Open Access

Frontiers in Sustainable Science and Technology
E-ISSN: 3064-4720
DOI: https://doi.org/10.69930/fsst.v2i1.379
Research Article

ScienceTech. Group

Vol. 2 (1), 2025
Page: 41-50

Detection of Land Cover Change in Nickel Mining Areas, in Weda Tengah Sub-district, Halmahera Island, Indonesia using Planet-Scope Satellite Images

Heinrich Rakuasa [1,*], Ahmat Rifai [2], Abdul Kadir Latulanit [3], Abd H Amahoru [4], Rizky Ahmad Laitupa [5], Diaz Astiza [6], La Mbeli Rajani [7]

[1] Department of Geography, Faculty of Geology and Geography, Tomsk State University, Russian Federation
[2] Department of Environmental Science, School of Environmental Science, Universitas Indonesia, Indonesia
[3] Directorate General of Animal Husbandry and Animal Health, Ministry of Agriculture of the Republic of Indonesia, Indonesia
[4] Islamic Astronomy Laboratory, Faculty of Sharia, IAIN Ambon, Indonesia
[5] Department of Geography Education, Faculty of Teacher Training and Education, Pattimura University, Indonesia
[6] Al-Quran and Tafsir Science, Ushuluddin and Humanities. Walisongo State Islamic University Semarang, Indonesia
[7] Social science study program, Postgraduate Faculty, State University of Malang, Indonesia
*Email (corresponding author): heinrich.rakuasa@yandex.ru

Abstract. *Land cover change is a global phenomenon triggered by human activities, including mining, which has significant impacts on the environment and ecosystems. In Indonesia, particularly on Halmahera Island, nickel mining has become one of the main economic sectors, but this activity often results in serious environmental degradation. The data used in this study is PlanetScope satellite image data for 2016, 2020 and 2024 which has a 3-meter spatial resolution. The image data was then interpreted and digitized to obtain land cover classes consisting of settlements, farming areas, vegetation and water bodies. The validation results of land cover in 2016, 2020, and 2024 obtained accuracy values of 92%, 90%, and 95%, respectively. In 2016, settlements had an area of 222.79 ha, mining area of 364.98 ha, vegetation of 52,938.88 ha, water body of 212.88 ha. In 2020, settlements were 343.92 ha, mining areas were 1,329.18 ha, vegetation was 51,853.55 ha, water bodies were 212.88 ha. In 2024, settlements are 563.92 ha, mining area is 4,498.32 ha, vegetation is 48,464.41 ha and water bodies are 212.88 ha. The mining area certainly continues to increase in area every year.*

Keywords: *Land cover, nickel mining, PlanetScope, Weda*

1. Introduction

Land cover change is a global phenomenon triggered by human activities, including mining, which has significant impacts on the environment and ecosystems (Madasa et al., 2021; Chang et al., 2021). In Indonesia, particularly on Halmahera Island, nickel mining has become one of the main economic sectors, but this activity often results in serious environmental degradation (Kurniawan et al., 2024). Weda Tengah sub-district, as one of the areas with the largest nickel reserves, is experiencing rapid land transformation due to mining expansion (Nasution et al., 2024). Detecting land cover change in this region is important for understanding environmental dynamics and formulating sustainable management policies (Salakory & Rakuasa, 2022; Rakuasa et al., 2023).

Received: 10 May 2025 / Accepted:10 June 2025 / Available online: 22 June 2025

Satellite imagery has become an effective tool for monitoring land cover change accurately and continuously (Gbedzi et al., 2022; Rakuasa, 2025). PlanetScope, with its high spatial resolution and daily recording frequency, offers excellent capabilities in monitoring small-scale land changes such as in mining areas (Basheer et al., 2024). The use of this satellite imagery enables the identification of temporal and spatial land changes with high precision, which can support the analysis of environmental impacts of mining activities. Previous studies have proven the effectiveness of PlanetScope in monitoring land change in various contexts, including mining areas (Pacheco et al., 2025; Szostak et al., 2021).

Nickel mining activities in Central Weda Sub-district have led to forest fragmentation and loss of biodiversity, impacting local ecosystems. Rapid land cover change also affects groundwater availability and increases the risk of erosion (Senamaw et al., 2022). Using PlanetScope satellite imagery, this study aims to identify land change patterns and quantify the level of environmental degradation occurring.

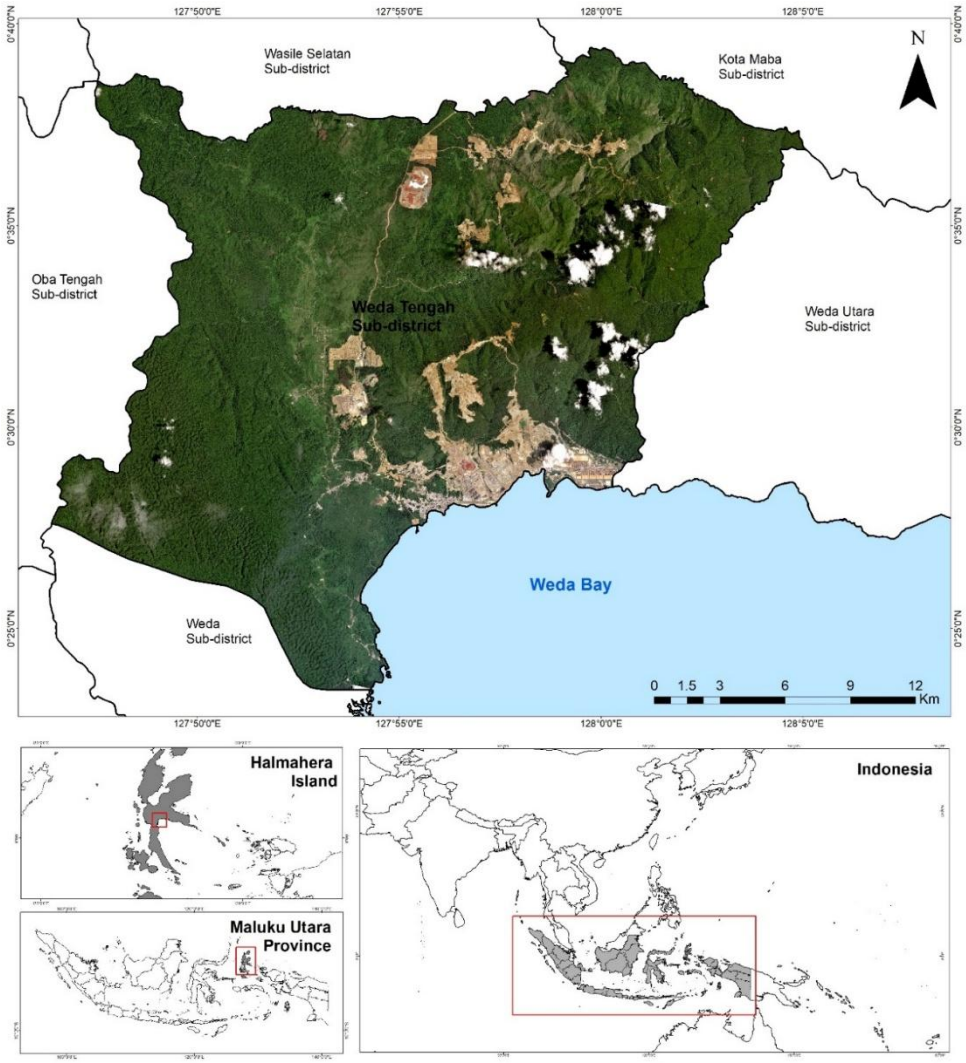

Figure 1. Research Location: Weda Tengah Sub-district, Indonesia

In addition to environmental impacts, land cover change also has socio-economic implications for local communities (Yu et al., 2024). Communities around mining areas often depend on natural resources for their livelihoods, so drastic land changes can threaten their sustainability. By mapping land cover change, this research also aims to identify critical areas that require policy intervention to protect the rights of local communities. This approach is in line with sustainable development principles that emphasize a balance between economic growth and environmental preservation.

This research is expected to make a significant scientific contribution to the field of remote sensing and environmental management, particularly in mining areas. By utilizing the latest technology such as PlanetScope satellite imagery, this research offers an innovative and accurate method for monitoring land change. The results of this research can also serve as a reference for the government and other stakeholders in formulating sustainable land management policies. As such, this research is not only academically relevant but also has broad practical implications for sustainable development in Indonesia.

2. Methods

This research was conducted in Weda Tengah sub-district, Central Halmaherea district, North Maluku province, Indonesia (Figure 1). Weda Tengah sub-district has an area of 53,739.53 ha. This research began with a preparatory stage containing literature studies from books, journals, or from the internet. The literature study was conducted to understand the basic theories related to the physical development of the city. After the preparation stage, the next stage is data collection. The data used in this research is PlanetScope satellite image data for 2016, 2020, and 2024. PlanetScope is a satellite image product recorded by a mini-sized satellite called Dove, which is owned and operated by an American company, Planet (Szostak et al., 2021).

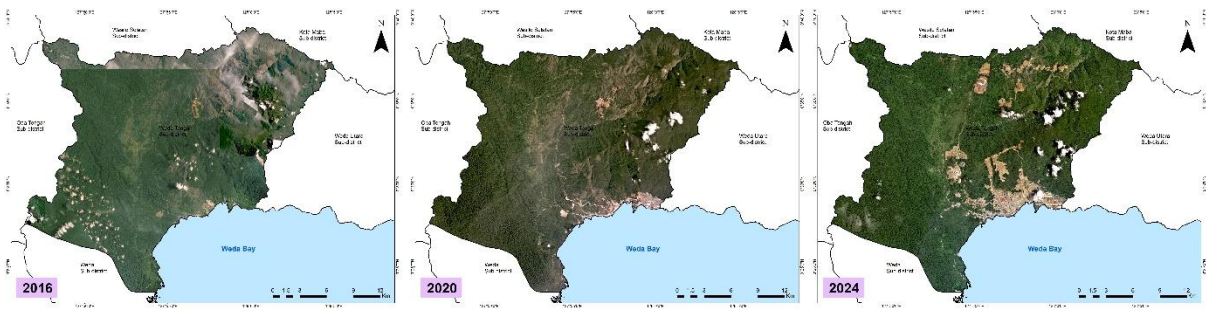

Figure 2. PlanetScope Satellite Imagery Data 2016, 2020, 2024

PlanetScope satellite imagery has an original spatial resolution of between 3.0 meters and 4.1 meters for images recorded by the Dove Classic and Dove-R satellite instrument types, while for SuperDove it starts from an original spatial resolution of 3.7 meters (depending on the recording angle), but for sales purposes, currently all

original PlanetScope satellite image data provided to customers has a spatial resolution class of 3 meters as for spectral resolution, PlanetScope satellite imagery produced from the recording of the Dove Classic and Dove-R satellite instrument types has a total of 4 bands (Red, Green, Blue, and Near InfraRed), while the SuperDove satellite instrument type has 8 bands (Red, Green, Blue, Near InfraRed, Yellow, Green I, Coastal Blue, and Red Edge) (Szostak et al., 2021).. PlanetScope satellite imagery is used to analyze land use change (Yu et al., 2024).

3. Results and Discussion

3.1. Results of Land Cover Validation of Weda Tengah Sub-district

The validation results of land cover in 2016, 2020, and 2024 obtained accuracy values of 92%, 90%, and 95%, respectively. From these accuracy values, it is found that the land cover in the results of visual interpretation and digitization on PlanetScope imagery in that period can be used. Validation of the land cover of Central Weda Sub-district in 2024 on 50 points spread across various land cover classes and areas of Central Weda Sub-district obtained various conformities between the land cover of the guided classification results which became the reference in determining the points, with the actual land cover. The validation results show that 46 out of 50 guided classification points match the actual land cover. These validation results show that the results of visual interpretation and digitization are used for further research.

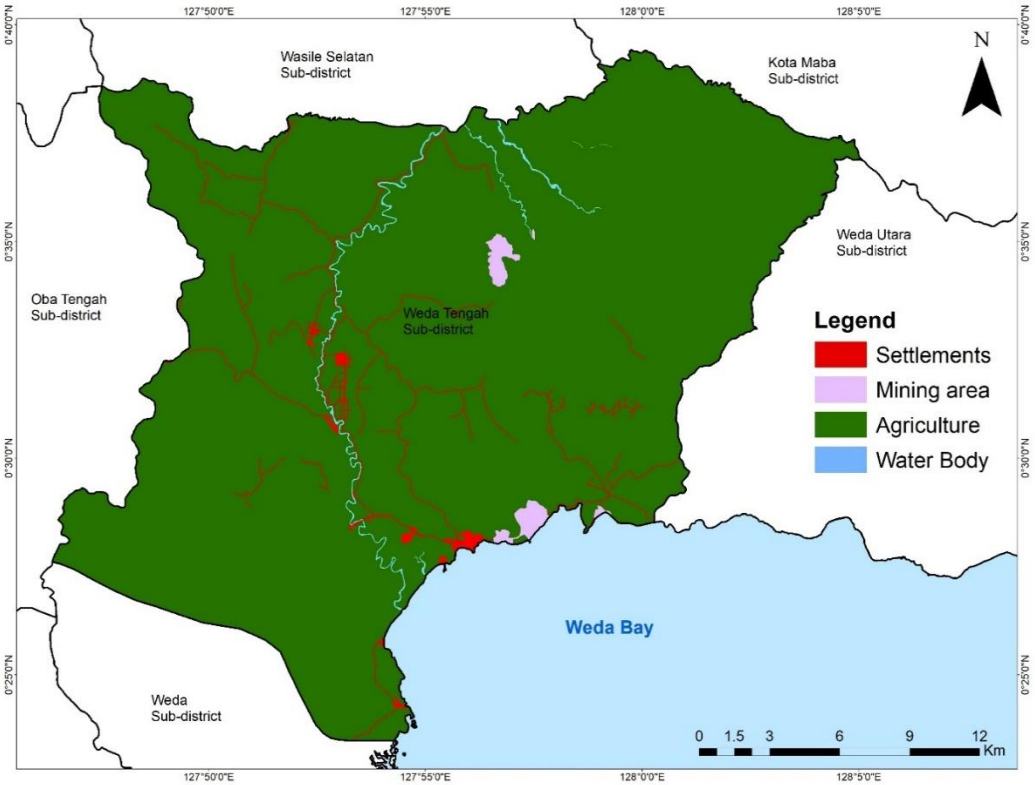

Figure 3. Land Cover of Weda Tengah Sub-district 2016

3.2. Land Cover of Weda Tengah Sub-district 2016

The results of the interpretation and analysis of PlanetScope imagery in 2016 show that agricultural land is the dominant land cover type in Central Weda Sub-district, with an area of 52,938.88 ha or 98.51% of the total area (Figure 3). This data shows the dependence of local communities on the agricultural sector as their main source of livelihood, where the sustainability of agricultural land is crucial in supporting the local economy and reducing the negative impacts of mining activities. In addition, the settlement area, which covers 222.79 ha (0.41%), shows that although it is small compared to agricultural land, settlement infrastructure is still important to support social and economic life in the area.

Mining areas covering 364.98 ha (0.68%) and water bodies covering 212.88 ha (0.40%) contributed to significant land cover change. Nickel mining activities in this area have caused environmental degradation, such as forest fragmentation and loss of biodiversity, impacting ecosystems and the availability of water resources. In response to these challenges, the use of PlanetScope satellite imagery to monitor land cover change provides a better understanding of land management dynamics in Central Weda, which can serve as a basis for formulating sustainable management policies. The spatial land cover of Kecamatan Weda Tengah in 2016 can be seen in Figure 3.

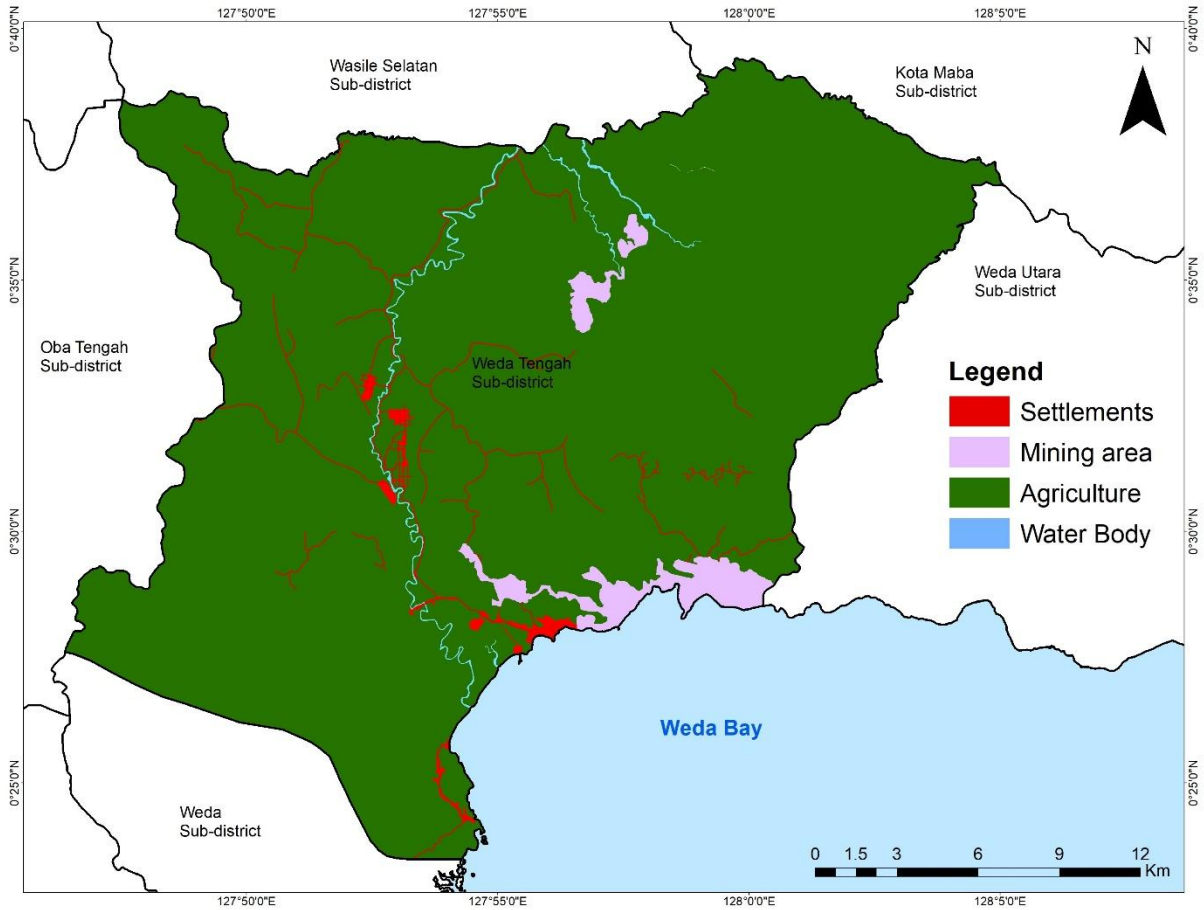

Figure 4. Land Cover of Weda Tengah Sub-district 2020

3.3. Land Cover of Weda Tengah Sub-district 2020

In 2020, land cover in Weda Tengah sub-district showed significant changes, especially in the mining area which reached 1,329.18 ha (2.47%). This increase in mining area reflects the continued expansion of the nickel industry, which often results in serious environmental impacts such as deforestation, decreased biodiversity and pollution. Meanwhile, agricultural land remains dominant at 51,853.55 ha (96.49%), indicating that this sector is still the backbone of the local economy. However, it should be noted that pressure from mining activities could threaten the sustainability of agricultural land and the welfare of local communities.

In addition to the increase in mining areas, the growth of settlement areas covering 343.92 ha (0.64%) signifies an increase in population as well as basic infrastructure needs, which must be managed wisely to avoid conflicts with agricultural land use and forest areas. Water bodies remain stable at 212.88 ha (0.40%), indicating that water resources are maintained despite mining activities. Through analysis using PlanetScope satellite imagery, this research aims to provide in-depth insights into the impacts of mining activities and how land management can be done sustainably to support community welfare in Central Weda. The spatial land cover of Weda Tengah sub-district in 2020 can be seen in Figure 4.

3.4. Land Cover of Weda Tengah Sub-district 2024

In 2024, Weda Tengah sub-district experienced a significant increase in the area of mining land cover reaching 4,498.32 ha (8.37%). This surge reflects the intensification of nickel mining practices, which could lead to further environmental degradation as well as negative impacts on local ecosystems. In addition, although agricultural areas still dominate with 48,464.41 ha (90.18%), the decline in the proportion of agricultural land compared to mining indicates continued pressure on the agricultural sector, which is the main source of livelihood for local communities. The balance between natural resource exploitation and environmental conservation is a challenge that needs to be addressed to achieve sustainable development.

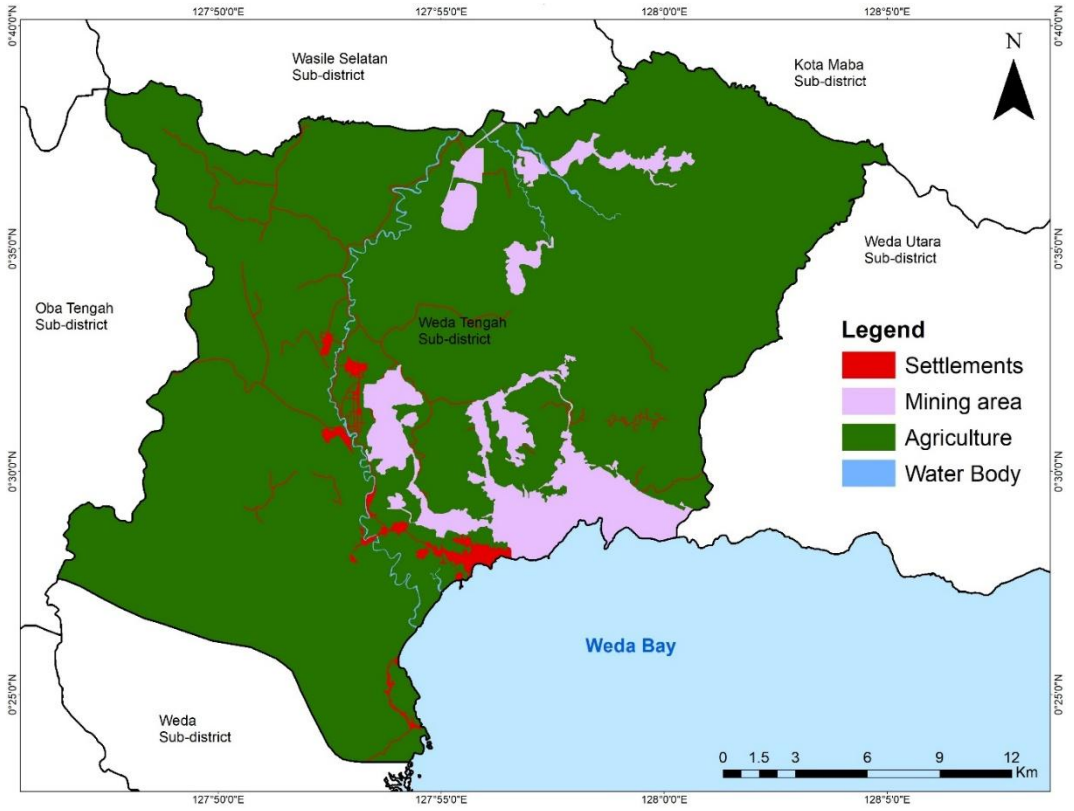

Figure 5. Land Cover of Weda Tengah Sub-district 2024

The growth in settlement area, which now stands at 563.92 ha (1.05%), indicates an increasing population that requires better infrastructure support. Special attention needs to be paid to the social impacts of these changes, as local communities may lose access to agricultural land and natural resources due to the expansion of mining areas. Identifying and mapping these changes through analysis of PlanetScope satellite imagery is critical to inform decision-making for sustainable natural resource management. By implementing responsive and data-based policies, it is hoped that the ecosystem and community economy can be well maintained in the Central Weda Sub-district. The spatial land cover of Central Weda Sub-district in 2024 can be seen in Figure 5.

3.5. Land cover change in mining area for the period 2016-2024

Land cover change in Weda Tengah sub-district, particularly in relation to nickel mining activities, shows a significant trend from year to year. Referring to the latest data, the mining area increased rapidly from 364.98 ha (0.68%) in 2016 to 4,498.32 ha (8.37%) in 2024. This increase reflects the intensification of nickel resource exploitation driven by global market demand. These activities not only lead to a reduction in forest area, but also contribute to habitat fragmentation, potentially threatening local biodiversity (Swetnam et al., 2011). In addition, the loss of vegetation cover can impact the hydrological cycle and increase the risk of soil erosion in neighboring areas (Gbedzi et al., 2022).

Table 1. Land Cover Change in Weda Tengah Sub-district

Land Cover	Area (Ha)					
	2016	%	**2020**	%	**2024**	%
Settlements	222,79	0,41	343,92	0,64	563,92	1,05
Mining area	364,98	0,68	1.329,18	2,47	4.498,32	8,37
Agriculture	52.938,88	98,51	51.853,55	96,49	48.464,41	90,18
Water Body	212,88	0,40	212,88	0,40	212,88	0,40
Total Area	**53.739,53**	**100,00**	**53.739,53**	**100,00**	**53.739.53**	**100,00**

On the other hand, although the dominance of agricultural land still exists with 48,464.41 ha (90.18%) in 2024, this proportion shows a relative decline along with the expansion of mining land. This indicates an increasing pressure on the agricultural sector, which is the main source of livelihood for local communities (Trisurat et al., 2019). These land cover changes may affect the food security and economic sustainability of the region, with communities dependent on agricultural products becoming vulnerable (Fikadu & Olika, 2023). Therefore, continuous monitoring and wise management are necessary to mitigate the negative impacts of mining activities, so that a balance between economic development and environmental preservation can be achieved in Weda Tengah sub-district.

Conclusions

This study shows that nickel mining activities in Weda Tengah sub-district, Halmahera, have led to significant changes in land cover, with an increase in mining area from 2016 to 2024, while agricultural land has proportionally decreased. Although the agricultural sector still dominates, pressures from mining expansion threaten its sustainability and negatively impact ecosystems, including forest fragmentation, loss of biodiversity, and decreased availability of water resources. Therefore, this study emphasizes the importance of continuous monitoring and wise management to create a balance between economic growth and environmental preservation for the socio-economic sustainability of local communities.

Funding

This research received no external funding

Acknowledgments

The authors are grateful to all those who contributed to this research.

Conflicts of Interest

The authors declare no conflict of interest

References

B, S., Kurniawan, A., & Arif, N. (2024). Deforestation Trends and Drivers in Central Halmahera Regency. *Jurnal Wasian*, *11*(1), 15–19. https://doi.org/10.62142/t6n6m231

Basheer, S., Wang, X., Nawaz, R. A., Pang, T., Adekanmbi, T., & Mahmood, M. Q. (2024). A comparative analysis of PlanetScope 4-band and 8-band imageries for land use land cover classification. *Geomatica*, *76*(2), 100023. https://doi.org/10.1016/j.geomat.2024.100023

Chang, X., Zhang, F., Cong, K., & Liu, X. (2021). Scenario simulation of land use and land cover change in mining area. *Scientific Reports*, *11*(1), 12910. https://doi.org/10.1038/s41598-021-92299-5

Fikadu, G., & Olika, G. (2023). Impact of land use land cover change using remote sensing with integration of socio-economic data on Rural Livelihoods in the Nashe watershed, Ethiopia. *Heliyon*, *9*(3), e13746. https://doi.org/10.1016/j.heliyon.2023.e13746

Gbedzi, D. D., Ofosu, E. A., Mortey, E. M., Obiri-Yeboah, A., Nyantakyi, E. K., Siabi, E. K., Abdallah, F., Domfeh, M. K., & Amankwah-Minkah, A. (2022). Impact of mining on land use land cover change and water quality in the Asutifi North District of Ghana, West Africa. *Environmental Challenges*, *6*, 100441. https://doi.org/10.1016/j.envc.2022.100441

Heinrich Rakuasa. (2025). Classification of Sentinel-2A Satellite Image for Ternate City land cover using Random Forest Classification in SAGA GIS Software. *DNS – DIGITAL NEXUS SYSTEMATIC JOURNA*, *1*(1), 34–36. https://doi.org/http://dx.doi.org/10.26753/dns.v1i1.1554

Madasa, A., Orimoloye, I. R., & Ololade, O. O. (2021). Application of geospatial indices for mapping land cover/use change detection in a mining area. *Journal of African Earth Sciences*, *175*, 104108. https://doi.org/10.1016/j.jafrearsci.2021.104108

Nasution, M. J., Tugiyono, Bakri, S., Setiawan, A., Murhadi, Wulandari, C., & Wahono, E. P. (2024). The Impact of Increasing Nickel Production on Forest and Environment in Indonesia: A Review. *Jurnal Sylva Lestari*, *12*(3), 549–579. https://doi.org/10.23960/jsl.v12i3.847

Pacheco, A. da P., Nascimento, J. A. S. do, Ruiz-Armenteros, A. M., da Silva Junior, U. J., Junior, J. A. da S., de Oliveira, L. M. M., Melo dos Santos, S., Filho, F. D. R., & Pessoa Mello Galdino, C. A. (2025). Land Cover Transformations in Mining-Influenced Areas Using PlanetScope Imagery, Spectral Indices, and Machine Learning: A Case Study in the Hinterlands de Pernambuco, Brazil. *Land*, *14*(2), 325. https://doi.org/10.3390/land14020325

Rakuasa, H., Sihasale, D. A., Somae, G., & Latue, P. C. (2023). Prediction of Land Cover Model for Central Ambon City in 2041 Using the Cellular Automata Markov Chains Method. *Jurnal Geosains Dan Remote Sensing*, *4*(1), 1–10. https://doi.org/10.23960/jgrs.2023.v4i1.85

Salakory, M., Rakuasa, H. (2022). Modeling of Cellular Automata Markov Chain for predicting the carrying capacity of Ambon City. *Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan (JPSL)*, *12*(2), 372–387. https://doi.org/https://doi.org/10.29244/jpsl.12.2.372-387

Senamaw, A., Gashaw, T., & Ehsan, M. A. (2022). Impacts of Land-Use/Land-Cover Changes on Water-Borne Soil Erosion Using Geospatial Technologies and RUSLE Model over Chimbel Watershed of Upper Blue Nile Basin in Ethiopia. *Earth Systems and Environment*, *6*(2), 483–497. https://doi.org/10.1007/s41748-021-00259-w

Swetnam, R. D., Fisher, B., Mbilinyi, B. P., Munishi, P. K. T., Willcock, S., Ricketts, T., Mwakalila, S., Balmford, A., Burgess, N. D., Marshall, A. R., & Lewis, S. L. (2011). Mapping socio-economic scenarios of land cover change: A GIS method to enable ecosystem service modelling. *Journal of Environmental Management*, *92*(3), 563–574. https://doi.org/10.1016/j.jenvman.2010.09.007

Szostak, M., Likus-Cieślik, J., & Pietrzykowski, M. (2021). PlanetScope Imageries and LiDAR Point Clouds Processing for Automation Land Cover Mapping and Vegetation Assessment of a Reclaimed Sulfur Mine. *Remote Sensing*, *13*(14), 2717. https://doi.org/10.3390/rs13142717

Trisurat, Y., Shirakawa, H., & Johnston, J. M. (2019). Land-Use/Land-Cover Change from Socio-Economic Drivers and Their Impact on Biodiversity in Nan Province, Thailand. *Sustainability*, *11*(3), 649. https://doi.org/10.3390/su11030649

Yu, M., Wang, Y., & Umair, M. (2024). Minor mining, major influence: Economic implications and policy challenges of artisanal gold mining. *Resources Policy*, *91*, 104886. https://doi.org/10.1016/j.resourpol.2024.104886