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RESEARCH ARTICLE

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Analysis of landcover changes and carrying capacity of coastal cities North Java of Central Java Province, Indonesia

Anjar Dwi Krisnanta, Hayati Sari Hasibuan, Rudy Parluhutan Tambunan

Master Program, School of Environmental Science, Universitas Indonesia, Jakarta, 10430, Indonesia

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ABSTRACT

North Coastal Central Java has been a strategic zone from the colonial era to the present because it supports the national socio-economic sector. Urbanization has threatened the development of districts/cities on the northern coast of Central Java. The physiographical conditions of coastal districts/cities along Pantura are formed from alluvial plains, making the environment's carrying capacity more vulnerable to changes in global conditions and pressures from the socio-economic activities of the population. This study aims to identify changes in land cover, its relationship to road infrastructure development, and its implications for environmental carrying capacity. The method used in this study uses GIS to determine changes in land cover and settlement growth patterns and calculates biocapacity and ecological footprint to obtain environmental carrying capacity conditions. The results show that land cover changes mainly occur in agricultural land, plantations, and settlements. In addition, the environment's carrying capacity experienced a deficit/overshoot in 2010, which continued until 2020. The result indicates the problem in the environmental dimension of sustainable development of coastal cities and requires serious intervention to increase environmental quality.

Introduction

Urbanization is closely related to the occurrence of urban sprawl. Urban sprawl occurs in almost all parts of Indonesia, especially Java Island, where the physical appearance of cities is almost unified and massively reduces the number of rice fields [1]. Some big cities in Java, including Semarang, Jakarta, Bandung, and Surabaya, are examples of the urbanization process due to industrial development factors that can attract human resources from rural areas. The link between urban sprawl and the development of cities along the North Coast of Central Java can be found in the Java-Bali Spatial Plan document listed in Presidential Regulation 28 of 2012. This regulation stipulated to manage and control the spatial plan changes in Java-Bali Island. Physiographically, Pantura (*Pantai Utara*) is an alluvial plain formed by sedimentation from the upper area and is carried away by the flow of water to form a new plain. Three categories of areas are affected by this sedimentation process: the western region (Cirebon to Banten), the central region (Brebes to Semarang), and the eastern region (Semarang to Surabaya). In addition, road construction along Pantura [2] in the 19th century was a milestone in increasing economic-based regional connectivity and the transition from river to land transportation. The development that occurred several centuries ago in Pantura has significantly impacted the condition of environmental independence in terms of population growth, especially after independence. The actual carrying capacity of the environment is challenging to measure accurately but can be anticipated with an ecological approach in every development intervention [3].

The evaluation of the spatial plan is the basis for assessing whether the spatial layout has been optimally implemented. If a spatial policy has been adequately implemented, it will provide protection and sustainability to a regional ecosystem. However, enforcing a land function is yet to be implemented at 100%. In the case of urban development, owing to the influence of the construction of the Jakarta-Bandung corridor

Corresponding Author: Anjar Dwi Krisnanta anjar.dwi11@ui.ac.id School of Environmental Science, Universitas Indonesia, Indonesia.

toll road, the presence of settlements along the road corridor on the toll road has increased faster than in the two cities [4]. In the agricultural sector, the suitability of allotment of agricultural land and the continued growth of settlements is a threat to the existence of the agricultural sector, and the government has issued regulations regarding *Lahan Pangan Pertanian Berkelanjutan* (LP2B) in an effort to prevent land conversion from agriculture to non-agriculture [5].

Infrastructure development has both positive and negative social, economic, and environmental impacts. Research conducted in Pekalongan City regarding the impact of toll road construction on the batik industry, economically, there was a decrease in turnover of up to 54.5% for batik sales and 72% for the hotel business [6]. Although for the people of Pekalongan City, the construction of the toll road provides more favorable benefits, it turns out that it has the opposite effect from the batik and hotel industry. Regarding land use, toll road infrastructure has increased the built-up area around the toll gate area in the Semarang District, which the Semarang-Solo Toll Road passes [7]. As for the case of the Industrial Estate in Kendal District, it has had an impact on the increase in built-up land every year and 88.05% is estimated to be in cultivation areas [8]. Another study by Wijaya et al. [9] showed an increase in built-up land reaching more than 100% from 2013 to 2020 and an increase in the Urban Heat Island (UHI) or surface temperature reaching 30 to 38 ^{o}C since the construction of the Kendal Industrial Area began. Land use changes are also a result of infrastructure development, especially on roads. The phenomenon of changing productive areas, such as rice fields and agricultural land, into settlements and other built-up areas has occurred along the Trans Java toll gate in a short period. The built area around the Ungaran toll gate increased from 2,974 ha to 41,883 ha after the construction and operation of the Trans Java toll road [7]. Meanwhile, in terms of environmental conditions, changes in land use have led to water surface runoff in the Pemalang District, Central Java [10].

The purpose of this study was to analyze changes in land cover due to road infrastructure development and the implications for the carrying capacity of the district/city environment on the North Coast of Central Java. This research is essential to provide input for planning and mitigating environmental degradation caused by development.

Method

Location and Time

The research was conducted in cities along the North Coast of Central Java (figure 1), covering 14 districts/cities with the characteristics of the coastal area and being the center of economic activity so far. Administratively, the research location is in Central Java Province and borders the Cirebon District (West Java) on the west side and Tuban District (East Java) on the east side. Meanwhile, on the north side, it is bordered by the Java Sea, and on the south side, it is bordered by districts in the central part of Central Java Province. The total area of the study area was 11,859 km^2. The population of the research locations in 2010 reached 13,625,424 people and increased to 15,278,395 people by 2020. It considers the amount of investment in intensive infrastructure development in the last ten years and plans for the next five years, especially from the road sector. When compared to the southern route (Pansela/*Pantai Selatan*) of Central Java, Pantura has a role in increasing the national economy as a good distribution road and economic activity [11,12]. On the other hand, the character of the Pantura region, which is formed from alluvial deposits, makes the location have various problems on the environmental side due to pressure from economic community activities to be the target of this research. There were 14 districts/cities where the research had the characteristics of a coastal ecosystem. Coastal ecosystems play an essential role in the carrying capacity of the environment, and anthropogenic factors have had an impact on population pressure, water pollution downstream of rivers, and the deteriorating role of mangroves in protecting land areas [13].

Data Collection

Secondary data was used, which was sourced from government institutions. The secondary data collected included land cover data from the Ministry of Environment and Forestry for 2011 and 2020. Calculating the carrying capacity of the environment requires population data sourced from the Central Statistics Agency. Infrastructure data were sourced from the Ministry of Public Works Housing and Geospatial Information Agency. Finally, information on built-up area data uses results from satellite imagery on the Global Human Settlement Layer platform [14].

Figure 1. Location of research.

Data Analysis

Landcover change analysis uses land cover data with a scale of 1: 250,000. The land cover data were processed again with ArcGIS 10.8 mapping software. The land cover shapefile data were clipped and overlaid with administrative area boundaries, and then the attribute data from each land cover category was checked according to the Ministry of Environment and Forestry standards. The next step was to calculate the land cover area per category and district per city. The tabulation process of the spatial analysis results was used to compare the changes in land cover. Then, to measure the built areas around the toll gate, researchers used buffer analysis to calculate and compare districts and cities.

To analyze the carrying capacity of the environment, researchers have carried out steps using the ecological footprint approach. Several studies have used this approach to assess the carrying capacity of the environment, emphasizing the measurement of population demand for nature in biocapacity metric units [15]. The Bioecological Carrying Capacity (BCC) was calculated based on the ecological footprint and bio-capacity variables).

$$BCC = BCt / EFt \quad (1)$$

DDB is the bioecological carrying capacity by comparing the total biocapacity (BCt) in hectare/capita and the total ecological footprint value (EFt).

Biocapacity Calculation

Biocapacity (BC) is calculated by multiplying a constant of 0.88 by the area of a specific type of land use (LUi) and the production factor of a specific land use (FLUi), then divided by the population (P).

$$BC = (0.88 \times LUi \times FLUi)/P \quad (2)$$

$$BCt = \sum_{i=1}^{k} BCi \quad (3)$$

Ecological Footprint Calculation

The ecological footprint (EFi) was calculated by multiplying the number of population (JP) by the value of the population's land requirement per land use (Ki) and the equivalent factor (EFi). The Total Ecological Footprint (EFt) is the sum of all ecological footprint values for each land-use type.

$$EFi = P \times Ki \times EFi \quad (4)$$

$$EFt = \sum_{i=1}^{k} EFi \quad (5)$$

Result and Discussion

Landcover Changes

Land cover changes can be used as a reference to measure the dynamics of community activities in an area. Physiographic units comprise geological units (lithology and structure) and geomorphology units (landforms and processes). Physiographic conditions affect the availability of natural resources in the region, affecting development activities and the use of space above them. The topography of the study area, based on land use in the western and central parts, is a lowland area, whereas the eastern part is a combined area of lowlands and hills with rows of mountains. Karst hill areas are found along the Purwodadi – Blora – Cepu route. The topographic division of Central Java based on land use can be described in Table 1 as follows.

Table 1. Physical aspect of research location.

Region	Physical Information
Western (Brebes-Batang)	Alluvial plain with sloping topography and sandy and muddy beaches dominates the beach. The upstream area is dry land and rice field cultivation.
Middle (Kendal-Semarang)	Dominated by alluvial plains with low and medium topography. Urban areas are directly adjacent to the beach/sea, and land use is dominated by settlements, industry, fisheries/agriculture.
Eastern (Jepara-Rembang)	It is dominated by alluvial plains with low and medium topography—a mix of sandy and rocky beaches. Agricultural/fishery areas are directly adjacent to the beach/sea. In addition, there are geological processes from the results of ancient volcanic rocks and limestone.

Like other provinces on Java Island, the Central Java Province has fertile land. The land on the island of Java comes from volcanic deposits and many rivers. Soil fertility in Central Java is primarily used for agricultural land, which has caused the research area to become a national rice producer. Most of the land cover for the research location was paddy fields with an area of 462,879.27 hectares (38%), followed by plantation forests covering 178,000 ha (14%). However, the area of settlements in 2020 will reach 14.6% of the total land cover, indicating that settlements play an essential role in all changes in the physical conditions of the region. This fact is relevant to studies on sustainable agriculture in Central Java due to soil capability and the need for support regulation of physically and economically [16]. Another study showed that land cover changes to built-up areas impact the surface urban heat island in Salatiga City [17].

Based on the spatial analysis of land cover in 2011 and 2020, as shown in Figure 2, land cover changed from agricultural land and industrial plantation forests to residential areas. The residential area increased by 70,439 hectares from approximately 2011 to 2020, which is also in line with the decreasing dry land agricultural area of 41,945 hectares. Spatially, the distribution of population growth is linear in the presence of road infrastructure. Apart from national and provincial roads, the figure above shows that settlements around toll roads in Semarang City, Pemalang District, and Tegal District have increased. On the other hand, land cover has changed in Ungaran Barat and Ungaran Timur after the development of the toll road along the Semarang and Solo Corridors [7].

The existence of toll gates has an impact on changes in land use, especially the increase in built-up zones, such as settlements and services. The analysis in this study examined the development of the built-up area around the toll gate with a radius of 5 km between 2010 and 2020. The results of the analysis are shown in the Table 2 below, where the characteristics of districts tend to have a higher level of built-up area development than cities. In several cities in the study area, where there are toll gates, the development of built-up areas is less than 10%, which is different from the district areas with an average development of 20%. Districts supported by urban areas, such as Batang District and Demak District, have an increase in built-up areas, reaching above 30%. This indicates that toll gates can encourage the growth of urban buffer areas.

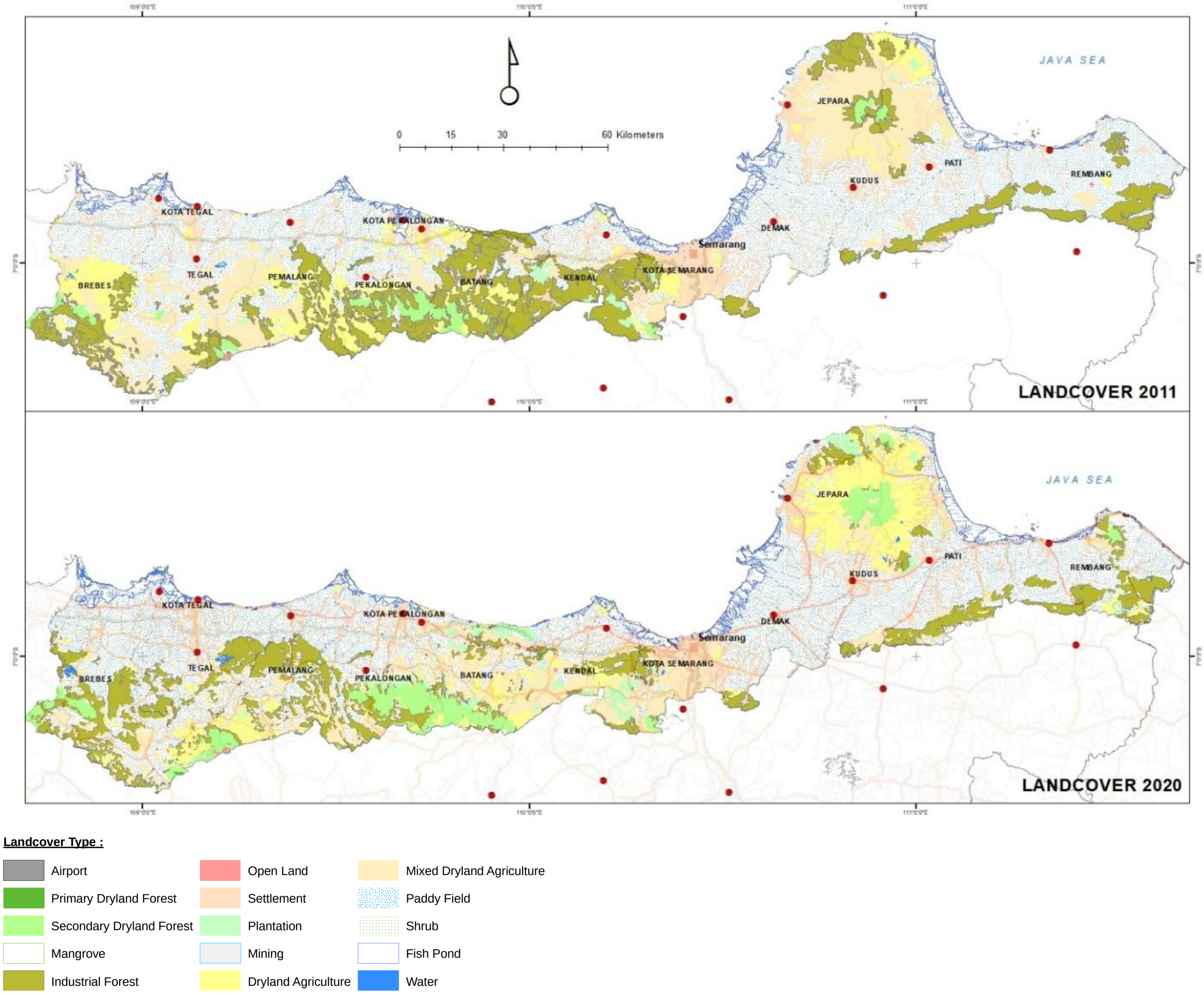

Figure 2. Landcover changes 2011 dan 2020.

Table 2. Landcover changes (Ha).

Landcover	2011	2020	Changes
Airport	-	334.34	334.34
Primary dryland forest	83.6	194.11	110.50
Secondary dryland forest	30,525.1	58,465.34	27,940.24
Mangrove	155.6	962.07	806,46
Industrial forest	249,234.8	178,794.99	–70,439.77
Settlement	144,396.1	177,806.67	33,410.56
Plantation	6,370.5	25,501.92	19,131.40
Mining	-	852.02	852.02
Dryland agriculture	116,725.3	114,566.95	–2,158.33
Mixed dryland agriculture	175,750.9	133,805.27	–41,945.58
Paddy field	462,328.1	462,879.27	551.13
Shrub	3,171.9	7,269.65	4,097.75
Fishpond	52,873.0	48,933.95	–3,939.07
Open land	1,026.6	987.50	–39.11
Water	3,928.6	5,891.54	1,962.93

Table 3. Built up area surrounding toll gate (Ha).

District/City	Toll gate	Built up area (Ha) with buffer 5 Km		Changes (Ha)	%
		2010	2020		
Brebes	3	4,215.69	4,689.11	473.42	11
Tegal	1	4,030.13	4,254.03	223.90	6
Pemalang	1	1,864.53	2,137.36	272.83	15
Pekalongan	1	2,524.34	3,227.37	703.03	28
Batang	2	2,404.47	3,129.10	724.63	30
Kendal	3	3,831.68	4,297.39	465.71	12
Demak	0	22.81	31.82	9.01	39
Semarang City	9	15,201.49	16,490.39	1,288.90	8
Tegal City	0	594.25	620.57	26.32	4
Pekalongan City	1	2,394.78	2,641.35	246.57	10
Total		37,084.17	41,518.50	4,434.33	12

Carrying Capacity

Analysis of the impact of infrastructure development on the carrying capacity of the environment and urban development is to compare the effect of road infrastructure development, that is, national, provincial, and district roads, with environmental capabilities as a factor affected by this development. The carrying capacity in this study was similar to the concept of ecological carrying capacity. Ecological carrying capacity (ECC) is the maximum of human activities that can be accommodated by natural resource capacity [18]. This approach uses land cover and ecological footprints as the main indicators of human activities when using natural resources. In addition, a city's development is affected by the existence of road infrastructure development. Several previous studies have shown that infrastructure development has a linear relationship with the environmental carrying capacity and urban development variables. One study on the impact of toll road development with the type of urban sprawl around 12 toll gates in Java Island included linear and leapfrog, concentric and leapfrog, and combinations of linear and radial with leapfrog [19].

The technical analysis carried out for the two variables calculates the carrying capacity of the environment using the ecological footprint approach (Figure 3). This approach uses the variables of population, land cover, and constants determined by previous studies for each type of land use. In addition, the types of land use sourced from the Ministry of Environment and Forestry in 2011 and 2020 were simplified into categories according to their coefficients. The types of land use used to calculate the carrying capacity of the environment included forests, production forests, agricultural land, pastures/livestock/fields, built-up land, and water. While the data used was land cover in 2011 because the Ministry of Environment and Forestry did not release data officially in 2010, the researchers used 2011 data with the assumption that there were no significant differences within one year. The carrying capacity of the environment is calculated by comparing the ability of the environment or biocapacity (supply) and the demand for the environment for human consumption needs (demand) or the Ecological Footprint (ecological footprint). When the need for ecological resources exceeds their availability, it causes the carrying capacity to be exceeded (overshoot/deficit).

Based on the analysis of the carrying capacity of the environment, it was found that most districts/cities in the study locations since 2010 have been in a deficit condition because the ability of the environment to provide human needs in the biocapacity index is smaller than the demand for human consumption in the ecological footprint index. The district/city average biocapacity value is 1.25 hectares/capacity, while the ecological footprint has reached 1.44 hectares/person. Comparing the two indicators produces a value of environmental carrying capacity with a value of 0.86. Even though it has a positive value because this carrying capacity index requires a value above 1 to indicate that the carrying capacity is still sufficient, this value can be categorized as a deficit or overshot condition. Such conditions still need to provide an overview of the causes of the low environmental carrying capacity due to what factors influence it. However, the researcher assumes that the condition of the environment's carrying capacity is caused by human interventions over a relatively long period, especially after the reform era. Many land use permits were issued for economic activities and other sectors during the post-reform era. The characteristics of coastal communities are usually accompanied by poverty and lack of welfare due to less income from the fishery sector, but the impact of reducing carrying capacity has not directly affected the level of communities. This phenomenon is caused by the local wisdom of the community to adapt to current environmental conditions [20].

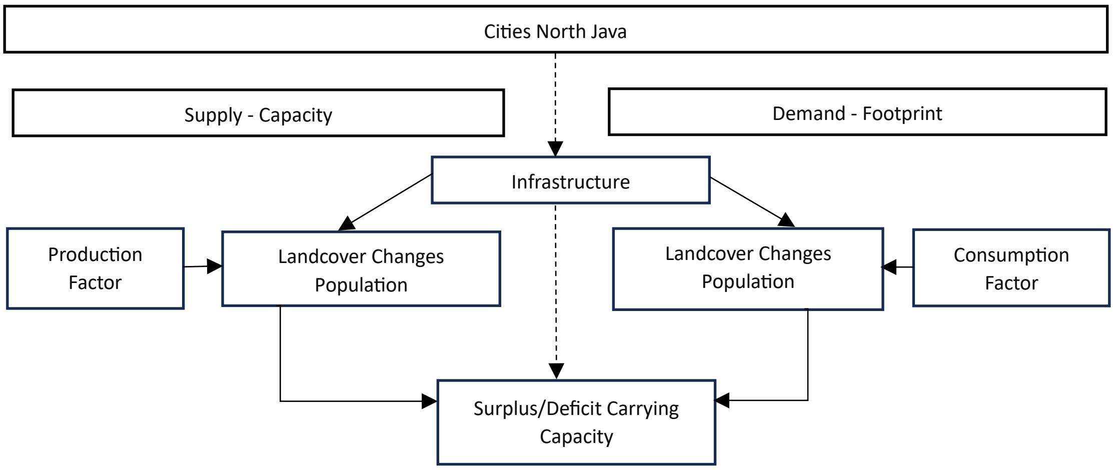

Figure 3. Carrying capacity calculation scheme.

A detailed analysis per district/city showed Table 4 that almost all districts/cities in the study locations were already in an overshot condition. However, one city, Pekalongan City in 2010, is still in surplus. That year, Pekalongan City still had water conditions that were relatively well maintained to meet the needs of its population. The biocapacity index of the city's water was 0.0069, whereas the ecological footprint was only 0.0034. The Demak and Tegal Districts are two districts with an index value close to 1 compared with other districts/cities. However, the same trend occurs in these two districts and Pekalongan City, especially in terms of water conditions, which are still in surplus. However, the other land cover categories tended to decrease in quality. The table below shows the results of calculating the environmental carrying capacity in the study area.

Table 4. Carrying capacity calculation.

District/City	2010				2020				Changes 2010-2020
	Biocapacity (Ha/capita)	Ecological footprint (Ha/people)	Carrying capacity	Status	Biocapacity (Ha/Capita)	Ecological footprint (Ha/people)	Carrying capacity	Status	
Brebes	0.0946	0.10665	0.8866	Overshoot	0.0888	0.1013	0.8768	Overshoot	–0.0099
Tegal	0.0629	0.07201	0.8728	Overshoot	0.0616	0.0719	0.8567	Overshoot	–0.0161
Pemalang	0.0858	0.09928	0.8640	Overshoot	0.0786	0.0920	0.8537	Overshoot	–0.0103
Pekalongan	0.1148	0.13424	0.8548	Overshoot	0.0985	0.1142	0.8625	Overshoot	0.0076
Batang	0.2009	0.24455	0.8215	Overshoot	0.1044	0.1206	0.8661	Overshoot	0.0446
Kendal	0.1243	0.14728	0.8440	Overshoot	0.0901	0.1024	0.8805	Overshoot	0.0364
Demak	0.0808	0.08707	0.9277	Overshoot	0.0703	0.0758	0.9284	Overshoot	0.0008
Kudus	0.0499	0.05725	0.8715	Overshoot	0.0450	0.0512	0.8787	Overshoot	0.0073
Pati	0.1225	0.13760	0.8899	Overshoot	0.1109	0.1244	0.8915	Overshoot	0.0015
Rembang	0.1707	0.19925	0.8568	Overshoot	0.1628	0.1899	0.8569	Overshoot	0.0002
Jepara	0.0923	0.10680	0.8641	Overshoot	0.0841	0.0959	0.8766	Overshoot	0.0125
Semarang City	0.0232	0.02621	0.8861	Overshoot	0.0214	0.0239	0.8925	Overshoot	0.0064
Tegal City	0.0139	0.01452	0.9545	Overshoot	0.0121	0.0126	0.9620	Overshoot	0.0075
Pekalongan City	0.0186	0.01670	1.1130	Surplus	0.0128	0.0139	0.9205	Overshoot	–0.1925
TOTAL	1.2549	1.44942	0.8658	Overshoot	1.0414	1.1900	0.8751	Overshoot	0.0093

The analysis results for 2020 show that all districts/cities are in a deficit (overshot). The environment's carrying capacity in 2020, when compared to 2010, has declined to 0.01. Even Pekalongan City, which experienced a surplus in 2010, became a deficit with an index of 0.92. This value is almost the same as that of the Demak and Tegal Districts, which have relatively stable indexes of 0.92 and 0.95.

Comparing the analysis results for 2010 and 2020 provides information that the environment's carrying capacity in the study locations has decreased but is yet to be significant. The non-significance of comparing the two research years was due to the slight change in the ten periods, namely 0.01. However, we also compared the changes in each district. In that case, it shows that the dynamics of changes in the environment's carrying capacity are in Tegal District, Pemalang District, Batang District, and Pekalongan City. The spatial distribution of these districts indicates a pattern of land-use change due to multiple factors, including toll roads throughout the districts, which have been operating since 2018.

The correlation test determines the relationship between variables used to calculate the impact of infrastructure development on environmental conditions. The interpretation of the statistical test results above is that the existence of road infrastructure strongly correlates with changes in the land cover of built-up areas and has a standardized significance value below 0.05. However, there is no significant relationship between the variable road infrastructure and the carrying capacity of the environment; therefore, further analysis is needed to provide a clear picture of environmental conditions.

Conclusion

Managing an area according to its designation and preventing environmental degradation is challenging in developing countries, such as Indonesia. The imbalance in the dimensions of sustainable development in terms of social, economic, and environmental aspects causes the development direction to fail to achieve the goal comprehensively. The government has issued regulations regarding environmental protection, including environmental law No. 32 of 2009, spatial planning law No. 26 of 2007, and the Law of Sustainable Food Agricultural Land No. 41 of 2009. The three principal regulations have been implemented for more than ten years now, but implementation in the field still needs to be improved, so environmental conditions continue to decline. Changes in land cover are one of the parameters used to measure the changes or physical dynamics of an area. The North Coastal area of Central Java is a crucial area for the economy of Java Island and even nationally because districts/cities are centers of economic activity. However, the existence of coastal ecosystems in the form of alluvial plains makes the area prone to environmental degradation.

The analysis of changes in land cover indicates that population settlements continue to increase, reaching 14.61%, and the area of dry land agriculture continues to decrease by 10.99%. The distribution pattern of most population settlements is around transportation access, be it toll roads or national to local roads. The condition of the environmental carrying capacity of 13 districts/cities using the biocapacity and ecological footprint approach, since 2010, has been an overshoot condition where the need to meet the needs of the population is greater than the resources provided by nature. Pekalongan City was the only region that had a surplus in 2010. In 2020, this overshoot will continue in all districts/cities on the North Coast of Central Java, including Pekalongan City. The above results can be used to evaluate infrastructure development and regional spatial planning systems. Thus, environmental conditions can be maintained and even improved according to their ability to support humans and other living things. This research still has limitations in the period and data scale used; therefore, in the future, more specific research can be carried out at a more in-depth analysis level.

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References

1. Nurrokhman, A. Urban Sprawl Di Indonesia Dan Kegagalan Implementasi Kebijakan Perlindungan Lahan Pertanian Pangan Berkelanjutan. *Departemen Geografi Pembangunan* **2019**, *1*, 1–14, doi:10.31227/osf.io/tqj8c.

2. Novenanto, A. Transjawa, Pertumbuhan Ekonomi, Dan Urbanisasi. *Bhumi J. Agrar. dan Pertanah.* **2018**, *4*, 123–139.
3. Whitten, T.; Soeriaatmadja, R.E.; Suraya, A. *The Ecology of Java and Bali*; Periplus Editions: Singapore, 1996; 978-1-4629-0504-1.
4. Rustiadi, E.; Pravitasari, A.E.; Setiawan, Y.; Mulya, S.P.; Pribadi, D.O.; Tsutsumida, N. Impact of Continuous Jakarta Megacity Urban Expansion on the Formation of the Jakarta-Bandung Conurbation over the Rice Farm Regions. *Cities* **2021**, *111*, 103000, doi:10.1016/j.cities.2020.103000.
5. Andriawan, R.; Martanto, R.; Muryono, S. Evaluasi Kesesuaian Potensi Lahan Pertanian Pangan Berkelanjutan Terhadap Rencana Tata Ruang Wilayah. *Tunas Agrar.* **2020**, *3*, 132–150, doi:10.31292/jta.v3i3.126.
6. Siswanto, V.A.; Wahjuningsih, T.P.; Murtini. Dampak Pembangunan Jalan Tol Terhadap Faktor Sosial, Ekonomi Dan Lingkungan Pada Usaha Batik Dan Perhotelan Di Kota Pekalongan. *J. Litbang Kota Pekalongan* **2019**, *17*, 83–92.
7. Wisnu, T.; Amarrohman, F.J.; Sudarsono, B. Analisis Perubahan Penggunaan Lahan Di Ungaran Timur Dan Ungaran Barat Pasca Pembangunan Jalan Tol Semarang-Solo. *J. Geod. Undip* **2019**, *9*, 115–125.
8. Mailendra, M. Pemanfaatan Data Penginderaan Jauh Dan Teknologi Sig Untuk Mengidentifikasi Built Up Area Dan Kaitannya Dengan RTRW Di Kabupaten Kendal. *Semin. Nas. Geomatika* **2019**, *3*, 521–528, doi:10.24895/sng.2018.3-0.1004.
9. Wijaya, M.I.H.; Ariyani, N.M.; Priambudi, B.N.; Gumelar, A.; Ichsanudin, H. Urban Heat Island: Identification of Spatial Patterns of Green Open Space for Mitigation in Kendal Industrial Park, Indonesia. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *887*, 1–7, doi:10.1088/1755-1315/887/1/012010.
10. Narendrasastri, D.E.; Sabri, L.M.; Wahyuddin, Y. Analisis Pengaruh Perubahan Penggunaan Lahan Jalan Tol Terhadap Limpasa Permukaan Di Kecamatan Pemalang. *J. Geod. Undip* **2021**, *10,* 11–20.
11. Husaini, H.W.; Junoasmono, T. Peran Infrastruktur Jalan Pantura Jawa Dalam Rangka Mendukung Peningkatan Ekonomi Nasional. *J. HPJI (Himpunan Pengemb. Jalan Indones.* **2017**, *3*, 1–10.
12. Hapsari, A.P.; Istiqomah, R.A.; Parhusip, V. A Comparasion Between Trans - Java Toll Road and Pantura Line on Distribution of Goods. *Advances in Transportation and Logistic Research* **2019**, *1*, 1–8.
13. Adyasari, D.; Pratama, M.A.; Teguh, N.A.; Sabdaningsih, A.; Kusumaningtyas, M.A.; Dimova, N. Anthropogenic Impact on Indonesian Coastal Water and Ecosystems: Current Status and Future Opportunities. *Mar. Pollut. Bull.* **2021**, *171*, 112689, doi:10.1016/j.marpolbul.2021.112689.
14. Schiavina, M.; Carneiro Freire, S.M.; MacManus, K. *GHS Population Grid Multitemporal (1975-2030)*; Publications Office of the European Union: Luxembourg, 2022; ISBN 978-92-76-13186-1.
15. Setiawan, D.; Susetyo, C. Optimasi Pemanfaatan Lahan Melalui Pendekatan Telapak Ekologis Di Kabupaten Sukoharjo. *J. Tek. ITS* **2021**, *10*, 62–68, doi:10.12962/j23373539.v8i2.46842.
16. Widyatmanti, W.; Umarhadi, D.A. Spatial Modeling of Soil Security in Agricultural Land of Central Java, Indonesia: A Preliminary Study on Capability, Condition, and Capital Dimensions. *Soil Secur.* **2022**, *8*, 100070, doi:10.1016/j.soisec.2022.100070.
17. Dewantoro, B.E.B.; Mahyatar, P.; Hayani, W.N. Detection and Analysis of Surface Urban Cool Island Using Thermal Infrared Imagery of Salatiga City, Indonesia. *Int. J. Remote Sens. Earth Sci.* **2021**, *17*, 115–126, doi:10.30536/j.ijreses.2020.v17.a3387.
18. Tang, Y.; Wang, M.; Liu, Q.; Hu, Z.; Zhang, J.; Shi, T.; Wu, G.; Su, F. Ecological Carrying Capacity and Sustainability Assessment for Coastal Zones: A Novel Framework Based on Spatial Scene and Three-Dimensional Ecological Footprint Model. *Ecol. Modell.* **2022**, *466*, 109881, doi:10.1016/j.ecolmodel.2022.109881.
19. Aditya, R.B.; Husna, Z. Identification of Sprawl Development Typologies around Toll Road Gates in Java, Indonesia. *Tataloka* **2022**, *24*, 1–14, doi:10.14710/tataloka.24.1.1-14.
20. Aziz, A.; Shodikin, A.; Rana, M. Java Coastal Community Empowerment Model. *SSRN Electron. J.* **2019**, *1,* 1–14, doi:10.2139/ssrn.3333949.