

Site suitability analysis for industrial zones in Boyolali Regency using geospatial data and random forest machine learning algorithm

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Abstract. The industrial sector plays a crucial role in driving regional economic growth. Therefore, the location of industrial areas is a fundamental aspect that directly impacts operational efficiency, the quality of life of the surrounding community, and environmental sustainability. Boyolali Regency, located at the heart of the Joglosemar triangle—connecting Yogyakarta, Solo, and Semarang—has a strategic location, making it suitable for industrial development. The development of the industry in Boyolali is expected to improve logistics efficiency and strengthen its appeal to investors and industries seeking expansion in Central Java. This study aims to determine potential locations for industrial area development in Boyolali Regency by utilizing the advantages of Geographic Information Systems (GIS) and geospatial data. The potential location model was analyzed using a random forest machine learning algorithm with existing industrial area location data as the training data. . The result obtained from this study is a map model of potential industrial development locations in Boyolali Regency. This study is expected to provide recommendations that will serve as important guidance for the government in taking initiatives and directing future investments, consistent with the region's long-term growth goals.

1 Introduction

The industrial sector is one of the key sectors that plays a vital role in driving a country's economic growth (1). In Indonesia, this role is reinforced by regulations that accommodate the involvement of the private sector. According to Presidential Decree Number 41 of 1996 concerning Industrial Zones, industrial activities in Indonesia may be carried out by private parties, both foreign and national, without the involvement of State-Owned Enterprises (BUMN). This policy has proven effective in providing various positive impacts on industrial development and the economy of Indonesia (2). Since the issuance of this regulation, many industrial zones in Indonesia have experienced rapid growth (3).

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The Boyolali region holds a strategic position at the center of the Joglosemar Golden Triangle (Yogyakarta-Solo-Semarang), making it a strong attraction for investment, particularly in the industrial sector. Its location, which is traversed by toll roads and supported by various logistical infrastructures, makes it an ideal site for industrial expansion (4). Industrial development in Boyolali can be a strategic step in addressing the existing socio-economic challenges. Although economic growth and investment are increasing, the data indicate that there are still issues that need to be resolved, especially regarding inequality and community welfare. The poverty rate in Boyolali Regency in 2024 was 9.63% (5). In addition, the data show that the average per capita expenditure for Boyolali residents is around Rp1.18 million per month, indicating that people's purchasing power needs to be improved (6). In this context, industrial expansion is a highly relevant solution. The manufacturing industry sector is one of the main contributors to Boyolali's Gross Regional Domestic Product (GRDP), along with the agriculture and trade sectors (7). Increased investment in this sector, which in 2023 reached Rp1.937 trillion (exceeding the RPJMD target), can create more job opportunities (8). With Boyolali's Open Unemployment Rate (TPT) reaching 3.16% in 2024 indicating a need for job creation (6). The development of new industries has the potential to integrate the existing workforce, thereby potentially reducing poverty rates and increasing the average income of residents (9). Therefore, accelerating the development of industrial zones in Boyolali is not only an economic agenda but also a strategic step to achieve more equitable social welfare.

This study aims to address these challenges by leveraging the advantages of Geographic Information Systems (GIS) and geospatial analysis. This approach enables us to simultaneously analyze and model highly diverse and complex spatial data. The study employs the Random Forest machine learning algorithm to build a predictive model for potential industrial area locations. This model will be trained using existing industrial area location data as a reference, and further enriched with various spatial variables. These variables include physical factors such as slope gradient and soil type, economic factors such as distance to trade centers, as well as infrastructure factors such as proximity to highways, rivers, electricity networks, and drainage systems. The final outcome of this research is a map model that visually and analytically identifies the most potential locations for industrial development in Boyolali Regency. It is hoped that the recommendations from this study can serve as a strategic guide for local governments in making decisions regarding the development of industrial area regions in Boyolali Regency.

2 Methodology

2.1 Location Study

The research area is located in Boyolali Regency, Central Java Province, Indonesia. Geographically, Boyolali Regency lies between the coordinates of 110°22' and 110°50' East Longitude, and 7°7' and 7°36' South Latitude.

3 Result

3.1 Industrial Zone Site Suitability in Boyolali Regency

Based on the results of processing potential industrial land in Boyolali Regency, it can be seen that there are five classifications of potential industrial land: non-potential land, low potential land, medium potential land, high potential land, and very high potential land. Of these five classifications, the potential industrial land in Boyolali Regency is dominated by medium potential land, with a total area of 28,3937.63 hectares. Medium potential land indicates that most areas in Boyolali Regency have adequate physical characteristics, accessibility, and infrastructure, but still require further development to reach optimal standards for industrial activities. This condition presents opportunities in industrial planning and development. The following is a breakdown of potential industrial land in each district in Boyolali Regency.

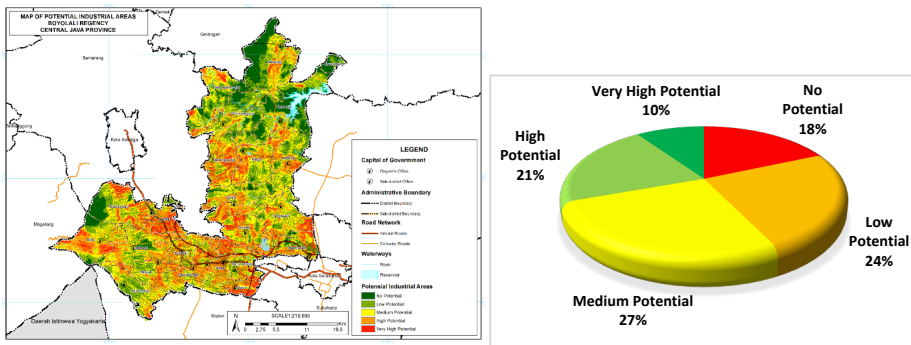


Fig. 3. Map of potential industrial zones in Boyolali Regency.

Based on the calculation of the land area for each classification of potential industrial land in Boyolali Regency, it is known that Ampel District is the subdistrict with the highest category of highly potential land, covering an area of 934.89 hectares—the largest among all subdistricts. This is supported by Ampel District's strategic position, optimal infrastructure, and accessibility for industrial development. In addition to Ampel, there are several other subdistricts with significant industrial potential, namely Sambu District, which has a highly potential land area of 881.69 hectares and a high potential land area of 1,429.7 hectares, as well as Karanggede District, which has 809.75 hectares of highly potential land and 1,611.03 hectares of high potential land. Meanwhile, Selo District exhibits unique characteristics by having the largest high potential land area in the whole regency at 1,619.29 hectares, although its highly potential land area is relatively smaller compared to Ampel, Sambu, and Karanggede. Ampel, Sambu, and Karanggede have high potential value because they are easily accessible from main transportation routes, including their proximity to arterial roads and collector roads that serve as the regional distribution network. Furthermore, these areas are also supported by infrastructure such as electricity networks, access to clean water, and drainage systems that are relatively better than those in other subdistricts. Most of the area in these three subdistricts is situated on gentle slopes and does not fall within protected zones, making large-scale land

use possible. These factors make the area more feasible and efficient for industrial development and increase its suitability score in the model.

In the moderate potential land category, Nogosari District dominates with an area of 2,049.69 hectares, followed by Cepogo with 1,806.72 hectares, and Andong with 1,775.38 hectares. The dominance of these three districts in the moderate potential category indicates the possibility of medium-term development, where with infrastructure investment and measurable land quality improvement, these areas could be upgraded into productive medium-scale industrial zones.

However, besides areas with highly to moderately potential land, there are also areas with low potential land, and even areas that lack any potential for industrial development. In Kemusu District and Juwangi District, non-potential lands dominate with areas of 4,097.19 hectares and 4,054.18 hectares, respectively. Kemusu District also shows a significant amount of low potential land at 2,737.78 hectares, while Juwangi has 2,670.03 hectares of low potential land. In addition, Wonosegoro District exhibits a similar pattern, with 1,596.07 hectares of non-potential land and 2,335.10 hectares of low potential land, indicating the need for alternative development strategies or a focus on non-industrial sectors such as agro-tourism or environmental conservation.

3.2 Potential land for industrial zone development in Boyolali

The determination of potential land for industrial area development in Boyolali Regency must take into account the prevailing regulations. One such regulation for industrial area development in Boyolali Regency is stipulated in the spatial planning policy. The spatial plan for Boyolali Regency is contained within the Regional Spatial Plan (RTRW) document of Boyolali Regency. The RTRW comprises both a spatial structure plan and a spatial pattern plan. The spatial structure plan consists of settlement centers and their networks, while the spatial pattern plan consists of designated land use areas. The spatial pattern plan includes protected areas and cultivation areas. According to Ministerial Regulation No. 11 of 2021, a protected area is a region designated primarily to maintain environmental sustainability, encompassing both natural and artificial resources, while a cultivation area is a region designated primarily for development based on the conditions and potential of natural resources, human resources, and artificial resources. The following is the map of the spatial pattern plan of Boyolali Regency for the years 2011–2031.

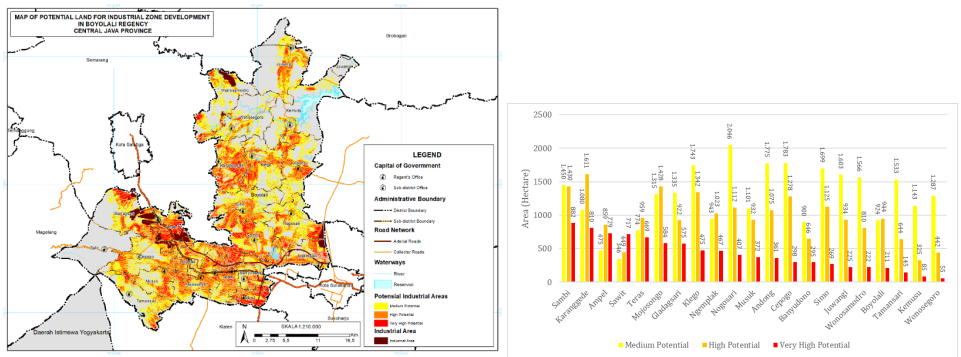


Fig. 5. Map of potential land for industrial zone development in Boyolali Regency

Based on Figure 5 above, the distribution of potential land for industrial area development in subdistricts designated as industrial zones in Boyolali Regency can be identified. The potential land available for the development of industrial areas falls into the medium, high, and very high classifications. These potential levels are determined by considering land quality as well as accessibility and supporting facilities. The potential land referred to the land that has been reduced by the industrial area directives in the spatial plan (RTRW) of Boyolali Regency. This potential land can serve as a recommendation for determining industrial areas in Boyolali Regency. The following is the area of potential land in each district. Based on the calculation, the district with the largest potential land for industrial area development is Sambi district, with an area of 3,761.68 hectares or 75% of the total land area, followed by Nogosari district, with 3,565.77 hectares or 65% of the total area. These sub-districts have extensive administrative regions with land quality suitable for use as industrial areas. In addition, accessibility for supporting industrial product distribution is also easy to reach. Not only that, supporting facilities and infrastructure for the industrial area in Sambi Sub-district are also quite adequate. Meanwhile, the district with the lowest potential land area is Sawit district with 1,511.38 hectares and Kemusu district with 1,552.70 hectares. Sawit district and Kemusu district have relatively small administrative areas, with land quality more suitable for agricultural use compared to industrial areas.

4 Conclusion

Based on the results of the land potential analysis for industrial areas in Boyolali Regency, it can be concluded that most regions have the potential for industrial development at varying levels. As much as 58% of the total land area falls into the medium, high, and very high potential categories. Districts such as Ampel, Sambi, and Karanggede stand out with land areas of high to very high potential. This is supported by factors such as strategic location, accessibility, and the availability of infrastructure. On the other hand, several districts like Kemusu, Juwangi, and Wonosegoro are dominated by land classified as having low or no potential, thus requiring alternative development approaches outside of the industrial sector. In terms of determining variables, factors such as proximity to rivers, drainage networks, and access to clean water have the greatest influence in assessing industrial land potential. This indicates that the availability of water resources and their

management systems are primary prerequisites for developing industrial areas. Additionally, accessibility factors such as road networks, electricity, and proximity to trade centers also play a significant role. Meanwhile, soil type and slope have a smaller impact, although they remain relevant for technical considerations in construction and land stability. The results of the potential land for industrial area development obtained from this research can be utilized by local governments in making decisions to designate industrial areas more accurately and in accordance with the Boyolali Spatial Plan guidelines (RTRW). The findings of this study can also support the government in infrastructure development as well as increasing investment in sub-districts with high potential. Thus, economic development can take place effectively, measurably, and sustainably.

References

1. M. Mardalena, A. Adji, S. Suhel, S. Andaiyani, H. Harunurrahyid How leading economic sectors stimulate economic growth, income and labor absorption? Input-output approach. *Int. J. Econ. Financ.* **9**, 234–244 (2019)
2. F. Salsabila, P.B. Santosa Analisis kriteria jamak dan AHP untuk evaluasi kesesuaian lokasi pengembangan kawasan industri di Kabupaten Wonogiri. *JGISE.* **7**, 91–102 (2024)
3. Sinurat, M.S.M. Purba, T. Purba, I.M. Tarigan, L.M. Ambarita, R. Napitu Spatial economic study of industrial regional development in Simalungun District. *Tec Empresarial.* **6**, 124–140 (2024)
4. E. Permanasari, F. Hendola, S. Tarigan, I. Tafrijd, F. Aurora Urban expansion in South Tangerang: Analyzing Bintaro Jaya as a private city. *Cities.* **144**, 104665 (2023)
5. Central Statistics Agency of Boyolali Regency Percentage of poor population in Boyolali Regency, Central Java, and Indonesia (in March). BPS Boyolali Stat, (Boyolali Regency, 2025)
6. Central Statistics Agency of Boyolali Regency. Boyolali Regency in Figures 2024. Badan Pusat Statistik Boyolali. (Boyolali Regency, 2024)
7. Regional Planning R and DA (BP3D) of BR. Final Report on the Preparation of the Regional Poverty Alleviation Plan (RPKD) Document for Boyolali Regency 2022–2026 (Boyolali Regency, 2022)
8. Boyolali Regency Investment and One-Stop Integrated Services Office. Investment Value of Boyolali Regency 2023. (Boyolali Regency, 2023)
9. D. Rodrik, J.E. Stiglitz A new growth strategy for developing nations (The New Global Economic Order. New York, Taylor & Francis Group, 2025)
10. Boyolali Regency Government. Boyolali Regency Regional Regulation Number 8 of 2019 concerning the Boyolali Regency Regional Spatial Planning Plan for 2011–2031. (8 Indonesia: Boyolali Regency Government; 2019)