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Research Article

Settlement land management based on land capability in Batu City

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Abstract

Urban expansion occurs in big cities in Indonesia, including Batu City. An increase in the built-up area occurred in Batu City by 554.4 ha or 2.78%, and a decrease in agricultural land by 341.1 ha occurred in 2008-2018. If the Batu City government does not pay attention to the availability of environmental services or consider the geomorphological conditions of Batu City for developing settlements. In that case, it will have an environmental impact. The environmental problem in Batu City during the 2009-2019 period was an increase in greenhouse gases by 0.75% per year. Batu City is located in a hilly area. It is necessary to explore land capability in Batu City so that land use planning follows its environmental services and is sustainable. This study aimed to determine the land capability for settlements in Batu City based on the Regulation of the State Minister for the Environment Number 17 of 2009 concerning Guidelines for Determining Environmental Supporting Capacity in Regional Spatial Planning. This study used a geographic information system (GIS) and ArcGIS 10.8 software. The method used was overlapping soil texture, slope, drainage, effective soil depth, erosion, and flood potential maps. Batu City has a slope of 30-45% and a total area of 6,581.03 ha, or 33% of the area of Batu City. The largest erosion rate reached 10,326.33 ha or 52% of the total area of Batu City. Erosion occurs on land used for agriculture or moorland. Soil protection and erosion control measures are strongly recommended. The area around Batu City, 1,174.28 ha, experienced considerable erosion, and 2,631.62 ha of land in Batu City is used for settlements. Land capability analysis can determine the starting point or basis for settlement land management in Batu City, which has a slope of more than 15%. There are only 461.9 ha of land management for settlement which follows the regional spatial planning and land capability in Batu City, spread over three different districts.

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Introduction

Urban expansion occurs in big cities in Indonesia, including Batu City. According to Pragmadeanti and Rahmawati (2022), urban development in Batu City was due to Batu City being a choice for the citizen for the location of settlements because of its proximity to Malang City as the economic center. The citizen's choice of a location for settlement areas has increased agricultural land conversion into built-up land. In line with this, Wisnubroto et al. (2021) reported land use change that the built-up area increased in Batu City by 554.4 ha or 2.78%, and a decrease in agricultural land area of 341.1 ha occurred during 2008-2018. An increase in population also occurred in Batu City. The results of the 2010 population census showed the population of Batu City was 190,184 people; in 2022, the population was 216,136 people (Department of Population and Civil Registration of Batu City, 2022). Qoriyati and Nurhayati (2020) explained that an increase in population could also lead to a rise in the need for settlement and land conversion.

Batu City is at an average altitude of 897 meters above sea level with hilly relief (Central Bureau of Statistics for Batu City, 2021; Surjono et al., 2022). Batu City has an average rainfall of 194 mm month^{-1}, with 160 rainy days (Central Bureau of Statistics for Batu City, 2021). According to Ruwayari et al. (2020), the environment's carrying capacity is needed to determine the ability of an area so that humans can utilize it to support life's needs without damaging the environment. The government of Batu City should pay attention to the availability of environmental services for settlements considering the geomorphological conditions of Batu City. Kang et al. (2018) pointed out that urban ecosystems can be declared healthy and sustainable if organizational structure, resilience, ecosystem services, and public health can be addressed and considered in regional development.

Batu City has started to experience environmental degradation due to massive land conversion for human activities. According to the Central Bureau of Statistics for Batu City (2021), environmental degradation took the form of 103 landslides, 25 cases of flooding, 12 cases of strong winds, and 2 earthquakes in Batu City. Another environmental problem in Batu City during the 2009-2019 period was an increase in greenhouse gases at 0.75% per year (Sari, 2021). During the 2006-2014 period, there was an increase in air temperature of 0.8 °C, and 23 cases of forest fires occurred during the period January-May 2020 (Surjono et al., 2022). The Batu City government has issued regional spatial planning for settlements covering an area of 2,976.03 ha. The regional spatial planning evaluation found that an area of 694.52 ha was not following the settlement plan issued by the government. The problems in Batu City include increased human activity in land use due to its proximity to Malang City and an increase in population resulting in rapid land conversion into settlements.

Geomorphological conditions in Batu City make the city vulnerable to natural disasters and environmental problems; settlement developers in sub-urban ecosystems such as Batu City, of course, need to pay attention to socio-economic and environmental conditions to create a healthy and viable ecosystem to be more sustainable. Settlement development requires ecological/environmental, cultural/social, water resources, and infrastructure carrying capacities as the basis for development so that the community's conditions can be improved and the available natural resources are fulfilled (Zhang T. et al., 2019). In addition, Pertiwi et al. (2021) also stated that assessment of the environment's carrying capacity for settlements could be done by assessing the land's capability. Therefore, research is needed regarding the land capability used to determine the available environmental capacity in developing settlements in Batu City.

This study aimed to determine the land capability based on the Regulation of the State Minister for the Environment Number 17 of 2009 concerning Guidelines for Determining the Carrying Capacity of the Environment in Regional Spatial Planning and Batu. This study also provided the direction of developing settlements based on land capability in hilly areas, Batu City.

Materials and Methods

Study area

The research location was in Batu City, East Java. Batu City is located at coordinates 122°17'-122°57' East Longitude and 7°44'-8°26' South Latitude. Batu City has an area of 19,921 ha with three districts, namely Batu District, with an area of 4,546.38 ha, Bumiaji District, with an area of 12,804.2 ha, and Junrejo District, with an area of 2,570.53 ha (Figure 1). Batu District has eight sub-districts. Bumiaji District has nine sub-districts. Junrejo District has seven sub-districts. Batu City is characterized by mountains supported by rivers and other natural resources such as forests. Batu City is experienced social changes, such as the transition from rural to urban culture (Sukmana et al., 2022). The average population growth rate from 2010-2022 was 1.11% per year. The population in Batu District was 99,046 people, Junrejo District was 54,819 people, and Bumiaji District was 62,271 people (Central Bureau of Statistics, 2021; Department of Population and Civil Registration of Batu City, 2022). Based on the population in 2022, Batu City is classified as a medium city and has the potential to become a big city (Bachtiar et al., 2019). The average rainfall in Batu City during the 2011-2021 period was 2,486.77 mm year $^{-1}$.

Data collections

The data used were secondary data and primary data. Time of data collection at one time/cross-sectional. Secondary data was obtained from agency survey instruments related to ownership of spatial data in the form of .shp (*shapefile*) extensions. The secondary data used were a soil texture map, a drainage map, an effective depth map obtained from the Indonesian Center for Agricultural Land Resources Research and Development with a map scale of 1:50,000, and a land use map obtained from the Batu City Government with a map scale of 1:50,000. The primary data were used to create slope maps by analysis DEMNAS (Digital Elevation Model National). The data used to create the erosion map was primary data obtained from the analysis of land use/land cover and rainfall analyzed by the USLE method. These data were overlayed to determine the land's capability for settlement.

Data analysis

The land capability was analyzed using a geographic information system with Geographic Information

System (GIS) software, namely ArcGIS 10.8. The land capability map was generated from the process presented in Figure 2.

Land capability classes for each indicator were needed in making land capability maps. The indicators were soil texture, slope, drainage, effective soil depth, erosion, and flood potential. Table 1 shows land capability classes according to the Regulation of the State Minister for the Environment Number 17 of 2009 concerning Guidelines for Determining the carrying capacity of the environment in regional spatial planning.

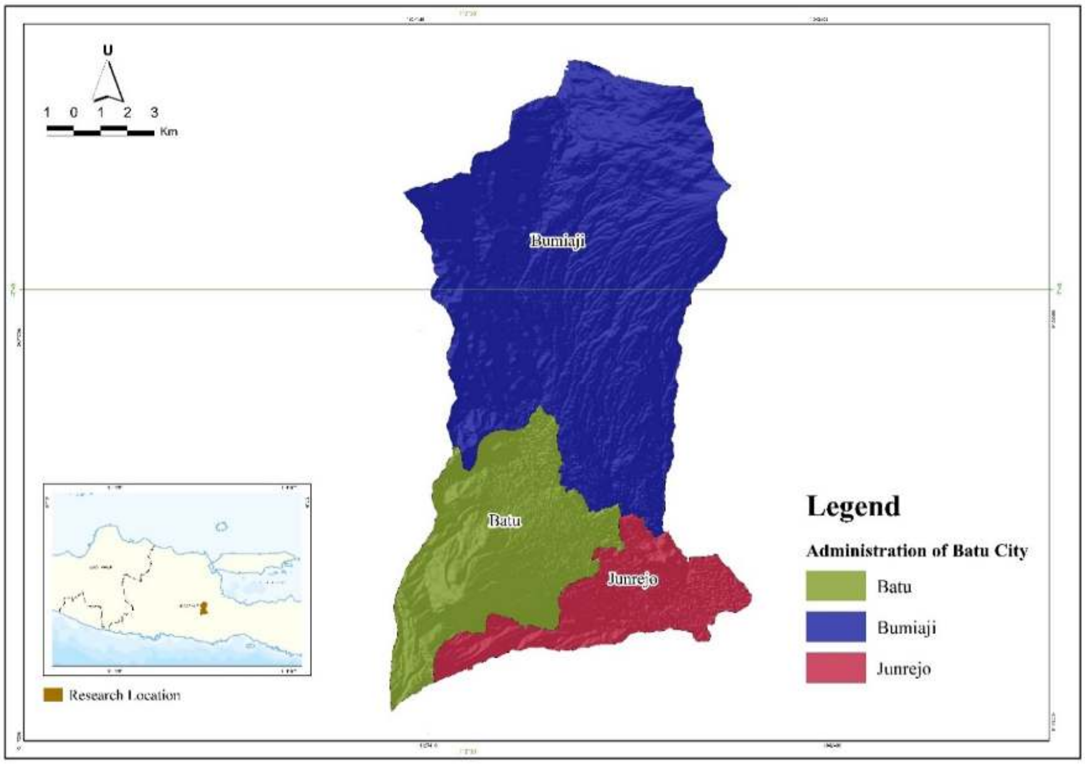

Figure 1. Administration map of Batu City.

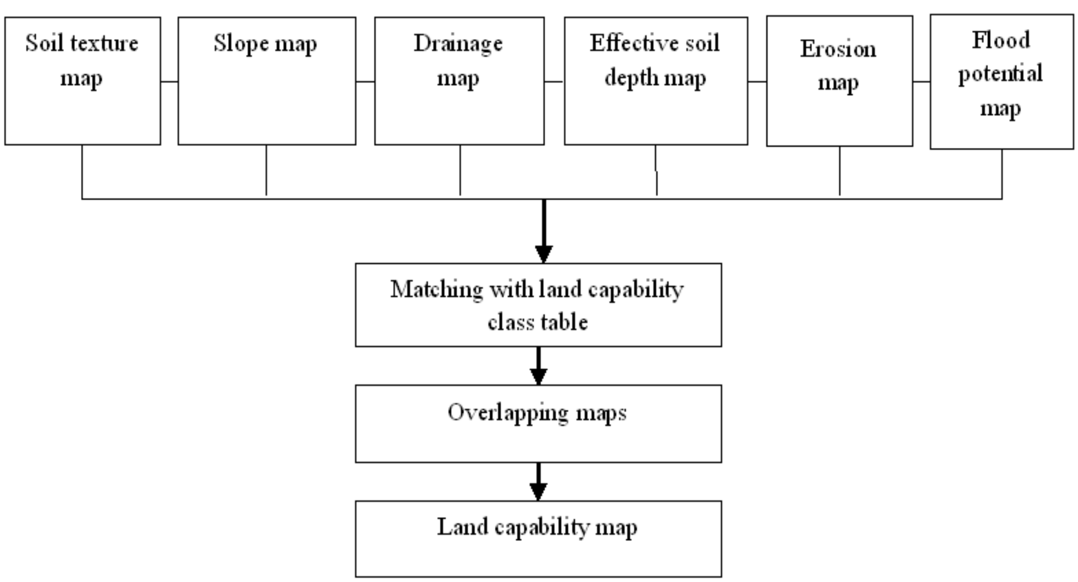

Figure 2. Flowchart for making a land capability map.

Table 1. Land capability class.

Category		Land Capability Class							
		I	II	III	IV	V	VI	VII	VIII
1.	Soil texture (t)	t_2/t_3	t_1/t_4	t_1/t_4	*	*	*	*	t_5
2.	Slope (l)	l_0	l_1	l_2	l_3	*	l_4	l_5	l_6
3.	Drainage (d)	d_0/d_1	d_2	d_3	d_4	**	*	*	*
4.	Effective depth (k)	k_0	k_0	k_1	k_2	*	k_3	*	*
5.	Erosion (e)	e_0	e_1	e_1	e_2	*	e_3	e_4	*
6.	Flood potential (o)	o_0	o_1	o_2	o_3	o_4	*	*	*

Information: *area has criteria from a lower class, **the area is always flooded.

Based on research by Hasmita et al. (2020), the assessment of land capability for settlements can use variables of slope, flood potential, drainage, gravel, soil texture, and effective depth by dividing them into four classes, namely S1 (very suitable), S2 (suitable), S3 (marginal), and N (not suitable). Based on the results of a literature search, the variables of soil texture, slope, drainage, effective soil depth, erosion, gravel, and flood potential can also be used to determine the capability class of settlement areas with the help of geographic information system software (Ambarwulan et al., 2018; Rahmadania et al., 2020). After obtaining a land capability map, the next step was to overlap the settlement land use map with the land capability map. This was done to determine whether the management of settlement areas that the government had carried out following the land capabilities. This research also discussed the potential of land for settlements that were still available so that land use management could be carried out according to their abilities. The research workflow is presented in Figure 3.

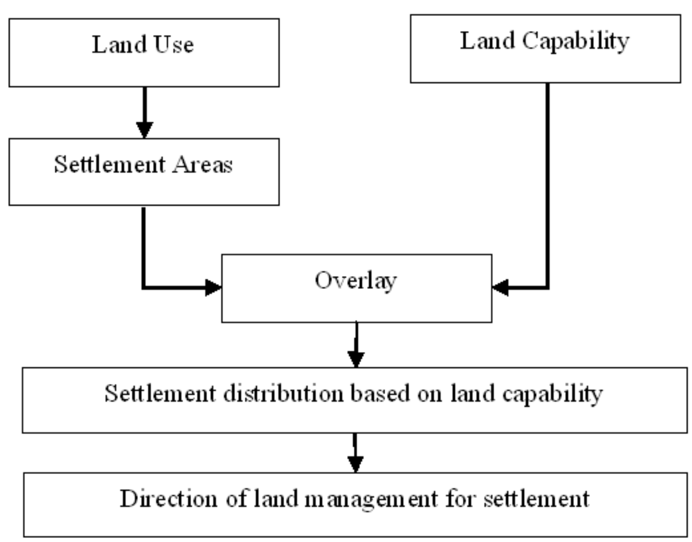

Figure 3. Research workflow.

Results and Discussion

The distribution of settlements in Batu City

Settlements in Batu City cover an area of 2,631.62 ha divided into three districts (Figure 4). Batu District has a settlement area of 1,296.87 ha. Bumiaji District has a settlement area of 716.13 ha. Junrejo District has a settlement area of 618.63 ha. Batu District has the largest settlement area because it is the center of the economy, the center of government, and the complete infrastructure in Batu City. People tend to choose locations where they live close to economic centers, government centers, and better infrastructures. According to Henn et al. (2020), settlement patterns are denser around trade centers, economic centers, and adequate infrastructure. A sustainable settlement is close to economic centers and areas with job opportunities (Garakani et al., 2020). The distribution of settlements in Batu City must be based on geomorphological conditions and land capability. Batu City has a slope of 30-45% with a total area of 6,581.03 ha or 33% of the area of the city (Figure 5). The total area with good drainage class in Batu City is 19,871.54 ha (Figure 6). Batu City has deep soil depth with an area of 14,927.01 ha or 75% of the total area of Batu City (Figure 7). The highest erosion class occurs in an area of 10,326.33 ha or 52% of the area of Batu City (Figure 8).

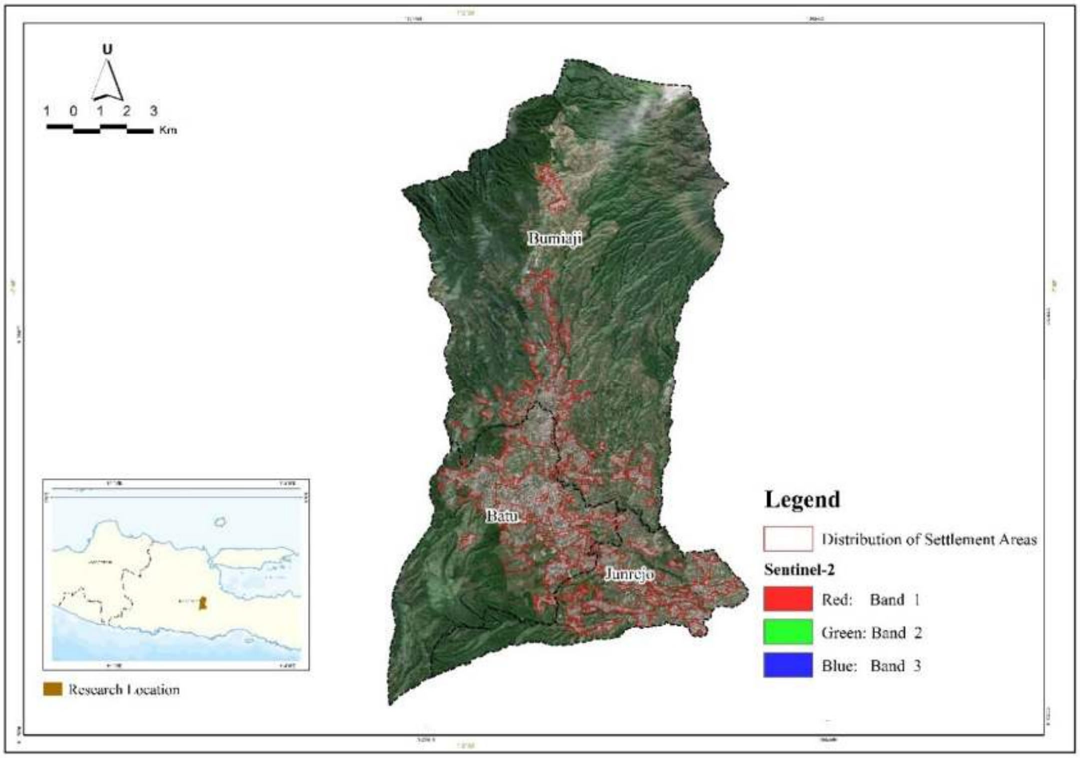

Figure 4. Distribution of settlement areas in Batu City.

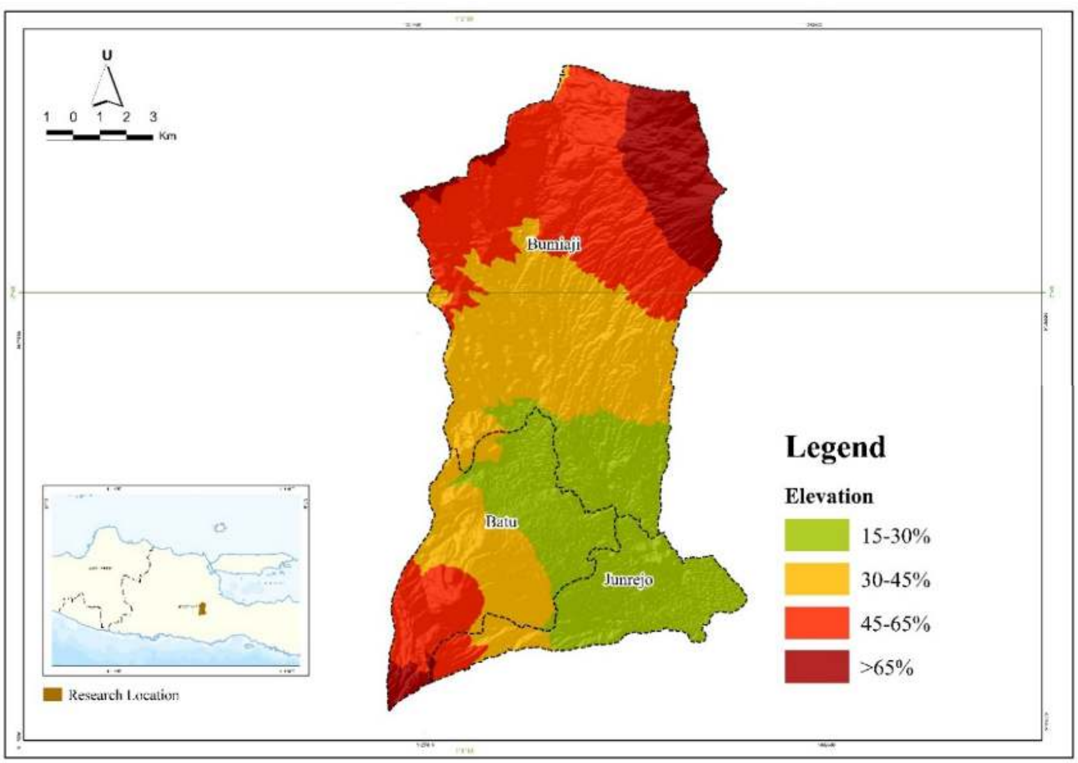

Figure 5. Elevation map of Batu City.

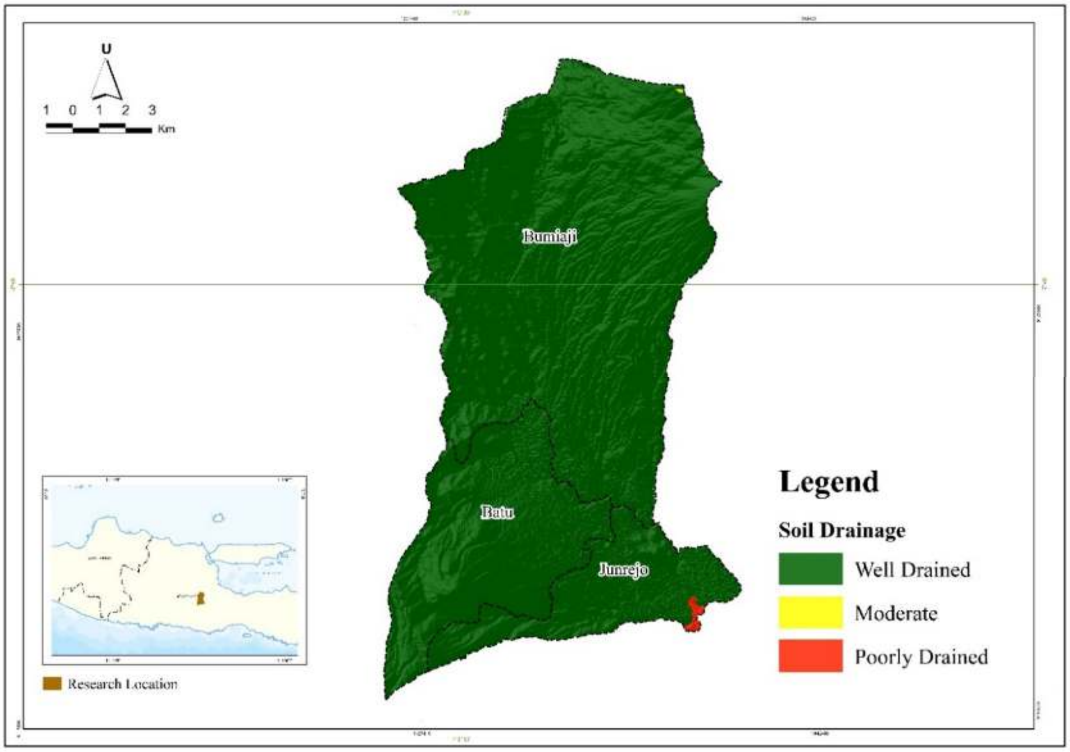

Figure 6. Soil drainage map of Batu City.

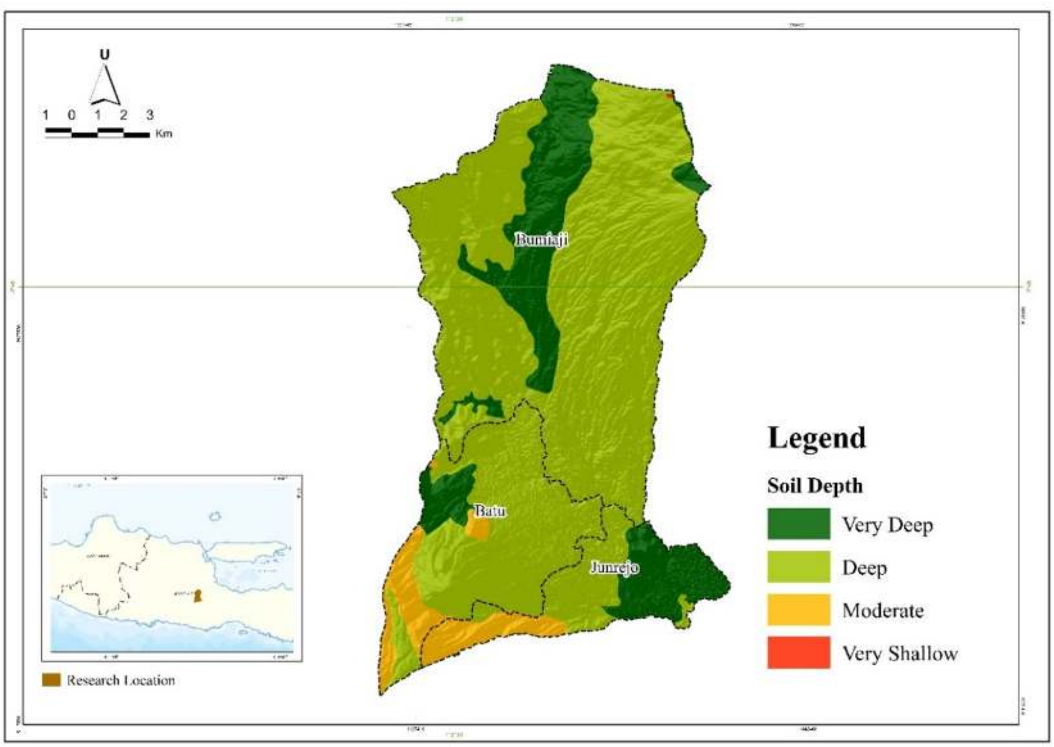

Figure 7. Soil depth map of Batu City.

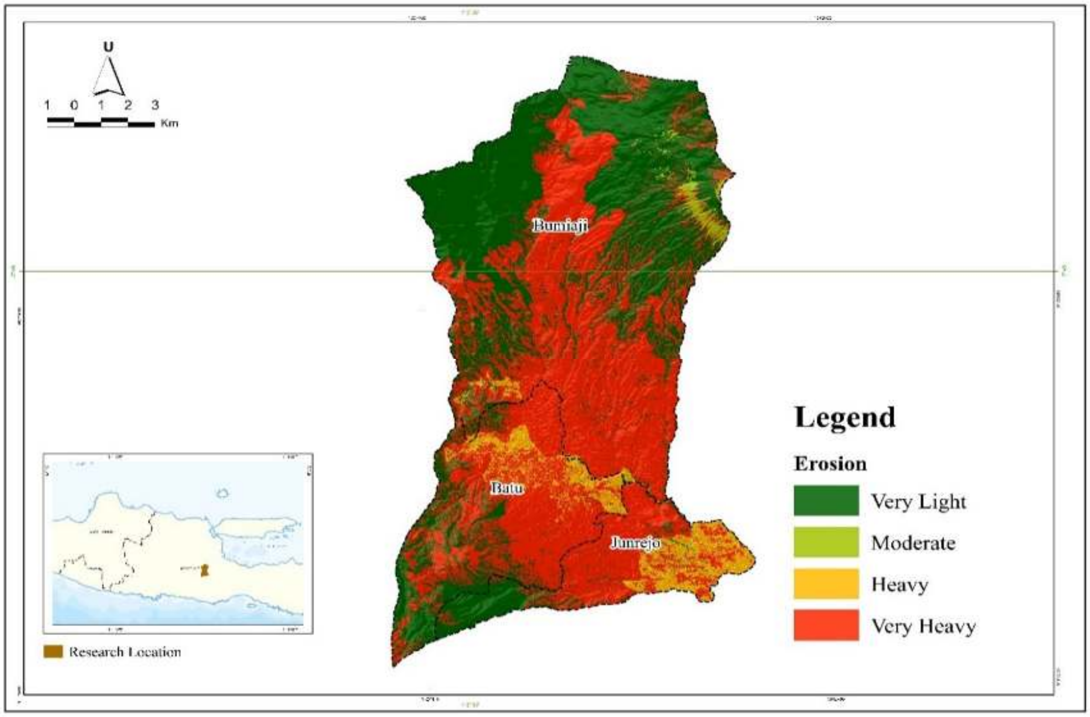

Figure 8. Erosion map of Batu City.

Batu City has never experienced flooding. However, in some areas, flooding periodically occurs. The area that periodically experienced flooding was 261.66 ha or only 1% of the total area of Batu City (Figure 9). The soil texture in Batu City was 84% moderate textured, 12% fine textured, and 3% slightly fine textured (Figure 10). Moderate soil texture categories were silt, silty loam, and loam. Soil with a moderate texture can bind and retain water more effectively because it has moderate pores. Moderate porous soil has space that can be filled with water. Loamy soil texture has micropores and a compact structure, so it has low permeability. In line with Huang et al. (2022), silty loam and silty clay textures have higher water permeability than clayey soils, which have low permeability due to their compact structure and micropores. During the dry season, clay soil texture has the potential to result in cracking. Furthermore, poor soil conditions that cannot retain water may lead to the formation of puddles, which can be detrimental to building structures.

Geomorphology and the availability of natural resources are essential considerations for efficient land use management. Even previous studies showed that an effective land use plan following geomorphology could avoid climate change, such as increasing air temperatures, flash floods, droughts, and landslides (Rienow et al., 2022). Humans can not exist independently because nature is an essential component of ecosystems. Batu City government recognizes that urban development needs to be based on ecology, in which the environment's carrying capacity will play an important role. The environment could not be sacrificed to achieve short-term economic progress. Zhou et al. (2022) also explained that policymakers need to incorporate land capability knowledge in land use planning to address the imbalance between humans and nature.

Settlement distribution based on land capability in Batu City

Based on the data of soil texture, elevation, soil drainage, soil depth, erosion, and flood maps obtained, the land capability class of Batu City consists of 4 classes (Table 2). The four classes include Class IV, Class VI, Class VII, and Class VIII. Class V was omitted because, in this study, no variables were found that had a distribution of inhibiting factors from lower classes. Shofarini et al. (2019) used the settlement land capability to determine a settlement. Capability classes VIII and VII are areas of limitation if developed as settlements, land capability class VI is a constrained area to be developed as a settlement area, while land capability class IV is an area of possibility to be developed as a settlement (Agnar et al., 2020). The total area of land capability class IV is 2,498.23 ha. The limiting factors found for land capability in Batu City are erosion and slope. Erosion occurs in built-up areas and fields/moors. For land use/cover, namely fields/moors, conservation techniques can be applied to decrease the erosion hazard class. Do et al. (2023) mention that conservation techniques that can be carried out in fields/moors are contour farming, terracing, mulching, and planting cover crops.

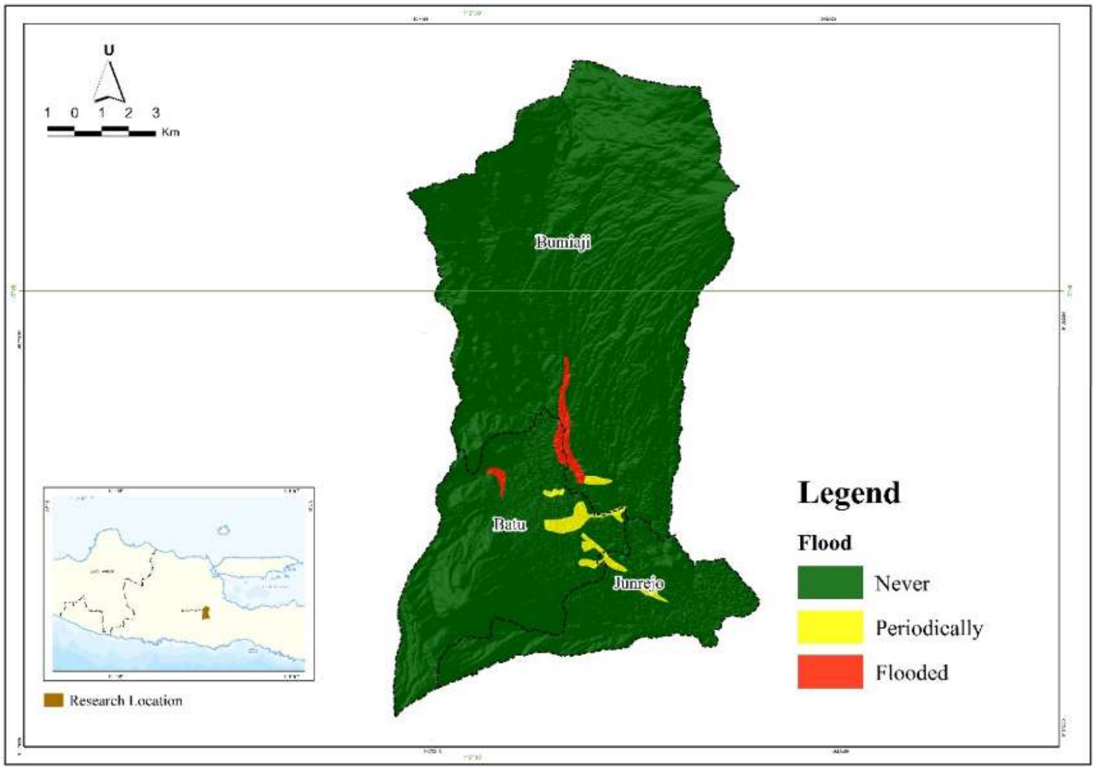

Figure 9. Flood map of Batu City.

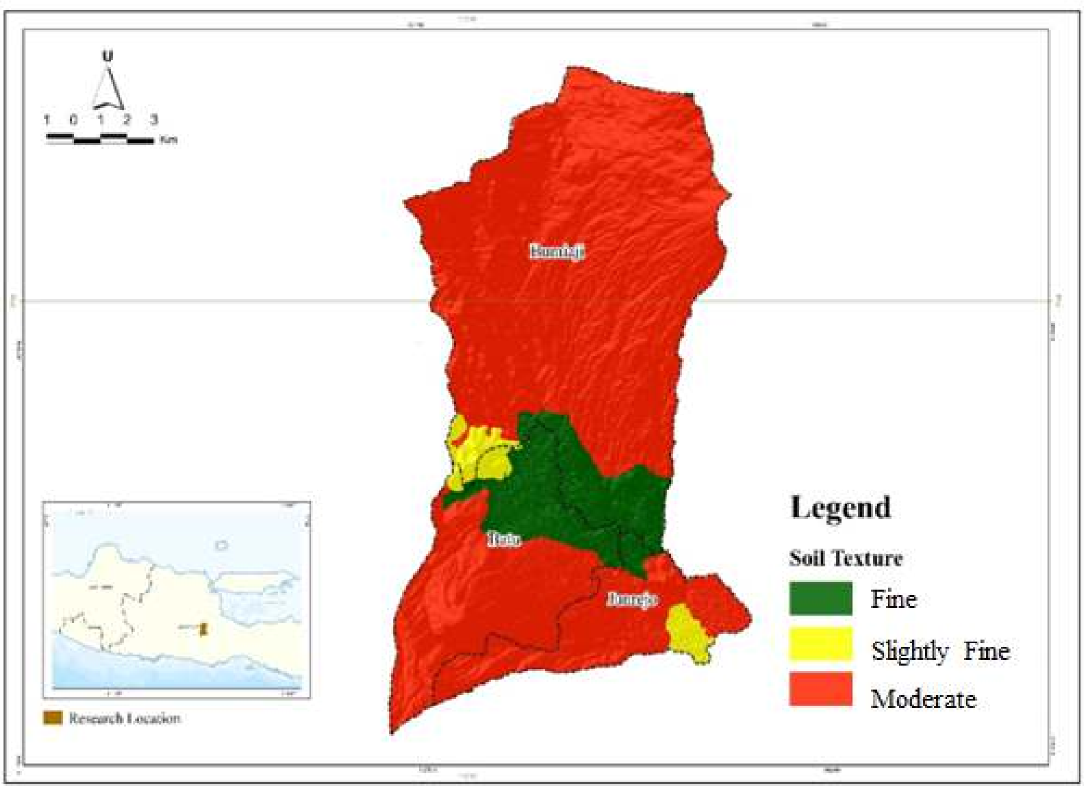

Figure 10. Soil texture map of Batu City.

Table 2. Land capability class.

No	Land capability class	Area per District (ha)			Total area (ha)
		Batu	Bumiaji	Junrejo	
1	IV	1,605.12	194.96	698.16	2,498.23
2	VI	1,757.99	4,158.39	1,648.79	7,565.17
3	VII	1,001.01	6,651.13	212.95	7,865.08
4	VIII	182.27	1,799.71	10.67	1,992.64

Stanchi et al. (2012) also mention that not only is terracing conservation very important for agriculture, but another benefit is also for aesthetics. As well as controlling erosion rates, conserving terraces can also be used as ecotourism, and it is economically feasible. The class of very heavy erosion also occurs in mixed agriculture. Conservation techniques for mixed agriculture can also be carried out with agroforestry techniques. Agroforestry techniques have advantages, such as protecting the soil from erosion, loss of soil nutrients, and also for soil conservation. Slopes have an important role in land management. Land management for settlements should be done in class IV. Capability class IV is on the slope of 15-45%. However, the area can only be used for settlement development on a 15-30% slope. Developing settlements on steep slopes or more than 30% is not recommended because it can cause landslides. In line with this, Wei et al. (2022) explained that densely populated land use is located at an altitude above 1,000 masl with a slope of more than 30% and is in a tectonic area prone to landslides. Settlements development in class IV can use engineering techniques. Engineering techniques were used to minimize the risk of landslides or natural disasters due to changes in land use (Roshan and Pal, 2022). The results of overlaying the settlement distribution map with the land capability map (Figures 11 and 12), show that only 1,083.82 ha of settlements were in class IV spread over the three districts (Table 3). Batu District covers an area of 921.57 ha, Bumiaji District covers an area of 25.27 ha, and Junrejo District covers an area of 136.98 ha ((Table 3). Settlement distribution was also found in classes VI and VII of land capability. Settlements in Class VI cover an area of 1,464.22 ha and are divided into three Districts. Batu District covers an area of 375.30 ha, Bumiaji District covers an area of 607.28 ha, and Junrejo District covers an area of 481.65 ha. Class VII settlements were only found in the Bumiaji District, covering an area of 83.58 ha. The results found that the Batu City government had managed settlements not following the land's capabilities. Land capability classes VI and VII should not be used as settlement areas but as conservation areas or primary forests.

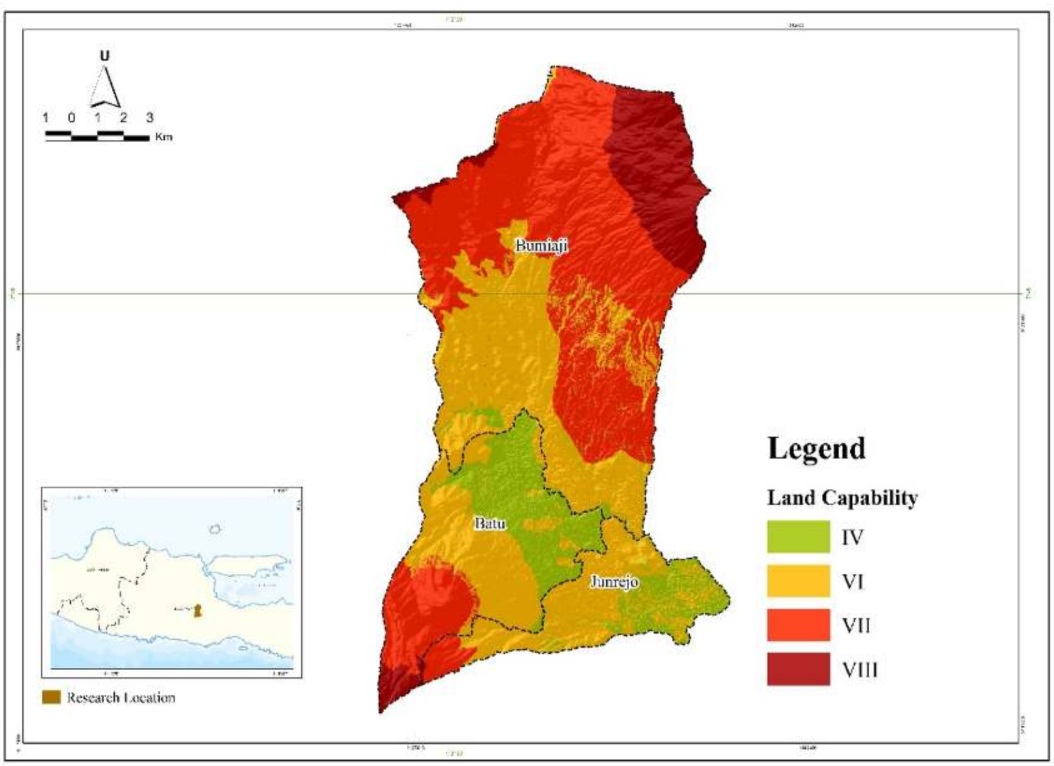

Figure 11. Land capability of settlement map of Batu City.

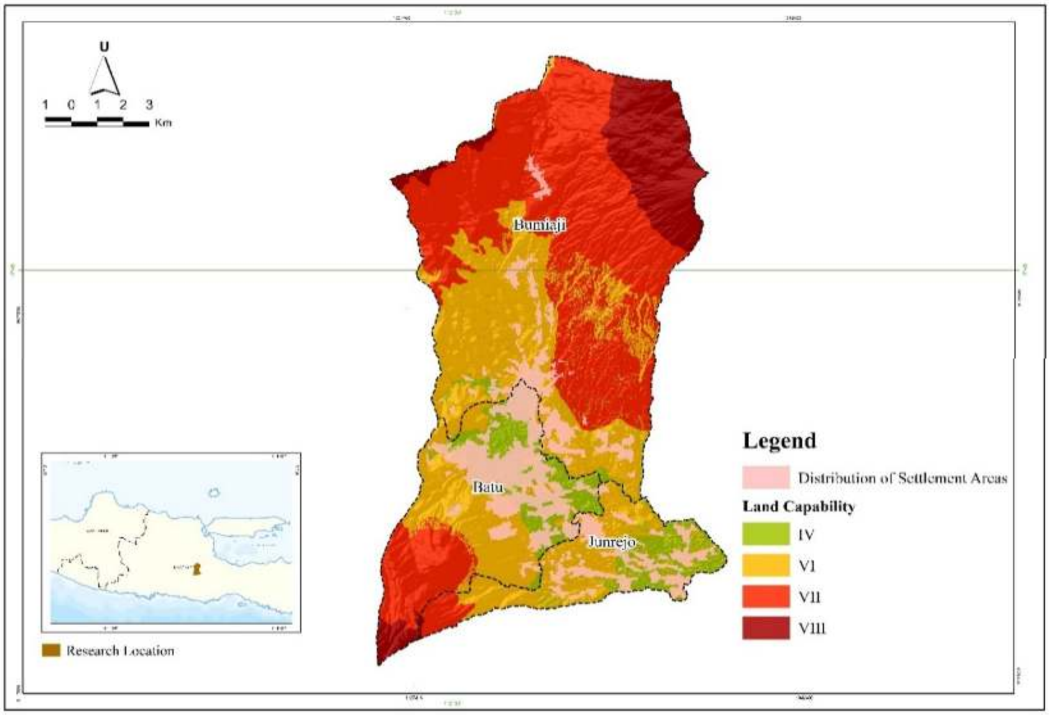

Figure 12. Overlay land capability map of Batu City.

Table 3. Settlement distribution based on land capability.

District	Settlement distribution based on land capability			
	Settlement Areas (ha)	Land Capability Class (ha)		
		IV	VI	VII
Batu	1,296.87	921.57	375.30	
Bumiaji	716.13	25.27	607.28	83.58
Junrejo	618.63	136.98	481.65	
Total	2,631.62	1,083.82	1,464.22	83.58

Capability classes VI and VII were on a slope of more than 30%. In areas with a slope of more than 30%, the value of ecosystem services reaches 70%. Hence, it is necessary to maintain it so that environmental stability and development function is maintained. In line with this, Guo et al. (2021) found a positive correlation between topography (slope and altitude) to the value of ecosystem services 70% of the total was at an altitude of more than 500 m. An efficient way of managing land can maintain landscape sustainability and protect nature. The Batu City government needs to quickly address the unsuitable settlement land management problem with land capabilities to minimize environmental impacts and natural disasters. Even previous studies explained that it was crucial to plan development by looking at the interaction between landscape patterns and land use/cover (LULC) (Wang et al., 2020).

The direction of land management for settlement

Land management for settlements in Batu City requires knowledge related to land capabilities. Rusdi et al. (2015) explained that analysis of the land capability for settlement provides information about the ability of the land to accept pressure if settlements are to be developed in that area and following regional spatial planning. Ihsan et al. (2020) also mention that land capability was primarily determined by the potential of a natural resource, the technology used in managing land resources, and the population in the area.

The land capability for settlement in Batu City was still available at only 1,414.41 ha and spread over three districts (Table 4). The Batu District covers an area of 683,554 ha, the Bumiaji District covers an area of 169,691 ha, and the Junrejo District covers an area of 561,169 ha. Capability classes VI, VII, and VIII were restricted areas and could not be developed. Capability classes VI, VII, and VIII have a 40-65% slope limiting factor. As seen in Figure 13, capability classes VI, VII, and VIII have hilly topography and were on a slope >35%. According to Agnar et al. (2020), land management for settlements on a slope of 23-35% or in class VI can still be done with engineering, but land management for settlements in class VII and class VIII was not possible even with engineering, and it is suggested to become a forest conservation area protect. Amir et al. (2020) explained that the distribution of settlements needs to be regulated to follow regional spatial planning, land capability, and suitability by considering aspects of ecological balance so that land quality does not decrease. The Batu City Government has regional spatial planning for a settlement of 2,976 ha. Evaluating the suitability of existing settlements following the regional spatial planning of settlement areas is very important to determine areas that can still be developed.

Table 4. Available land capability for settlement.

District	Available Land Capability for Settlement			
	Land Capability Class (ha)			
	IV	VI	VII	VIII
Batu	683.55	1,382.69	1,001.01	182.27
Bumiaji	169.69	3,551.12	6,567.54	1,799.71
Junrejo	561.17	1,167.14	212.95	10.67
Total	1,414.41	6,100.94	7,781.50	1,992.64

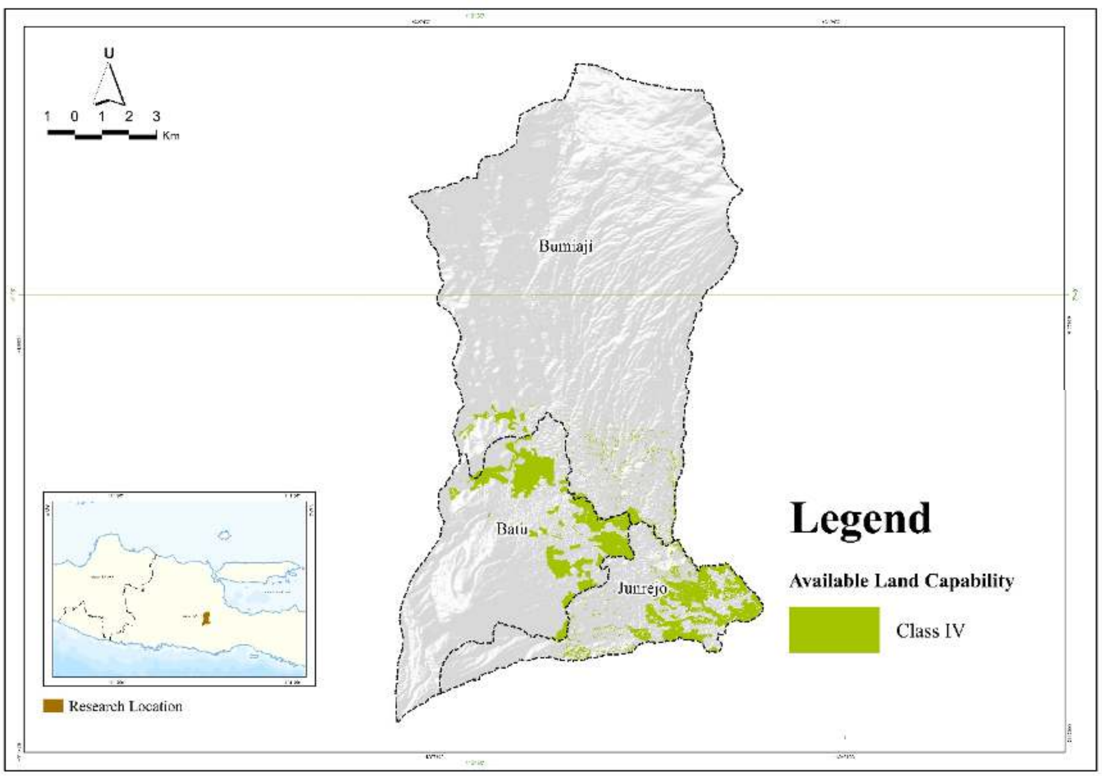

Figure 13. Available land capability for settlement in Batu City.

The evaluation results of the existing settlement area with the regional spatial planning were 694.52 ha, not following the regional spatial planning, and a place of 1,937.06 ha following. The settlement area that could still be developed based on the spatial pattern plan was 1,038.97 ha. The results of the analysis showed that the available land capability class IV is 1,414.41 ha. In this study, an overlay was carried out between the available land capability map and the regional spatial planning map of settlement areas to identify areas that have the potential to be developed as settlements following land capability and regional spatial planning. The overlay results of the available land capability with the spatial pattern plan of the settlement area are 461.9 ha suitable with land capability and 577.1 ha of planned settlements area spatial patterns that are unsuitable (Table 5). Settlements that are already suitable with the land capability can apply the green city development concept. This is done to minimize natural disasters due to land use. Settlement development on undulating contours can follow the contour lines. The top surface of the hill near the building must be planted with dense vegetation, this is done to hold water so that it does not erode and flash flood. Mallick et al. (2022) explained that future urban settlement areas should not negatively impact the environment, especially in areas with high ecosystem service values. Li L. et al. (2021) also explained flora and wildlife must be considered when constructing a new site safe for settlement building construction.

Table 5. Suitability of settlements to spatial regional planning and land capability.

District	Explanation	Suitable with land capability (ha)	Unsuitable with land capability (ha)	Grand Total (ha)
Batu	Settlement areas were available according to regional spatial planning	238.83	78.09	316.92
Bumiaji		8.21	222.15	230.36
Junrejo		214.86	276.83	491.69
Total		461.90	577.07	1,038.97

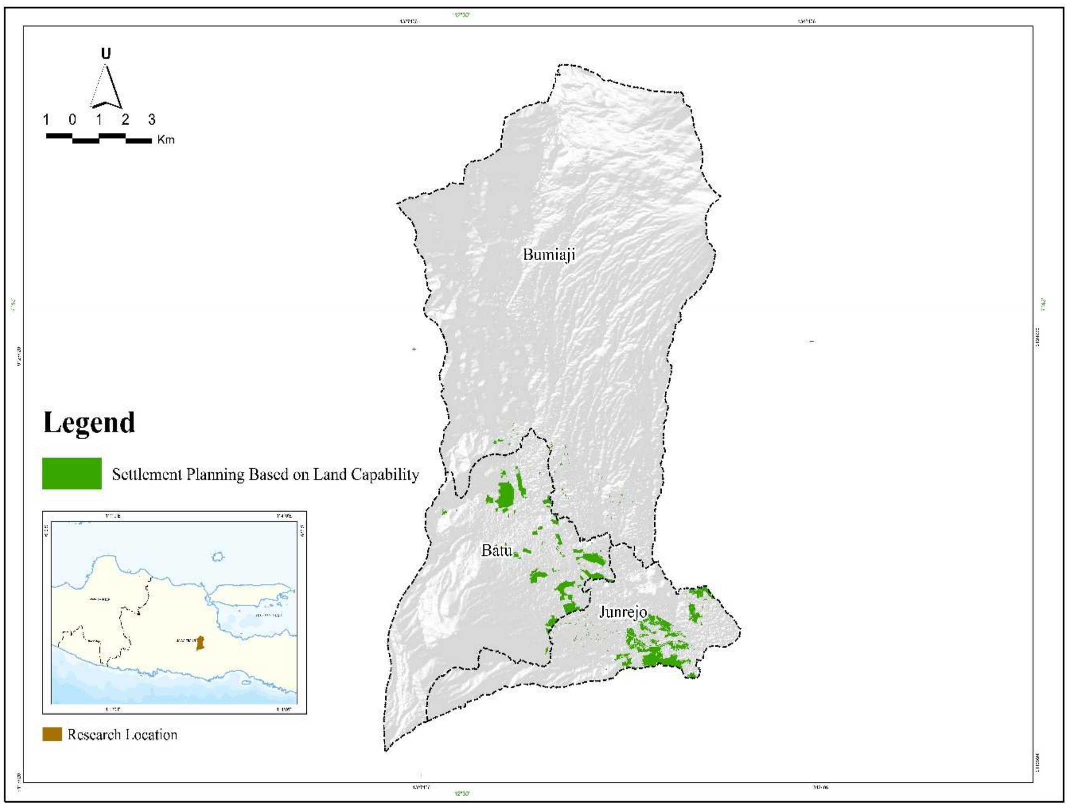

Figure 8. Settlement planning based on land capability.

Conclusion

Land capability analysis can be used as a starting point/ foundation in land management for settlements in Batu City with a slope >15%. The results of the land capability analysis in Batu City are 1,414.41 ha which can be used for settlement development. However, settlement development must also follow regional spatial planning. The Suitability of Settlements to Spatial Regional Planning and Land Capability in Batu City still available was 461.90 ha. Settlement distribution must be regulated according to land management, land capability, and regional spatial planning by considering aspects of ecological balance so that environmental quality does not decrease. Land capability classes VI, VII, and VIII are limited areas and cannot be developed. However, ease of accessibility, public facilities, and gentle slopes can become the dominant factors in land management for settlement. The government must evaluate and encourage developers to develop settlements in areas that meet the requirements and follow the land's capability. Settlements with hilly topography and elevations above 500 masl require environment-based regulations and green technology innovations to produce green cities. In areas with wavy contours, the building can follow the contour lines or not be perpendicular to the contours.

In land management, the Batu City Government must prioritize balancing the natural environment, humans, and the economy. Excellent urban quality can be seen from the determination of social interaction, environmentally friendly spatial planning, and balanced economic characteristics. In land management for settlements, coordination between stakeholders is also needed. Organizations, governments, and developers must create ecologically and socially sustainable innovations. This research only focused on land management based on land capability for settlements. Further analysis, such as social and economic carrying capacity, is needed to determine how land management is for sustainable settlements. Population control can then be carried out so that changes in land for settlements do not occur rapidly.

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References

Agnar, A.A., Brilian, C.H., Barkah, M.N. and Suganda, B.R. 2020. Residential land evaluation based on geological analysis of the Tanjungjaya Area, Kuningan Regency, West Java Province. *Padjadjaran Geoscience Journal* 4(5):401-410 (*in Indonesian*)

Ambarwulan, W., Widiatmaka, and Nahib, I. 2018. Land use/land cover and land capability data for evaluating land utilization and official land use planning in Indramayu Regency, West Java, Indonesia. *IOP Conference Series: Earth and Environmental Science* 149(1), doi:10.1088/1755-1315/149/1/012006.

Amir, A.K., Wunas, S. and Arifin, M. 2020. Settlement development based on land suitability. *IOP Conference Series: Earth and Environmental Science* 419, doi:10.1088/1755-1315/419/1/012083.

Bachtiar, F., Saraswati, A., Guswandi, G., Utomo, F.C. and Amelia, S. 2019. Typology of development of vertical residential environments in urban areas. *Proceedings TAU SNAR-TEK*, 27 November 2019 (*in Indonesian*).

Centra Buerau of Statistic Batu City. 2021. Batu City in the Year 2021 (*in Indonesian*).

Central Bureau of Statistics. 2021. Results of the 2020 Population Census for Batu City. In Statistical Official News (Vol. 2020) (*in Indonesian*).

Department of Population and Civil Registration of Batu City. 2022. Number of Population of Batu City June 2022 (*in Indonesian*).

Do, V.H., La, N., Bergkvist, G., Dahlin, A.S., Mulia, R., Nguyen, V.T. and Öborn, I. 2023. Agroforestry with contour planting of grass contributes to terrace formation and conservation of soil and nutrients on sloping land. *Agriculture, Ecosystems and Environment* 345(December 2022), doi:10.1016/j.agee.2022.108323.

Garakani, S.A., Lak, A. and Niyasati, M. 2020. Toward sustainable development in post-flood relocation of rural settlements in Iran. *International Journal of Disaster Resilience in the Built Environment* 11(3):359-377, doi:10.1108/IJDRBE-05-2019-0020.

Guo, C., Gao, J., Zhou, B. and Yang, J. 2021. Factors of the ecosystem service value in water conservation areas considering the natural environment and human activities: A case study of Funiu mountain, China. *International Journal of Environmental Research and Public Health* 18(21), doi:10.3390/ijerph182111074.

Hasmita, L., Sekarrini, C.E. and Septiana, K.N. 2020. Study of Environmental Carrying Capacity for Settlement Development in Ranah Batahan District, Pasaman Barat Regency. *IOP Conference Series: Earth and Environmental Science* 412(1):1-9, doi:10.1088/1755-1315/412/1/012002.

Henn, K., Friesen, J., Hartig, J. and Pelz, P.F. 2020. Spatial analysis of settlement structures to identify pattern formation mechanisms in inter-urban systems. *ISPRS International Journal of Geo-Information* 9(9), doi:10.3390/ijgi9090541.

Huang, Y., Miao, K., Liu, X. and Jiang, Y. 2022. The hysteresis response of groundwater to reservoir water level changes in a plain reservoir area. *Water Resources Management* 36(12):4739-4763, doi:10.1007/s11269-022-03275-1.

Ihsan, Rasyid, A.R., Asfan, L.O.M. and Yanti, S.A. 2020. Dynamics urban development to the carrying capacity of agricultural land Maros Region Province South Sulawesi. *IOP Conference Series: Earth and Environmental Science* 419(1), doi:10.1088/1755-1315/419/1/012017.

Kang, P., Chen, W., Hou, Y. and Li, Y. 2018. Linking ecosystem services and ecosystem health to ecological risk assessment: A case study of the Beijing-Tianjin-Hebei urban agglomeration. *Science of the Total Environment* 636:1442-1454, doi:10.1016/j.scitotenv.2018.04.427.

Li, L., Xin, H.X., Xiaofeng, C., Xi, C. and Qian, H. 2021. Research on key technology of soil erosion control of transmission line project in Hilly Area. *IOP Conference Series: Earth and Environmental Science* 831(1):1-5,doi:10.1088/1755-1315/831/1/012007.

Mallick, J., Ibnatiq, A.A., Kahla, N. Ben, Alqadhi, S., Singh, V.P., Hoa, P.V., Hang, H.T., van Hong, N. and Le, H.A. 2022. GIS-based decision support system for safe and sustainable building construction sites in a mountainous region. *Sustainability (Switzerland)* 14(2):1-33, doi:10.3390/su14020888.

Ministry of Environment. 2009. Regulation of the State Minister for the Environment Number 17 of 2009 concerning Guidelines for Determining the Carrying Capacity of the Environment in Regional Spatial Planning (*in Indonesian*).

Pertiwi, N., Dewanti, A. and Kadri, M.K. 2021. Analysis of the settlement carrying capacity in Manggar Baru Sub-District, Balikpapan City, East Kalimantan. *Ruang* 7(1):9-21, doi:10.14710/ruang.7.1.9-21 (*in Indonesian*).

Pragmadeanti, H.Z. and Rahmawati, F. 2022. Analysis of leading sectors and development potential of economic growth centers in the Greater Malang strategic area. *JURKAMI:Jurnal Pendidikan Ekonomi* 7(1):46-61, doi:10.31932/jpe.v7i1.1512 (*in Indonesian*).

Qoriyati and Nurhayati. 2020. Study of urban farming potency to support city landscape quality in the District of South Bogor. *IOP Conference Series: Earth and Environmental Science* 501(1):1-11, doi:10.1088/1755-1315/501/1/012009.

Rahmadania, A.N., Arsyad, U., Bachtiar, B. and Wahyuni. 2020. Compatibility of land use based on land capability in Tabo-Tabo Village, Bungoro District, Pangkajene Regency. *IOP Conference Series: Earth and Environmental Science* 575(1), doi:10.1088/1755-1315/575/1/012128.

Rienow, A., Kantakumar, L.N., Ghazaryan, G., Dröge-Rothaar, A., Sticksel, S., Trampnau, B. and Thonfeld, F. 2022. Modelling the spatial impact of regional planning and climate change prevention strategies on land consumption in the Rhine-Ruhr Metropolitan Area 2017-2030. *Landscape and Urban Planning* 217(October 2021), doi:10.1016/j.landurbplan.2021.104284.

Roshan, P. and Pal, S. 2022. Structural challenges for seismic stability of buildings in hilly areas. *Environmental Science and Pollution Research* 0123456789, doi:10.1007/s11356-022-23263-7.

Rusdi, M., Roosli, R. and Ahamad, M.S.S. 2015. Land evaluation suitability for settlement based on soil permeability, topography, and geology ten years after the tsunami in Banda Aceh, Indonesia. *Egyptian Journal of Remote Sensing and Space Science* 18(2):207-215, doi:10.1016/j.ejrs.2015.04.002.

Ruwayari, D., Kumurur, V.A. and Mastutie, F. 2020. Analysis of the carrying capacity and capacity of the land on Bunaken Island. *Spasial* 7(1):94-103 (*in Indonesian*).

Sari, K.E. 2021. Energy greenhouse gas emission inventory in Batu City. *IOP Conference Series: Earth and Environmental Science* 916:1-9, doi:10.1088/1755-1315/916/1/012003.

Shofarini, D.I., Arruzzi, R.K. and Firdauz, B.E.N. 2019. Land development recommendation of Bunguran Island as one of the national border areas based on the level of land suitability and land capability. *IOP Conference Series: Earth and Environmental Science* 328(1), doi:10.1088/1755-1315/328/1/012015.

Stanchi, S., Freppaz, M., Agnelli, A., Reinsch, T. and Zanini, E. 2012. Properties, best management practices and conservation of terraced soils in Southern Europe (from Mediterranean areas to the Alps): A review. *Quaternary International* 265:90-100, doi:10.1016/j.quaint.2011.09.015.

Sukmana, O., Salahudin, Robbie, I., Roziqin, A., Deniar, M.S., Sihidi, I.T. and Suhermanto, D.F. 2022. The involvement strategies of local knowledge in creating a sustainable city. In: Social and Political Issues on Sustainable Development in The Post Covid-19 Crisis (First, p. 254). Taylor & Francis.

Surjono, S., Zanuar, P. and Rizqi, A. 2022. Cross-border strategies to respond to the impact of climate change in the upstream Brantas Watershed, Indonesia. *Environment, Development and Sustainability* 0123456789, doi:10.1007/s10668-021-02000-z.

Wang, L., Wang, S., Zhou, Y., Zhu, J., Zhang, J., Hou, Y. and Liu, W. 2020. Landscape pattern variation, protection measures, and land use/land cover changes in drinking water source protection areas: A case study in Danjiangkou Reservoir, China. *Global Ecology and Conservation* 21:e00827, doi:10.1016/j.gecco.2019.e00827.

Wei, L., Hu, K., Hu, X., Wu, C. and Zhang, X. 2022. Quantitative multi-hazard risk assessment of buildings in the Jiuzhaigou Valley, a world natural heritage site in Western China. *Geomatics, Natural Hazards and Risk* 13(1):193-221, doi:10.1080/19475705.2021.2004244.

Wisnubroto, E.I., Rustiadi, E., Fauzi, A. and Murtilaksono, K. 2021. The dynamic changes in a peri-urban agricultural area and typology of multi-function agriculture in Batu City, Indonesia. *IOP Conference Series: Earth and Environmental Science* 667(1):1-11, doi:10.1088/1755-1315/667/1/012093.

Zhang, T., Hu, Q., Fukuda, H. and Zhou, D. 2019. A Study of Settlement Planning Strategy of Tableland Village, in Gully Regions of Loess Plateau, China. *IOP Conference Series: Earth and Environmental Science* 294(1):1-11, doi:10.1088/1755-1315/294/1/012098.

Zhou, Y., Li, J. and Pu, L. 2022) Quantifying ecosystem service mismatches for land use planning: spatial-temporal characteristics and novel approach-a case study in Jiangsu Province, China. *Environmental Science and Pollution Research* 29(18):26483-26497, doi:10.1007/s11356-021-17764-0.