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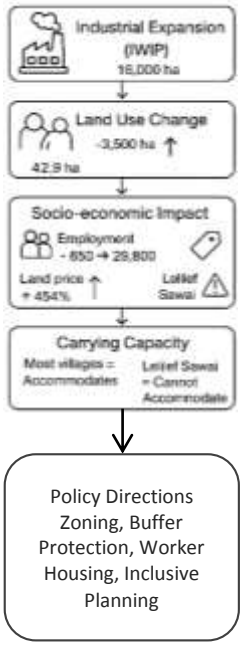
Full Paper

Spatial Transformation In Central Weda: Industrial Expansion, Land Use Change, And Settlement Dynamics In Indonesia's Nickel Frontier

Ibrahim Husni[1*], Ariyanto[2], Nabila Islamaiya Alhadar[3], Abdul Haris Musa[4]
[1*]Department of Urban and Regional Planning, Faculty of Science and Technology, Nahdlatul Ulama University of North Maluku, Indonesia
[2]Department of Public Works and Spatial Planning, Morotai Regency, Indonesia
[3]Department of Civil Engineering, Faculty of Engineering, Khairun University, Ternate, Indonesia
[4]Department of Urban and Regional Planning, Faculty of Science and Technology, Nahdlatul Ulama University of North Maluku, Indonesia

*Corresponding author
bhamzchikal89@gmail.com

Graphical Abstract



Abstract

The Indonesia Weda Bay Industrial Park (IWIP) has rapidly transformed Central Weda District's spatial structure between 2012 and 2022. This paper integrates satellite-based land-use change analysis, regional statistics, spatial plan (RTRW/RDTR) review, field survey summaries, and carrying-capacity computations to evaluate the impacts of industrial agglomeration on land conversion, housing pressure, tenure dynamics, and ecological buffer integrity. Results (from local datasets) show settlements increased from 39.3 ha (2012) to 82.2 ha (2022), while industrial area expanded to 16,000 ha. Industrial employment rose from 650 (2018) to 29,800 (2022), fueling a nearly 400% increase in local land prices (e.g., Lelilef Sawai: IDR 50,000/m² - IDR 277,000/m²). Carrying capacity calculations indicate most villages retain DDPm > 1 (sufficient capacity) except Lelilef Sawai (DDPm < 1), which already exceeds sustainable settlement thresholds. The paper concludes with policy recommendations for zoning enforcement, ecological buffer protection, worker housing programs, and integrated industrial-regional planning.

Keywords: Land use change, industrial agglomeration, settlement morphology, carrying capacity, Weda Bay

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1. INTRODUCTION

Indonesia is the world's leading nickel producer [1]. Since the government banned raw ore exports in 2020, domestic processing has expanded rapidly, giving rise to industrial estates such as IWIP in Central Halmahera [2]. As a national strategic project [3], IWIP has attracted global investment, notably from Tsingshan and Antam [4].

Industrialization produces employment and infrastructure, yet it also drives land-use conversion, price escalation, and settlement pressure [5], [6]. In mining frontiers worldwide, boomtown dynamics create rapid migration, urban expansion, and ecological strain [7]. In Weda Bay, settlements are expanding into buffer zones and carrying capacity thresholds are being exceeded, issues often neglected in prior research [8].

The phenomenon highlights the dual nature of extractive-led development: on one hand, contributing to economic growth and regional competitiveness, and on the other, intensifying social disparities and environmental vulnerabilities. Similar trends in other mining regions suggest that without proper spatial governance, development gains may be offset by long-term ecological degradation and settlement conflicts.

Accordingly, understanding spatial transformation in Central Weda is not only critical for anticipating demographic and environmental pressures but also for aligning local planning practices with national development agendas. By integrating industrial growth with settlement planning, policymakers can balance economic priorities with social equity and ecological sustainability.

This study analyzes spatial transformation in Central Weda, with five objectives: (1) quantify land-use change; (2) examine industrial agglomeration; (3) assess land prices and tenure; (4) analyze settlement morphology and carrying capacity; and (5) recommend policies for sustainable planning.

2. METHOD

Study Area

Central Weda, located in Central Halmahera Regency, North Maluku, covers 16,000 ha of IWIP industrial estate [9]. It has become one of Indonesia's fastest-growing nickel hubs [10].

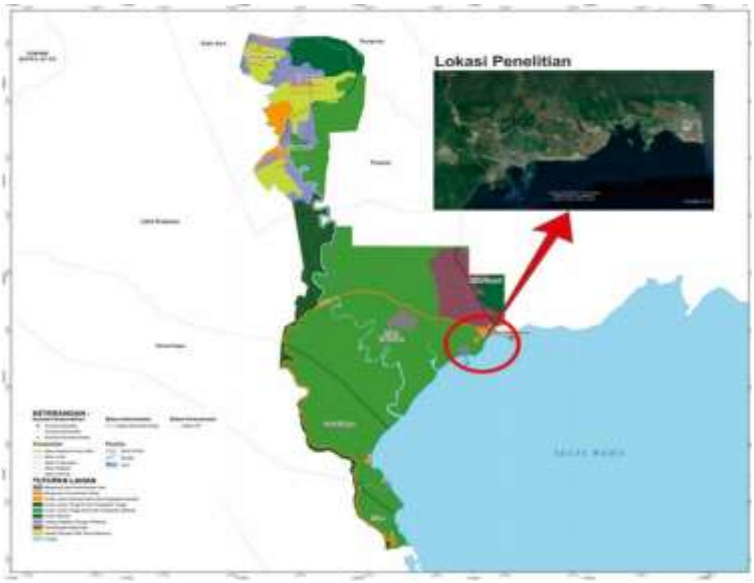


Figure 1 Map of Industrial Area Orientation in Central Weda as the Research Object

Data Sources

1. Satellite imagery: Google Earth, Landsat (2012, 2022).
2. Primary data: field surveys, interviews, local mapping (2023).
3. Secondary data: BPS statistics [11], RDTR & RTRW planning documents [12], IWIP company profiles [9].

Analytical Methods

1. Land-use change: overlay of 2012 & 2022 imagery, categorized into settlements, industrial, agriculture/forest, infrastructure.
2. Industrial agglomeration: employment growth and spatial clustering.
3. Land price dynamics: village-level survey of land market values (2015–2022).
4. Settlement morphology: analysis of growth patterns (linear, clustered).
5. Carrying capacity: Muta'ali's method [13],

$$DDPm = \frac{LPm}{JP \times k}$$

Where:

- DDPm = Residential Carrying Capacity
- LPm = Land Area Available for Settlement Development (ha),
- JP = population (persons),
- k = Coeficient of Soatial Requirement (ha/capita).

3. RESULTS AND DISCUSSION

Land Use Change (2012-2022)

Settlements expanded from 39.3 ha in 2012 to 82.2 ha in 2022, while industrial estates reached 16,000 ha. In contrast, forest and agricultural land decreased by 3,500 ha. This large-scale conversion illustrates the spatial dominance of IWIP's expansion. Similar cases of rapid land-use conversion have been observed in other nickel hubs, but the pace in Weda is among the fastest recorded [5], [7].

Table 1. Land use change in Central Weda, 2012-2022

Land Use Type	2012 (ha)	2022 (ha)	Change (ha)
Settlements	39.3	82.2	+42.9
Industrial estates	0	16.000	+16.000
Agriculture/forest	22.000	18.500	-3.500
Infrastructure	150	650	+500

Industrial Agglomeration

Industrial employment rose sharply from 650 workers in 2018 to 29,800 in 2022, indicating a massive influx of labor into Central Weda. This growth exemplifies the boomtown effect [10], driving not only demographic shifts but also increased demand for housing and services. The scale of this agglomeration resembles industrial expansion in Morowali, Sulawesi [14] .

Table 2. Growth of industrial employment in IWIP, Central Weda

Year	Industrial Employment	Remarks
2018	650	Initial operation
2020	12.4810	First smelters
2022	29.800	Large scale expansion

Land Piece and Tenure

Land prices in Lelilef Sawai increased by more than 454%, from IDR 50,000/m² in 2015 to IDR 277,000/m² in 2022. Neighboring villages such as Woekob and Gemaf experienced similar upward trends. This surge indicates speculative markets and poses risks of displacement for local communities, echoing patterns documented in other mining regions [6], [10].

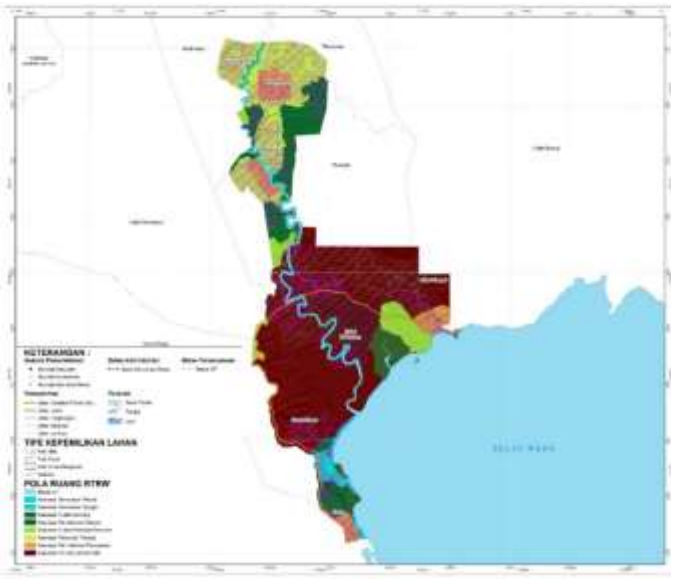


Figure 2 Map of Land Tenure and Ownership Changes in Central Weda District, 2022

Settlement Morphology

Settlements show both linear expansion along transportation corridors and clustered growth around service nodes. Informal worker housing, particularly boarding houses, dominates these new areas, creating localized congestion during shift changes. Such morphology reflects unplanned growth typical of resource frontier towns, consistent with earlier studies on Indonesian urbanization [15].



Figure 3 Development Patterns Around the Industrial Area

Carrying Capacity

Carrying capacity analysis shows that most villages remain sustainable with DDPm > 1. However, Lelilef Sawai records a DDPm of 0.8, indicating that its projected 2043 population will exceed available land. This unsustainable condition highlights the urgent need for targeted interventions in spatial planning and housing provision. Comparable issues have been reported in other industrial growth centers, underscoring the importance of environmental carrying capacity assessments [16], [17].

Table 3. Carrying Capacity of Central Weda Planning Area

No	Village	Potential Land (Ha)	Land Cover Ratio	LPM (Ha)	DDPM	Population Carrying Capacity	Population Projection in 2043	Difference	Remarks
1	Kobe	72,51	60%	43,51	3,30	3.271	990	2.281	Accommodates
2	Kulo Jaya	136,78	60%	82,07	10,15	6.171	608	5.563	Accommodates
3	Lelilef Sawai	48,47	60%	29,08	0,58	2.187	3.787	-1.600	Cannot Accommodate
4	Lelilef Waibulan	1.509,46	60%	905,68	21,87	68.096	3.113	64.983	Accommodates
5	Sawai Itepo	215,66	60%	129,40	6,91	9.729	1.408	8.321	Accommodates
6	Woejerana	453,22	60%	271,93	27,04	20.446	756	19.690	Accommodates
7	Woekob	520,73	60%	312,44	25,70	23.492	914	22.578	Accommodates
		Total	**2.957**		**1774,10**		**133.391**	**11.576**	**121.815**

Based on the analysis Table 3, it can be identified that the majority of villages in Central Weda Subdistrict possess adequate residential carrying capacity, meaning they are capable of accommodating population growth over the next 20 years. However, this does not apply to Lelilef Sawai Village, which falls under the category of insufficient residential carrying capacity and is therefore unable to accommodate the projected population growth within the same period. Hence, it is necessary to provide spatial development directives for residential areas in Lelilef Sawai Village to ensure its ability to accommodate future population growth.

Sustainable planning

The development of Central Weda shows a combination of linear and clustered settlement growth that follows road networks and existing urban grids. Land allocation in this area is divided into conservation zones (protected forests, mangroves, river buffers, and other ecological areas) covering 23,505 ha, and cultivation zones (production forests, agriculture, plantations, industrial areas, and settlements) covering 27,472 ha. Mining and industrial activities occupy more than half of the total land.

The rapid industrial expansion has changed the character of Central Weda from a rural landscape into a growing industrial town. This transformation brings employment and new infrastructure but also increases land conversion, population pressure, and environmental risk. At the same time, migration flows and social change create challenges for local communities in terms of inclusion and access to resources.

Several policy directions can be considered:

1. Strengthening spatial regulation through clear zoning to limit uncontrolled settlement growth near industrial zones and protect ecological buffers.
2. Maintaining conservation areas such as mangroves, protected forests, and water catchments to sustain environmental carrying capacity.
3. Integrating land-use management that considers industrial clustering, settlement patterns, and ecological thresholds together rather than separately.
4. Encouraging local participation so that planning reflects local knowledge and reduces potential social conflict.
5. Promoting inclusive economic opportunities by supporting small enterprises and ensuring fair access to jobs for both local residents and migrant workers.

These measures are expected to help balance industrial growth with environmental sustainability and social welfare, making spatial development in Central Weda more resilient in the long term.

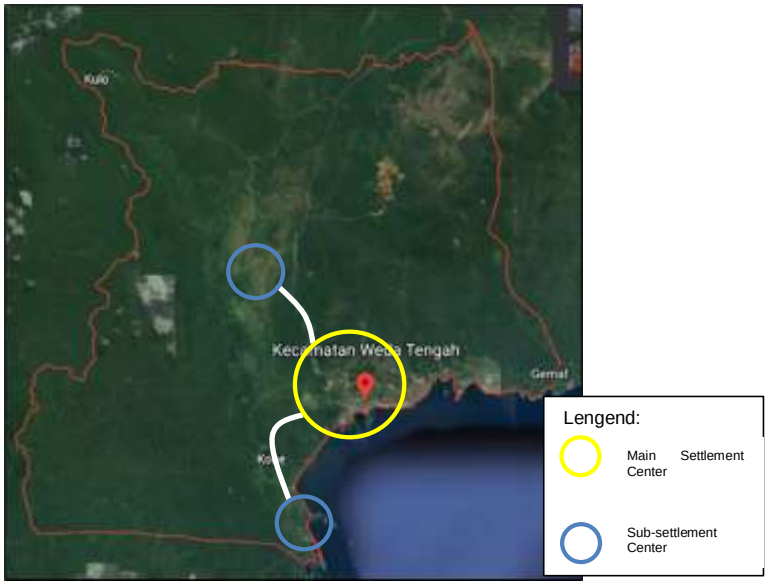


Figure 4 Building Mass Configuration Patterns in Central Weda Planning Area

4. CONCLUSION

This study confirms that the rapid expansion of IWIP has fundamentally transformed Central Weda, marked by the doubling of settlements, the conversion of 16,000 ha into industrial estates, a nearly thirty-fold increase in employment, and a fourfold rise in land prices. While most villages remain within sustainable thresholds, Lelilef Sawai has already exceeded it's carrying capacity, reflecting the acute spatial pressures of industrialization. These findings firmly demonstrate the urgency of integrating industrial growth with spatial planning through the provision of adequate worker housing, strict zoning enforcement, and ecological buffer protection to secure long-term sustainability and community resilience.

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