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RESEARCH ARTICLE

The Effects of Urbanization on Indonesian Community and Environment

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Abstract This research aims to analyze the impact of urbanization on environmental and socio-economic resilience of communities by investigating the Sukoharjo region in Indonesia. Several components of urban ecosystem were considered, including geological formations, geomorphological conditions, and eco-regions. Meanwhile, the analysis of urban socio-economic aspects focuses on community well-being and urban facilities. The research uses 180 observation samples in the analysis process. The result shows that urbanization deteriorates soil fertility, agricultural land, and the availability of clean water through panel data regression. In addition, urbanization has successfully increased per capita income, employment opportunities, and the development of public facilities, posing a dilemma for policymakers. This shift in population needs to be pursued by some communities to preserve urban ecosystem. Urbanization has a positive and negative impact on community welfare and ecosystems, respectively. In this context, future research must adopt effective methods for managing urbanization and urban ecosystems.

1. Introduction

The issue of urban population expansion is becoming a global concern. Besides fertility and mortality, urbanization is a mobilization mechanism of the population (Hari Mardiansjah & Rahayu, 2019) as well as an inevitable trend in social and economic development (R. Liu et al., 2021). In 2021, over 70% of the population in Europe and North America resided in cities, while 52% were reported in Asia (Tuholske et al., 2021). Urbanization movement shows that humans are adapting to urban life (Grimm et al., 2008).

According to the World Bank (2016), Indonesia is the third most densely populated country in East Asia after China and Japan, with urban land increasing by 1.1% per year between 2000 and 2010. Population density due to urbanization has three adverse effects on ecosystems. First, excessive growth disrupts ecosystem functions by converting natural vegetation into impermeable surfaces (R. Chen & Huang, 2021; Devi, Fitria, Roychansyah, & Herwangi, 2020; García-Nieto et al., 2018; Klimanova, Illarionova, & Grunewald, 2021; J. Wang, Zhou, Pickett, Yu, & Li, 2019). Second, ecosystem degradation has consequences for social and economic issues (D. Zhang et al., 2023). Third, relatively significant urbanization leads to land encroachment for private organizations and industries addressing various environmental issues (Z. Chen, Lin, & Huang, 2023; Fan et al., 2019). These issues show that high urbanization rates reduce urban ecosystems and environmental challenges (Murtala, Manaf, & Mohammad, 2020).

Ecosystems are determined by endogenous and exogenous factors reflected in three components, including estimates/proxies for eco-regional landscapes, vegetation communities, and land cover or land use (Baco S, Kahirun, Zulkarnain, & Albasri, 2020; Febriarta & Oktama, 2020). The ecosystem conditions of an area are crucial as the basis for formulating public policy regarding strategies or methods implemented to enhance environmental sustainability (R. Li, Shi, Feng, & Guo, 2021b). Urban ecosystems play a crucial role in maintaining quality of life and controlling ecological management systems (De Groot, Wilson, & Boumans, 2002; Y. Yang et al., 2019).

The observations show that the Sukoharjo Regency is a regency on Java Island, with a significantly high level of urbanization. According to data from the Local Environmental Authority, the soil environmental quality index fluctuated in 2020 to only 27.18, below the minimum threshold of 50. Therefore, this research was carried out to provide answers to the question, "Is urbanization beneficial?".

Urbanization in Sukoharjo, Indonesia, resulted in adverse environmental impacts, as outlined in the issues. The depletion of natural resources beyond the capacity for regeneration or environmental support leads to depletion (Muta'ali, 2015). Furthermore, urbanization is defined as the presence of urban population prevailing in the demographic composition of non-agricultural industries (Sumaryanto, Hermanto, Ariani, Yofa, & Azahari, 2015). The conversion of land cover from agricultural to non-agricultural affects environmental sustainability and quality (Petit, Celis, Weideman, Gouin, & Bertin, 2023; D. Zhang et al., 2023). This phenomenon has adverse effects on ecosystem health and the overall population (R. Li et al., 2021b). Different geological formations, such as rocks and sediments must be evaluated to assess the quality of urban ecosystems. Additionally, geomorphological conditions, including landscape features, can be considered. Regional eco-regions, including climate, soil, water, native flora, and fauna, can also be examined (Millennium Ecosystem Assessment, 2005).

High-quality ecosystems are crucial for sustainable human development in terms of economic, social, cultural, and ecological aspects. This is because ecosystems support natural and human systems through purification, recycling, and renewal of biological resources (De Groot et al., 2002; Terêncio et al., 2021). The services are categorized into provisioning, regulating, cultural, and supporting services (DeLoyde & Mabee, 2023; Richards et al., 2020; Y. R. Wang, Samset, Stordal, Bryn, & Hessen, 2023). The most essential service is the provisioning function, which directly relates to urgent and clear development targets such as food security, income improvement, employment, health, and nutrition (Ayompe, Schaafsma, & Egoh, 2021; Z. Yang et al., 2023). Based on a review of several literatures, urbanization can benefit the lives of different communities when there is continuity between social, economic, and environmental issues. An area experiencing relatively high urbanization needs to improve the ecosystem to balance the social and economic conditions.

The Research Area

Sukoharjo Regency consists of various geological and geomorphological formations that can form ecoregions with the characteristics of each region, as presented in Figure 1.

Geographically, the research object is Sukoharjo, which is one of the regions in Central Java Province, Indonesia, with astronomical coordinates ranging from 110°42’06.79” to 110°57’33.70” E and 7°32’17.00” to 7°49’32.00” S. Meanwhile, the area has various geological formations, as shown in Table 1.

Qa consists of clay, silt, loam, sand, gravel, and Quaternary-aged rocks originating from river sediments (Ahmed et al., 2022; Foroutan et al., 2020; Miller & Juilleret, 2020). Meanwhile, Qvm and Qvl are volcanic rocks composed of volcanic breccia, lava, and tuff from the Quaternary age due to lava deposits from active volcanoes (Alvarez-Codoceo, Cerda, & Perez-Quezada, 2021; Baldermann, Abbasov, Bayramova, Abdullayev, & Dietzel, 2020; Inostroza et al., 2022; Petronis et al., 2021). Furthermore, Tomm consists of andesitic-dacitic lavas and tuff with oligo-Miocene diorite fractures (Fodor & Johnson, 2016; Krzemińska, Poprawa, Pacześna, & Krzemiński, 2022). Regarding geomorphology, Sukoharjo Regency has six

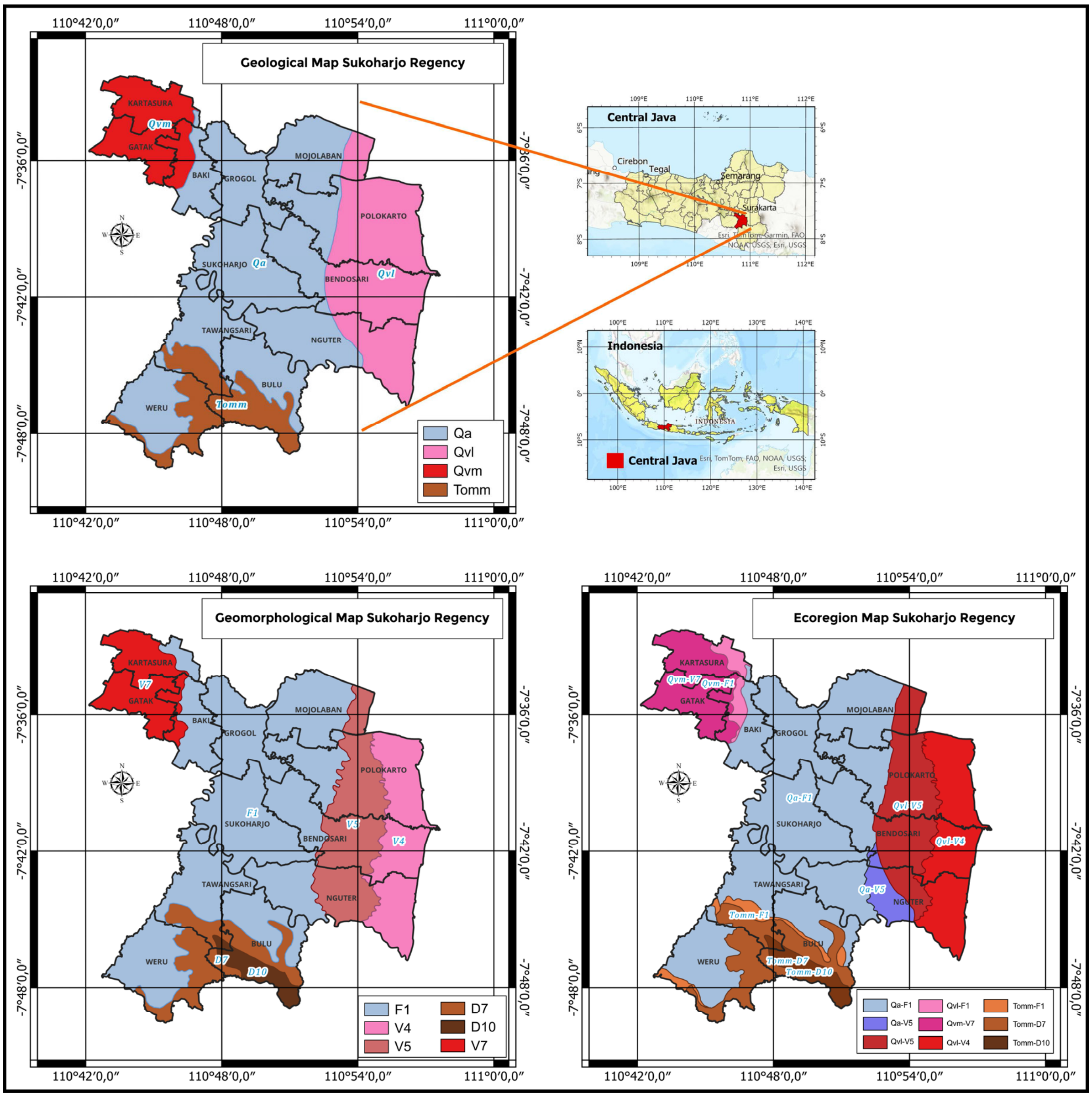


Figure 1. The Map of Geological, Geomorphology, and Ecoregions in Sukoharjo Regency

Table 1. Geological Formations

No	Symbol	Geological Formations	An area	
			Ha	%
1	Qvm	Merapi Volcano Rocks	5,009.70	10
2	Qvl	Lawu Volcano Rocks	11,788.83	24
3	Tomm	Mandalika Formation	5,059.06	10
4	Qa	Alluvium	27,465.90	56
Total Area			49,323.49	100

Source: Geological Map of Sukoharjo Regency Coverage Area (2022)

Table 2. Geomorphological data

No	Symbol	Geomorphology	An area	
			Ha	%
1	F1	Alluvial Plain	27,384.25	56
2	V7	Volcanic Foothills	4,185.20	8
3	V5	Lower Volcanic Slope	6,810.98	14
4	V4	Central Volcanic Slope	5,925.59	12
5	D7	Denudational Foot Slope	3,800.73	8
6	D10	Steep Denudational Slope	1,216.73	2
Total Area			49,323.49	100

Source: Geomorphological Map of Sukoharjo Regency (2022)

Table 3. Ecoregions

No	Symbol	Ecoregions	An Area	
			Ha	%
1	Qa-F1	Alluvial Plain with Alluvium	25,395.57	51
2	Qvm-F1	Alluvial Plain with Merapi Volcanic Rocks	832.16	2
3	Tomm-F1	Alluvial Plain with the Mandalika Formation	833.92	2
4	Qvm-V7	Volcanic Foothills with Merapi Volcanic Rocks	4,177.54	8
5	Tomm-D7	Denudational Foot Slope with the Mandalika Formation	3,804.26	8
6	Tomm-D10	Steep Denudational Slopes with the Mandalika Formation	1,213.45	3
7	Qa-V5	Lower Volcanic Slope with Alluvium	1,205.15	2
8	Qvl-V5	Lower Volcanic Slope with Rocks of Lawu Volcano	5,935.84	12
9	Qvl-V4	Central Volcanic Slope with Lawu Volcanic Rocks	5,925.59	12
Total			49,323.49	100

Source: Ecoregion Map in Sukoharjo Regency (2022)

natural landscapes based on Verstappen, as presented in Table 2.

Table 2 shows that the D10 is a landform resulting from denudation processes with relatively steep slopes due to erosion (Larsen, Montgomery, & Greenberg, 2014; Roering, Perron, & Kirchner, 2007). Meanwhile, V7 is a landform with flat characteristics formed by the deposition of volcanic material through fluvial processes (Kiryukhin, Nazhalova, & Zhuravlev, 2022; Mukherjee et al., 2012). V5 is located at the base of volcanoes used for agriculture, plantations, tourism, and settlements (Suprayogo et al., 2020). V4 is a landform originating from processes formed by the gradual deposition of volcanic material (Chang, Mitchell, & Quartau, 2021; Lavigne, Thouret, Voight, Suwa, & Sumaryono, 2000). Finally, D7 is a landform originating from deforestation processes, characterized by a relatively elongated and narrow area in mountains or hills (Vergari, Della Seta, Del Monte, Fredi, & Lupia Palmieri, 2013). Based on geological and geomorphology, Sukoharjo Regency is divided into 9 (nine) eco-regions as explained in Table 3.

2. Methods

Data and Data Sources

This research uses secondary data in the analysis process, as reported in Table 4.

Population, Sample Methods, and Measurement of Research Variables

The population includes 12 districts in Sukoharjo, Indonesia, over 15 years (2008 - 2022), making the total population 180 areas. This research uses saturated sampling to sample all sub-districts and urbanization as the dependent variable, which have several indicators, including urbanization ratio (UB), population density ratio (PD), and percentage of farming families (FF). Environmental carrying capacity is used as an independent variable explained through geological, geomorphological, and eco-regions. Additionally, district characteristics are adopted as independent variables, including per capita income (IC), number of jobs (JN), kindergartens (KN), junior high schools (JH), senior high schools (HS), healthcare facilities (HF), banks (BN), hotels (HN), restaurants

Table 4. Data and Data Sources

Data	Source
A.1. Geological formations A.2. Geomorphological conditions A.3. Regional ecoregions	District authority; Local authority environment department; Ministry of Environment and Forestry (https://www.menlhk.go.id/); Geological Bureau of the Ministry of Energy and Mineral Resources (https://www.esdm.go.id/id/).
Regional Characteristics: B.1. Population density B.2. Number of populations B.3. Income per capita B.4. Number of jobs B.5. The existence of a kindergarten B.6. The existence of high school B.7. The existence of cinemas B.8. Hospitals/clinics/doctors B.9. Banks/hotels/restaurants B.10. The existence of shops B.11. Market existence B.12. Percentage of electricity users B.13. Number of farming families	District authority; Local authority regional development department; Ministry of Home Affairs (https://www.kemendagri.go.id/); World Bank Indonesia (https://www.worldbank.org/en/country/indonesia); Bureau of statistics agency of Indonesia (https://bps.go.id); Ministry of Tourism and Creative Economy (https://kemenparekraf.go.id/); Ministry of Agriculture (https://psp.pertanian.go.id/#popup-modal); Ministry of industry (https://www.kemenperin.go.id/); State-owned electricity enterprises (https://web.pln.co.id/pelanggan/layanan-online).

Source: Researcher Analysis, 2023

Table 5. PLS Model

Model	Formula
Model 1. The relationship of urbanization to geological components	UBit = αi – β1 Qvmit – β2 Qvlit – β3 Tommit – β4 Qait + μit
Model 2. The relationship of urbanization to geomorphological components	UBit = αi – β1 F1it – β2 V7it – β3 V5it – β4 V4it – β5 D7it – β6 D10it + μit
Model 3. The relationship of urbanization to ecoregion components	UBit = αi – β1 Qa-F1it – β2 Qvm-F1it – β3 Tomm-F1it – β4 Qvm-V7it – β5 Tomm-D7it – β6 Tomm-D10it – β7 Qa-V5it – β8 Qvl-V5it – β9 Qvl-V4it + μit
Model 4. The relationship of urbanization to the socio-economic community	UBit = αi + β1 ICit + β2 JNit + β3 KNit + β4 JHit + β5 HSit + β6 HFit + β7 BNit + β8 Hnit + β9 RNit + β10 MRit + β11 EPit + μit
Model 5. The relationship of population density to geological components	KPit = αi – β1 Qvmit – β2 Qvlit – β3 Tommit – β4 Qait + μit
Model 6. The relationship of population density to geomorphological components	KPit = αi – β1 Fit – β2 V7it – β3 V5it – β4 V4it – β5 D7it – β6 D10it + μit
Model 7. The relationship of population density to ecoregion components	KPit = αi – β1 Qa-Fit – β2 Qvm-Fit – β3 Tomm-Fit – β4 Qvm-V7it – β5 Tomm-Dit – β6 Tomm-D10it – β7 Qa-V5it – β8 Qvl-V5it – β9 Qvl-V4it + μit
Model 8. The relationship of population density to the socio-economic community	KPit = αi + β1 ICit + β2 JNit + β3 KNit + β4 JHit + β5 HSit + β6 HFit + β7 BNit + β8 HNit + β9 RNit + β10 MRit + β11 EPit + μit
Model 9. The relationship of the peasant family to geological component	FFit = αi – β1 Qvmit – β2 Qvlit – β3 Tommit – β4 Qait + μit
Model 10. The relationship of peasant families to geomorphological components	FFit = αi – β1 Fit – β2 V7it – β3 V5it – β4 V4it – β5 D7it – β6 D10it + μit
Model 11. The relationship of farming families to the components of the ecoregion	FFit = αi – β1 Qa-Fit – β2 Qvm-Fit – β3 Tomm-Fit – β4 Qvm-V7it – β5 Tomm-Dit – β6 Tomm-D10it – β7 Qa-V5it – β8 Qvl-V5it – β9 Qvl-V4it + μit
Model 12. The relationship of peasant families to the socio-economic component of community	FFit = αi + β1 ICit + β2 JNit + β3 KNit + β4 JHit + β5 HSit + β6 HFit + β7 BNit + β8 HNit + β9 RNit + β10 MRit + β11 EPit + μit

Source: Researcher Analysis, 2023

(RN), shopping centers (MR), and percentage of electricity users (EP). Each variable is measured nominally according to the data and information obtained.

Analysis Design

This research uses the Pooled Least Squares (PLS) model to analyze the relationship between dependent and independent variables. PLS adopts regression specifications and panel data estimation (Canh, Schinckus, Su, & Chong, 2021) based on the dependent variables used to test hypotheses. EViews 9.0 software is used for the analysis process to establish twelve initial PLS models reported in Table 5.

To ensure clarity, *UBit* represents urbanization level at region *i* and time *t*, *Qvm* corresponds to Quaternary volcanic material, and *ICit* refers to the index of income per capita in region *i*. The choice of Partial Least Squares (PLS) methodology was due to the ability to handle multicollinearity, small sample sizes, and focus on variance explanation. The model was validated using cross-validation, and goodness-of-fit measures such as R^2 and predictive relevance Q^2.

Individual-level (i) data were used for 12 districts over a period (t) of 15 years (2008 – 2022). Data observations were repeatedly conducted on individual (i) at a given time (t). However, the methods have the potential for erroneous cross-sectional dependence (Fallatah, 2018; Shipilov, 2006). Panel data also comprise time series, necessitating an examination of stationarity. The variable was examined using the Im-Pesaran-Shin (IPS) unit root test and Fisher based on the Phillips – Perron unit root test Z type (Fisher – PP) (Choi, 2001; Im, Pesaran, & Shin, 2003).

3. Result and Discussion

Diagnostic Check

The diagnostic examination shows the cross-sectional dependence testing on error and stationarity diagnostics. The test reports that the probability values (p-values) of the CD-Stat are above 10% since there is no cross-sectional dependence on errors (Pesaran, 2021)

The results of checking data stationarity using the IPS unit root test and the Fisher – Phillips – Perron unit root test Z type (FPP) show that each variable has W-stat and Z-stat values with probabilities (p-values) below the 1% significance level. According to Granger & Newbold (1974), data without unit roots are stationary and prevent the model from experiencing autocorrelation and spurious regression. Other research report that stationary time series data represent constant mean and variance over time (Canh et al., 2021; Choi, 2001; Pesaran, 2021).

Model Selection

Chow test shows that the p-value of the Chi-square statistic is smaller for all 12 models at the 1% significance level, rejecting the null hypothesis. Therefore, the Fixed Effects Model (FEM) is superior to the Common Effects Model (CEM). These results suggest that the Random Effects Model (REM) is selected for seven models.

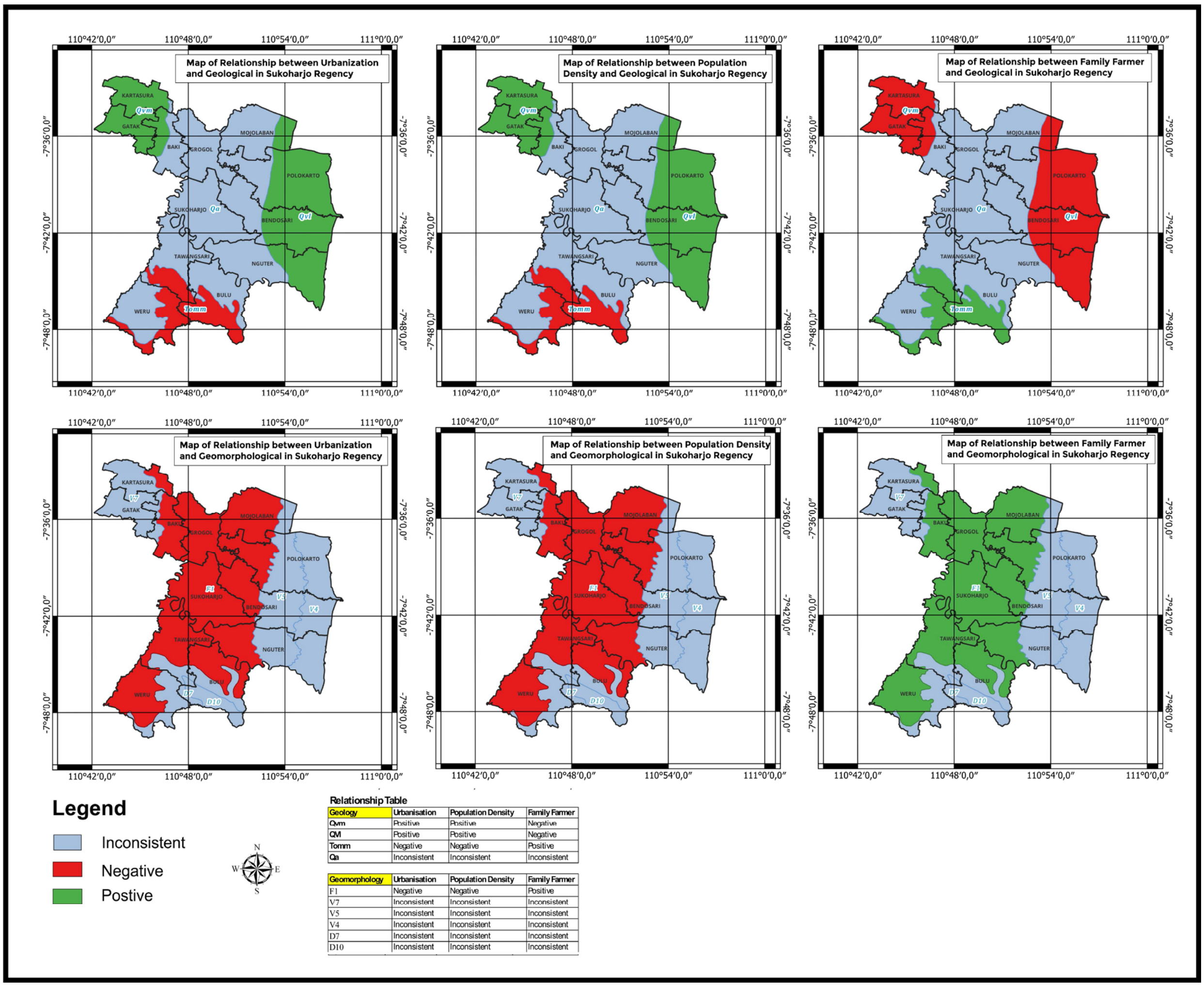
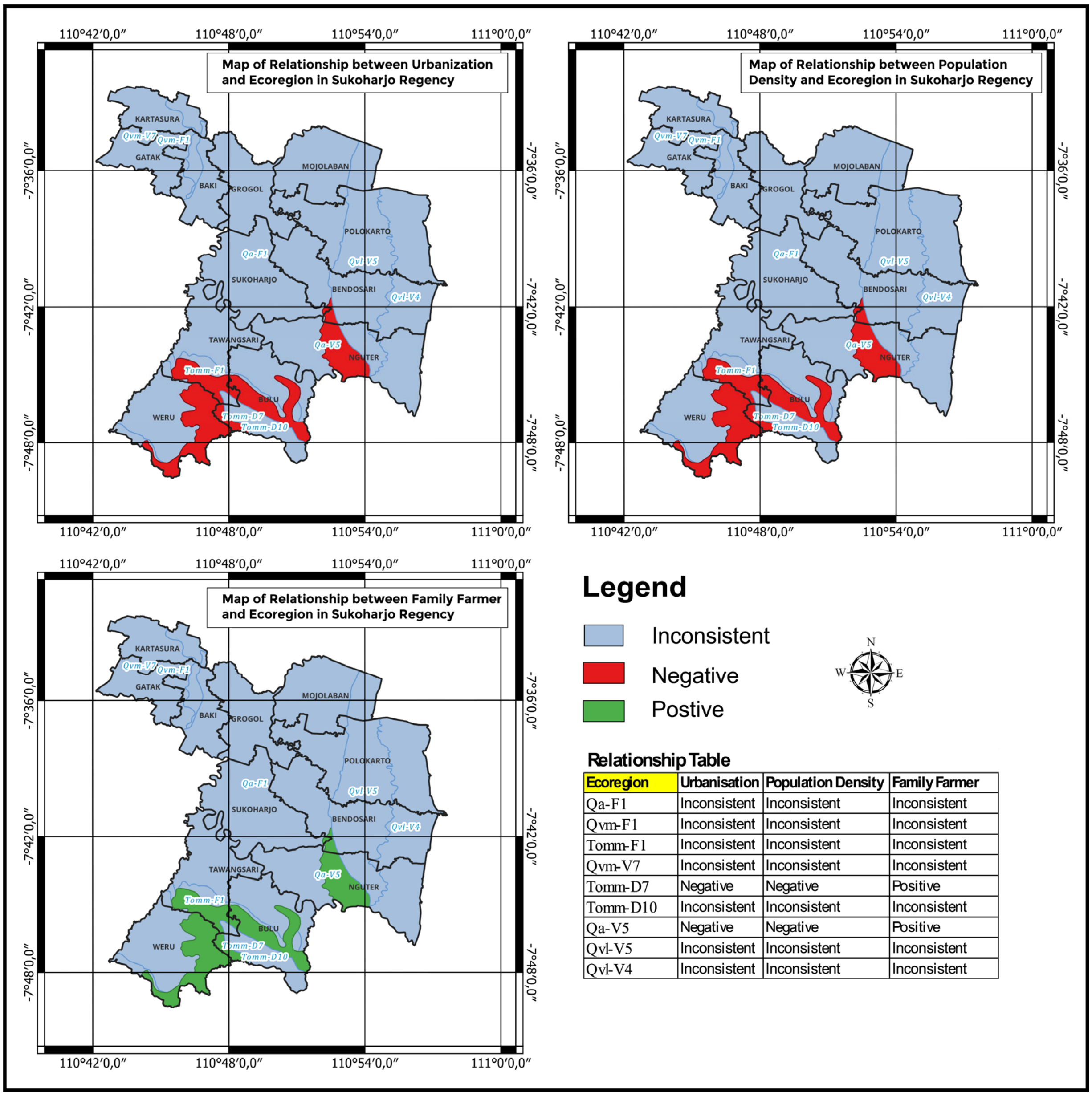


Figure 2. Map of Relationship between Urbanization with Geology and Geomorphology



Ecoregion	Urbanisation	Population Density	Family Farmer
Qa-F1	Inconsistent	Inconsistent	Inconsistent
Qvm-F1	Inconsistent	Inconsistent	Inconsistent
Tomm-F1	Inconsistent	Inconsistent	Inconsistent
Qvm-V7	Inconsistent	Inconsistent	Inconsistent
Tomm-D7	Negative	Negative	Positive
Tomm-D10	Inconsistent	Inconsistent	Inconsistent
Qa-V5	Negative	Negative	Positive
Qvl-V5	Inconsistent	Inconsistent	Inconsistent
Qvl-V4	Inconsistent	Inconsistent	Inconsistent

Figure 3. Map of Relationship between Urbanization with Ecoregions

Empirical Results

The variable Tomm has a negative coefficient (β) with a significance p-value below 1% in Models 1 and 5. These results show that geological formation area consisting of lava dasit, andesite, and tuff rocks in Sukoharjo, Indonesia, decreases with urbanization and population density growth. Meanwhile, the analysis results in Model 9 report that Tomm has a positive β nature in the soil and has been proven to increase the growth of exotic grasses (La Manna, Tarabini, Gomez, & Rostagno, 2021). Minasny, Fiantis, Hairiah, and Van Noordwijk (2021) also explained that volcanic content supplied a large amount of nutrients in the soil to support soil fertility. In this context, urbanization reduced soil fertility from geological perspective.

The test results suggest that urbanization and population density adversely affect alluvial plains. Previous research explained that alluvial plains benefited from the formation of groundwater flow (rivers) for human life (Jiang et al., 2023; Su, Li, Chen, Li, & Zhang, 2023). These results are confirmed in the testing of Model 10, where variable F1 is positively and significantly associated with farming families. The decrease in the area of alluvial plains in the form of a reduction in the area of fertile land or a decrease in soil quality is correlated with a reduction of farming families, stating the potential impact of urban expansion on agricultural feasibility. Furthermore, alluvial plains have a substantial impact on soil acidity (pH) and agricultural land fertility (Floreani, Zappella, Faganeli, & Covelli, 2023; Gao et al., 2023; Taylor, DeVilbiss, & Hicks, 2023). Testing variables V7, V5, V4, D7, and D10 obtained inconsistent results in all three models, as presented in Figure 2.

The relationship between urbanization, and eco-regional aspects suggest that Tomm-D7 and Qa-V5 have negative β coefficients and p-values below the 10% significance level in Models 3 and 7. Previous research showed that lower volcanic slopes in alluvial plains contributed to alluvium pumped for water supply (Groover & Izbicki, 2019). Testing results on other variables reported inconsistent outcomes and no correlation among models, as presented in Figure 3.

Variables IC, JN, HN, and MR obtain similar outcomes in Models 4 and 8, which are identified by positive β coefficients and p-values below the 10% significance level. Therefore, urbanization has expanded physical infrastructure development for secondary schools, health facilities, and the hotel industry, leading to decreased agricultural land and the number of farming families. Previous research provided similar evidence that rural-to-urban migration aimed to attain a decent living, significantly impacting the development of public infrastructure facilities (Skoufias & Olivieri, 2013).

Discussion

Ecosystems can support life by providing benefits through the availability of clean water (Yu et al., 2023). In this context, water availability is beneficial for various purposes, including personal, household, industrial, agricultural, plantation, and other activities requiring water. Therefore, ecosystem services for providing clean water are influenced by rainfall, soil or rock layers, and other factors such as ecoregion, vegetation, and land cover (Huang, Wang, He, & Liu, 2023). Urbanization has damaged the ecosystem, which is characterized by a decrease in air quality and soil fertility around dacite, andesite, tuff lava, and alluvial plains. Previous research showed that urbanization damaged habitat quality, carbon sequestration, grain supply, flood mitigation, water purification, and Sustainable Development Goals (SDGs) (J. Li, Xie, Dong, Zhou, & Zhang, 2023; Ren, Liu, & Liu, 2023; Xu et al., 2023; X. Zhang et al., 2023). However, contrasting results were obtained from the analysis of the socio-economic issues of the community since urbanization benefited the welfare of the population. This is characterized by growth in per capita income and increased job opportunities. Urbanization also positively impacts the development of physical infrastructure such as schools, shopping centers, and hotels. These results are consistent with research in China, where the phenomenon has driven sustainable urban development and contributed significantly to economic growth, specifically in flatland cities (Huang et al., 2023). Furthermore, research in Vietnam found that urbanization positively impacted the ability to eradicate poverty successfully (Fan et al., 2019).

Urban ecosystems have been disrupted regarding plant fertility and the availability of clean water but some areas in Sukoharjo, Indonesia, can still adequately manage green spaces. Natural conditions appear favorable, as reported in the Baki district with coordinates at 7°36’29.34”S and 110°46’28.85” E. Figure 4 shows the natural conditions of vegetation and geological rivers at the location.

(a) (b) (c)

Figure 4. (a) Agricultural, (b) Vegetation, (c) River Geology in Baki District

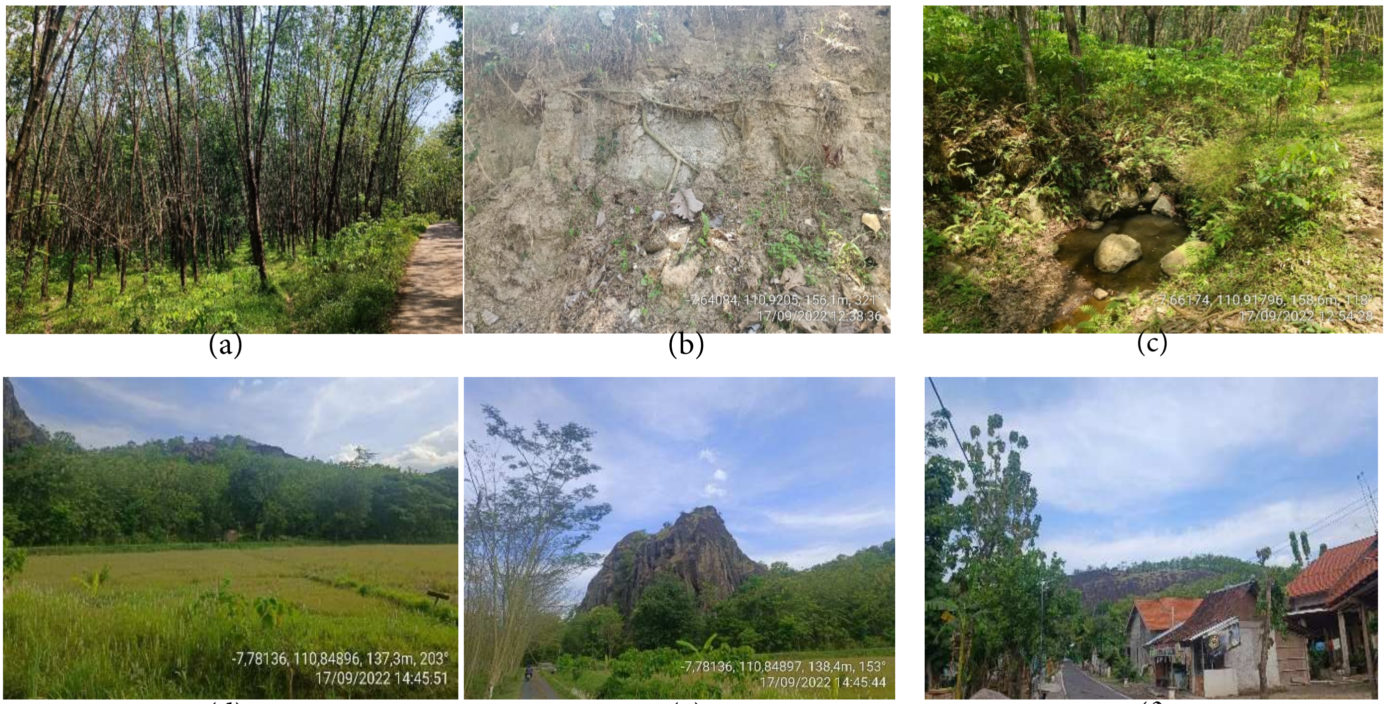


Figure 5. (a) Land Vegetation, (b) Soil Layers, (c) River Flow in Polokarto District, (d) Rice Fields, (e) Hills, (f) Ecoregions in Bulu District

Polokarto District, with coordinates 7°38'27.02"S and 110°55'13.76"E, still has adequate ecosystems identified by land vegetation, soil layers, and river flow. In the Bulu district area with coordinates 7°46'52,90"S and 110°50'56,26"E, ecosystem management is adequate, identified by rice fields, hills, and ecoregional features.

Based on field observations, ecosystems in the Sukoharjo region can be managed with urbanization growth in the area. However, the sustainable development agenda for terrestrial ecosystems (SDGs-15) is affected by increased urbanization. This decreases the ecosystem functions of a region subjected to natural disasters, such as floods. Research in Nepal has reported that urbanization is closely connected to geographic risks (Poudel et al., 2023). Several countries face significant challenges in dealing with severe natural disasters due to rapid urbanization (Coates, 2022; R. Li, Shi, Feng, & Guo, 2021a; Y. Liu, Huang, & Yang, 2022).

4. Conclusion

In conclusion, this research extensively explored the impact of urbanization on urban ecosystems and the socio-economic conditions of communities in Indonesia. Geological, geomorphological, and ecoregional indicators were used to analyze the effects of urbanization on urban ecosystems. Simultaneously, different urban social and economic conditions were considered to assess the impact of urbanization on community welfare. The analytical process proceeded systematically, starting with the examination of regional ecosystems and socio-economic issues. Subsequently, this research evaluated the effects of urbanization on three ecosystem metrics and urban socio-economic development. The results showed that urbanization positively impacted community welfare and urban economic growth. However, the phenomenon reduced soil fertility, agricultural land, and clean water availability, posing risks of natural disasters, particularly floods. Urbanization should be rejected to preserve urban ecosystems even though the concept benefits community welfare.

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