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Assessment of Watershed Carrying Capacity and Land Use Change on Flood Vulnerability Areas in Semarang City

Dewi Liesnoor Setyowati[1,*], Satria Adji Wilaksono[1], Ananto Aji[1], Muhammad Amin[2]
[1] Universitas Negeri Semarang, Department of Geography, Gunungpati Semarang Indonesia
[2] Universitas Lampung, Department of Agriculture Engineering, Bandar Lampung, Indonesia
[*)] Corresponding Author (e-mail: liesnoor2015@mail.unnes.ac.id)

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Abstract. Human behaviour induced watershed problems where the use and carrying capacity of the watershed contradict each other. The research objectives were to determine the land use conditions and the carrying capacity of the watershed, and to analyze the carrying capacity of the watershed based on changes in land use and flood vulnerability areas. The research was conducted in five watersheds flowing in flood-prone areas of Semarang City. There are Babon, Banjir Kanal Timur, Garang, Silandak, and Beringin watersheds covering the area of 48,994.62 Ha. The quantitative analysis approach was used to calculate land-use change and watershed carrying capacity. The watershed carrying capacity variables included land conditions, water quality, population, water building, and watershed space utilization. The results showed that 1) an average of 12.27% of land use for each watershed unit had been converted into a settlement with the most extensive conversion in the Banjir Kanal Timur watershed, 2) the carrying capacity of the Banjir Kanal Timur watershed got 113 scores, which fall in the poor category, and 3) at the watershed level, the surge in land conversion into settlements correlated to the carrying capacity of the watershed. Conversion of land use into settlements is one of the determinants of the carrying capacity of the watershed. The land use arrangement in the watershed by considering flood-vulnerability areas will be able to reduce watershed damage and the frequency of floods.

Keywords: watershed carrying capacity, land use change, flood, Semarang City

1. Introduction

A watershed is a land area enclosed by topographic water divisions, that in the event of rain channels rainfall to an interconnected river system to the main channel and eventually accumulated water through a single outlet (Setyowati, 2016). Potential problems include highly contrasting characteristics where excessive water flows in the rainy season (flood disasters) and drought in the dry season. This drawback continues to develop over time as land productivity declines in the upper section of a watershed.

The ability of a watershed to create the sustainability and harmony of its ecosystem and optimize the benefits of natural resources for humans and other living things sustainably is called the carrying capacity of the watershed (Government Regulation No. 37 of 2012; Maulana *et al.*, 2020). Natural and anthropogenic factors have rapidly changed the watershed landscape in recent decades (Afrin *et al.*, 2019). Land cover and land use change can change landscape patterns and affect regional ecosystems (Zhang *et al.*, 2017). In addition, vegetation plays an important role in changing global or regional ecological environments (Nie *et al.*, 2021). Therefore, the conversion of forest to agricultural land can cause loss of hydrological function associated with infiltration (Suprayogo *et al.*, 2020). A previous study in the Rathbun watershed, South Central Iowa, USA shows that intensive agricultural use in the border area results in excessive erosion (ranging from 8.6 to 38.3 cm/year) creating river flow damage and a decrease in the carrying capacity of the watershed (Tufekcioglu, 2020).

Changes in land use will affect the carrying capacity of a watershed. Population activities in the watershed are the trigger or driving factor for watershed decline, such as increasing population pressure on land, water consumption patterns, and the level of urbanization which affect the carrying capacity of the watershed. The results of research by Deng *et al.* (2021), prove that the carrying capacity of the watershed (WCC) has increased from year to year, by applying the Driver-Pressure-Engineering water deficiency-State-Ecological basis-Response-Management (DPESBRM) concept to identify and assess the carrying capacity of the karst area water resources (Peng *et al.,* 2021).

Land use describes the way and the purposes for which human beings employ the land and its resources. Land cover refers to physical characteristics of the land including human-made structures, which make up the earth's landscape. Historically, land use and cover changes have occurred primarily in response to population growth, technological advances, and economic opportunity (Turner *et al.,* 1995). Human activities have directly or indirectly modified the natural environment. This is due to the production demands by humans cannot be fulfilled without modification or conversion of land cover. Among the challenges facing the earth over the next century, land use and cover changes are likely to be the most significant (Nugraha & Utomowati: 2013; Mustard *et al.,* 2012).

Beringin, Silandak, Garang, Banjir Kanal Timur, and Babon are national priority rivers that must be managed in Indonesia (BPDAS, 2015). Five main watersheds in Semarang City have experienced land use changes and caused floods in the downstream area of the river. Some areas are at risk of flooding due to violating spatial planning and, consequently, narrowing water retention areas upstream. Land use conversion requires serious attention as it potentially interferes with watershed responses to rainfall, starting from less water infiltration into soil layers to reduced groundwater aquifer capacity and increased ratio of direct runoff to rainfall, the combination of which leads to floods (Setyowati, 2019; Eman, *et al.,* 2016). The form of damage to the watershed is in the form of sedimentation in rivers and at river mouths, high discharge fluctuations occurrence, and the decrease of river quality. The existence of the river is getting shallower and cannot accommodate rainwater, causing river water to overflow and flood.

Floods are river flows that overflow and pass through riverbanks and water enters settlements because rivers are unable to accommodate rainwater (Asdak, 2010). Data on the number of flood events in five watersheds in Semarang City from 2011 to 2015 are Babon watershed ten flood events, Banjir Kanal Timur watershed 24 flooding events, 'Garang' watershed 16 flooding events, Silandak watershed 16 flooding events, and Beringin watershed 14 flooding events (BPDAS, 2015). Flood events hit the coastal areas of Semarang City, covering the areas of Genuk District, Gayamsari District, East Semarang District, Tugu District, West Semarang District, and North Semarang District. The flood phenomenon resulted from the increased water discharge of the Beringin River, Silandak River, Garang River, Banjir Kanal Timur, and Babon River.

One of the causes of flood vulnerability in Semarang City is changes in land use in the watershed. Changes in watershed carrying capacity due to changes in land use also affect flood vulnerability in Semarang City. The level of flood vulnerability in Semarang City is categorized into bad and moderate. WCC Value of Bad is in the Banjir Kanal Timur watershed and WCC Value of Moderate is in Beringin watershed, Garang watershed, Silandak watershed, and Babon Watershed.

The purpose of the study was to determine the condition of land use in five watersheds that empty into the city of Semarang in 2002 and 2018, and to analyze the carrying capacity of the watershed based on changes in land use and flood vulnerability.

2. Research Method

This study used mainly a quantitative approach, with qualitative descriptive methods as support. The location of the research is Semarang City, Indonesia. The research object was watersheds that flow into Semarang city, there are Silandak, Beringin, Garang, Babon, and Banjir Kanal Timur (Figure 1).

Primary data includes observation and checking of image interpretation, including land use information and flood vulnerability data at five watershed locations. Secondary data were obtained from geomorphological maps, soil maps, statistics Indonesia data, and archive data of reports on hydrological conditions of watersheds in Semarang City which were obtained from the Pemali Jratun Watershed Management Center (BPDAS). Secondary data includes land conditions in the form of critical land area and vegetation cover; watershed hydrological data; social, economic, institutional data; water construction investment data; use of protected & cultivated areas.

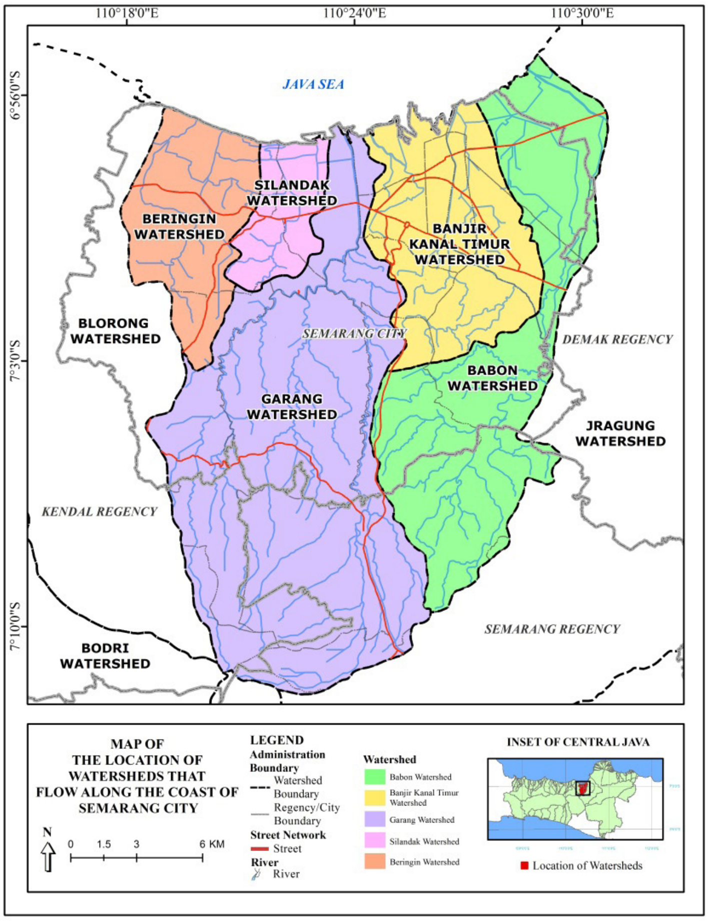

Figure 1. Locations of five watersheds that flow along the coast of Semarang city.

Table 1. Description of land use types.

No	Land Use	Description Land Cover (according to SNI, scale 1: 250,000)
	Forest	Land for conservation areas, which grows on dry land habitats in the form of lowland forests, mountains or hills, some forms of forest that have not experienced human intervention, some have experienced human intervention (there are traces of logging).
	Mixed Garden	Land associated with rural garden areas, planted with annual plants of more than one type or not uniformly, the method of harvesting the results is not by cutting down trees.

No	Land Use	Description Land Cover (according to SNI, scale 1: 250,000)
	Settlement	Land used as a residential or residential environment and a place for activities that support human life.
	Rice Field	Cultivation land for agricultural activities of short-lived food crops, namely rice, uses irrigation or rain-fed systems.
	Dry Land	Cultivation land for agricultural activities of seasonal crops on dry land, with a rain-fed system.
	Open Land	Unproductive land because it is not used by humans, usually without land cover or shrubs.
	Water Body	Cultivation areas in the form of ponds or swamps in coastal areas, in the form of large brackish water puddles, there are fishing or salting activities.

Table 2. Watershed carrying capacity assessment.

No	WCC Indicator	Weight %	Value	
			Lowest	Highest
1	Land Condition	40	20	60
	a. Percentage of Critical Land	20	10	30
	b. Percentage of Vegetation Cover	10	5	15
	c. CP value	10	5	15
2	Water Quantity and Continuity (Water Management)	20	10	30
	a. Annual Flow Coefficient	12	6	18
	b. Flood	8	4	12
3	Socio-Economic and Institutional	20	10	30
	a. Population Pressure on Land	14	7	21
	b. Presence and Enforcement of Regulations	6	3	9
4	Water Building Investment	10	5	15
	a. City Classification	5	2.5	7.5
	b. Water Building Value Classification	5	2.5	7.5
5	Territorial Space Utilization	10	5	15
	a. Protected area	5	2.5	7.5
	b. Cultivation Area	5	2.5	7.5
	Total		50	150

Source: Modification of the Regulation of the Minister of Forestry of the Republic of Indonesia Number: P.61/Menhut-II/2014 with WRCC (Deng, et al., 2021)

Table 3. Classification of Watershed Carrying Capacity.

No	Value	Category
1	WCC ≤ 70	Very Good
2	70 < WCC ≤ 90	Good
3	90 < WCC ≤ 110	Moderate
4	110 < WCC ≤ 130	Bad
5	WCC > 130	Very bad

Source: Regulation of the Minister of Forestry of the Republic of Indonesia Number: P.61/Menhut-II/2014 concerning Monitoring and Evaluation of Watershed Management.

Land use data were obtained from the interpretation of Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) and Landsat 8 OLI (Operational Land Imager) satellite images to determine the area and type of land use. Landsat 7 ETM satellite imagery was for making land use maps in 2002 and Landsat 8 of 2016 was used together with field checking in 2018. Landsat 8 OLI is a generation 8 Landsat satellite that describes the land surface with a multispectral spatial resolution of 30 m, panchromatic 15 m. Land use change was calculated from 2002 and 2018 data.

Data analysis techniques consist of spatial analysis of land use changes and analysis of watershed carrying capacity (WCC). Spatial analysis was applied to determine the area, location, and land use changes in five watersheds in Semarang City. Types of land use were classified into the criteria of the forest, mixed garden, settlement, rice field, dry cultivated land, open land, water body (Table 1).

The analysis of the carrying capacity of the watershed uses the criteria stipulated in the Regulation of the Minister of Forestry of the Republic of Indonesia Number: P.61/ Menhut-II/2014, with modifications. The modification was in the form of sub-indicator reduction because no data is available. The WCC indicators used are the same as the five indicators, while the sub-indicators that are reduced are the annual flow coefficient, sediment load, water use index, and the level of population welfare. The analysis of the carrying capacity of the watershed in this study uses five assessment indicators, namely land conditions; water quality, quantity and continuity; social, economic and institutional; water construction investment; and use of regional space. The value of the assessment score for the evaluation of the carrying capacity of the watershed is obtained from the results of the analysis with the value of the weights and scores of the indicators and their parameters. The assessment of the watershed carrying capacity is presented in Table 2.

Based on the results of the assessment of the carrying capacity of the watershed, the watershed carrying capacity (WCC) is grouped, and it is presented in Table 3.

3. Results and Discussion

3.1. Land Use of Five Watersheds in 2002 and 2018

Land use is a form or alternative of business activities or land use such as agriculture, plantations, grasslands, settlements and so on which refers to the function of land cover (Lin *et al.*, 2008). Based on the results of the interpretation of Landsat 7 ETM+ images (recorded in 2002), Landsat 8 OLI images (recorded in 2016), and field checks (in May 2018), land use data were generated for five watershed units. The accuracy of land use maps resulting from image interpretation is carried out by field survey activities on each land use class sample using a GPS (ground check) tool to prove the results of land use image interpretation and obtain the current (existing) land use. Furthermore, the results of the calculation of the accuracy test produced a value of 93%, where these results have met the minimum limit of 85% requirement.

Land use is all human intervention, either permanently or cyclically on a group of natural resources and artificial resources as a whole called land, to fulfil their needs both materially and spiritually or both. Changes in land use are changes in land cover and use from forest to agricultural land, from agricultural land to residential or industrial land, from grassland land to residential land.

In the Babon Watershed, there has been an increase in the area of settlements from 1,492.24 Ha in 2002 to 2,540.14 Ha in 2018, or 8.61%, dominating the land conversion. This is inversely proportional to the narrowing of paddy fields from 3,107.91 Ha in 2002 to 2,300.15 Ha in 2018, or 6.63% (807.76 Ha). Data of land use changes in the Babon watershed between 2002 and 2018 are presented in detail in Table 4 and Figure 2.

The pattern of land use change in the five watersheds is relatively the same, as when the area of settlements increases, the area of mixed gardens also increases, while the area of use of forest land, open land, rice fields, dry land and water bodies decreases. The percentage increase in the area of settlement is different, the Banjir Kanal Timur watershed and the Silandak watershed have the largest percentage increase, while the other three watersheds increase by less than 10% (Figure 2).

Table 4. Land use area in five watersheds in Semarang city, 2002-2018.

Watershed	Total Area (Ha)	Area of land use in 2002 and 2018 (hectares)						
		Forest	Mixed Garden	Open Land	Settlement	Rice Field	Dry Land	Water Body
Babon	12,177.19	2,106.46	743.56	88.51	1,492.24	3,107.91	3,617.54	1,020.98
		1,726.52	1,049.28	54.89	2,540.14	2,300.15	3,630.23	875.98
Banjir Kanal Timur	7,858.03	120.24	330.39	90.43	3,863.82	641.06	2,094.59	569.95
		55.94	384.18	72.55	5,541.42	464.66	863.15	328.58
Garang	21,277.36	8,479.45	1,652.77	91.67	2,018.81	4,911.18	3,961.87	151.01
		8,461.02	1,725.69	51.25	3,608.90	2,710.82	4,548.91	160.18
Silandak	2,391.42	78.97	133.87	50.72	902.98	202.22	456.21	538.86
		10.87	186.29	44.14	1,243.66	327.35	226.37	325.15
Beringin	5,176.12	719.56	726.42	68.96	761.26	868.56	843.06	1,188.31
		504.82	1,037.53	56.14	1,231.63	769.92	518.24	1,057.42

Source: Analysis of Map and Data, 2018

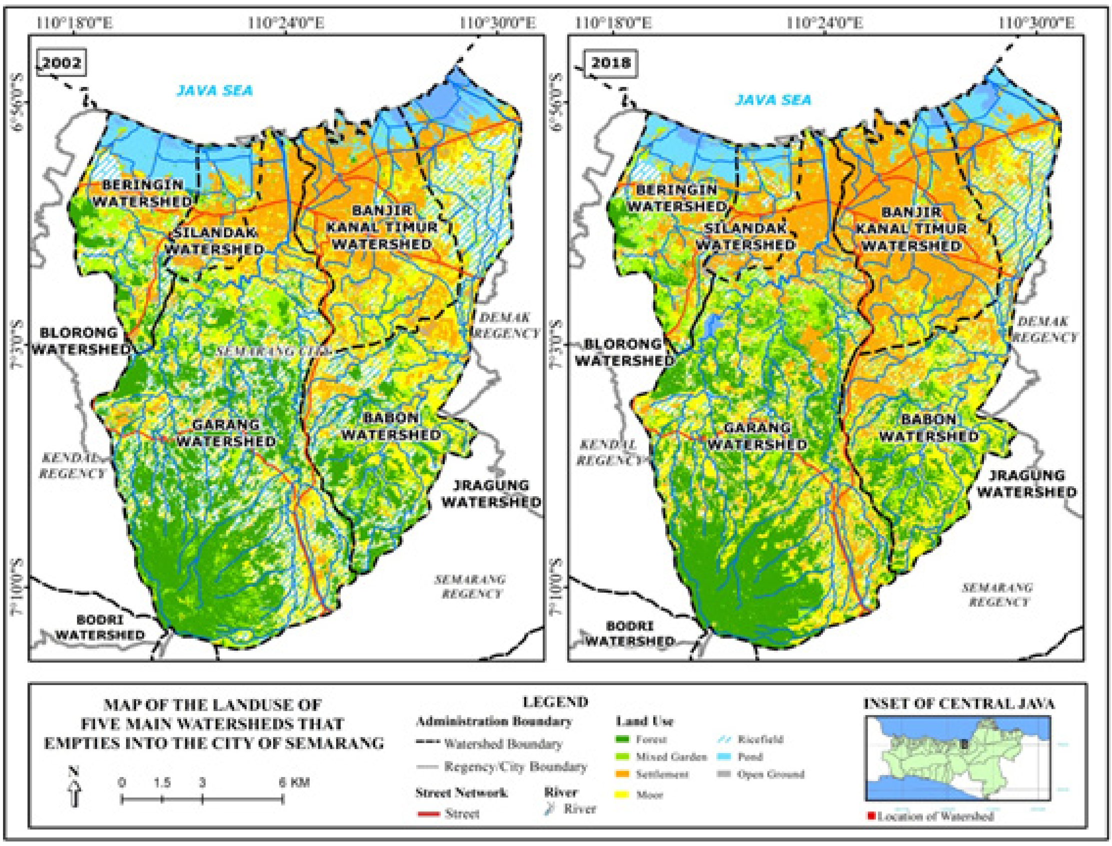

Figure 2. Land use map of Silandak watershed, Beringin watershed, Banjir Kanal Timur watershed, Garang watershed, dan Babon watershed in 2002 and 2018.

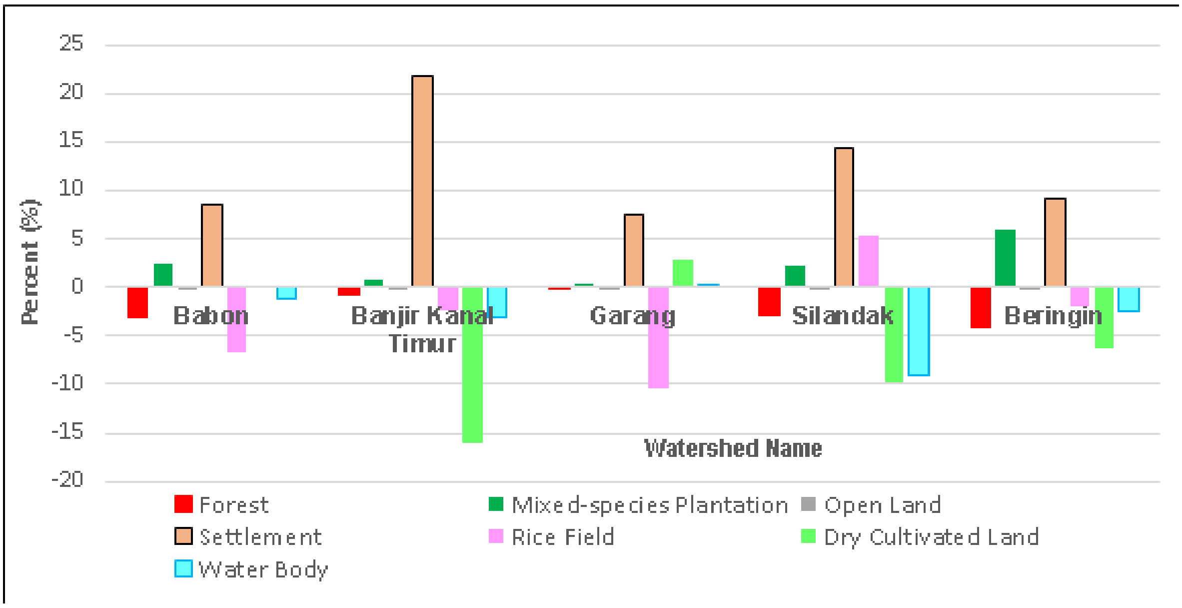

Figure 3. Land use change 2002-2018 at five watersheds in Semarang city.

In the Banjir Kanal Timur watershed, in 2002 the residential area was 3,863.82 Ha, and in 2018 it increased to 5,541.42 Ha, meaning that the increase in residential land reached 21.76% (1,677.60 Ha). In the Garang watershed, the area of residential land increased by 7.48% (1,590.09 Ha), in 2002 settlement data covered an area of 2,018.81 Ha and in 2018 the figure increased to 3,608.90 Ha. The area of settlements in the Silandak watershed increased rapidly from 1,243.66 Ha in 2002 to 902.98 Ha in 2018, or 14.25% (340.68 Ha). The Babon watershed area of settlement increased by 8.61% (1,047.9 Ha), from settlement data in 2002 which was 1,492.24 Ha to 2,540.14 Ha in 2018. Settlements in the Beringin Watershed in 2002 covered an area of 761.26 Ha, in 2018 it became 1,231.63 Ha, showing an increase of 9.09% (470.37 Ha). Details of land use changes area in 2002 and 2018 are presented in Table 4 and Figure 3.

The relationship of human behaviour must be in harmony in utilizing land and water resources with the environment's carrying capacity. Overexploitation that reduces the carrying capacity of the watershed can trigger environmental degradation. The increase of settlements and land use around the watershed will reduce the environment's quality around the watershed.

3.2. Carrying Capacity of Five Watersheds in 2002 and 2018

The carrying capacity of the five watersheds followed the Regulation of the Minister of Forestry No. P.61/Menhut-II/2014. Its condition was drawn from the weight values of the research indicators and their respective parameters. Mathematically, carrying capacity was the sum of the multiplication product of the score obtained through data analysis by the weight value of each parameter. The results of the assessment of the carrying capacity at five units of watersheds are presented in Table 5.

The Banjir Kanal Timur watershed, with an area of 7,858.03 Ha, has a WCC value of 113. This value indicated that the current condition of the Banjir Kanal Timur watershed showed a poor classification, which was 110 < WCC 130. The Banjir Kanal Timur watershed needed to be handled urgently in a comprehensive and integrated manner considering the poor condition of the watershed carrying capacity. Each indicator in this watershed showed a higher value, resulting in the final value of the carrying capacity of the watershed also poor.

Table 5. Calculation of watershed carrying capacity in five watersheds in Semarang City.

Watershed Carrying Capacity (WCC) Indicator	Babon Watershed		BKT Watershed		Garang Watershed		Silandak Watershed		Beringin Watershed	
	Data	WCC	Value	DDD	Value	DDD	Value	DDD	Value	DDD
1. Land Condition										
a. Percentage of Critical Land	1.60	10	0.28	10	3.03	10	0	10	0	10
b. Percentage of Vegetation Cover	22.58	12.5	5.60	15	47.88	10	8.24	15	29.81	12.5
c. factor value	0.19	7.5	0.40	10	0.14	7.5	0.3	7.5	0.16	7.5
2. Water Quantity and Continuity										
a. Annual Flow Coefficient	0.2	6	0.68	18	0.19	6	1.77	18	0.58	18
b. Flood (times)	2	12	5	12	3	12	3	12	3	12
3. Socio-Economic and Institutional										
a. Population Pressure on Land	0.2	21	0.31	21	0.41	21	0.15	21	0.28	21
b. Enforcement of Regulations	0	4.5	0	4.5	0	4.5	0	4.5	0	4.5
4. Water Building Investment										
a. City Classification	376.033	5	728.372	6.25	523.060	6.25	104.768	5	101.853	5
b. Water Building Value (billion rupiahs)	135.7	7.5	55.86	6.25	981.09	7.5	25.4	3.75	34.45	5
5. Territorial Space Utilization										
a. Protected area (%)	56.51	3.75	0	7.5	42.27	5	0	7.5	36.91	5
b. Cultivation Area (%)	87.67	2.5	92.52	2.5	65.35	3.75	90.60	2.5	78.87	2.5
WCC value =		92.25		113		93.5		107		103
Classification =	Moderate		Bad		Moderate		Moderate		Moderate	

On the other hand, the Babon watershed, with an area of 12,291.69 Ha, has a WCC value of 92.25 or 90 < WCC 110, which was moderate. The WCC indicator showed that the Babon watershed had not met the criteria to become a watershed with good carrying capacity. Several WCC indicators need attention to improve the carrying capacity. Meanwhile, the Garang watershed's carrying capacity assessment results were 93.5 and classified in the moderate category. Based on this assessment, the carrying capacity of the Garang watershed needs to be maintained, particularly in terms of land conditions, water management, and regional spatial planning. In addition, the Garang watershed area was vast, so its management must be comprehensive.

Furthermore, the Silandak watershed is a small watershed with an area of 2,391.42 Ha and a WCC assessment score of 107, which is in medium classification concerning its carrying capacity. The score is close to the limit score for the poor watershed classification. If there is no corrective action on each indicator or parameter, then the Silandak watershed's carrying capacity can turn from moderate to poor. In contrast, the carrying capacity of the Beringin watershed is in the moderate classification with a WCC value of 103 or 90 < WCC 110. The Beringin watershed, with an area of 5,176.12 Ha, is in the medium classification based on the watershed's carrying capacity assessment. However, the Beringin watershed has several problems, such as the condition of the land and water system and the use of regional space that affect the final score of the watersheds carrying capacity.

Based on the calculation results, the carrying capacity of the five watersheds observed in this study was moderate and bad.

Babon, Garang, and Beringin had moderate carrying capacity, while Banjir Kanal Timur fell into the bad category. Although the carrying capacity of Silandak was classified as moderate, it was bordering on bad. Babon, Garang, Silandak, and Beringin need to maintain the current conditions of relevant indicators, including land, water systems, socioeconomic circumstances, building investment, and spatial use in the region.

The concept of carrying capacity was initially proposed in the ecological community and was adopted to measure the maximum of individuals maintaining a certain species in a certain area under certain conditions. Nowadays, this concept has been extended into hydrological sciences and is widely used to represent the capacity of the environment or ecosystem to sustain development and specific activities (Deng *et al.*, 2021; Yuan & Tian, 2008). Carrying capacity was originated from the fields of demographics, ecology, and it was discussed in the looming limits of resource consumption and environmental degradation resulting from excessive human activities (Bao *et al.*, 2020).

3.3. Watersheds Carrying Capacity Reviewed from Land Use and Flood Vulnerability

The land use of each watershed determines the carrying capacity indicators or parameters analyzed in this study, mainly through the effect of land conversion into built-up land or settlements. In general, residential land use continues to grow from year to year. The Banjir Kanal Timur Watershed experienced the highest increase in settlement area (21.35%) from 3,863.82 Ha in 2002 to 5,541.42 Ha in 2018 so that the WCC score was high at 113 and the carrying capacity of the watershed was bad.

The relationship between WCC and changes in built-up land, particularly settlements are presented in Table 6 and Figure 4. The greater the score of the percentage change in residential land use, the higher the carrying capacity of the watershed. The Banjir Kanal Timur watershed, which has a high percentage of settlement changes, also has a decreased watershed carrying capacity. The dominant land use changes that occur are from the conversion of forest land into agricultural land, and the conversion of some agricultural lands (rice fields, mixed gardens, dry fields, water bodies) into settlements. The area of settlements as built-up land is increasing from year to year.

The development of settlements in the lower part of Semarang City, precisely as a downstream area of the river from the Banjir Kanal Timur River and the Garang River leads to an alluvial plain landscape. Geomorphologically, alluvial plains from rivers or beaches are areas of flood vulnerability (Dahlia *et.al.*, 2016). The alluvial plain area in the Banjir Kanal Timur watershed is 38.59%, the alluvial plain area in the Babon watershed is 45.15%, while the alluvial plain area is in the Garang watershed (6.73%), Silandak (4.02%), and Beringin (5.52%) (Table 6). The estuary is the most vulnerable area because it is a large water catchment area, wide estuary valley is a meeting between flow outlets from rivers that enter the sea, but there are also fluctuations in ocean waves. Coastal landscapes are areas that are prone to flooding which results in erosion and inundation (Rogers & Woodroffe, 2016).

Table 6. Assessment of watershed carrying capacity by land use area.

Name of Watershed	Watershed Area (Ha)	Settlement (%)	Change Settlement 2002-2018 (%)	Watershed Carrying Capacity (%)	Area of Alluvial Plains (%)
Babon	12,291.69	20.86	8.61	61.5	45.15
Banjir Kanal Timur	7,858.03	71.87	21.35	75.3	38.59
Garang	21,277.36	16.97	7.48	62.3	6.73
Silandak	2,391.42	52.61	14.25	71.3	4.02
Beringin	5,176.12	23.80	9.09	68.7	5.52
Amount =	48,994.62				

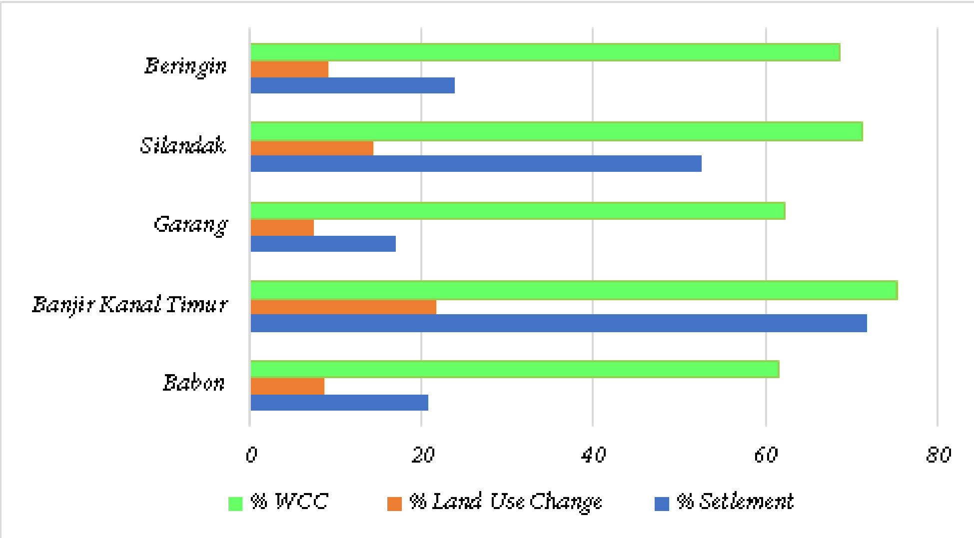

Figure 4. Percentage of watershed carrying capacity by settlement area.

Changes in land use to settlements directly affect the decline in land cover vegetation and land or plant management functions (Nugraha & Utomowati, 2013; Mustart, 2012). This change also impacts the watershed's capacity in water management conditions because the annual water flow increases when the forest and vegetation area is reduced in large numbers or the vegetation type is shifted from deep-rooted to shallow-rooted plants. The more significant the change in land use, such as from forest land to agricultural land, or rice fields and dry fields change into the settlement, the greater the changes in surface water flow. Moreover, changes in land use into industrial areas, offices and settlements are mostly located in the alluvial plains of rivers and beaches of Semarang City. The lower part of Semarang City which is located on the alluvial plain is prone to flooding. The lower part of Semarang City is located on an alluvial plain with flood vulnerability. Changes in land use and physical environmental conditions, especially morphometry and landforms, need to be the focus of attention, because there is a correlation between land use and physical conditions in the watershed, which can increase runoff and flooding (Bisht *et al.*, 2018; Rogers & Woodroffe, 2016). The ecosystem watershed upstream part is very important because it has a protective function against all parts of the watershed, one of them as a function of the water system that can reduce the impact of floods (Susanti *et al.*, 2020). Both land use and land cover can greatly impact hydro-ecological processes of the watershed including ecosystem productivity, evapotranspiration, soil infiltration, and runoff. Some studies showed that agricultural practices, urbanization, deforestation, and industrialization are major drivers affecting water quality and quantity (Alemayehu *et al.*, 2009).

4. Conclusion

Watersheds in Semarang City from 2002 to 2018 have experienced significant changes in land use, especially the increase in settlement area (with an average of 12.27%). The addition of settlements in the Banjir Kanal Timur watershed is at most 21.76% resulting in a high WCC value of 113 so that the carrying capacity of the watershed is categorized as bad. WCC conditions in the Silandak, Baboon, Garang and Beringin watersheds are in the moderate category so that the four watersheds must continue to be managed. WCC parameters include land conditions, water quality, population conditions, water building, watershed space utilization. Conversion of land use into settlements is one of the determinants of the carrying capacity of the watershed. Spatial planning in the

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upstream and downstream watersheds will be able to reduce watershed damage and reduce the frequency of flooding in coastal rivers while considering the flood vulnerability of Semarang City. Policy formulation is based on land conditions, vegetation cover, water management, sustainable use of space according to the carrying capacity of the watershed. Collaboration between all parties, institutions, and individuals involved in watershed management, including government agencies, the private sector, and the community, must be well established to realize a watershed with a sustainable carrying capacity.

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