# Evaluation of built-up land incompatibility with land capability and its implications for critical land in the Serang Watershed

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**Abstract.** The increase in population encourages land conversion from non-built-up land to built-up land. These conditions often do not consider the land's capability, resulting in an increase in land degradation. The Serang Watershed is one of 108 priority watersheds in Indonesia that require restoration, and is in a state of significant increase in land degradation due to rapid land conversion. Also, Climate change is one of the challenges that can contribute to the decline in watershed function and services. This study aims to analyze the impact of built-up land growth on critical land through land capability mapping. The Analytic Hierarchy Process (AHP) method was used to produce a land capability map, followed by a tiered overlay analysis with built-up land data from sentinel 2A image extraction and critical land data in 2022. The result was that 2,866.72 hectares of land that had exceeded its capability limit was still not classified as critical land, while another 6,113.03 hectares was only categorized as moderately critical despite having exceeded its capability limit. These findings highlight the importance of regularly updating critical land data to support sustainable watershed management and policy making.

**Keywords:** critical land, land capability, built-up land, serang watershed

## 1 Introduction

In 2018, the Ministry of Environment and Forestry (KLHK) announced through Decree No. 306/MENLHK/DAS.0/7/2018 that the total area of critical land in Indonesia reached 14 million hectares. Of the approximately 17,000 watersheds scattered throughout Indonesia, at least 108 watersheds are prioritized for treatment because they are in critical condition. This condition needs to be taken into consideration because watershed provides functions and

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services to support human livehoods [1]. Climate change is one of the challenges that can contribute to the decline in watershed function and services [2]. Critical land is a condition resulting from land use that is not in accordance with its capacity, causing physical, chemical, and biological damage [3]. Based on priority scale and budgeting factors, 15 of the 108 priority watersheds were addressed first and included in the 2015-2019 National Medium-Term Development Plan (RPJMN). During the 7-year period covered by the information on the list of critical watersheds released up to this year, the Indonesian Central Statistics Agency recorded an increase in Indonesia's population of 17.44 million people. This condition indicates that the need for space for both residential and cultivation activities will continue to increase. The impact of population growth is a sign and trend of increasing degradation of land resources. Land degradation to a critical level is a dynamic change [4]. If it is not immediately addressed in watersheds that are already in a critical condition, it will worsen the condition of these watersheds. The dynamics of land use change due to population growth without regard for the environment will cause further land degradation [5].

The Serang watershed is one of 108 watersheds that are prioritized for immediate restoration. This condition indicates that the watershed has experienced land degradation that could be caused by various factors. The Ministry of Environment and Forestry, through Ministerial Decree No. SK.49/PDAS/2022, has published spatial data related to critical land in Indonesia in 2022. Based on this data from BPDAS Serayu Opak Progo, it is known that the Serang watershed, which has a total area of 24,567 ha, has 16,823.7 ha or 68.48% of its area classified as moderately critical and 2,944.37 ha or 11.98% of its area classified as critical. The percentage of critical land area in the Serang Watershed should be a concern for stakeholders and the community in the region because the ongoing dynamics of land use change will expand the critical land area in the watershed. This study aims to evaluate the critical land data released by the Ministry of Environment and Forestry in 2022 by analyzing the growth factors of built-up land in 2024. The two-year time period will determine whether the condition of critical land in the Serang Watershed has changed, either increasing or decreasing. This study will focus on the aspect of built-up land growth in relation to land capacity in the Serang Watershed. Monitoring for signs of critical land is essential to suppress and prevent the occurrence of critical land [6].

Previous related studies have tended to focus on creating critical land maps using various approaches. Research by Achmad et al. [7] and Melania and Prasetyo [8] utilized remote sensing imagery and GIS to identify critical land with variables of erosion, land cover, and slope. Soil erosionResearch related to land carrying capacity through land capability has also been conducted by Wirawan et al. [9] and Gunena et al. [10] using the guidelines of Permen PU No. 20 of 2007. Their research focused more on creating critical land maps or land capability maps. Unlike their research, this study will analyze the evaluation of critical land in terms of the unsuitability of built-up land use based on its capability.

The main objective of this study is to analyze the impact of built-up land growth on critical land. This study uses a quantitative method with an AHP (Analytic Hierarchy Process) approach to produce a 2024 land capability map using various thematic data sources obtained from local governments and digital elevation model (DEM) data extraction. The land capability classes obtained will be overlaid with a built-up land map obtained from Sentinel 2A satellite imagery recorded in 2024 to assess the suitability of built-up land use to its capabilities. The data on the incompatibility of developed land will be overlaid again with the critical land map issued by the Ministry of Environment and Forestry in 2022 as material for evaluating the critical land map.

This research is expected to be used as a basis for decision-making in efforts to prevent and restore the negative impacts of built-up land on watersheds. In addition, the evaluation results are also expected to encourage the acceleration of updating critical land data, which currently takes a long time for the Ministry of Environment and Forestry and can be done

independently by local governments. Critical land is the result of complex and rapid dynamic processes. Delays in assessing critical land will result in the products of spatial planning instruments in critical watershed areas not functioning optimally, potentially increasing land degradation and failing to achieve sustainability.

## 2 Methodology

All data used in this study is secondary data, especially for thematic maps needed to compile land capability maps. All data is processed and analyzed using Arcmap (GIS) software. Thematic map data such as soil type, rainfall, and disaster hazard zones are obtained from local governments and related agencies. Slope, elevation, and morphology data were obtained from Digital Terrain Model (DTM) from DEMNAS extraction issued by BIG (www.tanahair.indonesia.go.id ). DEMNAS has a spatial resolution of 7.5 m per pixel, which was extracted in ArcMap (GIS) software to obtain information on elevation classes, slope (%) and morphology in accordance with the guidelines in the Description of Indonesian Ecoregion Maps [11]. Data related to land cover, especially built-up land, was obtained from Sentinel-2A Satellite Imagery recorded in 2024, which has been published publicly at https://livingatlas.arcgis.com/landcoverexplorer . The critical land map was obtained from the Ministry of Environment and Forestry.

### 2.1 Sub-Watershed Delineation

The delineation of the Serang watershed was obtained from the Serayu Opak Progo Watershed Management Agency (BPDAS). Sub-watershed delineation was carried out to obtain more detailed mapping units and as material for analysis related to this study. The method used in the Sub-DAS delimitation was DEMNAS data extraction using the hydrology tool in the GIS program in accordance with the flow diagram scheme in Fig. 1 [12]. Before extraction, the DEMNAS data had to be cut in the Serang watershed area as the focus of the research area.


**Fig.1.** Flowchart for Creating Sub-Watershed Maps

### 2.2 Analysis of Developed Land Changes

The analysis of developed land changes uses two different time periods, namely 2022 and 2024. Built-up land for 2022 refers to the same year that critical land data was issued through the Minister of Environment and Forestry Decree Number SK.49/PDAS/2022, while built-up land data for 2024 is used as information on the extent of changes in built-up land that occurred within a period of 2 years. The delineation of land cover is available in raster form on Sentinel 2A imagery, which is then transformed into vector data using GIS software. The change in form to vector facilitates the data overlay process and the extraction of area data. The method of land change analysis uses the overlay process in two different years to determine the distribution of land conversion and the extent of the change.

### 2.3 Land Capability Mapping

Land capability maps will be created in accordance with the guidelines of Minister of Public Works Regulation No. 20 of 2007, as done in the studies by Wirawan et al. [9] and Gunena

et al. [10] , with several adjustments. The method involves combining 8 land capability unit (SKL) maps using the AHP (Analytic Hierarchy Process) method.

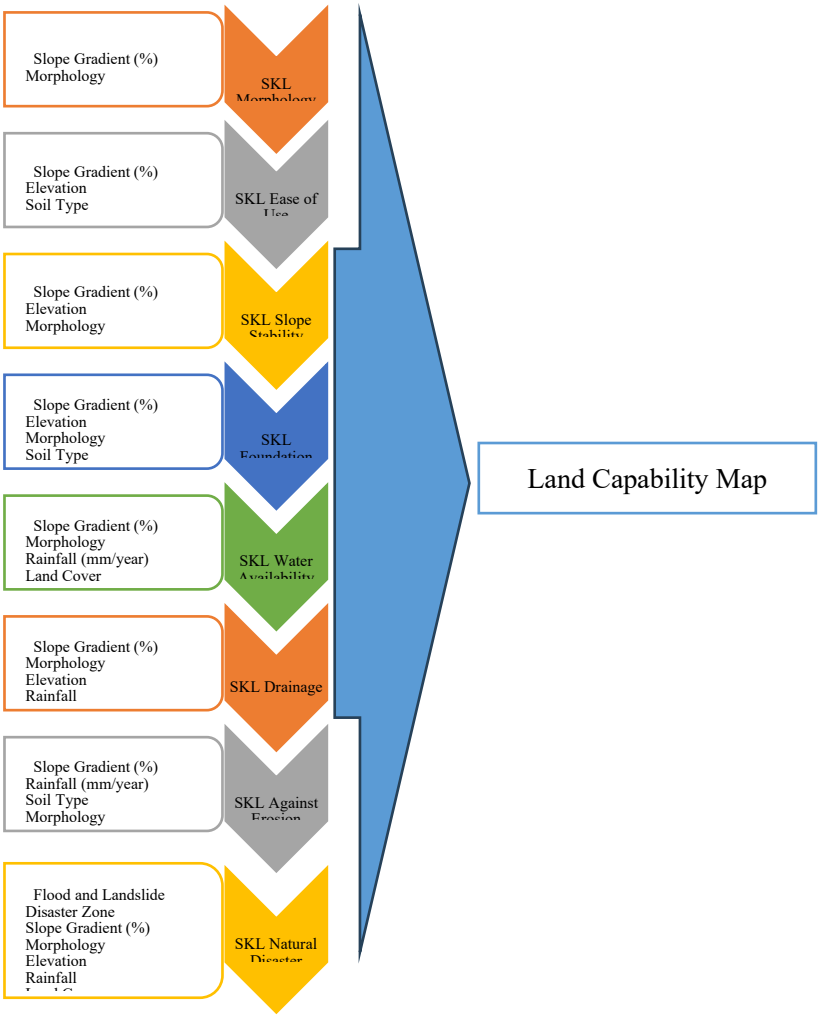


**Fig. 2.** Flowchart for Compiling Land Capability Maps

## 2.4 Land Suitability Analysis

Land suitability in this study refers to the suitability of developed land in relation to its capacity. The results of the land capacity map have been integrated with the developed land obtained from Sentinel 2A satellite image data extraction. Each class of land capacity has a different carrying capacity for developed land. Land capacity with a very low class has a built-up land ratio of 0%, while land capacity with a very high class has a built-up land ratio of 50%. Each land capacity class and its built-up land ratio can be seen in Table 1. The method used is to overlay the land capability map and the developed land map, then compare the area of developed land formed in each land capability class with the developed land ratio. The output of this activity is to obtain information on how much of the Serang watershed area has exceeded its carrying capacity for developed land.

**Table 1.** Built-up Land Ratio for Each Land Capability Class

| Land Capability Class | Built-Up Land Ratio |
|---|---|
| Very Low | 0 % |
| Low | 10 % |
| Medium | 20 % |
| High | 30 % |
| Very High | 50% |

### 2.5 Critical Land Assessment

Critical land assessment is conducted using an overlay method between the 2024 map of unsuitable developed land and the 2022 map of critical land. The results of this overlay provide information related to the comparison of data on the distribution and area of unsuitable developed land with the classes of land criticality in each sub-watershed. The output obtained in this process is the evaluation of critical land classes in 2022 against the dynamics of land use change that caused the uncontrolled growth of built-up land beyond its carrying capacity. Analysis and relevance of critical land classes, which were produced in 2022, to determine whether they can still be used as a basis for policy-making in 2024.

## 3 Result and Discussion

The Serang watershed is one of the watersheds with complex physical conditions and land use. The upstream watershed area is a hilly region that also forms a clear boundary between the Special Region of Yogyakarta Indonesia and Central Java Indonesia on the western side. The central watershed area is the urban area of Wates, which not only serves as the administrative capital but also as the economic, social, and cultural center of Kulonprogo Regency. Meanwhile, the downstream area is filled with protected agricultural land (LSD) and is home to Yogyakarta International Airport (YIA), which forms an aerotropolis and has been included in the detailed spatial plan for Kulon Progo Regency through Kulon Progo Regency Regulation (PERBUP) Number 47 of 2023. The Menoreh Hills area has gained increasing recognition with the emergence of Yogyakarta International Airport, marked by a rise in visitors and the development of tourist areas in the region. The growth of tourist areas has stimulated the development of built-up areas to support these activities, in addition to being utilized as residential areas.

### 3.1 Sub-Watershed Boundaries

There are 37 sub-watersheds divided from the DEMNAS data extraction results as shown in Figure 3. The extraction process produced a larger number of sub-watersheds, but the researchers eliminated sub-watersheds with narrow coverage areas, such as slivers. The sequence of Sub-DAS code numbers was created by the researcher based on the sequence of

Sub-DAS boundary formation, starting from the upstream area to the downstream area.

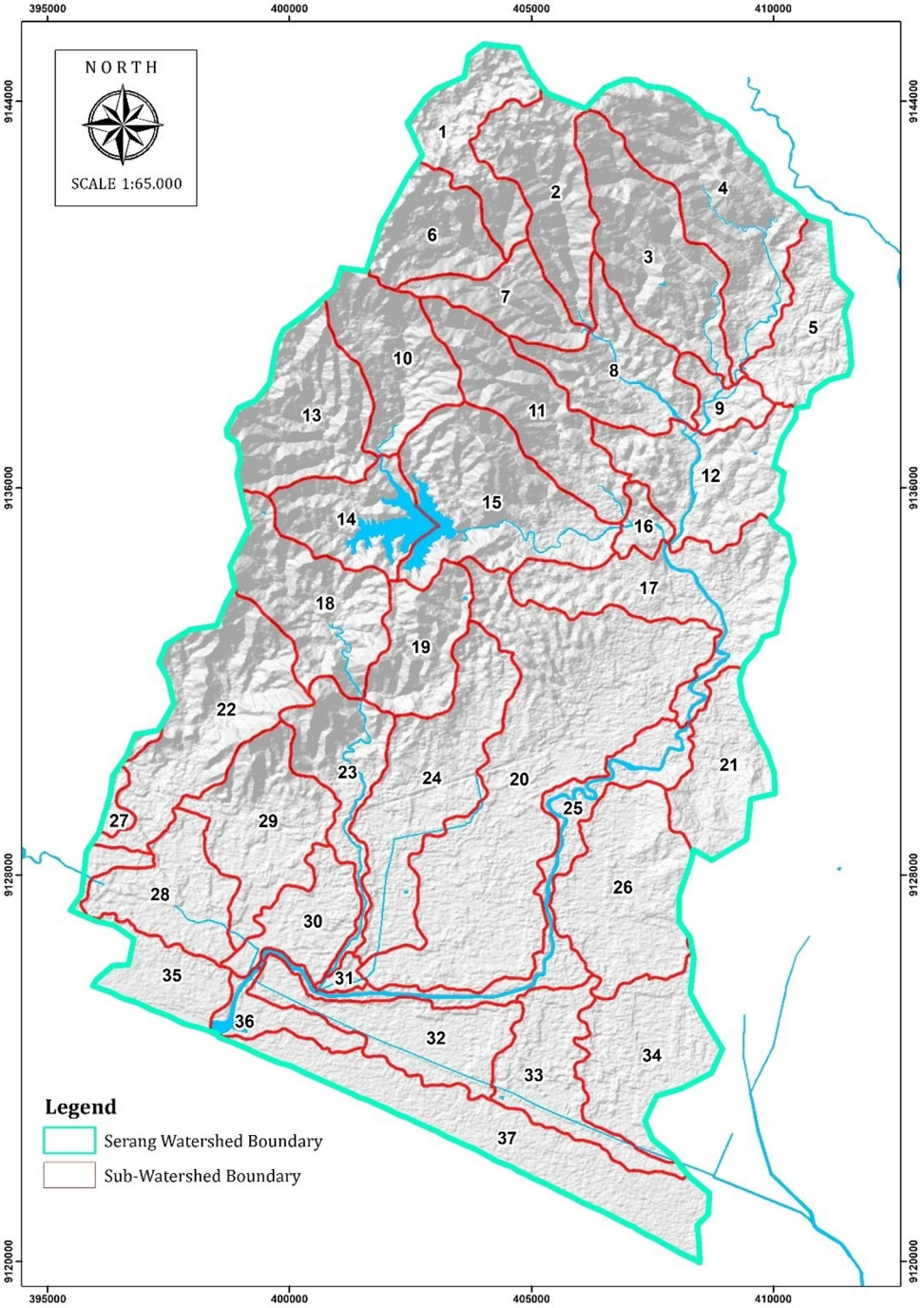


**Fig. 3.** Division of Sub-Watersheds

### 3.2 Built-up Land Growth

Built-up land growth in the Serang watershed has increased rapidly. Within a period of two years, there has been an additional 1,854.19 hectares of built-up land, as shown in fig. 4. Almost all 37 sub-watersheds in the Serang watershed have experienced an increase in built-up area, including in the upstream watershed area. The largest increase was in the sub-watersheds located in the middle and downstream areas, especially around the Serang River. The increase in built-up land is also a sign of a change in land use from non-built-up to built-up areas.

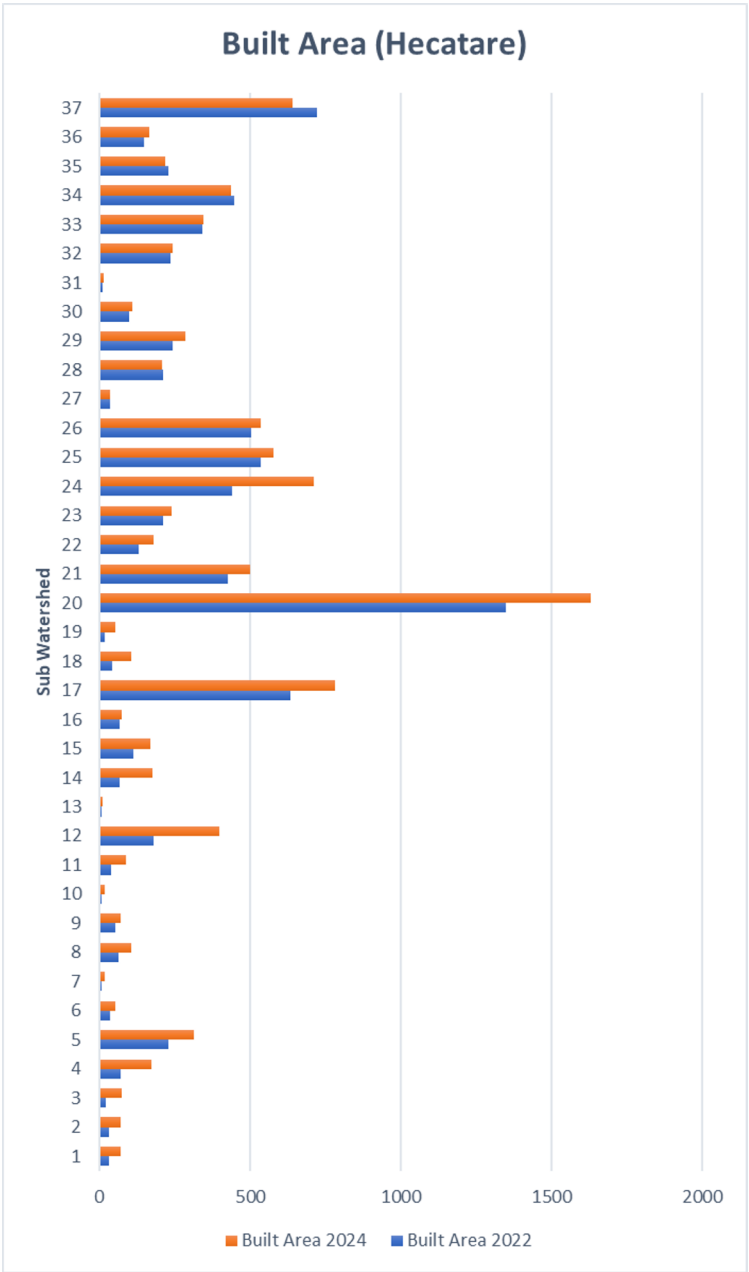


**Fig. 4.** Diagram of Built-up Area in 2022 and 2024 in Serang Watershed

### 3.3 Land Capability of the Serang Watershed

There are 9 Land Capability Units (SKL) as referred to in Minister of Public Works Regulation No. 20 of 2007, but in this case the researchers only used 8 SKL. The researcher did not use the Land Capability Unit variable for waste disposal because during the weighting process to obtain the land capability map, the weight value for that SKL was 0, meaning it had no effect on the results. This differs from the research by Wirawan et al. [9] and Gunena et al. [10], which used all SKLs in forming the land capability map.

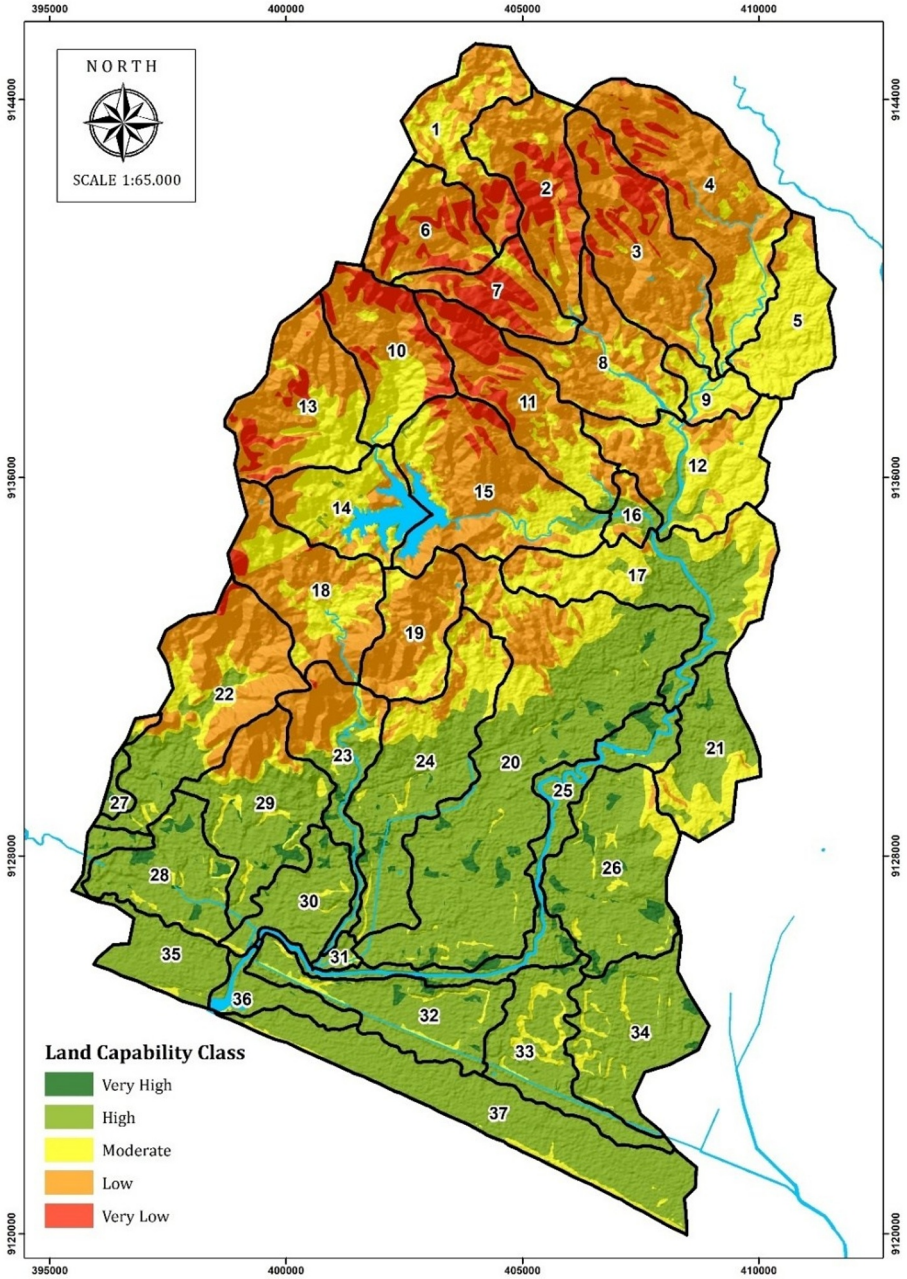


**Fig. 5.** Map of Land Capability in the Serang Watershed

The land capability map shown in Fig. 5 has the same number of classes as the land capability unit map. This land capability map refers to conditions in 2024. In addition to being used to evaluate the unsuitability of land use, this land capability map is often used as a recommendation for land use in each land capability class, as studied by [13].

### 3.4 Land Use Incompatibility

Land capability is an instrument for controlling land use change and land incompatibility. Inappropriate land use is one of the factors causing land degradation [14]. Research conducted by Wirawan et al. [9] and Gunena et al. [10] using land capability as an instrument to guide future land use is a form of mitigation against potential land degradation. Gunena et al [10], used land capability as an instrument to evaluate spatial planning, which found that residential areas were located in areas with high land capability. This study is conceptually similar to that of Gunena et al, [10], except that it evaluates the condition of watersheds that have experienced land degradation.

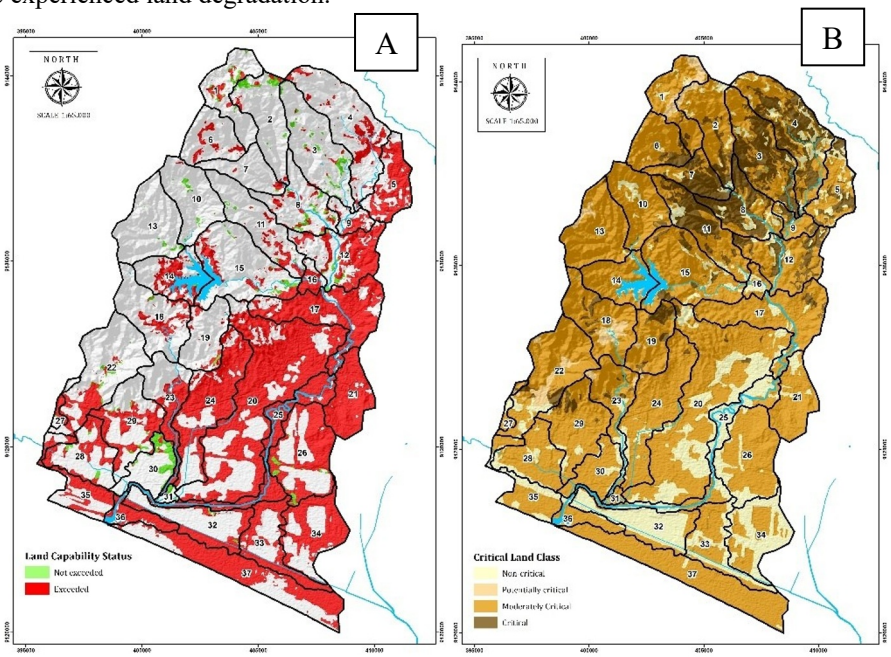


**Fig. 6.** Map of land capability status in 2024 (A) and Map of Critical Land in 2022 (B)

The allocation of developed land, which should be limited to 20.09% of the total area, has actually reached 38.37% of developed land, as shown in Table 2. Nearly 20% of the Serang watershed area has exceeded its land capability status. Research by Taufan and Pratomo [5], related to the implementation of zoning regulation instruments in handling critical land proves that the dynamics of land use change without regard for the environment have led to increasingly severe land degradation. A similar condition occurs in the Serang watershed, which has been designated as one of the priority watersheds for management, experiencing increasingly severe degradation due to the high level of incompatibility between built-up land use and its capacity. A total of 33 sub-watersheds out of 37 sub-watersheds that have exceeded their status according to the results in Fig. 6 and Table 2 should be given serious attention and handling by stakeholders in land use recovery and reinforcement activities. This condition is in line with the statement by Dariah and Wahyunto [4] that

increasingly degraded land resources are characterized by population growth activities and impacts.

**Table 2.** Evaluation of Critical Land Classes Against Land Capacity Status That Has Been Exceeded

| Sub-Watershed | Area (Ha) Status of Land Capacity Exceeded in Relation to Critical Land Class | | | | Area (Ha) |
|---|---|---|---|---|---|
| | Non-critical | Potentially critical | Moderately Critical | Critical | |
| 1 | 15.31 | 7.14 | 26.24 | 0.56 | 49.25 |
| 2 | 16.59 | 1.36 | 10.48 | 1.37 | 29.81 |
| 3 | 3.45 | 0.00 | 10.20 | 4.20 | 17.85 |
| 4 | 88.06 | 0.00 | 42.02 | 41.26 | 171.34 |
| 5 | 89.37 | 0.00 | 157.94 | 66.96 | 314.27 |
| 6 | 3.06 | 1.68 | 36.98 | 12.28 | 54.00 |
| 7 | 7.48 | 0.00 | 0.62 | 7.52 | 15.62 |
| 8 | 27.18 | 0.00 | 15.10 | 29.00 | 71.27 |
| 9 | 5.15 | 0.00 | 57.55 | 6.32 | 69.02 |
| 10 | 0.10 | 0.00 | 1.79 | 0.00 | 1.89 |
| 11 | 19.71 | 0.00 | 42.96 | 14.65 | 77.32 |
| 12 | 38.00 | 0.00 | 226.70 | 109.57 | 374.27 |
| 14 | 18.80 | 3.84 | 146.50 | 0.04 | 169.19 |
| 15 | 14.84 | 0.00 | 119.09 | 6.80 | 140.73 |
| 16 | 37.52 | 0.00 | 36.01 | 0.00 | 73.53 |
| 17 | 66.71 | 0.00 | 696.08 | 19.30 | 782.08 |
| 18 | 9.16 | 27.58 | 57.87 | 5.75 | 100.35 |
| 19 | 0.10 | 0.00 | 48.34 | 0.93 | 49.37 |
| 20 | 617.82 | 0.00 | 1,004.20 | 7.01 | 1,629.03 |
| 21 | 54.15 | 0.00 | 444.77 | 0.00 | 498.92 |
| 22 | 55.83 | 51.81 | 53.24 | 2.23 | 163.11 |
| 23 | 79.56 | 0.69 | 149.29 | 9.30 | 238.83 |
| 24 | 58.61 | 0.26 | 647.90 | 5.08 | 711.84 |
| 25 | 409.07 | 0.00 | 166.38 | 0.00 | 575.45 |
| 26 | 165.45 | 0.00 | 338.84 | 0.00 | 504.29 |
| 27 | 15.35 | 1.54 | 16.66 | 0.00 | 33.56 |
| 28 | 76.36 | 0.00 | 116.32 | 0.00 | 192.68 |
| 29 | 42.03 | 0.00 | 222.79 | 2.94 | 267.76 |
| 30 | 1.59 | 0.00 | 9.83 | 0.00 | 11.43 |
| 32 | 118.00 | 0.00 | 115.76 | 0.00 | 233.76 |
| 33 | 183.73 | 0.00 | 161.49 | 0.00 | 345.22 |
| 34 | 387.18 | 0.00 | 48.10 | 0.00 | 435.28 |
| 35 | 98.07 | 0.00 | 121.21 | 0.00 | 219.28 |
| 36 | 30.22 | 0.00 | 134.96 | 0.00 | 165.18 |
| 37 | 13.08 | 0.00 | 628.83 | 0.00 | 641.91 |
| Area Total (Ha) | 2,866.72 | 95.90 | 6,113.03 | 353.05 | 9,428.69 |

### 3.5 Changes in Critical Land Class

The results obtained in table 2 show that there are 2,866.72 hectares of land in the Serang watershed that have exceeded their land capacity but are still classified as non-critical. This

is in line with Tuhehay et al. [3], who state that critical land is caused by land use that is not in accordance with its capacity. This condition will damage the physical, chemical, and biological aspects of the watershed area. The analysis conducted by the researchers evaluated the change in the critical land class in 2022, which was initially non-critical but became critical land. The largest area of critical land class that experienced inappropriate land use was in the moderately critical class, covering an area of 6,113.03 hectares. The moderately critical class in the Serang watershed has a high potential to experience a similar situation to the previous non-critical class, namely a change in critical land class to a more severe condition than before. The lowest class of critical land data is the highly critical class, but according to 2022 data from the Ministry of Environment and Forestry, this class does not exist in the Serang watershed. Updating the critical land data released by the Ministry of Environment and Forestry in the next period has a high potential that the Serang watershed will find a very critical class in its area. This condition proves that critical land and land unsuitability are very dynamic and change rapidly. The short time period of only two years proves the rapid growth of developed land, especially since the central and downstream areas of the Serang watershed are fast-growing areas.

### 3.6 Critical Land for Food Security

The Kulonprogo Regency Government has taken serious steps to maintain sustainable agricultural land through Regency Regulation (Perbup) Number 20 of 2024 concerning the Second Amendment to Regency Regulation Number 118 of 2016 concerning the Protection of Sustainable Food Agricultural Land. Most of the protected agricultural areas are located in the downstream area of the Serang River Basin. Critical land has an impact on river basin damage, characterized by an abnormal hydrological cycle in the river basin. Research conducted by Indra [15] shows the condition of the Citarum River Basin, which is experiencing water scarcity due to changes in forest land use to other areas. The threat of water scarcity is also experienced in the Serang watershed and directly threatens food security in the region due to a lack of harvestable land in the agricultural sector.

### 3.7 Updating Critical Land

The mapping of critical land issued in accordance with the Decree of the Minister of Environment and Forestry Number SK.49/PDAS/2022 is a reference in the watershed management and planning process. Previously, similar data had been released in 2018 through Decree No. SK.306/MENLHK/DAS.0/7/2018, which means that there was a 4-year gap in the updating process. This study proves that within a period of 2 years, there have been many changes in the addition of built-up land, most of which has exceeded the capacity of the land. The Ministry of Environment and Forestry has made efforts through Minister of Environment and Forestry Regulation No. 10 of 2022 concerning the Preparation of General Plans for Forest and Watershed Land Rehabilitation and Annual Plans for Forest and Land Rehabilitation, which provides technical guidelines for preparing critical land maps so that local governments can use these guidelines to update critical land data. The spatial planning instrument is a form of affirmation and control of land use in accordance with its capacity because it is based on sustainability. In the planning process, there is an analysis of land capacity that refers only to the location of the plan. When considering the cause-and-effect relationship of spatial interactions, land capacity analysis must be conducted comprehensively at the watershed level or at least the sub-watershed level, which can then be used as the basis for spatial planning in the planning area. Critical land updates must also comply with the technical standards issued by the Ministry of Environment and Forestry. The latest data should be used to obtain a critical land model that closely reflects actual conditions.

## 4 Conclusion

The findings of this study indicate that the expansion of built-up land in the Serang Watershed has substantially exceeded the area's land capability, thereby intensifying the progression of land degradation. A total of 2,866.72 ha of land that had surpassed its capability threshold remained classified as non-critical in the 2022 dataset, while 6,113.03 ha were still designated as moderately critical despite clear evidence of land-use incompatibility. These results affirm that the growth of built-up land constitutes a significant driver of critical land formation and that the existing critical land map no longer accurately represents current watershed conditions.

In light of the rapid dynamics of land-use change, the routine and more frequent updating of critical land data is imperative to ensure the validity of watershed management, rehabilitation planning, and spatial policy development. Strengthening alignment between land use and land capability is essential to prevent further degradation and to safeguard the ecological integrity of the Serang Watershed.

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