FORUM GEOGRAFI
ISSN: 0852-0682 | E-ISSN: 2460-3945
HTTPS://JOURNALS.UMS.AC.ID/INDEX.PHP/FG/

Analysis of Urbanisation's Relationship with Clean Water Supply Ecosystem Services in Sukoharjo Regency, Indonesia

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Citation:
Saputra, A. E., Nugraha, S., Noviani, R. (2023) Analysis of Urbanisation's Relationship with Clean Water Supply Ecosystem Services in Sukoharjo Regency in 2022. Forum Geografi. 37(2), 178-190.

Article history:
Received: 10 February 2023
Accepted: 13 October 2023
Published: 26 December 2023

Abstract

The phenomenon of urban population growth is a global concern which will result in a decrease in the value of ecosystem services in an area. Sukoharjo Regency is an area affected by the development of Surakarta City; therefore, rapid growth is taking place. The objective of this study is to investigate the interplay between urbanization, ecosystem services, and the provision of clean water in Sukoharjo Regency in 2022. The methods used in the study were calculating the percentage of the urban population to determine the level of urbanisation, AHP and overlay to ascertain the ecosystem service score, together with cross-tabulation to establish the relationship between these two variables. The result of this study is that the level of urbanisation produces a pattern that districts in the north tend to comprise a higher level. The clean water supply ecosystem services in Sukoharjo Regency obtained results dominated by the low to medium level. The situation regarding the level of urbanisation and ecosystem services in Sukoharjo Regency reveals a relationship where an increase in the level of urbanisation will reduce the value of ecosystem services.

Keywords: AHP, urbanisation rate, ecosystem services, Sukoharjo Regency.

1. Introduction

The phenomenon of urban population growth is a significant concern. In addition to fertility and mortality, urbanisation is a fascinating process pertaining to population mobilisation. According to Liu *et al.* (2021), urbanisation is an inevitable social and economic development trend. According to the World Bank, by 2021, more than half of the world's population lived in urban areas. In Europe and North America, over 70% of people inhabit urban areas, while in Asia, 52% of the population resides in urban areas. The currents of urbanisation suggest that humanity is shifting to urban living (Grimm *et al.*, 2008).

Indonesia is one of numerous countries that is experiencing an increase in urban population annually. According to the World Bank (2016), between 2000-2010, Indonesia was the third-ranked country in the Asian region in terms of the amount of urban lands after China and Japan. The increase in urban land stood at 1.1% annually, which is consistent with the increasing rate of urbanisation in Indonesia. Urbanisation will have a significant impact on land cover change. Changes in land cover will result in a downward trend in environmental ecosystem services (García *et al.*, 2018). Urbanisation impacts economic, cultural and social development and indirectly decreases ecological quality, notably in the downtown area and its surroundings. In line with urbanisation, increasing population density and building transportation infrastructure in a city that is not environmentally friendly will reduce the supply of ecosystem services and environmental quality, given that ecosystem services are crucial for human survival (Li *et al.*, 2021).

The impact of increasing urbanisation does not only occur in urban development centres, but even the influence of urban areas on ecosystems goes far beyond urban boundaries (García-Nieto *et al.*, 2018). Urban expansion generally occurs when suburban naturally vegetated land is changed into a watertight surface, thereby interfering with natural processes and ecosystem functions (Klimanova *et al.*, 2021). This indicates that areas that previously had significant ecosystem service capabilities and were able to support urbanisation within a specified time when they crossed the threshold of ecosystem services, would experience a reduction. Chen *et al.* (2021) emphasise that urbanisation is the principal controller of landscape change and the primary factor driving the loss of ecosystem services. According to Bintarto (cited in Hose *et al.* 2018), the central and peripheral regions are one complete spatial system. The ecosystem services in question produce various products and services that support the survival and development of the human population (Yang *et al.*, 2019).

Sukoharjo Regency is directly adjacent to Surakarta City, the centre of development in the Sukoharjo, Boyolali, Surakarta, Wonogiri, Sragen and Klaten Regency (Subosukawonosraten) area. Sukoharjo Regency is impacted more compared to other regions bordering Surakarta City. Mardiansjah *et al.* (2018) suggest that spatially, urban development in the suburban area of Surakarta City is inclined to be towards the south or specifically, in the direction of Sukoharjo Regency. Four Districts in Sukoharjo Regency are directly adjacent to Surakarta City, notably Grogol, Baki,

Mojolaban and Kartasura Districts. These particular districts will stimulate urbanisation in Sukoharjo Regency. Muta'ali (2015) asserts that the urbanisation rate can be determined by the percentage of the urban population. The increase in the level of urbanisation in Sukoharjo Regency has been observed to be significant. Mardiansjah *et al.* (2018) point out that between 1980-2010, urbanisation in Sukoharjo Regency increased. In 1980, the urbanisation rate was only 21.26%. Nevertheless, by 2010, it had experienced a significant increase reaching 76.72%, almost four times the initial rate. The urban population in Sukoharjo Regency is presented in Figure 1.

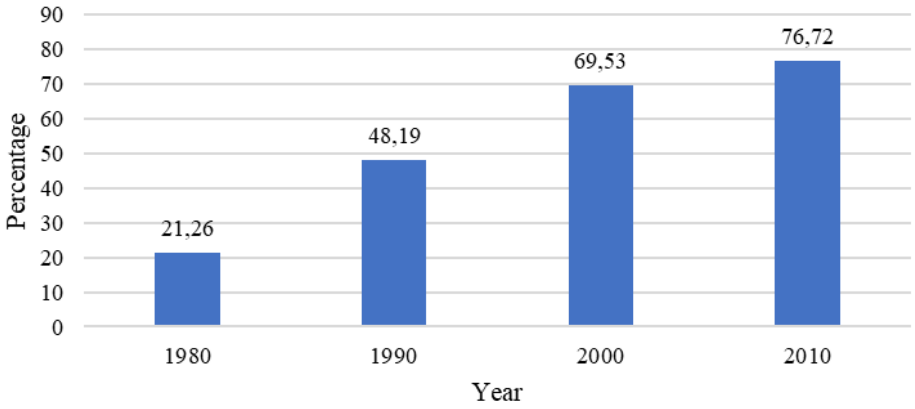

Figure 1. Urban Population Level in Sukoharjo Regency 1980-2022.

Urban population growth also has environmental and social implications (Selang *et al.*, 2018). In their study, Klimanova *et al.* (2021) state that there was a change in land function from initial vegetation to a watertight area in the suburban area. Urbanisation is an key factor influencing the decline of ecosystem services (Noviani, 2021). Land expansion can reduce ecosystem services, which can also be indirectly reflected by means of population growth and economic development (Wang *et al.*, 2019). Similarly, population growth will result in population density due to limited land. One of the characteristics of urban areas is population density (Nurjannah *et al.*, 2018). Based on data from the Central Statistics Agency of Sukoharjo Regency, between 2016-2020, the population density of the Sukoharjo Regency increased from 1852 people/km^2 to 1945 people/km^2.

The population growth in the periphery area contributes the most to the formation of built-up land (Selang *et al.*, 2018). The allocation of land is incompatible with planning based on personal and industrial interests, causing various problems. In reality, land cover changes in Sukoharjo Regency are inclined toward industry and communities (Okmaliasari, 2021). Ecosystem services are affected by landforms, vegetation, as well as land cover (Baco *et al.*, 2020). Trends generally indicate a reduction in the supply of ecosystem services due to changes in land cover in suburban areas (Nieto *et al.*, 2018). Each region has different natural resources according to its capacity. The area will appear neglected if the environment cannot support life appropriately. Moreover, slums are the unhealthiest of residential locations; hence, it is vital to consider ecosystem services which support human life (Winayanti, 2016). The most important ecosystem services in urban areas pertain to the provision of ecosystem services. The provision of ecosystem services relates to those services that are primarily associated with urgent and well-defined development goals, such as food security, attempts at income generation, along with the conditions associated with employment, health and nutrition (Lossack *et al.*, 2012).

Water is an essential natural resource providing socio-economic and ecological benefits for all life on earth, notably people (Molla *et al.*, 2023). The existence of and access to water is fundamental for human life, and as the population increases, the availability of raw materials for clean water will begin to diminish (John *et al.*, 2023). Additionally, if not balanced with good water resource management, every single human activity that require water can impact the quality and quantity of water resources (Muchtar *et al.*, 2023). Ecosystem services providing clean water are crucial for life (Baco *et al.*, 2020). Likewise, access to water is a human right (Portillo *et al.*, 2023). Clean water is an important indicator of ecosystem functioning and is imperative in regard to sustainable development (Admasu *et al.*, 2023; Roziaty *et al.*, 2023). In their study, Wang *et al.* (2019) assert that urbanisation results in a substantial reduction in ecosystem services with respect to providing clean water. Ecosystem services are essential for equitable and sustainable development (Lossack *et al.*, 2012). Admasu *et al.* (2023) argue that urban growth can reduce the amount of water supply. Land-use change has a considerable impact on the distribution pattern of water availability and rapid urbanisation is a key driver of increased demand for water (Chen *et*

al., 2023). According to Wei *et al.* (2021) water has a direct impact on the sustainable development and ecosystem of a region. Furthermore, the utilisation of natural resources that exceed the restoration of natural potential or the environment's carrying capacity will trigger the loss of natural resources (Muta'ali, 2015). The calculation of clean water supply ecosystem services is essential for the sustainability of a city. The objectives of this study are (1) Identifying the state of the level of urbanisation; (2) Understanding the state of ecosystem services providing clean water; and (3) Recognising the relationship between the level of urbanisation and ecosystem services for providing clean water in Sukoharjo Regency in 2022.

2. Research Methods

2.1. Urbanisation Rate

Munir (cited in Nurjannah *et al.* 2018) asserts that urbanisation can be conducted by analysing the population within a defined city area. Demographically, urbanisation can be measured by the percentage of people living in urban areas (Muta'ali, 2015). Therefore, measuring urbanisation can be performed by using Equation 1; where U is level or rate of urbanisation (%), JPk is Number of residents living in the city, and JP is total population.

$$U = \frac{JPk}{JP} X\ 100\% \quad (1)$$

Determination of the classification of urban and rural areas over villages using the method for determining the Badan Pusat Statistik Republik Indonesia (BPS RI) value/score (2020). The classification of the values/scores employed is as follows: (1) classification of urban villages if all three criteria has a score of 9 (nine) or more; (2) the classification of rural villages in the three criteria has a score below 9 (nine). The third score, the classification criteria score for urban and rural villages in the research location. According to the Central Statistics Agency of the Unitary State of the Republic of Indonesia (2020), the value/score for population density, percentage of agricultural families and urban presence/access are presented in Table 1. The results of calculating the urbanisation rate are then classified (see Table 2).

Table 1. Urban and Rural Village Classification Criteria Value/Score.

No	Criterion	Score
1	Population Density Per km²	
	<500	1
	500-1,249	2
	1,250-2,499	3
	2,500-3,999	4
	4,000-5,999	5
	6,000-7,499	6
	7,500-8,499	7
	8,500	8
2	Percentage of Family Farms (%)	
	≥ 25 %	0
	< 25 %	1
3	Urban Facilities	
	Kindergarten or equivalent	1
	Junior High School or equivalent	1
	High School or equivalent	1
	Pass	1
	Shops	1
	Cinema	1
	Hospital/ Maternity home/ Puskesmas/ Clinic	1
	Hotel/Bank	1
	Percentage of Electricity User Families	
	< 95,00	0
	≥ 95,00	1

Source: Muta'ali, (2015); BPS RI (2020)

Table 2. Classification of Urbanisation Rate.

No	Urbanisation Rate	Level
1	>66.66%	High
2	33.33-66.66%	Medium
3	<33.33%	Low

2.2. Clean Water Supply Ecosystem Services

Measurement of the environment's carrying capacity for the provision function applying two parameters or indicators, in particular ecoregion and land cover, is given a score that was obtained based on prioritising the role using the Analytic Hierarchy Process (AHP). The Analytic Hierarchy Process (AHP) is a method that can be employed in role determination (Agus *et al.*, 2019) and which also supports decision-making using more than one criterion to overcome complex problems (Muta'ali, 2015). The application of the AHP determines the role of an ecoregion and land cover in determining ecosystem services (Ferreira *et al.*, 2023). This approach involves stakeholder groups, scientific experts or by way of workshops to determine the role of each criterion (Wibowo *et al.*, 2011). The AHP method can provide a role for a factor by way of the existing conditions of an area because it is supplied by the opinions of experts residing in the region (Seena *et al.*, 2023). As role determination, this stakeholders in this study are the Head of the Inventory Division, RPPLH and KLHS - DLH Sukoharjo, specifically Abdul Rahman Saleh, ST. Score determination is performed based on the results of the completed questionnaire. The results of the AHP questionnaire are in the form of scores or values for land cover and ecoregions, which are subsequently used as the basis for calculating ecosystem services as regards the provision function (Agus *et al.*, 2019).

The Analytic Hierarchy Process (AHP) generates relative weights between criteria and alternatives. A criterion will be compared with another regarding its importance in relation to achieving the goals. The scores that have been obtained need to be matched by means of data normalisation. In this case, the Consistency Ratio (CR) in the AHP is not allowed for more than 10% or CR<0.1. If CR>0.1, the data retrieval must be repeated because the data is too biased. The results of the stacking process obtained maximum scores and minimum scores, which were then divided into three levels, for example (1) low, (2) medium and (3) high. The classification of levels of ecosystem services is presented in Table 3.

Table 3. Ecosystem Service Classification.

No	Urbanisation Rate	Level
1	>66.66%	High
2	33.33-66.66%	Medium
3	<33.33%	Low

Source: Data Processing Researcher, 2022

2.3. Relationship between the Urbanisation Rate and Clean Water Supply Ecosystem Services

This study uses cross-tabulation to establish the relationship between the level of urbanisation and ecosystem services pertaining to the role of a clean water supply. Cross-tabulation is a basic analysis of relationships between variables (Haniff & Syafriharti, 2017). According to Hernández *et al.* (2023), cross-tabulation can explain relationships utilising a simple method and can also help to determine the direction the relationship is proceeding. Cross-tabulation can be employed in regional planning as a decision-making tool (Indratno *et al.*, 1998). The level of urbanisation and carrying capacity based on ecosystem services in Sukoharjo Regency is divided into three separate levels, notably low, medium and high, in each district. The two variables will then be superimposed, with the aim of understanding the existing relationship. The relationship in this study is assumed to be negative where areas with a high level of urbanisation will have a low carrying capacity based on ecosystem services (Burlakova *et al.* 2023). This study did not test the sample but the entire population. Hence, there is no need for a relationship test where the relationship cross-tabulation and overlay are applied.

3. Results and Discussion

3.1. Urbanisation Rate

Sukoharjo Regency is divided into 12 districts that have their own distinct characteristics. Districts in the north of Sukoharjo Regency tend to have higher urbanisation than districts in the southern part. Based on the calculation of the urbanisation rate, Sukoharjo Regency is included in the medium level with an urbanisation rate of 63%, signifying that 552,793 people live in urban areas. The urbanisation rate of each sub-district in Sukoharjo Regency is presented in Table 4.

Table 4. Sukoharjo Regency Urbanisation Rate in 2022.

No	District	Urban Population (people)	Population (people)	Urbanisation Rate (%)	Level
1	Baki	49.617	70.841	70	High
2	Bendosari	30.049	65.260	46	Medium
3	Bulu	10.039	39.520	25	Low
4	Gatak	36.687	16.495	69	High
5	Grogol	110.731	121.414	91	High
6	Kartasura	105.311	109.724	96	High
7	Mojolaban	65.135	91.775	71	High
8	Nguter	11.576	57.285	20	Low
9	Polokarto	32.843	87.611	37	Medium
10	Sukoharjo	64.324	98.044	66	Medium
11	Tawangsari	14.678	57.815	25	Low
12	Weru	21.803	59.495	37	Medium
Sukoharjo Regency		552.793	875.279	63	Medium

Source: Data Processing (Researcher, 2022)

Based on Table 4, it is evident that most districts in Sukoharjo Regency have a high level of urbanisation. Kartasura District boasts the highest urbanisation rate in Sukoharjo Regency at 96%, with 105,311 out of 109,724 residents living in urban areas. Along with Kartasura District, Grogol Subdistrict is an area with a high level of urbanisation. The urbanisation rate in Grogol District is 91%, indicating that 110,731 of the 121,414 people live in urban areas, while Mojolaban District has an urbanisation rate of 71%. Other districts with high urbanisation rates are the districts of Baki and Gatak. The high level of urbanisation suggests that most of the population in the five districts live in urban areas.

Sukoharjo Regency comprises four districts that have a medium level of urbanisation, for example Bendosari, Sukoharjo, Polokarto and Weru. Within the district of Sukoharjo, urbanisation is in the medium level but is acknowledged to be approaching a high level. Sukoharjo Subdistrict where 64,324 of the 98,044 inhabitants live in urban areas, has an urbanisation rate of 66%. Other districts with a medium level of urbanisation are Bendosari, with an urbanisation rate of 46%, along with Polokarto and Weru districts, with 37%.

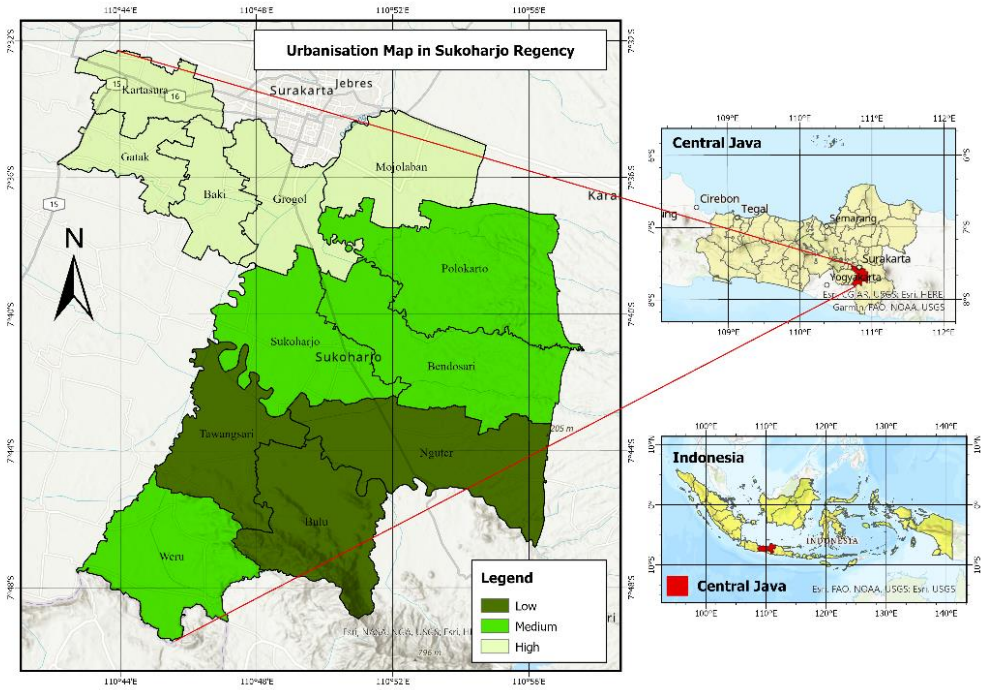

Figure 2. Map of the Urbanisation Rate in Sukoharjo Regency in 2022.

Pertaining to Sukoharjo Regency, the level of urbanisation in the low level is observed in three particular districts, including Bulu, Nguter and Tawangsari. The definition of a low-level urbanisation rate is that most of the population in the region lives in rural areas. The district with the lowest urbanisation rate is Nguter District at 20%, with only 11,576 of the 57,285 people living in urban areas. Bulu Subdistrict with only 10,039 of the 39,520 inhabitants living in urban areas has an urbanisation rate of 25%. Likewise, Tawangsari Subdistrict also comprises an urbanisation rate of 25%. The low-level urbanisation rate in the Sukoharjo Regency is predominantly in the southern region. Figure 2, illustrates the distribution of urbanisation rates in the Sukoharjo Regency.

Figure 2 presents the spatial pattern in relation to the high urbanisation levels in the northern part, including Kartasura, Gatak, Baki, Grogol and Mojolaban districts. Sukoharjo Regency is close to Surakarta City, thereby indirectly impacting the city's development. Sukoharjo Regency has a sub-district with a medium level of urbanisation in the central part of the district, including Polokarto, Sukoharjo and Bendosaeri districts, as well as one area in the southern region, namely Weru District. The low urbanisation rate in Sukoharjo Regency is spread across the southern part of Sukoharjo Regency, including Tawangsari, Bulu and Nguter districts. The urbanisation pattern, starting from the northern part of Sukoharjo Regency, is similar to the development in Surakarta City, although the southern part has a lower rate. The situation regarding the urbanisation distribution pattern has the potential to redevelop towards the south in Sukoharjo District and Polokarto District.

There are several reasons for the high urbanisation rate in Grogol and Kartasura District. In both areas, the percentage of farming families <25% ranges from 0-22.7%. Both areas have up-to-date urban amenities. The population density in Grogol District ranges from 1,126-12,833 people/km², whereas Kartasura District has a population density of 2,381-11,206 people/km². The factor that affects the lower urbanisation rate in Baki, Gatak and Mojolaban districts compared to other districts that have a high urbanisation rate, is the low population density. Of note is that the facilities in the three regions are still not as advanced as those in Grogol and Kartasura. Moreover, to accommodate the high level of urbanisation, it is essential that amenities in each of the districts are modernised.

Districts with medium urbanisation rates are located in Sukoharjo, Polokarto, Bendosari and Weru districts. Sukoharjo Subdistrict has a large area of irrigated paddy land cover. As a consequence, it has a farming population that ranges from 7-79% and a population density of between 1,155-4,528 people / km², which is still below Kartasura and Grogol. Owing to its lower population density, Sukoharjo Regency does not have appropriate urban facilities, resulting in a moderately low urbanisation level. Polokarto District and Bendosari District have the same characteristics as Sukoharjo and Polokarto districts. They have a small number of urban villages, although the number of inhabitants in the urban villages is high compared to other regions. A distinctive situation is that Weru District has an urbanisation rate of 37%, whereas in relation to the different districts south of Sukoharjo Regency, Weru District has fairly reasonable urban facilities. As it is the meeting point for Gunung Kidul and Klaten, Weru District has relatively adequate urban facilities**.** Districts with low urbanisation rates are observed in Tawangsari District (25%), Bulu District (25%), along with Nguter District (20%). All three districts continue to exhibit relatively low population densities, a high percentage of the farming population (mostly >25%) and inadequate facilities. To bridge the gap between the northern and the southern districts, the local government should prioritise the three districts characterised by low urbanisation rates.

3.2. Clean Water Supply Ecosystem Services

Thomaz (2023) contend that ecosystems can support life by providing benefits through the availability of clean water, whilst Petrova *et al.* (2023) maintain that water is essential for the life of living beings, particularly humans. Furthermore, rain and soil or rock layers help to provide clean water. Other factors such as ecoregions, vegetation, in addition to land cover impact the ecosystem services providing clean water. The potential of clean water will be significant in supporting the lives of people in peri-urban areas.

The criteria score is measured using the AHP matrix to determine the score for each criterion. The Consistency Ratio (CR) is 5% for both ecoregions and land cover; hence, the data is valid for use. The criteria used are ecoregion and land cover, which are subsequently overlaid to create an ecosystem services map. The ecoregion and land cover map of Sukoharjo Regency is presented in Figure 3.

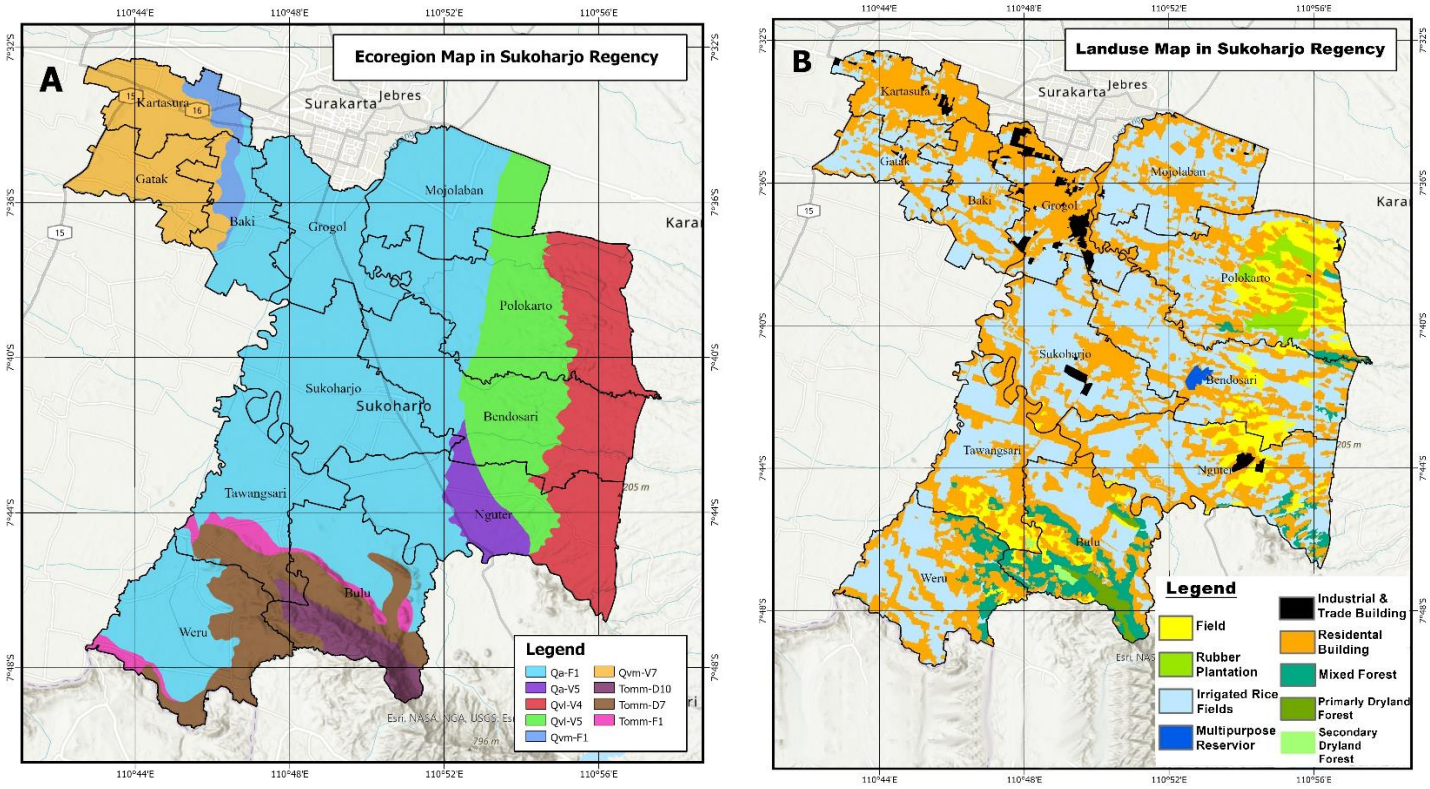

Figure 3. Map of Ecoregion (A) and Land Cover (B) of Sukoharjo Regency.

The first criterion relates to ecoregions. There are nine ecoregions within Sukoharjo Regency (Figure 3). The AHP analysis conducted based on the results of the questionnaire is presented in Table 5. This table presents pairwise comparisons between ecoregions (Qa-F1, Qvm-F1, Tomm-F1, Qvm-V7, Tomm-D7, Tomm-D10, Qa-V5, Qvl-V5, Qvl-V4). The total value of the pairwise comparison is indicated as negative, meaning that the higher the total value of an ecoregion, the smaller the role it will play in influencing the ecosystem services of providing clean water. The ecoregions with the smallest role in influencing ecosystem services are Qvl-V5 and Tomm-D10 which have the highest total similarity scores of 14.00 and 10.83 respectively.

Table 5. AHP Analysis of the Ecoregion in Sukoharjo Regency

Ecoregion	Qa-F1	Qvm-F1	Tomm-F1	Qvm-V7	Tomm-D7	Tomm-D10	Qa-V5	Qvl-V5	Qvl-V4
Qa-F1	1	2	3	2	3	3	1	1	1/2
Qvm-F1	1/2	1	2	2	2	3	1/2	1/2	1/2
Tomm-F1	1/3	1/2	1	1/2	2	3	1/3	1/4	1/2
Qvm-V7	1/2	1/2	2	1	2	3	1/2	1/2	1/3
Tomm-D7	1/3	1/2	1/2	1/2	1	2	1/4	1/2	1/3
Tomm-D10	1/3	1/3	1/3	1/3	1/2	1	1/5	1/4	1/4
Qa-V5	1	2	3	2	4	5	1	1/2	1/3
Qvl-V5	1	2	4	2	2	4	2	1	1/3
Qvl-V4	2	2	3	3	3	4	3	3	1
Total	7.00	10.83	8.50	6.00	10.00	14.00	2.58	2.75	2.17

Source: Analysis of AHP Questionnaire for Ecoregion Based on Expert Opinion (2022)

The second criterion pertains to land cover. Sukoharjo Regency has nine types of land cover. The results of the AHP analysis based on the questionnaire are presented in Table 6. This table provides an assessment of land cover types and their relationships, with values representing their level of importance. The higher the total value, the smaller the role in influencing ecosystem services. The highest total pairwise comparison scores are Industrial and Trade Buildings and Residential Buildings with scores of 56.00 and 50.00 respectively, meaning that these two land covers have the smallest role in influencing water supply ecosystem services.

Based on the results of the AHP questionnaire, normalisation can then be performed with the aim of determining the score for each criterion (see Table 7). This table provides a concise overview

of land cover scores and their corresponding ecoregion scores. Multipurpose reservoirs in the "Land Cover" category have the highest score at 2.08, followed by mixed forest and Primary Dryland Forest at 2.14. The ecoregion Qvl-V4 has the highest score of 2.14. The high scores in Table 7 indicate that these criteria have a large influence on the ecosystem services of providing clean water.

Table 6. AHP Analysis of Land Cover in Sukoharjo Regency.

Land Cover	Industrial and Trade Building	Mixed Forest	Primary Dryland Forest	Secondary Dryland Forest	Fields	Rubber Plantation	Irrigated Rice Fields	Multipurpose Reservoir	Residential Buildings
Industrial and Trade Building	1	1/9	1/9	1/7	1/5	1/9	1/6	1/9	1
Mixed Forest	9	1	1	2	4	1	3	1	9
Primary Dryland Forest	9	1	1	2	4	1	3	1	9
Secondary Dryland Forest	7	1/2	1/2	1	2	1/3	2	1/4	7
Fields	5	1/4	1/4	1/2	1	1/5	1/4	1/6	4
Rubber Plantation	9	1	1	3	5	1	3	1/2	7
Irrigated Rice Fields	6	1/3	1/3	1/2	4	1/3	1	1/5	3
Multipurpose Reservoir	9	1	1	4	6	2	5	1	9
Residential Building	1	1/9	1/7	1/7	1/4	1/7	1/3	1/9	1
Total	56.00	5.31	5.34	13.29	26.45	6.12	17.75	4.34	50.00

Source: Analysis of AHP Questionnaire of Land Cover from Expert Opinion, 2022

Table 7. Score for Ecoregion and Land Cover in Sukoharjo Regency.

Land Cover	Score	Ecoregion	Score
Industrial and Trade Building	0.15	Qa-F1	1.27
Mixed Forest	1.58	Qvm-F1	0.88
Primary Dryland Forest	1.58	Tomm-F1	0.59
Secondary Dryland Forest	0.83	Qvm-V7	0.71
Fields	0.42	Tomm-D7	0.46
Rubber Plantation	1.54	Tomm-D10	0.30
Irrigated Rice Fields	0.64	Qa-V5	1.28
Multipurpose Reservoir	2.08	Qvl-V5	1.38
Residential Buildings	0.17	Qvl-V4	2.14

Source: AHP Analysis for Ecoregions and Land Cover (2022)

Following the AHP and scoring process, Sukoharjo Regency has three ecosystem services levels for providing clean water, specifically low, medium and high. Two existing parameters, notably ecoregion and land cover, were then superimposed to produce an ecosystem services map for clean water supply in Sukoharjo Regency. Significant is that variations in rock types and topography within specific areas of Sukoharjo Regency will affect the ecosystem services level. The type of land cover in Sukoharjo Regency will also impact ecosystem services regarding providing clean water because it is related to the infiltration process and whether water can permeate the soil or develop into surface flows. Table 8 presents the distribution of ecosystem services for providing clean water in Sukoharjo Regency in 2022.

Based on Table 8, Sukoharjo Regency is dominated by medium level clean water supply ecosystem services covering an area of 25,133.92 ha (51% of the total area of the Sukoharjo Regency). Ecosystem services for providing clean water within the smallest area in Sukoharjo Regency are observed to be of a high standard covering an area of 1,030.23 ha (2% of the total area of

Sukoharjo Regency). Polokarto is the subdistrict with the largest high and medium level clean water supply ecosystem services, notably 1,030.23 ha for high level and 4,415.43 ha for medium level. Conversely, the sub-district with the most extensive low level ecosystem services is Weru with 2,305.25 ha. Figure 4 illustrates the map of clean water supply ecosystem services.

Table 8. Distribution of Ecosystem Services Clean Water Supply in Sukoharjo Regency.

No	District	Ecosystem Services Clean Water Supply (ha)			Total (ha)
		Low	Medium	High	
1	Baki	1,567.22	772.75	0.00	2,339.97
2	Bendosari	1,441.05	3,953.34	177.75	5,572.14
3	Bulu	2,256.97	2,383.07	0.00	4,640.04
4	Gatak	1,994.87	0.00	0.00	1,994.87
5	Grogol	2,131.98	1,001.42	0.00	3,133.40
6	Kartasura	2,166.03	0.00	0.00	2166.03
7	Mojolaban	1,558.26	2,271.01	0.00	3,829.27
8	Nguter	1,797.56	3,759.94	227.15	5,784.65
9	Polokarto	1,648.15	4,415.43	625.34	6,688.92
10	Sukoharjo	2,027.46	2,654.88	0.00	4,682.34
11	Tawangsari	2,264.53	1,667.21	0.00	3,931.74
12	Weru	2,305.25	2,254.86	0.00	4,560.12
Sukoharjo Regency		23,159.34	25,133.92	1,030.23	49,323.49
Percentage (%)		47%	51%	2%	100%

Source: Map Analysis of Clean Water Ecosystem Services in Sukoharjo Regency (2022)

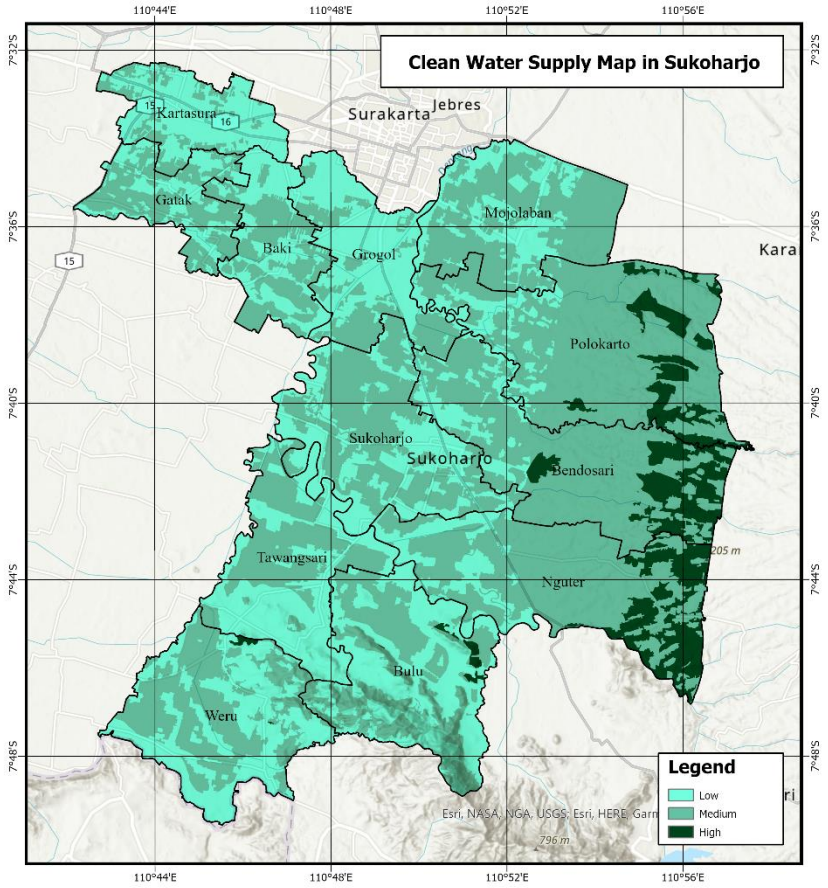

Figure 4. Map of Clean Water Supply Ecosystem Services in Sukoharjo Regency (2022).

Ecosystems can support life by providing benefits for living things, notably humans, related to the availability of clean water (Nguea, 2023). Water is essential for human life and has various uses with respect to households, industry, agriculture, plantations, and other activities (Ge *et al.*, 2023). Rain and soil or rock layers that can store water and other factors, such as ecoregions,

vegetation and land cover influence ecosystem services by providing clean water (Yang *et al.*, 2023). Ecoregions characterised by the geological features of the Merapi and Lawu volcanoes are appropriate for producing clean water. However, if we examine land cover, multi-purpose reservoirs and land cover that has vegetation will tend to be better at producing clean water. Clean water can emanate from surface water, groundwater or rainwater (Deng *et al.*, 2023).

Sukoharjo Regency is poor at producing clean water. The dominance of ecosystem services in providing medium and low-grade clean water is influenced by the lack of stands (a tree with a wooden trunk or vegetation), given that stands are primarily spread throughout the southern and eastern regions. The spatial pattern pertaining to the low-grade clean water ecosystem services supply in Sukoharjo Regency is predominantly observed in Gatak and Kartasura Districts, which are situated in the north and dominated by residential buildings.

3.3. Relationship between Urbanisation Rate and Clean Water Supply Ecosystem Services

The need for clean water is fundamental for the reason that water is essential for all living things, specifically humans. The production of clean water in an area varies according to the characteristics of each region (Yu *et al.*, 2023). Criteria that affect production include ecoregions and land cover. The level of urbanisation is one factor that can increase the number of inhabitants in an area; the more people there are in an area, the greater the need for clean water (Ming *et al.*, 2023).

The level of urbanisation and carrying capacity of the environment based on ecosystem services for providing clean water in Sukoharjo Regency each has three levels. Hence, the results of the cross-tabulation of eight levels are obtained. Table 6 presents the relationship between the urbanisation rate and ecosystem services related to the clean water supply in Sukoharjo Regency.

Table 6. Cross-Tabulation of the Urbanisation Level with Clean Water Supply Ecosystem Services.

	Relationship Level Area (ha)		
Urbanisation/ES Clean Water	**Low**	**Medium**	**High**
Low	6,319.07	7,810.22	**227.15**
Medium	7,421.92	**13,278.51**	803.08
High	**9,418.35**	4,045.19	0,00
Total			49.32349
Extent of Relationships			22.92401
Relationship Percentage			46%

Source: Researcher Analysis (2022)

Based on Table 6, the high urbanisation associated with ecosystem services providing low level clean water is 46% or medium level. The results of calculating the relationship establish that the urbanisation rate's ability to reduce the value of ecosystem services is at a medium level. This suggests that the level of urbanisation will correlate with ecosystem services. The minimal provision of ecosystem services providing high-quality clean water in Sukoharjo Regency is not only a result of urbanisation, but also involves other factors, primarily the existing anthropogenic activities.

3.4. Discussion

The impact of Surakarta City's urban expansion exacerbates the anthropogenic impact across Sukoharjo Regency and the expanding population results in an even higher population density (Peng *et al.*, 2023). Signs of the increase will cause changes to land cover or land conversion, transforming open land into built-up land or agricultural land into non-agricultural land. This urban population growth also has considerable environmental and social implications (Selang *et al.*, 2018). Sukoharjo Regency is an area that is significantly affected by the development of Surakarta City, causing the northern part of the regency to experience rapid growth, to the extent that it will ultimately penetrate other regions. Klimanova *et al.* (2021) assert that there was a change in land function from initial vegetation to a watertight area in the suburban area. Likewise, Selang *et al.* (2018) maintain that the population growth on the periphery contributes the most to the formation of built-up land. More specifically, development towards urban areas will cause problems, for example, in Sukoharjo Regency, which has low water supply ecosystem services (Petsch *et al.*, 2023).

Urbanisation is an important factor influencing the decline of ecosystem services (Noviani, 2021). Similarly, urbanisation will reduce the value of ecosystem services providing clean water resulting in a relatively low level (Tripathi *et al.*, 2023). García *et al.* (2018) claim that trends generally indicate a decrease in the supply of ecosystem services due to changes in land cover in suburban areas. The change in Sukoharjo Regency as regards urban areas undoubtedly increases the demand

for water. In 2022, ecosystem services providing high-quality clean water were accessible in practically half of Sukoharjo Regency. The existence of water is crucial for all humans, and when the population increases, the supply of raw materials for clean water will begin to halt (John *et al.*, 2023). Also, increased anthropogenic activity will encourage a reduced supply of ecosystem services for clean water, indicating that clean water will be scarce (Thomaz, 2023). Furthermore, all human activities that require water, if not balanced with robust water resource management can have an impact on the quality and quantity of water resources (Muchtar *et al.*, 2023). Increased anthropogenic activity in Sukoharjo Regency also has the potential to reduce the quality of clean water. Securing the preservation of clean water is imperative because access to water is vital as regards the city's desire to become sustainable. According to Baco *et al.* (2020), ecosystem services providing clean water are essential for life. Controlling urbanisation in peri urban areas, principally by focusing on ecosystem services as a guide to making development decisions is essential. Moreover, mapping ecosystem services in Sukoharjo Regency can be a solution for development planning in peri-urban areas (Abanyie *et al.*, 2023).

4. Conclusion

The level of urbanisation creates a pattern where districts close to Surakarta City or in northern Sukoharjo have higher levels than the southern region. An obvious gap in development exists between the northern and southern parts of Sukoharjo Regency. If the gap in development associated with urbanisation is not successfully addressed, there will be no equitable development. Owing to this, the northern part of Sukoharjo Regency will also be more densely populated increasing the likelihood that slums will develop. Moreover, this paper explains that the pattern of ecosystem services providing clean water in the northern region of Sukoharjo Regency tends to be low level. The relationship is 46% (middle level), signifying that the higher level of urbanisation in Sukoharjo Regency will reduce the value of ecosystem services.

Acknowledgments

The author would like to thank the Sukoharjo Regency Environmental Service for their assistance in providing some of the data and completing the questionnaire. The author also would like to thank Geography Education, Sebelas Maret University. Finally, the author would like to thank all parties who have supported both in terms of writing, funding and data collection.

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