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Assessment of Regional Spatial Planning Utilization and Environmental Impacts: A Case Study in Buntulia District, Pohuwato Regency, Indonesia

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study aims to: 1) analyse the utilization direction of the Regional Spatial Plan (RTRW) and its influence on land use change in Buntulia Sub-district, Pohuwato Regency; 2) analyse the pattern of land use change in Buntulia Sub-district during the period 2012-2024. This research uses a quantitative descriptive method with a spatial approach through ArcGIS 10.8 software. Data was obtained from overlaying the 2012 and 2024 land use maps and analysing the transition matrix to see the pattern of land use change. The results showed that the implementation of the RTRW direction in Buntulia Sub-district was not optimal. Of the total area of 43,422.71 hectares, 1,877.85 hectares of land use is not in accordance with the RTRW direction. Significant land use change

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occurred in primary and secondary forest areas that were converted into plantations, mixed agriculture, and open land. Analysis of land use change patterns for the 2012-2024 period revealed an increase in the area of plantations by 231.57 hectares and mixed agriculture by 980.44 hectares, while the area of primary and secondary forests decreased significantly. The conclusion of this study shows that the dynamics of land use change in Buntulia Sub-district are influenced by a lack of compliance with the RTRW, population growth, and economic development pressures. Strengthening spatial planning policies, stricter supervision, and mitigation are needed to minimise the environmental impact of uncontrolled land use change.

Keywords: Regional spatial plan; land use change; spatial analysis; sustainable development.

1. INTRODUCTION

[Regional spatial planning (RTRW) includes planning the structure and pattern of spatial use, which includes land use, air and space use, and the use of other natural resources adapted to the security defence function of the spatial planning subsystem, the procedure for its preparation (Meta, 2020). Spatial planning can be understood as a process of planning, utilisation, and control of space, which is carried out systematically. Based on Law Number 26 of 2007 Article 2 concerning Spatial Planning, spatial planning in Indonesia is carried out on the basis of the following principles: integration; harmony, harmony, and balance; sustainability; empowerment and usefulness; openness; togetherness and partnership; protection of the public interest; legal certainty and justice; and accountability (Government of North Sumatra Province, 2013). The development policy of a region aims to optimise the development efforts and processes that take place so that a directed development can be achieved. This policy is realised in all aspects of development including spatial aspects. Spatial aspects are needed to harmonise various development activities, both in terms of regional and sectoral aspects so that the objectives of development targets in a region are fulfilled (Conway & Lathrop, 2005; Huang et al., 2009; Zwirowicz-Rutkowska & Michalik, 2016).

Spatial planning and development of forest areas in Gorontalo Province aims to make regional development planning adjust to the function of existing forest areas. One of the districts that needs special attention in this province is Pohuwato District. This district has diverse natural resources potential compared to other districts in Gorontalo Province.

Spatial utilisation in Pohuwato Regency is a consequence of regional growth and development that is exacerbated by inconsistencies in spatial planning, which will result in various impacts on environmental change (Huang et al., 2015; Medeiros, 2019). The potential impact of environmental change as a result of the direction of spatial utilisation that is not in accordance with existing land use shows that in line with the development and socio-economic activities and development results in an increase in land use needs from time to time. If no regulation is made regarding the direction of RTRW utilisation, it will have an adverse impact on the environment. Spatial utilisation is still often a deviation from the spatial arrangement stipulated in the Regional Spatial Plan (RTRW). Increased development and land use due to population growth can affect the preservation of the function of the area as a protection area that should be protected, so spatial planning is the right initial solution (Nuryanti, 2020).

The sustainable use of space for human activities without causing degradation is done through the spatial planning process. Spatial planning is generally related to land use planning that aims to organise physical space and determine appropriate activities on the land (Santun, 2016). Land use change has a causal relationship with various social, political economic and biophysical aspects. Population increase (social aspects), economic development (economic aspects), government political policies, such as plantation land extensification (political aspects) and relocation of settlements due to natural disasters (political and biophysical aspects), all of which require the availability of land (Raedjani, 2022). Therefore, the direction of utilisation of the Pohuwato Regency spatial plan and its impact on the environment needs to be studied to determine the extent of utilisation of the spatial plan.

2. MATERIALS AND METHODS

2.1 Type of Research

This research uses quantitative descriptive statistical methods. Descriptive statistical method is a statistical analysis method used to provide

an overview or description of the data that has been collected (Aziza, 2023). This study uses an analytical survey method with a cross sectional approach, namely making observations or measuring variables at one time.

2.2 Location and Time of Research

The research was conducted in Pohuwato Regency, a case study in Buntulia District with an estimated time of 3 months from August to October 2024.

2.3 Type of Research

This research uses geographic data-based spatial analysis combined with quantitative analysis techniques. This type of research uses an analytical survey with a quantitative approach, which involves collecting secondary data and primary data measured in numerical form for statistical analysis.

2.4 Population and Sample

Population is a generalisation area consisting of objects or subjects that have certain qualities and characteristics that are applied by researchers to study and then draw conclusions (Hadju & Aulia, 2022). The population and sample in this study are the administrative areas of Pohuwato Regency, especially Buntulia District, which are included in the RTRW.

2.5 Data and Data Sources

Primary data is primary data is data collected directly by researchers from the field or through certain research instruments. Primary data in this study is in the form of data from field surveys. Secondary data in this study are spatial data and maps, policy documents and regulations or other literature relevant to the research topic can be a source of data to build a theoretical foundation or to strengthen the findings.

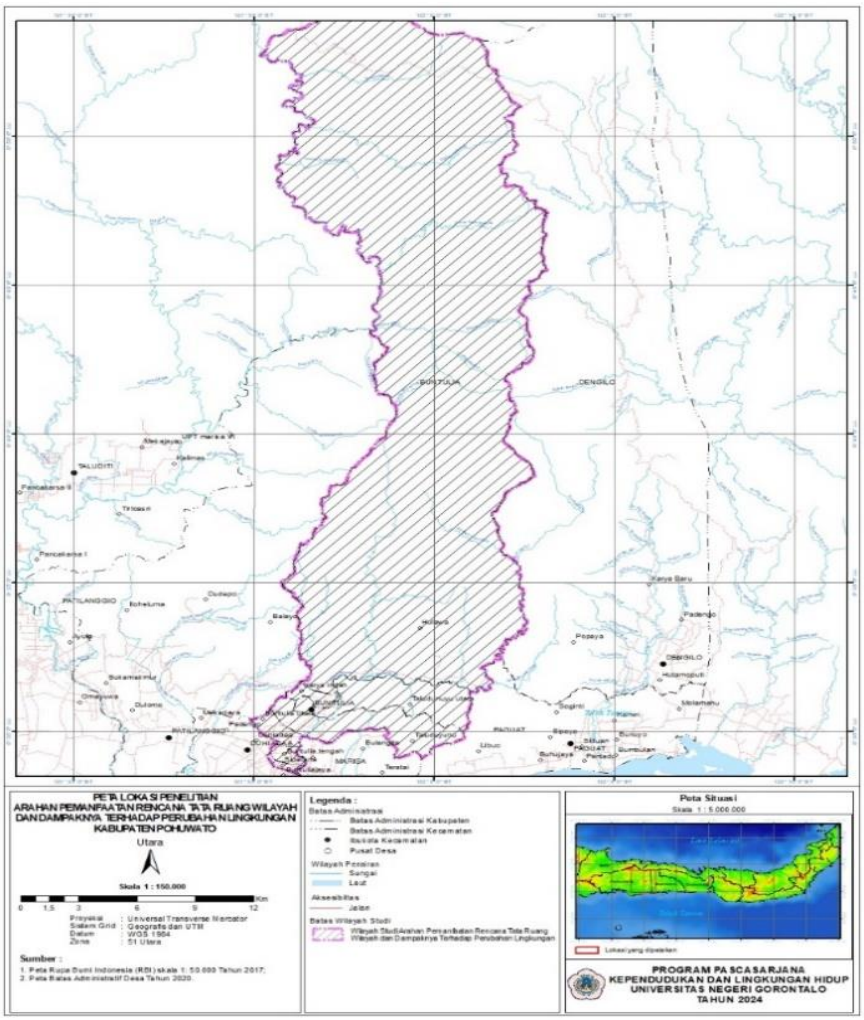


Fig. 1. Research location map

2.6 Data Collection and Analysis Techniques

Data in this study were obtained through the use of GIS software for spatial analysis, GPS, digital camera and stationery. Data analysis techniques that will be carried out by researchers in this study are grouped as follows:

1. Analysis related to the direction of utilisation of the Pohuwato Regency Spatial Plan was carried out by interpreting and overlaying spatial data on the spatial pattern of the RTRW, administrative areas, land cover and data from field observations. Data interpretation in the study area was conducted visually and desk analyses using the ArcGIS 10.8 application with a digitisation scale of 1:25,000. The results of the analysis will be overlaid and queried based on the logic matrix of land use with spatial pattern.

2. Analysis of land use change patterns in Pohuwato Regency was conducted by desk analysis of satellite imagery and land cover data in 2013 which will be compared with satellite imagery and land cover data in 2023. The pattern of land use change resulting from desk analyses will be corrected in the field by conducting ground checks, so that the results obtained are more accurate. The results of desk analyses and ground checks related to land use change patterns are processed by overlay and querry methods using the ArcGIS 10.8 application with the digitisation scale used is 1:25,000.

3. Analysis of the direction of spatial utilisation recommendations was carried out by comparing the existing conditions of spatial utilisation with the spatial pattern contained in the 2012 Pohuwato District RTRW. Existing condition data and 2012 RTRW data were analysed using the ArcGIS 10.8 application, then the results of the analysis were compiled in a table (matrix) to see the extent and distribution of locations that were not in accordance with the direction of spatial use of the 2012 Pohuwato District RTRW. The results were used as a direction for recommendations on spatial utilisation and improvements in the framework of the RTRW review.

3. RESULTS AND DISCUSSION

3.1 Results

Based on its geographical position, Buntulia sub-district borders Buol District (Central Sulawesi Province) to the north, Marisa sub-district to the south, Patilanggio sub-district to the west and Paguat sub-district to the east. This sub-district with an area of 375.64 km2 consists of 7 villages. Buntulia sub-district is located at coordinates 0°‘41'14.852’ LU and 121°58'12.222’ East and is located in zone 51N. The results of spatial data analysis are described as follows.

Based on the results of the analysis between the spatial direction of Buntulia Sub-district, Pohuwato Regency and land use in the field, it is known that there are several locations where land use is not in accordance with the existing spatial direction as presented in Table 2.

Based on the Table 2, it is known that the suitability of spatial direction and land use in Buntulia District there is an area of 41,544.85 Ha that is in accordance with spatial direction, while an area of 1,877.85 Ha of land use is not in accordance with the spatial direction contained in the RTRW of Pohuwato Regency.

Calculations carried out to determine the pattern of land use change in Buntulia Subdistrict were obtained from the results of overlaying the land cover map in the 2012 and 2024 periods as presented in Table 3.

Based on the Table 3, the transition matrix provides an overview of land use change that occurred between the two time periods. Based on the matrix, there are significant shifts in several land use categories.

3.2 Discussion

3.2.1 Analysis of spatial direction conformity to land use in Buntulia sub-district in 2024

This research shows that land use change in Buntulia sub-district is not always in line with the RTRW direction.

Based on the map interpretation, most of the area in the central to northern part is fully green, indicating that the land use in the area is in accordance with the spatial plan. These are areas with conservation functions, protected

areas, or relatively stable land uses such as forests and natural vegetation. This conformity indicates that the area has successfully maintained the spatial utilisation plan in accordance with established policies, which has a positive impact on environmental sustainability. However, in the south, especially in areas closer to settlements, the red boundary line indicates a potential mismatch between actual land use and RTRW directives.

Significant changes, such as the conversion of primary and secondary forest areas to plantations and agriculture, indicate pressure on conservation areas, such as the Panua Nature Reserve, as well as other protected areas. The decrease in primary forest by 36.51 ha and secondary forest by 533.21 ha between 2012 and 2024 illustrates intensive land conversion. There was a decrease in the area of CA. Panua, which is supposed to be a conservation area and not subject to land use change.

The surge in land use for plantations (an increase of 231.57 ha) and mixed agriculture (an increase of 980.44 ha) also reflects the need for more adaptive spatial management to accommodate new land use pressures while preserving protected areas. A decrease in dryland agriculture may indicate non-conformity with the RTRW if this land has been converted to other uses. Meanwhile, mixed dryland farming experienced a significant increase, which may reflect the expansion of farming areas outside of RTRW provisions, especially if these areas fall within conservation areas or forests that should be protected.

In addition, based on the data table of conformity between spatial direction and land use in several villages, this analysis provides an overview of the extent to which actual land use is in accordance with regional spatial planning. Overall, out of a total area of 43,422.71 hectares, there are 41,544.85 hectares of land that are in accordance with spatial direction and 1,877.85 hectares of land that are not. This Fig. 2 shows that most areas are still in conformity with the spatial plan, but there remain significant

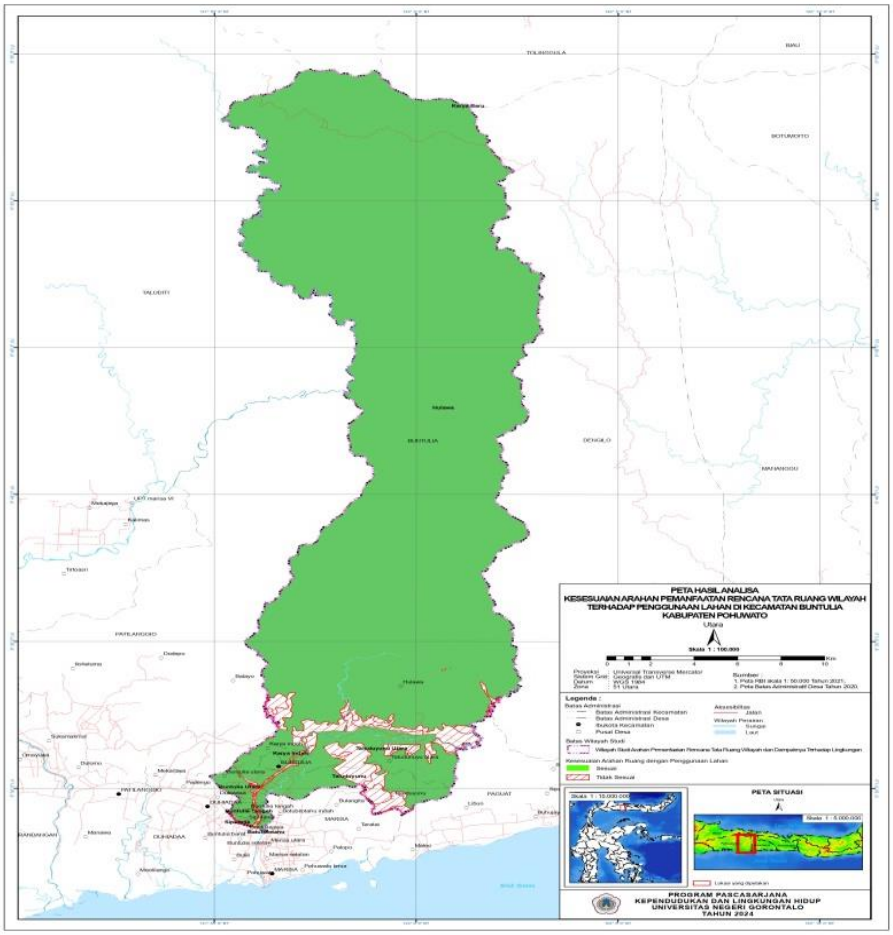


Fig. 2. Map of the suitability of RTRW utilisation direction for land use

Table 1. Comparison of spatial direction of land use in 2012 and land use in 2024 in Buntulia district, Pohuwato regency

Arahan Ruang	Penggunaan Lahan (Ha)																					
	Hutan Lahan Kering Primer		Hutan Lahan Kering Sekunder		Pemukiman		Perkebunan		Pertambangan		Pertanian Lahan Kering		Pertanian Lahan Kering Campur		Sawah		Semak Belukar		Tanah Terbuka		Tubuh Air	
	2012	2024	2012	2024	2012	2024	2012	2024	2012	2024	2012	2024	2012	2024	2012	2024	2012	2024	2012	2024	2012	2024
CA. Panua	6772,20	6748,64	5137,82	5142,90						32,76	0,00	34,15	194,38	217,52			330,58	248,82		10,21	2,54	2,53
Hutan Lindung	4269,39	4269,39	7830,25	7830,25																	2,36	2,36
Hutan Produksi Terbatas	5898,45	5885,50	7779,06	7241,81						288,31	273,81	580,39	488,69	290,64			550,52	721,59	61,59	29,88	8,92	22,93
Hutan Produksi Tetap	308,88	308,88	485,08	485,08																		
Hutan Produksi yang Dapat Dikonversi			2,60	2,59							5,79	52,19	532,66	569,76			200,00	116,51			8,25	8,25
Kawasan Perkebunan			1,41	0,38	7,57	7,68					2,08	498,68	655,69	243,31	42,47	42,47	172,67	87,92			15,22	16,67
Kawasan Pertanian					55,08	81,10		231,52			17,99	453,65	726,40	373,97	176,85	167,58	343,75	8,81			29,41	32,85
Permukiman					20,97	22,50	2,29	2,34				4,28	5,96		3,06	3,16						
Tubuh Air													0,00	0,00							0,00	0,00
Total	**17248,92**	**17212,41**	**21236,21**	**20703,02**	**83,61**	**111,27**	**2,29**	**233,86**	**0,00**	**321,08**	**299,68**	**1623,33**	**2603,78**	**1695,19**	**222,38**	**213,21**	**1597,52**	**1183,65**	**61,59**	**40,09**	**66,71**	**85,59**
Selisih (2024 - 2012)		**-36,51**		**-533,20**		**27,67**		**231,57**		**321,08**		**1323,66**		**-908,59**		**-9,17**		**-413,87**		**-21,51**		**18,87**
Keterangan Kesesuaian Ruang																						
		Sesuai																				
		Tidak Sesuai																				

Source: Processed data, 2024

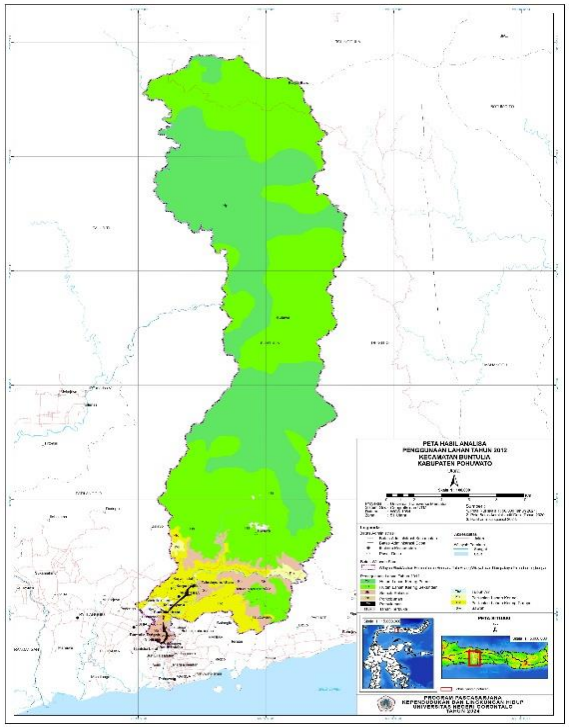
Table 2. Conformity of space direction to land use of Buntulia sub-district in 2024

Village	Conformity to Space and Land Use Directions (Ha)		Total (Ha)
	Appropriate	Not Appropriate	
Buntulia Tengah	139,63	12,98	152,60
Buntulia Utara	264,74	23,95	288,69
Hulawa	38623,48	869,56	39493,03
Karya Indah	181,84	12,78	194,61
Sipatana	58,57	19,74	78,31
Taluduyunu	1071,03	491,88	1562,92
Taluduyunu Utara	1205,56	446,97	1652,53
Total	**41544,85**	**1877,85**	**43422,71**

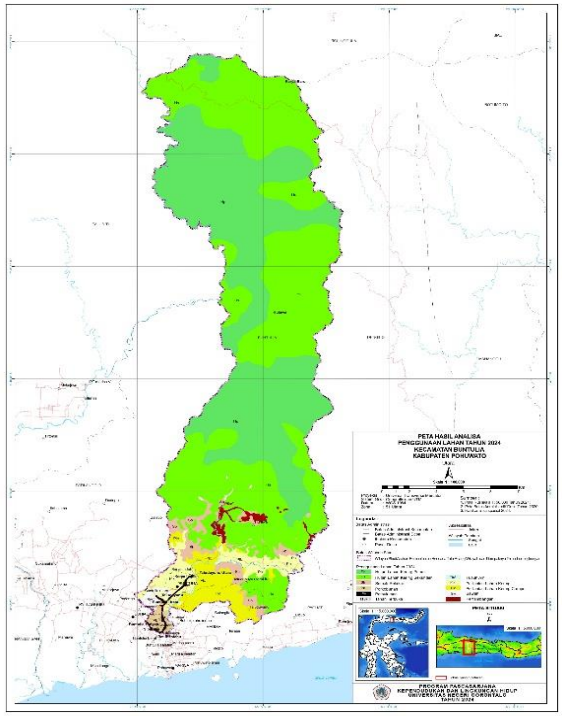
Table 3. Patterns of land use change in Buntulia subdistrict, Pohuwato regency for the period 2012 – 2024

Land Closure		Year 2012 (Ha)										Total (Ha)
		HLKp	HLKs	Sb	Pkb	Pmk	Tnh	A	Pt	Pc	Sw	
Tahun 2024 (Ha)	**HLKp**	17212,41										**17212,41**
	HLKs	22,68	20585,00	79,42			5,63	0,01		10,28		**20703,02**
	Sb	11,30	356,40	705,72			7,27		0,00	102,95		**1183,65**
	Pkb			225,98	1,51					6,37		**233,86**
	Pmk			5,82	0,78	83,06				11,89	9,73	**111,27**
	Tnh		38,92				1,16	0,01				**40,09**
	A		0,00	4,88				66,70		14,01		**85,59**
	Pt		9,88	320,39				0,00	208,43	1084,63		**1623,33**
	Pc		54,44	197,02					91,24	1352,49		**1695,19**
	Sw					0,55					212,66	**213,21**
	Ptb	2,52	191,57	58,30			47,53			21,16		**321,08**
Jumlah		**17248,92**	**21236,21**	**1597,52**	**2,29**	**83,61**	**61,59**	**66,71**	**299,68**	**2603,78**	**222,38**	**43422,71**

Source: Processed data, 2024



(a)



(b)

Fig. 3. Comparison of land use objectives (a) 2012 (b) 2024

discrepancies in some villages. In general, large areas such as Hulawa show high levels of conformity, but some villages such as Taluduyunu and Taluduyunu Utara are of particular concern due to high levels of land use non-conformity. It is therefore important to review the implementation of the RTRW and make efforts to mitigate the environmental impacts of these land use changes, for example through reforestation, strengthening spatial supervision, and implementing sustainable development policies. To address these non-conformities, a stricter approach to spatial utilisation control is needed, especially in villages with higher non-conformity rates. Regular evaluations, land use monitoring, and socialisation efforts on the importance of following spatial plans can help reduce the number of non-conformities in the future.

The increase in settlement areas indicates an expansion of settlement areas that may violate the RTRW, especially when these areas are located in forest zones or protected areas. Further evaluation is needed to ensure that settlement development does not threaten the sustainability of existing ecosystems and land functions. The decline of primary and secondary forests reduces the area's ability to maintain the water cycle, prevent erosion and store carbon. Conversion of forests to agriculture or plantations can increase the risk of soil erosion, especially in areas with steep topography. Meanwhile, a decrease in vegetation cover reduces the soil's ability to absorb and store water, which can increase the risk of flooding in the rainy season and drought in the dry season. This is in line with the results of research conducted by Adhiatma et al., (2020) Forest conversion to open land or agriculture can also increase carbon dioxide (CO_2) emissions and reduce carbon sequestration capacity, which has an impact on global warming.

3.2.2 Analysis of land use change patterns in Buntulia district, Pohuwato regency for the period 2012 – 2024

The results showed that there were significant land use change dynamics in Buntulia Sub-district during the 2012-2024 period. Land use change is dominated by the conversion of naturally vegetated land, such as primary and secondary forests, into plantations, mixed gardens and other more intensive areas. These changes are influenced by socio-economic pressures, the need for new land for productive activities, and suboptimal implementation of spatial plans (Suni et al., 2023).

Based on the results of the land use transition matrix analysis, the main patterns of change during the 2021-2024 period include the conversion of primary forest to secondary forest (22.68 ha), open land (38.92 ha), and mining areas (2.52 ha). This primary forest loss affects biodiversity and critical ecosystem functions, including its role as a carbon sink. Secondary forest conversion to mixed agriculture (197.02 ha) and shrubs (356.40 ha). The decrease in secondary forest area contributes to the degradation of natural vegetation and loss of habitat for local fauna. Shrubs showed massive conversion, with conversion to mixed agriculture (102.95 ha) and secondary forest (356.40 ha). The conversion of shrubs reduces the area of natural vegetation transition, which usually serves as an environmental buffer. Plantation areas increased in size by 231.57 ha, while mixed agriculture increased by 980.44 ha. This increase is due to the economic needs of the community, such as plantation development and subsistence farming activities. The area of water bodies increased by 18.87 ha, reflecting conservation initiatives or improvements to water resources infrastructure. The area of open land increased, which can be attributed to development and land preparation activities (Nuryanti, 2020).

This map reflects the dynamics of land use influenced by development factors, population growth, and growing economic activity. In 2012, the majority of the area, especially in the central to northern parts, was still dominated by light green and dark green colours, indicating forest areas and land with relatively preserved natural functions. This signalled that most of the land at that time was still in good condition, with little pressure from human activities. On the other hand, the southern areas begin to show signs of land use intensification with the appearance of yellow, which represents cultivated land, agriculture or settlements. In the 2024 map, land use patterns undergo significant changes, especially in the south and parts of the centre. Areas that were green in 2012 begin to shift to yellow and red colours, indicating an increase in the intensity of land use for settlements, economic activities, or conversion of cultivated land. The red colour that appears clearly in the southern region indicates high development pressure, such as the development of residential

areas, agriculture and mining. This change indicates a rapid land conversion within 12 years.

This pattern of change indicates a trend of natural land degradation towards more intensive land utilisation for economic activities. This conversion reflects the need for alignment between economic development and environmental conservation. Novriyal et al. (2024) argued that the pattern of land change indicates the need for more careful planning to control land use change, especially in areas experiencing the highest development pressure. Strengthening regional spatial planning policies, law enforcement, and land rehabilitation efforts are key in ensuring a balance between development needs and environmental preservation (Aron, 2022). In addition, sustainable approaches and involving local communities in land management can help mitigate the negative impacts of land use change. Thus, ecosystem sustainability and community welfare can be maintained amidst the dynamics of land change that are intensifying.

4. CONCLUSION

The direction of the RTRW utilisation in Buntulia Sub-district, Pohuwato Regency has not been fully implemented properly, as can be seen from the existence of land use / function change that is not in accordance with the spatial designation. Primary and secondary forest areas have experienced a significant decrease in area due to conversion to plantations, mixed agriculture, and open land. These changes not only threaten protected areas such as the Panua Nature Reserve, but also affect overall environmental quality, such as increased risk of erosion, degradation of biodiversity and disruption to the hydrological cycle. The pattern of land use change in Buntulia Sub-district during the 2013-2023 period is dominated by the conversion of primary and secondary forests to mixed farmland and plantations. Primary forests are mostly converted to secondary forests, open land, and agricultural land, while secondary forests experience significant conversion to shrubs and mixed agriculture. Shrubs also showed massive conversion to agricultural areas. An increase in the area of water bodies indicates conservation efforts, but not enough to offset the negative impacts of other land changes.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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