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Study of Spatial Pattern Suitability Based on Land System Data in Malang Regency and Malang City

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ABSTRACT
The study objective is to describe the land characteristics of Malang Regency and Malang City and to evaluate the suitability of spatial patterns using data on the land system in these two locations. This study used spatial and descriptive analysis to discuss the land characteristics at the research site concerning land use as a cultivated area and protected area based on land system data and adjusted to the spatial plan, namely the Regional Spatial Plan (RTRW) of the research locations. There are 24 land systems data in Malang Regency and Malang City, six of which dominate, namely: Asembagus (ABG) 22.9%, Barong Tongkok (BTK) 16.9%, Tanggamus (TGM) 15.4%, Bukit Balang (BBG) 7.38%, Donomulyo (DML) 7%, and Muna (MNA) 6.8%. The results show that the spatial pattern contained in the RTRW map of Malang Regency and Malang City is suitable for the physical characteristics of the land.

INTRODUCTION

Land system data represents the terrestrial component of the earth system, encompassing a comprehensive set of processes and activities associated with land use. These include socio-economic, technological, and organizational investments and arrangements, the discernible benefits of the land, and the consequential social and ecological ramifications of societal activities (Verburg et al., 2013). Land system data have spurred methodological innovations and empirical insights on land cover changes and land use, ranging from spatial patterns to underlying processes and causal factors (Meyfroidt et al., 2018). Consequently, land system data offer valuable insights and options for adapting to and mitigating environmental changes.

Environmental transformations are intricately linked to the spatial patterns that Regional Spatial Plans (*Rencana Tata Ruang Wilayah* in Indonesian, abbreviated as RTRW) govern. The overarching objective of formulating RTRW is to optimize community welfare by regulating land use to conserve the environment, facilitating the optimal and sustainable utilization of spatial resources (Hasyim et al., 2019). This aligns with the strategic development of spatial plans within Indonesian territories, specifically in Malang Regency and Malang City, aimed at enhancing the efficiency, productivity, and strategic utilization of land resources to achieve public welfare, social equity, and environmental sustainability (Malang Regency Government, 2010; Malang City Government, 2011). The spatial plan for Malang Regency was governed by Regional Regulation Number 03 of 2010, while Malang City adhered to Regional Regulation Number 04 of 2011.

In this study, the term "suitability of spatial patterns" refers to the harmonization between designated land use plans outlined in the RTRW and the actual physical characteristics of the land in Malang Regency and Malang City. The research objective is to describe the land features of these areas and evaluate how well the existing spatial plans align with observed land conditions. Specifically, the term implies a positive correlation or appropriateness between the planned spatial patterns depicted in the RTRW map and the tangible attributes of the land systems. The suitability assessment involves considerations such as topography, soil types, and other morphological features, aiming to determine whether the planned land use, whether for cultivation or protected areas, is in concordance with the intrinsic characteristics of the land (Dora & Roziqin, 2020).

The spatial pattern contained in the RTRW necessitates cross-sectoral studies to assess the efficacy of the spatial sustainability plans that have been developed. Furthermore, studying spatial patterns with environmental characteristics is essential in managing and allocating land resources to identify suitable areas, thus supporting regional development and space sustainability in the region. Spatial patterns unsuitable for the land's carrying capacity will have various environmental consequences, including the emergence of disasters (Nogués et al., 2019).

As described above, studying spatial patterns in Malang Regency and Malang City is necessary. The study objective is to understand the land characteristics of Malang Regency and Malang City and to evaluate the suitability of spatial patterns using data on the land system in these two locations. This study can provide an overview of the spatial patterns that are suitable and unsuitable for their carrying capacity in terms of the physical aspects of the environment in Malang Regency and in Malang City.

RESEARCH METHODS

Study Area

The study area includes Malang Regency and Malang City. Administratively located in East Java Province, Indonesia. Malang Regency is located at 7°44'55,11" - 8°26' 35,45" S and 112°17'10,90" -112°57' 00,00" E with the total area of 2.997 km². Malang City is located at 07°46'48" - 08°46'42" S and112°31'42" - 112°48'48" E with a total area of 110,06 km². The topography of Malang Regency is a highland surrounded by several mountains and lowlands at an altitude of 250-3.600 masl. The topography of Malang City consists of mountains, hills, and plains with a height above sea level that varies from 300 m to 1.694 m.

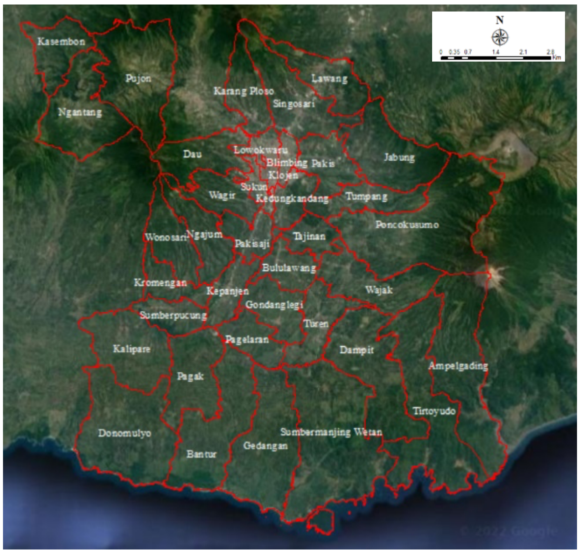

Figure 1. Regional Boundary of Malang Regency and Malang City
(Source: Data Processing, 2024)

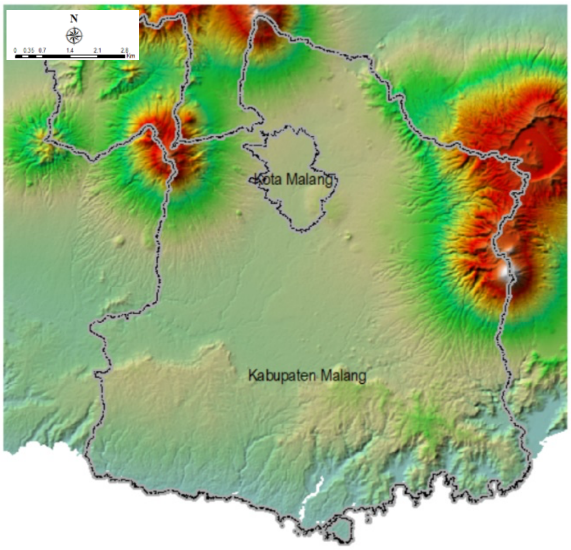

Figure 2. Topography of Malang Regency and Malang City
(Source: Data Processing, 2024)

Method of Analysis

Based on land system data, the research methodology employed spatial and descriptive analyses to elucidate the land characteristics at the research site, specifically about land use as cultivated areas and protected areas. Subsequently, the findings were adjusted to comply with the research locations' RTRW. The land feasibility assessment in this analysis adheres to the guidelines stipulated in Minister of Agriculture Decree Number 837/KPTS/UM/11/1980 and Number 683/KPTS/UM/8/1981, necessitating a score value for each parameter function. According to these decrees, factors considered in determining the protection forest in an area encompass the slope, soil type, sensitivity to erosion, and rainfall intensity in the respective area. Therefore, the parameters utilized in this study include land slope, rainfall, and soil type, which are then scored to ascertain the suitability of the land. The data utilized comprises land system data from Malang Regency and Malang City. The scoring criteria are as follows: the higher the score, the more suitable the land used as protected areas.

Following the scoring provisions outlined in Minister of Agriculture Decree Number 837/KPTS/UM/11/1980 and Number 683/KPTS/UM/8/1981, each parameter class value is multiplied using a weight of 20 for the slope parameter, 15 for the soil type parameter, and 10 for the rainfall intensity parameter. The scores corresponding to each forest area function (protected forest, production forest, and limited production forest) are as follows:

- Score $\geq$ 175, maintain as protected forest
- Score 125–174, maintain as production forest
- Score $\leq$ 124, as a free production forest and cultivation area

In the realm of forestry and land management, the scoring values stipulated in Minister of Agriculture Decree Number 837/KPTS/UM/11/1980 and Number 683/KPTS/UM/8/1981, as delineated in Tables 1, 2, and 3, serve as a systematic framework for evaluating the suitability of land for various purposes. The criteria incorporated in these tables encapsulate fundamental environmental factors crucial for sustainable land-use planning. The scoring values in Table 1, reflecting slope class categories from flat to very steep, convey the degree of difficulty and risk associated with land management, considering factors such as erosion control and stability. Table 2's scoring values for rain intensity classes, stratified by varying levels of annual rainfall, are designed to assess the impact of precipitation on soil erosion, water availability, and vegetation growth. Meanwhile, Table 3's scoring values for soil classes, categorized by different soil types, offer insights into the suitability of each soil type for forestry activities, considering factors like drainage, nutrient content, and erosion risk.

RESULTS AND DISCUSSION

Land Characteristics

Land characteristics in the study area were delineated based on the geomorphological attributes presented in the land system map. The data encompassing Malang Regency and Malang City revealed 24 land systems, with six dominating ones: Asembagus (ABG) at 22.9%, Barong Tongkok (BTK) at 16.9%, Tanggamus (TGM) at 15.4%, Bukit Balang (BBG) at 7.38%, Donomulyo (DML) at 7%, and Muna (MNA) at 6.8% (refer to Figure 3). Other land systems occupy less than 10,000 hectares or below 3%, as detailed in Table 4.

Table 1. Slope Class

No	Slope Class	Slope (%)	Description	Score
1	I	0-8%	Flat	1
2	II	8-15%	Sloping	2
3	III	15-25%	Rather Steep	3
4	IV	25-45%	Steep	4
5	V	>45%	Very steep	5

(Source: Research Results, 2022)

Table 2. Rain Intensity Class

No	Rain Intensity Class	Rain Intensity (mm/year)	Description	Score
1	I	0-1000	Very low	1
2	II	1000-2000	Low	2
3	III	2000-3000	Moderate	3
4	IV	3000-4000	High	4
5	V	>4000	Very high	5

(Source: Research Results, 2022)

Table 3. Soil Class

No	Soil Class	Soil Type	Description	Score
1	1	Alluvial, clay soil, planosol, gray hidromorph, groundwater laterite	High suitability	1
2	2	Latosol	Suitability	2
3	3	Brown forest soil, non calric brown, mediteran	Quite suitability	3
4	4	Andosol, lateric, grumusol, podsol, podzolic	Low suitability	4
5	5	Regosol, litosol, organosol, renzina	Not suitability	5

(Source: Research Results, 2022)

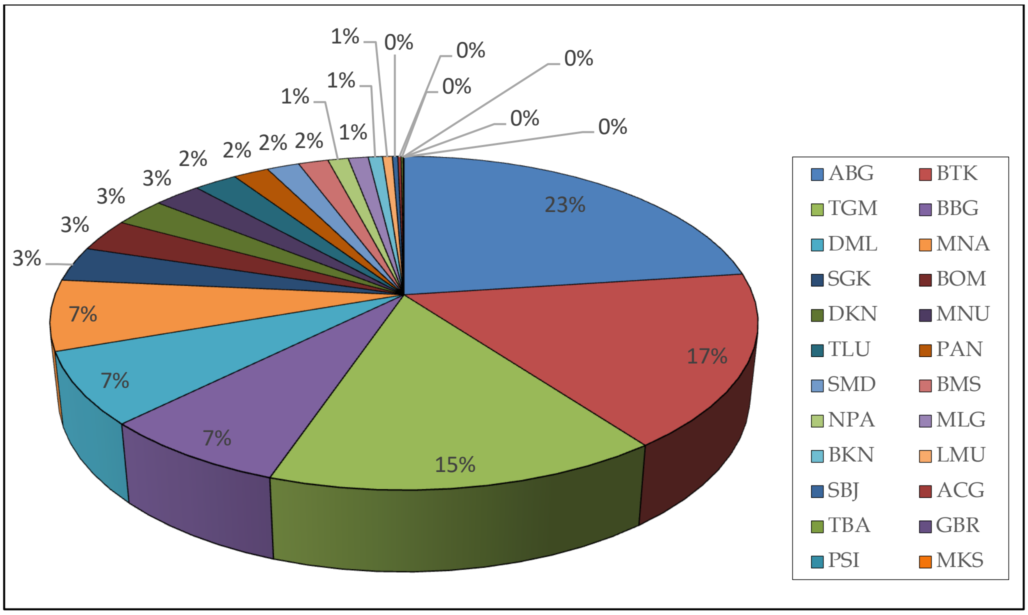

Figure 3. Percentage of Land Systems in Malang Regency and Malang City
(Source: Research Results, 2022)

Table 4. Characteristics of Land Systems in Malang Regency and Malang City

No	Symbol	Land System Name	Land Type	Slope	Slope Length	Terrain	Area (km²)	Area (%)
1	ABG	Asembagus	Flat to undulating volcanic plains in dry areas	2%	101-200m	Flat, Undulating	80.987,34	22,9199
2	BTK	Barong Tongkok	Moderately dissected lava flows	16-25%	100-200m	Rolling, Hillocky	59.717,12	16,9003
3	TGM	Tanggamus	Young stratovolcanoes on basic volcariics	41-60%	>5.000m	Mountainous	54.436,61	15,4059
4	BBG	Bukit Balang	Irregular mountain ridges on intermediate basaltic volcanics	41-60%	101 -200m	Mountainous	26.089,35	7,3835
5	DML	Donomulyo	Rolling tilted plateaus in dry areas	9-15%	50-100m	Rolling	24.806,06	7,0203
6	MNA	Muna	Rolling plain with conical karst hillocks	41-60%	50-l00m	Hillocky	24.128,90	6,8286
7	SGK	Sangkrah	Strongly dissected tilted limestone plateaus	41-60%	50- l00m	Hillocky	11.909,71	3,3705
8	BOM	Bombong	Undulating to rolling basic volcanic plains in dry areas	9-15%	>5.000m	Rolling	11.219,06	3,1751
9	DKN	Dukun	Moderately dissected tilted plateaus on limestone	16-25%	<50m	Hillocky	9.794,01	2,7718
10	MNU	Maninjau	Very steep montainous calderas on intermediate/ basic volcanics	41-60%	101-200m	Montainous	9.000,58	2,5472
11	TLU	Talamau	Moderately steep and dissected lahar slopes	16-25%	50-100m	-	8.228,21	2,3286
12	PAN	Pandeglang	Hillocky plains on intermediate to basic volcanics	16-25%	50-l00m	Hillocky	6.745,44	1,9090
13	SMD	Sungai Medang	Undulating to rolling basic	9-15%	>500m	Rolling	6.173,38	1,7471
14	BMS	Bukit Masung	Very steep ridges on basaltic volcanics	41-60%	101-200m	Hilly	5.672,10	1,6052
15	NPA	Nusa Penida	Raised tilted hillocky karstic terraces in dry areas	16-25%	50-100m	Hillocky	3.869,44	1,0951
16	MLG	Malang	Moderately steep hills on basaltic volcanics in dry areas	16-25%	201 -500m	Hilly	3.795,32	1,0741
17	BKN	Bakunan	Minor river floodplains within hills	<2%	-	Flat	2.702,82	0,7649

No	Symbol	Land System Name	Land Type	Slope	Slope Length	Terrain	Area (km²)	Area (%)
18	LMU	Lemiru	Tilted plateaus with conical karst hillocks in dry areas	41-60%	50-100m	Hillocky	1.864,07	0,5275
19	SBJ	Sumber-manjing	Moderately dissected tilted plateaus on limestone in dry areas	16-25%	<50m	Hillocky	1.027,79	0,2909
20	ACG	Air Cawang	Braided river floodplains	<2%	-	Flat	635,95	0,1800
21	TBA	Tambera	Extremely steep volcanic cones or plugs on acid igneous roc	>60%	101-200m	Hilly, Mountainous	370,04	0,1047
22	GBR	Gunung Batur	Cinder cones	41-60%	101-200m	Mountainous	132,50	0,0375
23	PSI	Pulau Sapudi	Rolling plain with hillocks on marl in dry areas	9-15%	50-100m	Rolling	41,97	0,0119
24	MKS	Makasar	Coalescent estuarine/riverine plains in dry areas	<2%	-	Flat	1,22	0,0003
			Total				353.349	100%

(Source: Research Results, 2022)

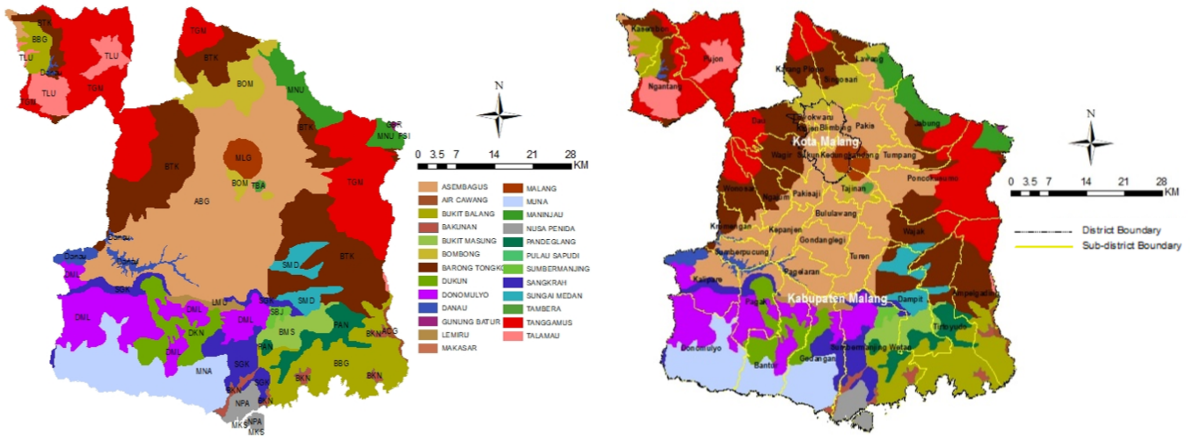

Figure 4. Map of Malang Regency and Malang City land system
(Source: Data Processing, 2024)

Table 4 elucidates the morphological characteristics of Malang Regency and Malang City areas. Asembagus, the most extensive and dominant region, showcases flat to undulating volcanic plains in dry zones, characterized by a relatively low slope of 2%, a slope length of 101–200m, and flat undulating terrain. Asembagus is primarily located in Malang City and the surrounding sub-districts of Malang Regency (refer to Figure 4). Given these morphological conditions, Asembagus is considered suitable for cultivation according to the spatial pattern outlined in the RTRW of Malang City Number 04 of 2011. Malang City sustains a higher population density at 7,677/km², contrasting sharply with its surroundings, where Malang Regency records only 752/km² (BPS, 2021). The flat morphology of Asembagus facilitates faster construction of settlements and other structures, as the area is less prone to landslides. This information underscores the strategic suitability of Asembagus for cultivation activities and highlights the demographic distinctions between Malang City and its adjacent regions in Malang Regency.

Barong Tongkok (BTK) represents the second-largest land system in Malang, comprising 17% of the total area. This soil type is characterized by dissected lava flows resulting from land fractures, with slopes ranging from 16–25% and a rolling to hillocky morphology, featuring slope lengths of 10–200 meters. The moderately steep central slope renders the area susceptible to erosion. The subsequent dominant land system is Tanggamus, located adjacent to Barong Tongkok due to its positioning as a young stratovolcano in the base volcano in the upper part of BTK (refer to Figure 4). The slope inclination in Tanggamus ranges from 41–60%, with a slope length exceeding 5.000m, rendering it mountainous. This topographical condition implies a high susceptibility to erosion due to the elevated and extensive upper slopes, which can generate substantial water flow energy during heavy rainfall. In spatial planning, the Tanggamus land system is categorized as a protected area, prohibiting residential development due to its heightened vulnerability to landslides and the potential risk of volcanic eruptions.

In the southern part (refer to Figure 4), the dominant land systems are Donomulyo (DML) and Muna (MNA), constituting 7% and 6.8% of the Malang area, respectively. Donomulyo is characterized by rolling tilted plateaus in arid regions, featuring a slope of 9–15% and a slope length of 50–100m. On the other hand, Muna is a rolling plain with conical karst hillocks located along the Malang coast. It exhibits a steep slope level of 41–60% with hillocky terrain. This coastal region is typified by infertile agricultural land, prone to erosion and landslides, and possessing low aeration pores. Additionally, this karst region demonstrates slow permeability and is predominantly composed of micropores.

Another prominent land system in the Malang area is Bukit Balang (BBG), with 7.4% coverage, located in the southeastern part of Malang, adjacent to the Muna land system (refer to Figure 4). BBG is an irregular mountain ridge on an intermediate basaltic volcano, featuring a steep slope ranging from 41–60% and a mountainous slope of 101–200m in length. The configuration of this slope signifies susceptibility to erosion on the upper slope, which is steep and long, facilitating a significant water flow energy.

Each land system in Malang Regency and City exhibits distinct facets. In general, Malang's land types are characterized by two or, in some cases, three facets. Only eight land systems present four types of facets, as detailed in Table 5. Asembagus (ABG), Malang's most dominant land system, comprises two facets, with 65% being plains and the remaining 35% consisting of flood plains. Barong Tongkok (BTK) features a crest covering 50% of the area, while the remaining 50% encompasses the valley side adjacent to Tanggamus, a land system in mountainous areas.

Tanggamus (TGM), the third-largest land area in Malang, encompasses four facets: 40% upper slope, 30% middle slope crest, 15% middle slope valley side, and 10% lahar. In the southern part, three dominant land systems—BBG, DML, and MNA—exhibit distinctive facets. Bukit Balang has three facets, comprising 90% steep ridge areas, 5% old lava flows, and the remaining 5% rock outcrops. Muna, a coastal area, consists of 50% karst, 35% plains, and 15% humus. Meanwhile, Donomulyo, situated directly adjacent to Muna, exhibits facet characteristics of 60% valley side, 20% crest, 15% hummock, and 5% valley bottom area.

Table 5. Characteristics of Facets of Land Systems in Malang Regency and Malang City.

No	Symbol	Facet 1	Facet 2	Facet 3	Facet 4
1	ABG	Plain 65% area	Flood plain 35% area	-	-
2	BTK	Crest 50% area	Valley side 50% area	-	-
3	TGM	Upper slope 40% area	Mid slope crest 30% area	Mid slope valley side 15% area	Lahar 10% area
4	BBG	Steep ridges 90% area	Old lava flow 5% area	Rock outcrop 5% area	-
5	DML	Valley side 60% area	Crest 20% area	Hummock 15% area	Valley bottom 5 % area
6	MNA	Karstic hillocks 50% area	Plain 35% area	Hums 15% area	-
7	SGK	Very steep hilisips 60% area	Fotsps 35% area		
8	BOM	Rolling plain 50% area	Undulating plain 40% area	Valley side 5% area	Valley bottom 5% area
9	DKN	Hillock 65% area	Rolling plain 20% area	Valley side 10% area	Valley bottom 5% are
10	MNU	Slopes 95% area	Crest 5 % area	-	-
11	TLU	Volcano lower slope 85% area	Valley bottom 10% area	Valley side 5% area	-

No	Symbol	Facet 1	Facet 2	Facet 3	Facet 4
12	PAN	Valley side 70% area	Crest 25% area	Valley bottom 5% area	-
13	SMD	Rolling plain 45% area	Undulating plain 40% area	Valley side 10% area	Valley bottom 5% are
14	BMS	Hillslopes 70% area	Crest 15% area	Valley side 10% area	Valley bottom 5% are
15	NPA	Karstic hillock 70% area	Rolling plain 25% area	Very steep slope 5% area	-
16	MLG	Hilislopes 75% area	Valley side 20% area	Valley bottom 5% area	-
17	BKN	Backland 75% area	Terrace 20% area	Levee 5% area	-
18	LMU	Karstic hillocks 65% area	Plain 20% area	Hums 15% area 4 % area	-
19	SBJ	Hillock 65% area	Rolling plain 20% area	Valley side 10% area	Valley bottom 5% are
20	ACG	Flood plain 80% area	Channel 20% area	-	-
21	TBA	Slope 80% area	Rock outcrop 10% area	Colluvial fan 10% area	-
22	GBR	Volcano slopes 90% area	Crater 10% area	-	-
23	PSI	Rolling plain 55% area	Hillock 25% area	Undulating plain 10% area	Valley side 5% area
24	MKS	Estuarine plain 75% area	Levee 20 % area	Swamp margin 5% area	-

(Source: Research Results, 2022)

Land System Material

The land system comprises base and cover materials, with lithology as a geological term to categorize rock formations, including sedimentary, igneous, and metamorphic rocks (Guo et al., 2008). Information related to the types and characteristics of rocks, along with their constituent minerals influencing land system formation, is encapsulated in lithology (Mukhtar & Nurwadjedi, 2020). Material characteristics of the land systems in Malang Regency and Malang City are presented in Table 6.

Asembagus (ABG), previously identified as the predominant land system (see Table 4), is characterized by hard and soft volcanic rocks with soil associations of Ustropepts, Tropaquepts, and Chromesterts, representing Brown Forest Soil. While this land system exhibits good drainage, it is not flawless. The second-largest land system, Barong Tongkok (BTK), features volcanic rock with a high hardness level. The soil domains within this system include Eutropepts and Tropudaifa, with an association of Dystropepts, Eutropepts, and Tropudalfs—classified as Inceptisol-Alfisol soil types or Mediterranean soils. Barong Tongkok demonstrates good drainage capability. Following Barong Tongkok is the Tanggamus land system (TGM), also characterized by volcanic rock with a high hardness level. The soil domain consists of Humitropepts, Hydraride, and Dystrandepts soil association, representing Andosol soil type with good drainage ability.

The Bukit Balang land system (BBG), ranked as the fourth largest, is predominantly composed of volcanic rock with high rock hardness. Soil associations within this land system encompass Dystropepts, Humitropepts, and Tropohumults, categorized as Inceptisol-Ultisol soil types or latosol. The Bukit Balang land system exhibits commendable drainage capabilities. Subsequently, the Donomulyo land system (DML) is characterized by sedimentary rock with high rock hardness, demonstrating efficient drainage capabilities. The soil associations in this land system include Paleustalfs and Ustropepts, classifying them as Inceptisol-Alfisol soil types, commonly referred to as Mediterranean soils.

The Muna land system (MNA), the sixth most extensive, features sedimentary rock with high rock hardness. Soil domains within this land system comprise Tropudalfs and Eutropepts, along with the association of Rendolls soil, categorizing it as an Inceptisol-Alfisol soil type, commonly known as Mediterranean soil. This land system exhibits commendable drainage capabilities.

Table 6. Material Characteristics of Land System in Malang Regency and Malang City

No	Symbol	Land System Name	Lithology	Indurat	Soil Domain	Soil Asosiation	Drainage	Annual Rain
1	ABG	Asembagus	Volcanic	Hard, Soft	-	Ustropepts, Tropaquepts, Chromusterts	Well Drained, Imperfect	1.600-2.400mm
2	BTK	Barong Tongkok	Volcanic	Hard	Eutropepts, Tropudaifa	Dystropepts, Eutropepts, Tropudalfs	Well Drained	2.000-5.000mm
3	TGM	Tanggamus	Volcanic	Hard	Humitropepts, Hydraride	Dystrandepts	Well Drained	1.600-5.000mm
4	BBG	Bukit Balang	Volcanic	Hard	-	Dystropepts, Humitropepts, Tropohumults	Well Drained	1.000-4.100mm
5	DML	Donomulyo	Sedimentary	Hard	-	Paleustalfs, Ustropepts	Well Drained	1.900-2.300mm
6	MNA	Muna	Sedimentary	Hard	Tropudalfs, Eutropepts	Rendolls	Well Drained	2.400-4.200mm
7	SGK	Sangkrah	Sedimentary	Hard	-	-	Well Drained	2.000-2.500mm
8	BOM	Bombong	Volcanic	Hard	-	Ustropepts, Haplustalfs	Well Drained	900-3.100mm
9	DKN	Dukun	Sedimentary	Hard	-	Ustropepts, Haplustalfs	Well Drained	2.200-3.600mm
10	MNU	Maninjau	Volcanic	Hard	Dystropepts, Troporthent	Dystrandepepts	Well Drained	2.300-3.200mm
11	TLU	Talamau	Volcanic	Soft	Eutropepts	Dystrandepts, Tropudults	Well Drained, Imperf	1.800-5.000mm
12	PAN	Pandeglang	Volcanic	Hard	-	Tropudults, Tropudalfs	Well Drained	2.400-4.700mm
13	SMD	Sungai Medang	Volcanic	Hard	Tropudults	Tropudalfs	Well Drained	2.000-4.400mm
14	BMS	Bukit Masung	Volcanic	Hard	-	Dystropepts, Tropudults, Troporthents	Well Drained	1.400-4.800mm
15	NPA	Nusa Penida	Sedimentary	-	Ustorthents, Haplustalf	-	Well Drained	1.400-2.600mm
16	MLG	Mallang	Volcanic	Hard	Haplustults	Paleustalfs	Well Drained	1.500-3.100mm
17	BKN	Bakunan	Sedimentary	Soft	-	Tropaquepts, Tropofluvents, Eutropepts	Poor	2.200-4.500mm
18	LMU	Lemiru	Sedimentary	Hard	Haplustalfs, Ustropepts	Calciustolls	Well Drained	2.000-2.900mm
19	SBJ	Sumbermanjing	Sedimentary	Hard	Haplustalfs, Chromustert	Ustropepts	Well Drained	1.800-2.300mm
20	ACG	Air Cawang	Sedimentary	Soft	Tropofluvents	Tropaquepts, Eutropepts	Imperfect, Poor	1.800-2.500mm
21	TBA	Tambera	Volcanic	Hard	Dystropepts, Tropudults	Troporthents	Well Drained	1.700-4.600mm
22	GBR	Gunung Batur	Volcanic	Hard, Soft	Vitrandepts	Troporthents	Excessive	2.700-2.800mm
23	PSI	Pulau Sapudi	Sedimentary	Soft	-	Paleustalfs, Haplustalfs, Ustropepts	Well Drained	1.500-2.000mm
24	MKS	Makasar	Sedimentary	Soft	Fluvaquents, Ustropepts	Tropaquepts	Imperfect, Poor	1.000-2.400mm

(Source: Research Results, 2022)

Geomorphological Processes

Geomorphological processes encompass all physical and chemical alterations occurring on the earth's surface. Endogenous forces, such as tectonic and volcanic activities, and exogenous forces, including water, wind, glaciers, and human intervention influence these processes (Ichikawa, 2011). Landforms, in turn, emerge as outcomes of these geomorphological processes. An understanding of lithology facilitates the elucidation of geomorphological processes within each land system. Table 7 presents the lithology of land systems in Malang Regency and Malang City.

Table 7. Land System Lithology in Malang Regency and Malang City

No	Symbol	Land System Name	Lithology
1	ABG	Asembagus	Volcanic
2	BTK	Barong Tongkok	Volcanic
3	TGM	Tanggamus	Volcanic
4	BBG	Bukit Balang	Volcanic
5	DML	Donomulyo	Sedimentary
6	MNA	Muna	Sedimentary
7	SGK	Sangkrah	Sedimentary
8	BOM	Bombong	Volcanic
9	DKN	Dukun	Sedimentary
10	MNU	Maninjau	Volcanic
11	TLU	Talamau	Volcanic
12	PAN	Pandeglang	Volcanic
13	SMD	Sungai Medang	Volcanic
14	BMS	Bukit Masung	Volcanic
15	NPA	Nusa Penida	Sedimentary
16	MLG	Mallang	Volcanic
17	BKN	Bakunan	Sedimentary
18	LMU	Lemiru	Sedimentary
19	SBJ	Sumbermanjing	Sedimentary
20	ACG	Air Cawang	Sedimentary
21	TBA	Tambera	Volcanic
22	GBR	Gunung Batur	Volcanic
23	PSI	Pulau Sapudi	Sedimentary
24	MKS	Makasar	Sedimentary

(Source: Research Results, 2022)

Based on Table 7, Malang Regency exhibits 24 distinct land systems, 13 of which display volcanic lithology. These volcanic land systems, namely Asembagus (ABG), Barong Tongkok (BTK), Tanggamus (TGM), Bukit Balang (BBG), Bombong (BOM), Maninjau (MNU), Talamau (TLU), Pandeglang (PAN), Sungai Medang (SMD), Bukit Masung (BMS), Malang (MLG), Tambera (TBA), and Gunung Batur (GBR), are characterized by landforms resulting from the extrusion of volcanic materials, such as lava and pyroclastic fragments (de Silva & Lindsay, 2015). Lava flow, an effusion of low-viscosity magma at high temperatures, extends over expansive areas, with the mineral composition of basaltic lava playing a pivotal role in shaping the specific volcanic landforms (Gharehchahi, 2017).

Conversely, the geomorphological processes observed in the land systems of Donomulyo (DML), Muna (MNA), Sangkrah (SGK), Dukun (DKN), Nusa Penida (NPA), Bakunan (BKN), Lemiru (LMU), Sumbermanjing (SBJ), Ari Cawang (ACG), Pulau Sapudi (PSI), and Makasar

(MKS) pertain to the formation of fluvial land characterized by sedimentary rocks. Fluvial landforms, shaped by the movement of water, particularly rivers, encompass a broad spectrum of dimensions, ranging from minor features like small rivers to continental-scale hydrological units such as large rivers and drainage basins. The drainage network is crucial in transporting water and sediment from elevated areas to lowlands and, ultimately, oceans. As principal agents in landscape evolution, Fluvial systems substantially influence interconnected geomorphic systems, including hillslopes, alluvial fans, deltas, and coasts (Gutiérrez & Gutiérrez, 2016).

The fluvial system can be conceptually divided into three dominant zone processes: (1) upper source zone, (2) middle transfer zone, and (3) lower accumulation zone (Schumm, 1977). These zones are associated with three standard processes—erosion, transport, and deposition—each occurring at varying rates in their respective zones (Kondolf, 1994). The morphology of fluvial systems is generally flat, comprising alluvium as the predominant material, with drainage often impeded, resulting in waterlogged conditions, susceptibility to flooding, shallow groundwater, fine soil texture, and a solum depth (adequate soil depth) greater than 1 m, characterized by alluvial soil types such as Entisol or Inceptisol.

Spatial Pattern Suitability of Malang City

Policies aimed at consolidating Malang City as a National Activity Center (PKN) are oriented towards enhancing the preparedness and infrastructure of the city to accommodate national-scale activities. Consequently, the spatial planning of Malang City predominantly revolves around the categorization of specific areas, mainly developed land, encompassing settlements, commercial and service zones, industrial and warehouse areas, military installations, and public facilities (refer to Figure 5). Spatial data conforms to the primary provisions of the RTRW laws of Malang City, specifically Article 17, which dictates policies governing the development and regulation of cultivation areas intended to allocate space for the city's social, cultural, economic, defence, and security activities. An additional zoning designation pertains to protected areas, precisely green open spaces, mandated to constitute a minimum of 30% of the city's total area, aligning with Article 15 of the RTRW.

The land system data reveals two predominant land types in Malang City: Asembagus (ABG) and Mallang (MLG). Asembagus exhibits characteristics of relatively flat volcanic plains with a 2% slope, rendering it suitable for inclusion in the cultivation area outlined in the RTRW spatial pattern. The flat topography facilitates the construction of settlements and other infrastructure, mitigating the risk of landslides. According to the land suitability assessment, Asembagus is classified as a Free Production Forest (FPF) (see Table 8), indicating its potential for cultivation and development as built-up land.

In contrast, MLG represents steep hills in the southeastern part of Malang City, with 16-25% slopes. Based on the land suitability assessment for MLG, it is designated as a Limited Production Forest (LPF), indicating specific criteria that restrict cultivation due to the challenging terrain. The spatial pattern map (see Figure 5) highlights green open spaces in the southeastern Kedungkandang District, aligning with the hilly terrain. As stipulated in Article 54 of the RTRW of Malang City, Kedungkandang is recognized as a disaster-prone location. The main roads connecting disaster-prone locations in Mergosono, Madyopuro, Lesanpuro, Kedungkandang, and Kotalama Villages to designated disaster evacuation sites are critical components of the disaster preparedness strategy.

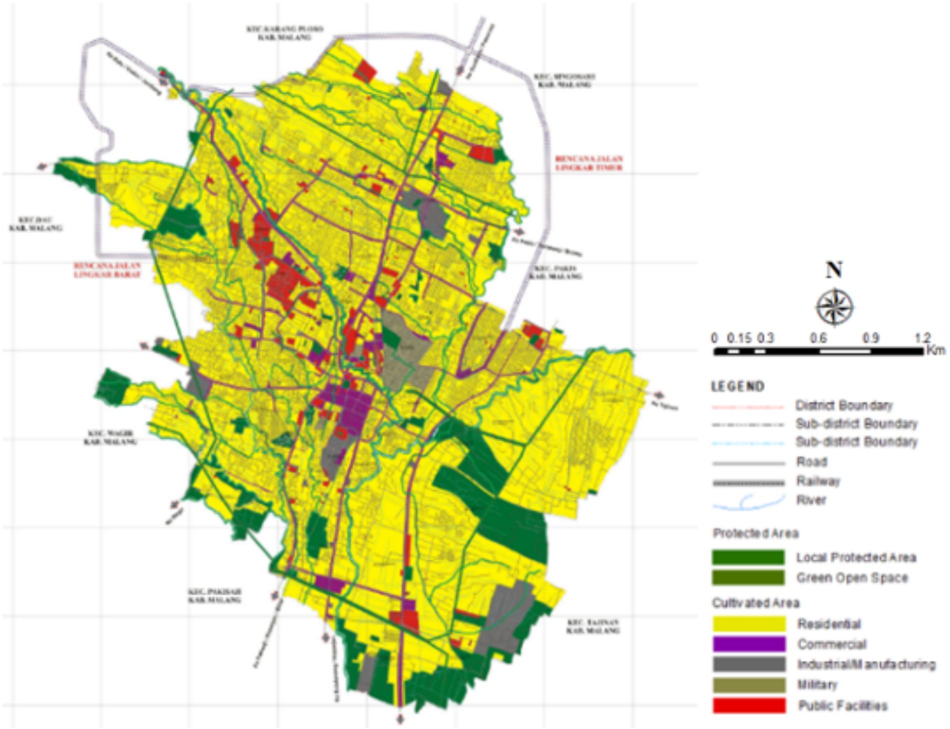

Figure 5. Spatial Pattern Map of RTRW Malang City (Source: Data Processing, 2024)

Table 8. Land System Designations in Spatial Planning

Symbol	Land System	Weighted Value	Designation
ABG	Asembagus	85	Free Production Forest
BTK	Barong Tongkok	145	Limited Production Forest
TGM	Tanggamus	200	Protected Forest
BBG	Bukit Balang	160	Limited Production Forest
DML	Donomulyo	115	Free Production Forest
MNA	Muna	165	Limited Production Forest
MLG	Malang	150	Limited Production Forest

Source: Research Results, 2022

Spatial Pattern Suitability of Malang Regency

Malang Regency identifies six dominant land systems: Asembagus, Barong Tongkok, Tanggamus, Bukit Balang, Donomulyo, and Muna. The upper region (in the North, Northwest, and Northeast) is a mountainous area predominantly dominated by Tanggamus and Barong Tongkok. According to the results of the weightage analysis (see Table 8), Tanggamus has been classified under the Protected Forest (PF) criteria owing to its steep slope characteristics (41-60%) and substantial annual rainfall. The spatial pattern map (refer to Figure 6) designates the northeastern part (Poncokusumo District) and the northeast part (Pujong District and Ngantang District) as PF, indicating that the determination of the spatial pattern aligns with the land conditions prevalent in these areas.

The subsequent dominant land system is Barong Tongkok, situated on the middle slopes below Tanggamus. The most suitable designation for Barong Tongkok is LPF, rendering it conducive for plantation purposes. The spatial pattern determined for this land condition encompasses dry land and plantation areas distributed across several sub-districts in the western and eastern parts. Specific trees, such as cypress, are strategically planted in these areas to support and protect other crops. For instance, cypress trees are frequently planted within crop plantations to shield the crops from strong winds and heavy rainfall. This practice serves the purpose of enhancing crop resilience against adverse weather conditions.

Asembagus, recognized as the most dominant land system in Malang Regency and Malang City, exhibits the flattest terrain compared to other land systems. Based on the weighting score, it's designation categorizes it as a FPF. Generally, the Asembagus score is the lowest, implying that this land is not earmarked as a protected area, allowing for diverse activities. Spatial patterns within the Asembagus land system area include irrigated rice fields, residential zones, commercial areas, dry fields, and plantation areas (see Figure 6).

In the southern region of Malang Regency, Bukit Balang (BBG), Donomulyo (DML), and Muna (MNA) emerge as dominant land systems. Bukit Balang is characterized by irregular mountain ridges featuring steep slopes (41-60%) and high annual rainfall. Given these morphological conditions, it is fitting to designate it as a protected area in the RTRW spatial pattern. Settlement is deemed unsuitable in this area due to its high landslide susceptibility. According to the results of land suitability weighting, Bukit Balang is designated as a LPF, signifying that cultivation is feasible but constrained by various criteria owing to the steep slope levels.

The next dominant land system, Donomulyo, comprises rolling tilted plateaus with a 9-15% slope. Based on the weighted results, these morphological conditions render Donomulyo suitable for designation as a FPF, implying its potential for cultivation and use as a built-up area. The final dominant land system, Muna, features undulating plains with karst hills with steep slopes ranging from 41-60%. Considering these morphological conditions, Muna is appropriately designated as a LPF due to its reasonably steep slope. Generally, the southern part of Malang is deemed suitable for plantation activities.

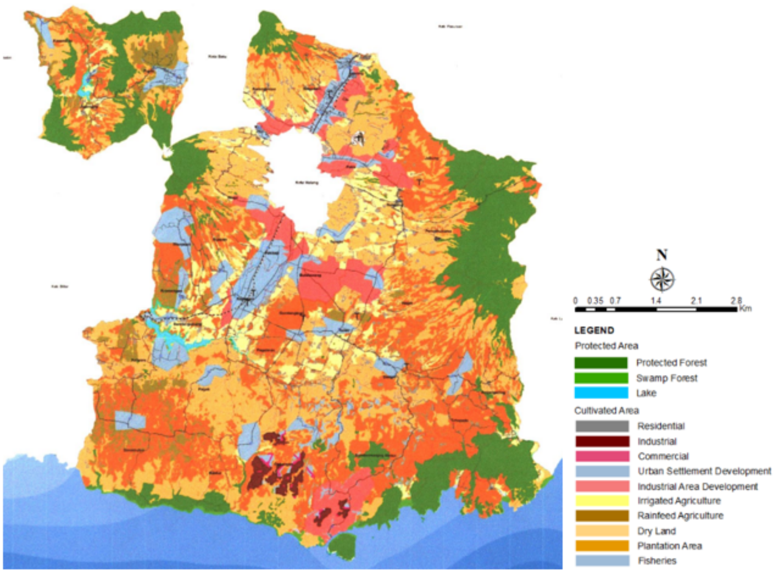

Figure 6. Map of the Spatial Pattern of Malang Regency Regional Spatial Plans
(Source: Data Processing, 2024)

CONCLUSION

In conclusion, the comprehensive analysis of land system data in Malang Regency and Malang City reveals a diverse array of 24 land systems, with six dominant ones significantly shaping the landscape. These dominant land systems, including Asembagus (ABG), Barong Tongkok (BTK), Tanggamus (TGM), Bukit Balang (BBG), Donomulyo (DML), and Muna (MNA), showcase distinctive spatial percentages, illustrating their prevalence in the region.

Furthermore, Asembagus (ABG) and Mallang (MLG) emerge as the key contributors to the local land system composition in Malang City. The prevalence and distribution of these dominant land systems underscore the complexity of the region's geomorphological characteristics.

Crucially, the spatial patterns outlined in the RTRW maps of both Malang Regency and Malang City demonstrate a harmonious alignment with the physical attributes of the land. This alignment signifies a strategic integration of land use planning, considering topography, soil types, and other morphological features. The suitability of the spatial patterns for the observed land characteristics indicates a thoughtful approach to ensuring optimal land utilization, aligning with sustainable development goals. This study contributes valuable insights into the current state of the land systems in Malang Regency and Malang City. It provides a foundation for informed decision-making in regional planning and environmental management. The findings serve as a basis for developing strategies to promote sustainable land use practices and mitigate potential environmental risks associated with specific land systems.

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