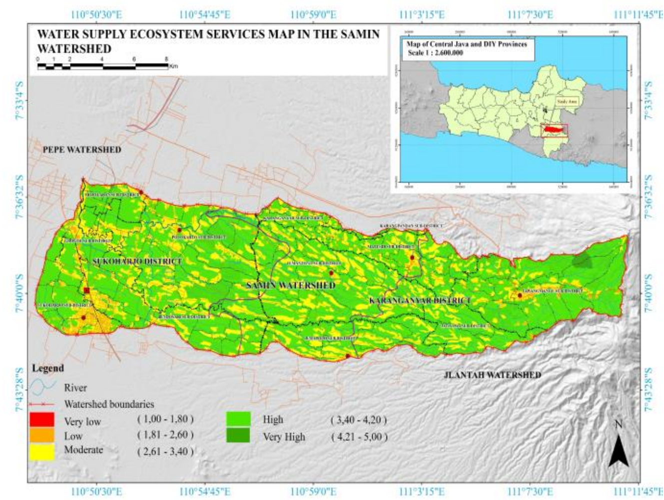

Figure 4. Map of Samin watershed water supply ecosystem services in 2021

The analysis showed that most of the Samin watershed area has high water supply ecosystem services covering an area of 23,326.13 Ha (72%) and moderate water supply ecosystem services covering an area of 8,657.03 Ha (27%). High-class water supply ecosystem services mean the area can be categorized as having a high water availability. The ecoregion and land cover conditions of the Samin watershed influence the high water supply ecosystem service in Samin. The land cover of the Samin watershed is mostly (72.96%) in the form of land cover that functions for water absorption and only 27.04% in the form of settlements. The condition of land cover density in the Samin watershed, most of which (49.721%) includes perfect density, and 29.219% including good land cover density, affects the high ecosystem services of clean water supply in the Samin watershed. Land use and land cover changes will affect the hydrological balance [42-44] and water supply ecosystem services. A low water supply can result in low yields, thus affecting the availability of food [45].

3.4 Land use planning

An analysis of ecosystem services of food supply and water supply is used to determine the direction of the Samin watershed's land use, as presented in Table 4. The land use planning system is able to achieve a balance between the ecological environment and sustainable development [46]. Landscape planning for effective management of ecosystem services is the most important task because each natural territorial complex has its characteristics in the context of the structure and type of landscape and, therefore, its approach to zoning [47]. Land Use Planning Samin Watershed is divided into three zones: the Upstream Watershed, the Central Watershed, and the Downstream Watershed. The upstream area zone of the Samin watershed is intended for protected areas with land use in the form of production forests, protected forests and nature reserves. Meanwhile, the Central and Downstream zones are intended to use cultivated and protected land such as rice fields, moor, production forests, protected forests, and nature reserves.

3.5 Discussion

Samin watershed is one of the watersheds in Indonesia that has complex problems. The problems of Samin watershed include forest exploitation by humans for agriculture and settlements and a decrease in the function of land-carrying capacity. These conditions make Samin watershed one of Indonesia's watersheds in critical condition [29]. Efforts to solve these problems include analyzing ecosystem services as a basis for sustainable land use guidelines. Land cover and ecoregion data are the primary data for exploring ecosystem services. The ecoregion approach is crucial to understanding how different ecoregions contribute to various ecosystem services [48]. The types of land cover found in Samin watershed include buildings, settlements, secondary highland forests, grasslands, irrigated rice fields, rainfed rice fields, dry land, plantations, and pine forests. The type and area of land cover will affect the level of food and water supply ecosystem services.

The food supply ecosystem services in the Samin watershed is classified as very high. The main factor in the high food supply ecosystem services is due to the area of agricultural land that dominates. Agricultural land in the Samin watershed includes rice fields and dry fields. Food supply ecosystem services are distributed mainly in the Samin watershed's downstream area. The downstream area of the Samin watershed is dominated by the Fluvio-volcano plain pyroclastic material Ecoregion, which is considered very fertile and suitable for developing agricultural regions. The Fluvio-volcano plain pyroclastic material Ecoregion Ecoregionted by the type of Volcanic soil formed from material originating from volcanic eruptions, which are generally fertile [49]. This land is suitable for agricultural land and can support the growth of various plants.

Moreover, the Fluvio-volcano plain pyroclastic material Ecoregion water resources because it is passed by rivers, which are very important for agriculture [50]. The river flow in this area is used as a source of irrigation water, which supports the growth of plants and plantations. The plants in the downstream area are dominated by plants that require a lot of water, namely rice. In contrast, the Central and Upstream Areas of the Samin watershed are dominated by dry land plants such as tubers and vegetables. The downstream and Central areas with the Ecoregion Fluvio-volcano plain pyroclastic material are directed towards developing sustainable agricultural land to meet the food needs of the community living in the Samin watershed by considering sustainability and the environment. The Samin watershed dramatically benefits from its location at the foot of the volcano and the fluvial-volcanic plain, so this condition can support high food supply ecosystem services. The physical condition of the ecoregion only correlated with the value of food supply ecosystem services. This correlation is also shown by the results of Febriarta's research [51] conducted in Semarang Regency. The results of his study show that the class of high food supply ecosystem services is spread across the Ecoregion of the Foot of the Volcano, Slopes of the Volcano, and Fluvio-volcanic Plains.

Table 4. Samin watershed land use planning based on food supply and water supply ecosystem services

No	Watershed Section	Water Carrying Capacity	Land Balance Carrying Capacity	Food Supply Ecosystem Services	Water Supply Ecosystem Services	Land Use Planning
1	Upstream	Surplus	Deficit	Medium - Very High	Medium- High	Production Forest, protected forest and nature reserve
2	Central	Surplus	Deficit	Medium - Very High	Medium- High	Rice fields, Dryland, production forest, protected forest, nature reserve
3	Downstream	Surplus	Deficit	Medium - High	Medium- High	Rice fields, dry land, production forest, protected forest, nature reserve

Food supply ecosystem services are interrelated with water supply ecosystem services. Low water ecosystem services result in low crop production, thus affecting food availability [46]. Water supply ecosystem services in the Samin watershed are dominated by high classes influenced by land cover type and vegetation density. Viewed from the ecoregion as a whole, the Samin watershed area is located on a volcanic slope, making it easy to plant various types of vegetation. The characteristics of the ecoregion that support high water supply ecosystem services in the Samin watershed are reinforced by the research results of Febriarta et al. [51] and Widodo et al. [52], which state that most areas with high potential for clean water provision are located in the Volcanic Slope, Volcanic Foot, Alluvial Plain, and Fluvio-volcanic Plain ecoregions. Volcanic processes significantly influence this ecoregion, which consists mostly of alluvial material, which can form potential aquifers due to its flat morphology. This condition results in relatively shallow groundwater reserves or availability (<10 m), creating groundwater reservoirs or hydrogeological basins [51, 52]. The upstream area of the Samin watershed is dominated by areas with high vegetation density and forest land cover types, making the value of the water supply ecosystem service class high. Forest land cover is precious because the forest ecosystem uses water through evapotranspiration, which helps regulate hydrological flow to store water in the soil [53]. In the downstream area of the Samin watershed, the Sukoharjo City Center area is dominated by built-up land cover. Hence, the value of the water supply ecosystem service is low.

Currently, the high class dominates the value of food and water supply ecosystem services in the Samin watershed. Future challenges in the Samin watershed are changes in land cover, such as deforestation for tourism development in the Upper Samin watershed and Urbanization in the downstream area, which affects the value of food and water supply ecosystem services in the Samin watershed. Issues related to changes in land use in the Samin watershed have been identified by Rahayu et al. [54] that there is an increase in residential land of 26.8 per year and a decrease in agricultural lands such as rice fields, dry fields, and plantations, where rice fields decrease by an average of 44.76 per year, dry fields decrease by an average of 54.07 per year, and plantation land decreases by 26.82 per year. Efforts to maintain the high value of ecosystem services are through land use planning. Land use planning must consider the area's characteristics so that a zoning-based approach must be applied in the Samin watershed. The upstream zone of the Samin watershed is designated for protected areas with land use in the form of production forests, protected forests, and nature reserves.

Meanwhile, the Middle and Downstream zones are defined for using cultivated land and protected land such as rice fields, dry fields, production forests, protected forests, and nature reserves. The approach that can be used in land use planning is through conservation in reforestation activities (greening), especially in damaged forest areas. Conservation efforts can be carried out on mixed agricultural land by making ridges and terracing. Conservation efforts can be carried out on rice fields by making bench terraces and improving irrigation. Conservation efforts can be carried out on residential land by implementing water absorption technology, such as making absorption wells and bio pore absorption hole technology around residential land [55].

4. CONCLUSIONS

Ecoregion conditions and land cover affect the quality of ecosystem services in the Samin watershed. Food and water supply ecosystem services can be used as a basis for sustainable land use planning. The Samin watershed ecoregion is mostly (54%) in the form of Fluvio-volcanic Plains Pyroclastic material and land cover dominated by irrigated rice fields (43.69%) affecting the high food supply ecosystem services in the Samin watershed so that most (59%) including food supply ecosystem services are very high. Most of the water supply ecosystem services in the Samin watershed are in the high category (72%), influenced by the Samin watershed's ecoregions and land cover conditions. The land cover of the Samin watershed is mostly (72.96%) in the form of land cover that functions for water absorption, and the density of land cover is 49.721%, including very high density. The direction of sustainable land use in the Samin watershed is based on ecosystem services for food supply and water supply, which are adapted to the characteristics of the upstream, middle and downstream watersheds.

The limitation of the study is that in the assessment of ecosystem services using ecoregion data and land cover on a medium scale, therefore it is necessary to conduct further research for the assessment of ecosystem services using a large scale so that it can be used for land use planning at a detailed level. In this study, the parameters used in the assessment of ecosystem services are ecoregion and land cover, so it is necessary to conduct further research by considering other parameters such as social, economic and local knowledge conditions. In addition, this study only analyzes ecosystem services for food supply and water supply. Therefore, it is necessary to analyze other ecosystem services such as supporting ecosystem services, regulatory ecosystem services, and cultural function ecosystem services so that they can be used as a basis for more comprehensive land use planning in the Samin watershed.

Based on the research findings that most of the Samin watershed has very high food and water supply ecosystem services, it can be recommended to the local government (Karanganyar and Sukoharjo Regencies) including (a). Land use planning is to maintain land cover in the form of irrigated rice fields and land cover that functions as water absorption for plantations, pine forests, secondary highland forests, shrubs, and moorlands (b). To improve water supply ecosystem services, land cover in the form of forests must be increased (c). The study's results can be used as a basis for sustainable land use planning because it considers food supply ecosystem services and water supply ecosystem services according to the area's characteristics. Furthermore, the study results can also be applied as land use planning based on food supply ecosystem services and water supply ecosystem services in other watershed areas with the same characteristics as the Samin watershed.

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