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Land Capability and Suitability Assessment for Reducing Risk Disaster in Small Island: The Case of Sulabesi Island, Indonesia

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***Abstract*—Small islands possess the main character, namely limited land resources; thus, their development must pay attention to the land's capability to support life. Sulabesi is one of the small islands located in the North Maluku Islands with a very low to very high level of land capability. As a small island and center of activity, it faces several problems, including population growth, land availability, and vulnerability to natural disasters. The study aimed to assess the suitability of land capability with land cover and disaster risk and provide direction for the development. Additionally, it employed an overlap analysis method using the ArcGIS 10.5 tool with spatial data, namely land capability and disaster risk, and land cover changes from Landsat 7 & 8 satellite imagery throughout 2000, 2010, and 2020. The research finding denoted that Sulabesi Island continues to experience changes in land cover, particularly the increase in built-up land for 20 years. These changes were then spread over the land capability of class A and class B development capability characteristics of 280.46 ha. Furthermore, the suitability between land capability and disaster risk areas was also observable in classes A, B, and C, with the risk of tsunamis, earthquakes, and landslides. Thus, efforts to manage sustainable land use, mainly built-up lands, must be directed at the capability of land with a very high - medium development classification and free from disaster risk. It can be a reference for future research in developing small islands that are more resilient.**

***Keywords*—Land capability; land suitability; small island; disasters risk; overlap technique.**

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I. INTRODUCTION

The coast has very diverse uses since it is a place that provides enormous resources for human life. As a place of transition between land and sea, the coast holds a wide variety of resources [1]–[4]. In its development, the coast began to experience a decline in quality due to excessive utilization [5]–[8]. At the same time, the coast is also prone to various natural disasters such as high winds, tsunamis, erosion, tidal flooding, and climate change [9], [10]. Various challenges faced by the coast will highly affect people's lives, especially on the coast of small islands [11].

Moreover, due to limited land resources, most small islands' population highly depends on the coast and the sea. Managing coastal and marine areas on small islands has become a vital issue due to the increasing human and environmental pressures in coastal areas, which significantly impact coastal systems and coastal ecological changes. This is also because the coast is a place where many social, economic, and political activities intersect with natural processes [12]–[14]. As an archipelagic state, Indonesia continues to face significant population growth in coastal areas. Currently, the growth rate of the rural and urban villages on an urban scale on the Indonesian coast is 15.32% [15].

Moreover, the population growth results in various uses on the coast caused by different interest factors that affect the coastal ecosystem and the socio-economic community [16]. The coastal problems in Indonesia are highly complex, even entering an ironic condition [17], [18]. This is due to the high inequality faced by people living on the coast, not to mention the community's resilience to environmental changes. Most importantly, coastal management in Indonesia, especially on small islands, can be carried out in an integrated and sustainable manner [19]. One of the efforts in realizing coastal sustainability in small islands can be made by determining land capability.

The availability of land capability mapping can direct land use to reduce disaster risk and ecosystem degradation [20], [21]. The land capability on small islands is essential because of the limited land resources. In general, the most dominating land use is settlements [22], which is in line with the coastal conditions on small islands dominated by community settlements. One of the main challenges coastal settlements face on small islands is realizing coastal settlements to support life in it [23], [24].

In Indonesia, the determination of land capability is regulated in the Regulation of the Minister of Public Works No. 20/PRT/M/2007 concerning technical guidelines for the analysis of physical and environmental, economic, and socio-cultural aspects in the preparation of spatial planning, as well as Regulation of the Minister of the Environment No. 12 of 2009 concerning guidelines for determining environmental carrying capacity in regional spatial planning. Mostly, the contents of the two guidelines have similarities in determining the land capability of an area, yet the Regulation of the Minister of the Environment No. 12 of 2009 is more directed at the land capability for agriculture. Thus, this research relies on the Minister of Public Works Regulation No. 20/PRT/M/2007.

In addition, several previous studies have discussed land capability, which was more focused on agriculture [25], [26], water [27], irrigation [28], and tourism [29]. Meanwhile, studies on land capacity on small islands, as done on Sulabesi island [30] and Bunguran island, remain limited [31]. Moreover, both land capability studies on the small island employ the same land capability calculation method based on the Regulation of the Minister of Public Works No. 20/PRT/M/2007. However, this research was still focused on calculating land capability, so there was still work that has not been done; namely, the existing land capability can be directed to the development of small islands.

Therefore, to fill this gap, this present research employed land capability data based on the same guidelines. However, this research sought to elaborate further, not only looking at an island's land capability but also at the risk of coastal disasters and the distribution process of community settlements. Hence, it is expected to provide recommendations for future development based on multidimensional disaster and social.

Furthermore, Sulabesi Island is a small island located in the southernmost part of the North Maluku Islands that has limited land conditions. Based on the spatial pattern map in the Sula Islands Regency Spatial Plan for 2011 – 2031, the land use on Sulabesi Island is dominated by plantations, especially coconut plantations, by 38%. While the community's residence by 32% and located in coastal areas. In previous studies, an assessment of land capability on Sulabesi Island has been carried out with the results that settlements on Sulabesi Island are in the land capability for development or moderate development [30]. However, this study did not consider other factors, such as disasters and changes in land use on the island of Sulabesi. This is highly significant in order to be able to plan the use of island land in supporting community activities in it.

Thus, this study aims to map planning directions for more sustainable land use based on the capacity of land with disaster risk and changes in land cover over the last 20 years on Sulabesi Island, a small island. This study is critical because it considers the character of small islands with limited land resources and high vulnerability to coastal disaster threats. In the future, development must be planned according to the physical conditions of the area, especially the ability of the land owned. These development directions are also part of efforts to deal with threats to climate change. Therefore, this research is expected to contribute to understanding related to planning for sustainable small island development.

II. Materials and Method

A. Study Area

This research was conducted on Sulabesi Island, the southernmost of the island group in the North Maluku Islands (Fig. 1). Administratively, the Sulabesi Island is included in the Sula Island Regency and is one of the small islands of 20 of the 22 islands in the Sula Island [32]. In addition, Sulabesi Island has six sub-districts, including Sanana, North Sanana, West Sulabesi, South Sulabesi, Central Sulabesi and East Sulabesi sub-districts with 42 villages in total. Overall, the community's residence is located on the coast, so it is not surprising that the coast of the Island of Sulabesi continues to increase because the center of the economy and government is on this island. Demographically, this island has the largest population in the Sula Islands, namely 65,955 people, and this continues to increase since this island is the center of the economy and government.

Besides, the total area of Sulabesi Island is only 532.42 km^2. The progress of coastal development is also more massive on the Sulabesi Island; for instance, the addition of land in coastal areas or coastal reclamation from 2011 until now. Geologically, the condition of the island of Sulabesi has a type of soil with *peleng* and *alluvium* formation properties. As a small island, the average slope of Sulabesi is slightly sloping (0-8%) to sloping (8-15%), with an altitude between 0-1500 meters above sea level (masl). Due to the condition, it is significant to apply the concept of sustainability to the planning and development of the Sulabesi Island. At the same time, the land capability assessment can be the leading indicator of achieving small island sustainability in North Maluku, nationally and globally.

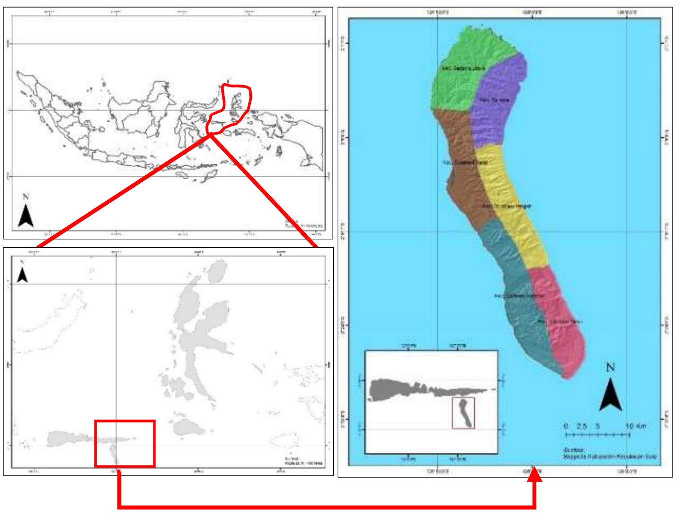

Fig. 1 Map of Sulabesi Island in North Maluku

B. Data Collection

The data used in this research were secondary data in the form of spatial data. Specifically, spatial data for land capability (Fig. 2) were obtained from the Regional Development Planning Agency of the Sula Islands Regency

(Bappeda Sula), with the results of the analysis using technical guidelines for analyzing physical and environmental, economic, and socio-cultural aspects in the preparation of spatial planning stipulated in the Regulation of Minister of Public Works No. 20/PRT/M/2007. Then, there was data on natural disaster risk (Fig. 2) which was also sourced from Bappeda Sula. Meanwhile, data on land cover changes were taken from Landsat Satellite Imagery with an interval of 20 years, namely 2000 – 2020. The focus of attributes in land cover change was built-up lands and non-built-up lands.

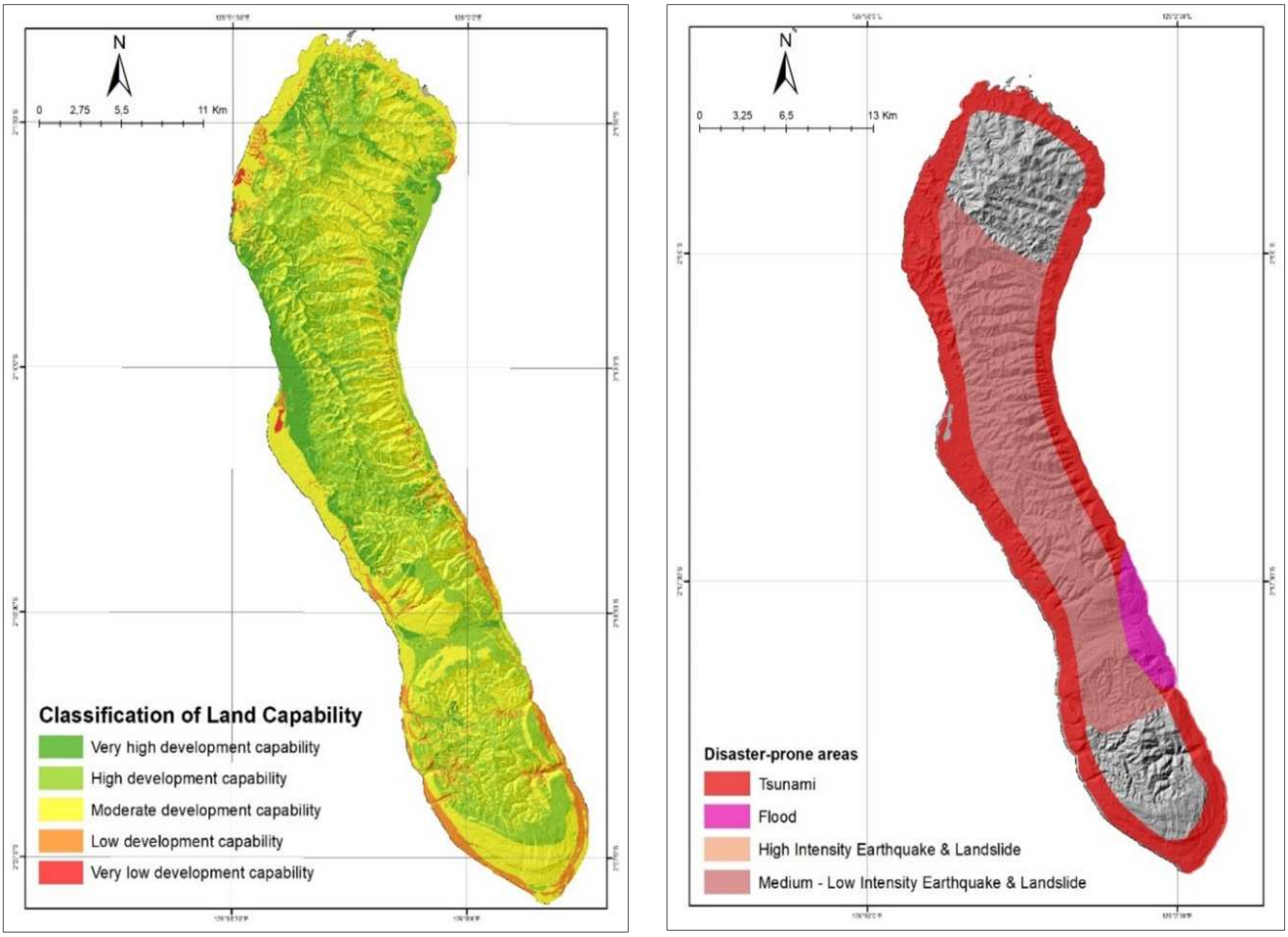

Fig. 2 Map of the land capability of Sulabesi Island

TABLE I
CLASSIFICATION OF LAND CAPABILITY

Land Capability Class	Development Criteria
Class A	Very low development capability
Class B	Low development capability
Class C	Moderate development capability
Class D	High development capability
Class E	Very high development capability

Source: Regulation of Minister of Public Works No. 20/PRT/M/2007

Built-up land was all types of land use whose land has undergone development or pavement, while vegetation here was all types of land that were still green or had not yet experienced development.

C. Data Analysis

The analysis process was carried out in several phases: analysis of land cover changes within 20 years, analysis of land cover distribution with land capability, analysis of disaster risk with land capability, and mapping of development directions based on previous analysis. There were five classes for the land capability data obtained, as shown in Table 1. Overall, the analysis employed a Geography Information System (GIS) with ArcGIS 10.3 software.

Specifically, the analysis phases were as follows: first, the analysis of land cover changes was carried out by classifying the Landsat image maps obtained in a guided manner up to the distribution of land cover type classifications from 2000, 2010, and 2020. After the analysis result of land cover changes was obtained, it was then overlapped with the land capability map to determine the distribution of built-up land in the land capability class. Furthermore, a suitability analysis was undertaken between the land capability and the risk of natural disasters. This analysis aimed to discover high-development capability classes in disaster risk areas. Finally, mapping for the direction of island development by looking at the overlay results between land capability with disaster risk and land cover changes was carried out. The flow chart of analysis is presented in Fig. 3.

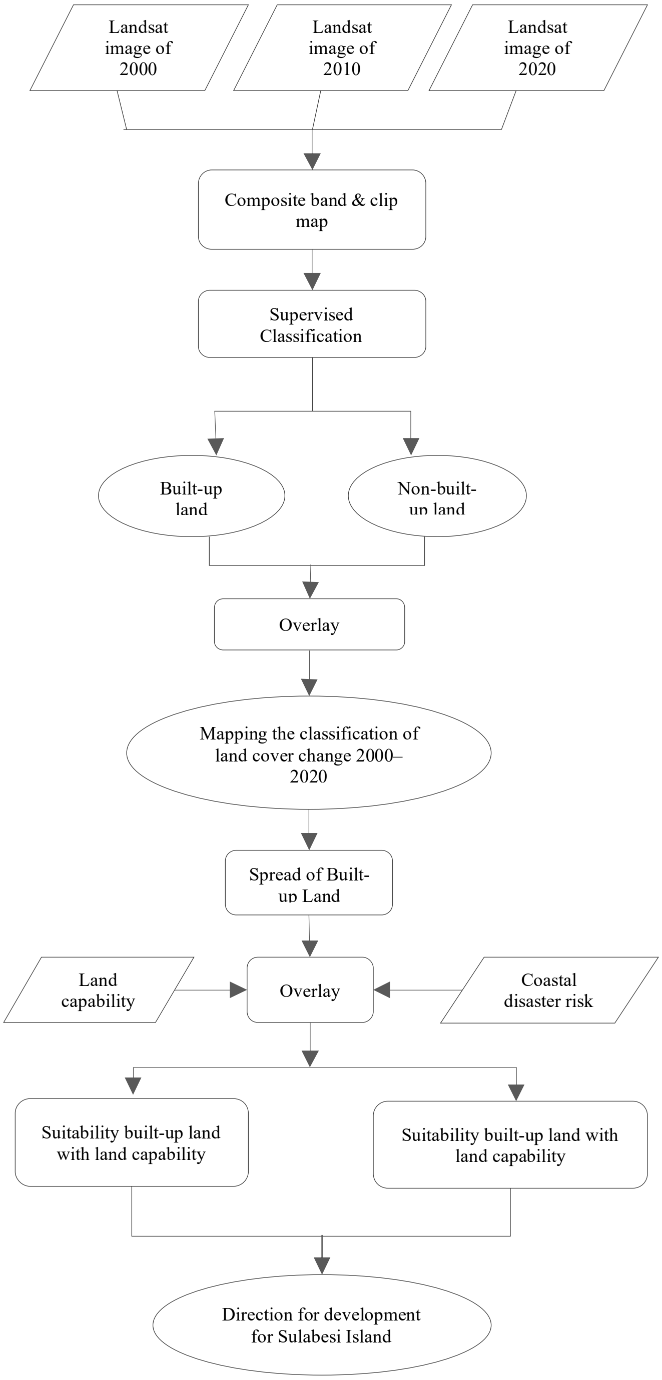

Fig. 3 Flow chart of suitability land for direction developing in Sulabesi Island

III. Results and Discussion

A. Changes in Land Cover and Distribution in Land Capability Class

The result of the analysis of changes in land cover in Sulabesi Island over the last 20 years using Landsat Satellite Imagery indicate that there is an increase in built-up land in the coastal area of Sulabesi Island (Fig. 4). The total built-up land in 2000 was 823.877 Ha, and the non-built-up land was 52604.1 Ha. Then in 2010, the built-up land increased to 1133.84 Ha, and the non-built-up land decreased to 51322.3 Ha. These changes continued to occur until 2020, in which the area of built-up lands increased to 1383.5 Ha, and the remaining non-built-up lands were 51136.1 Ha.

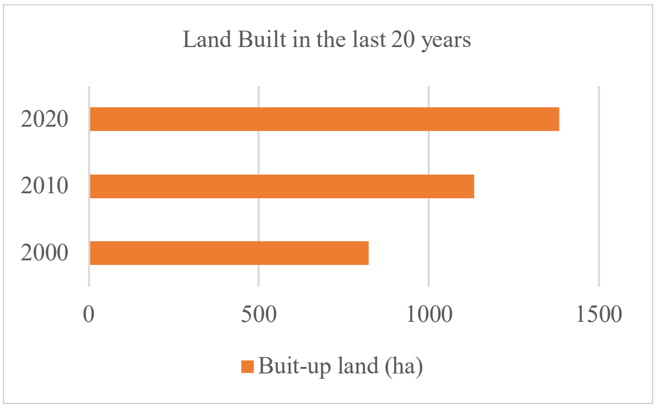

Fig. 4 Increase in built-up land on Sulabesi Island within a period of 2000, 2010 and 2020

This land cover change is caused by the character of Sulabesi Island, which is the center of the economy compared to other islands in the Sula Island. The high growth in land demand is in line with the population growth rate, which also increased by 1.29% in 2019 [33]. In addition, based on the analysis result, most of the increase in built-up land occurred in the northern of the island, such as in Sanana Sub-district and Sanana Utara Sub-district. It is because Sanana Sub-district is the capital city of Sula Island Regency as well as the center of services and the community's economy, while Sanana Utara Sub-district is the center of government. The condition of the two areas causes an increase in development, which then changes land cover due to the need for basic infrastructure and land for a living [34]. However, the change in land cover on Sulabesi Island is not too significant, but this is still important to be considered in future development, especially in seeing the suitability of the growth of built-up land in areas with low land capability.

Changes in land cover that occurred on the Sulabesi Island have a growth center for built-up land that is quite intensive (Fig. 5), especially in Sanana Sub-district. This area has continued to experience land growth for 20 years. Even from 2009 to 2010, there was a beach reclamation along the coastal area of Sanana. The high land use in the area is because the Sanana Sub-district is the center of activities of the Sula Island, such as the center for trade and services, transportation, and education. As stipulated in the Regional Spatial Planning of Sula Island Regency 2011-2031, Sanana Sub-district is designated as the center of regional activities.

After knowing the change in land cover on Sulabesi Island, an analysis of the overlap of the existing land cover in 2020 with the land capability is carried out. The analysis shows that the built-up land cover Sulabesi Island is spread out on a low land capability for development. There is built-up land on a very low (class E) and low (class D) land capability with a total of 280.46 Ha (Table 2). In fact, both classes of land capability should be free from development activities because they have a low level of development.

The overlap results reveal the discrepancy in the current development of Sulabesi Island because it is located in an area that should not be designated for development. The calculation result shows that 1203.16 Ha of built-up land is spread over land with a low (class B) and a very low (class A) development capability (Fig. 6). In fact, it is important to pay attention to the direction of future development in Sulabesi Island. Built-up lands must be located in areas with very high (class E) and high (class D) land capability. This can make the island more sustainable, especially in terms of land use for housing and other activities.

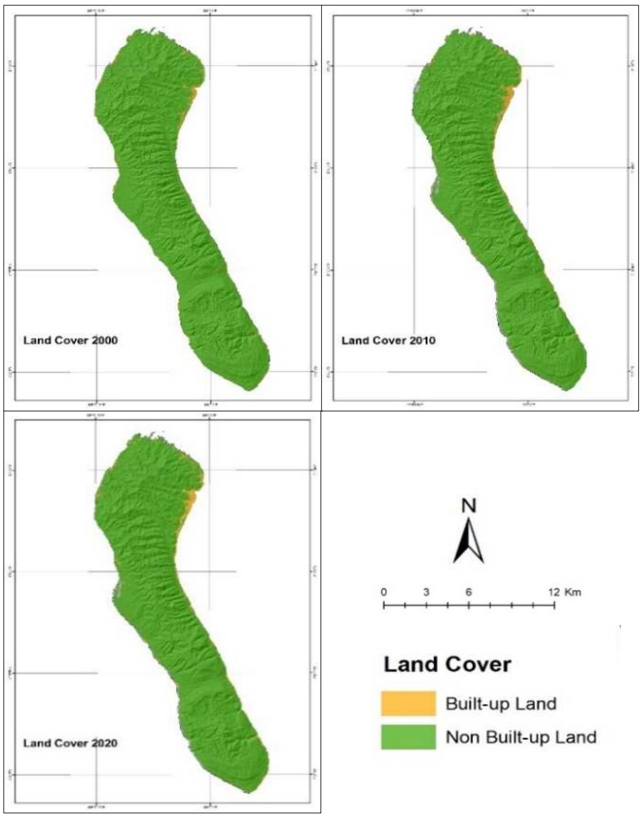

Fig. 5 Map of land cover change on Sulabesi Island in 20 years

The land-use of small islands that pay attention to land capabilities can avoid the risk of natural disasters, including increasing land productivity [21]. As an area with limited land area, there should be a concern about land use as a place to live. In small islands, settlements become very vulnerable areas, both physically, socio-economically, and from disasters [35]–[37]. In general, the coastal area in small islands, especially in developing countries, provide diversity in ecosystem services and are also highly vulnerable to increasing pressure from urbanization and the activities of the people therein [38]. Therefore, developing the use of built-up land Sulabesi Island that pays attention to the land capability can be a mitigation effort, especially since there is an increase in settlements in Sulabesi Island.

B. The suitability of natural disaster risk with land capability

The overlap technique can determine the suitability of natural disaster risk with land capability class. Based on the result of the analysis, the very high land capability class (class E) is included in disaster-prone areas, like tsunamis, earthquakes, and landslides. Also, the high land capability class (class D) is also included in the disaster-prone area, such as flooding (Fig. 6). These results indicate that in the future development of Sulabesi Island, apart from looking at the land capability, it is also necessary to pay attention to disaster-prone areas.

TABLE II
LAND COVER AREA ON LAND CAPABILITY

Land Capability Class	Land area (Ha)	
	Not Built-up Land	Built-up Land
Class A	803,76	22,70
Class B	12700,9	257,75
Class C	39666,6	922,69
Class D	32,36	15,67
Class E	123,65	97,69
Total	**53327,28**	**1316,531**

Thus, the land capability is not the only benchmark in the development plan Sulabesi Island. In addition, there is a moderate development capability class (class C) spread out in non-disaster-prone areas, so this type of land capability can be directed to become a development area for residential areas and quite dense activities. Overall, the suitability of natural disaster risk with land capability and direction of development is presented in Table 3.

Based on the result of the analysis, it can be concluded that it is important to take into account disaster risk in the development of Sulabesi Island, especially for residential areas. This is because the land capability class designated for development has vulnerability to disasters, as in the land capability class D and E, which are designated for development activities, it turns out to have a vulnerability to tsunami disasters. Therefore, in its development, it must pay attention to tsunami disaster mitigation, such as providing space on coastal borders, evacuation routes, and maintaining natural coastal forts, like mangroves.

However, various land functions on the coast are diverse, so it is not uncommon for land conversion to occur on the beach [2]. Uncontrolled land use can also increase disaster risk for small islands [39]. It leads to the degradation of fragile coastal ecosystems [40]. Coastal ecosystems have an essential role in reducing the risk of the impact of coastal disasters [41]. Strengthening coastal ecosystems can mitigate the effects of natural disasters they face.

As a small island, vulnerability to natural disasters is very high and is exacerbated by climate change conditions [42]. This threatens global sustainability, especially in coastal rural communities [43]. Disasters include floods, erosion, drought, storms, and sea-level rise caused by climate change faced by small islands [39], [44]. Therefore, it is essential to increase the island's physical and social resilience. Resilience on small islands can be a measure to reduce hazards and ensure rapid recovery during and after disasters, especially in promising to mitigate disaster risk [45], [46].

Concerning the disaster risks faced and the land capacity of the island of Sulabesi, it can be an effort to achieve the physical resilience of the island. Resilience is seen as a desirable quality, and coastal management policies and practices are increasingly maximizing it [47]. In addition, it can carry out by understanding the impact of climate change, especially sea-level rise, with the type of land use on the coast [48]. Thus, in future development, Sulabesi Island must maintain the current coastal ecosystem, especially in areas with very high land capabilities for growth.

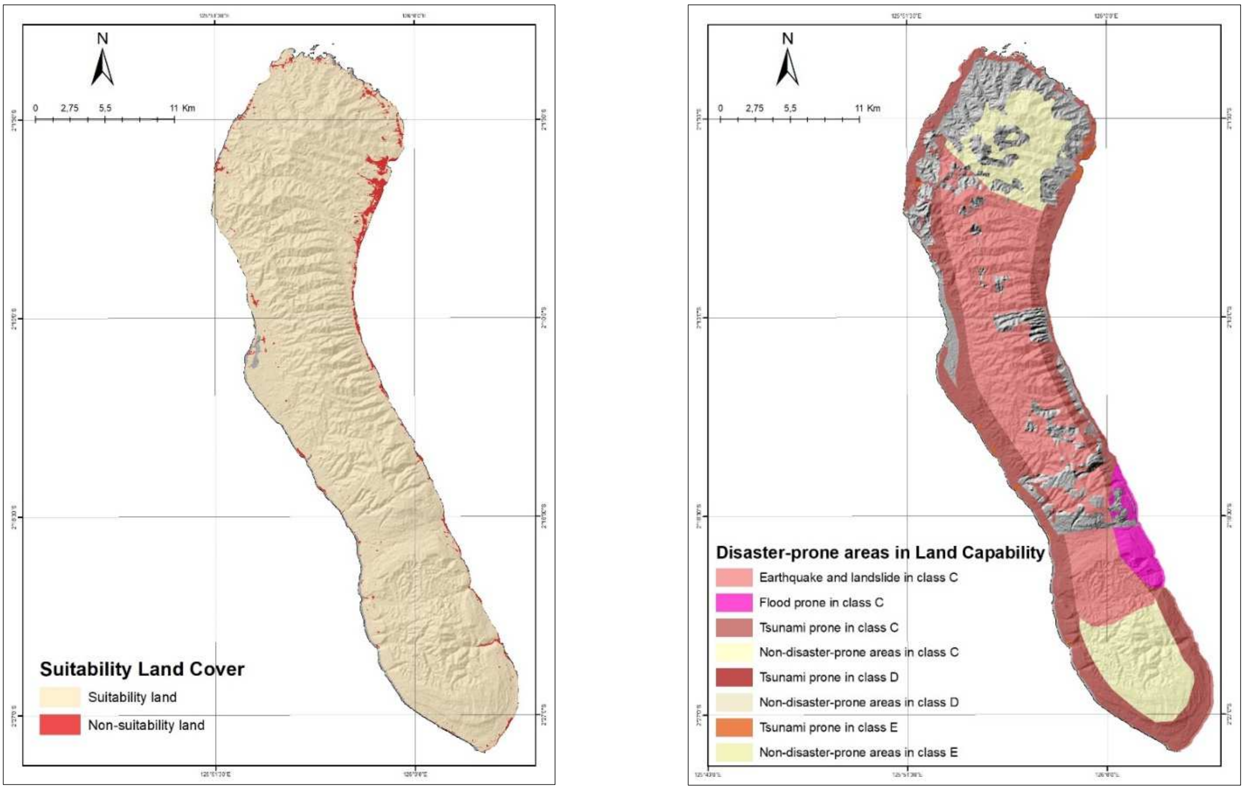

Fig. 6 Map of suitability of land capability with; (a) land cover and (b) disaster-prone areas

TABLE III
DISASTER-PRONE AREAS IN LAND CAPABILITY

Land Capability Class	Disaster Prone Type	Land area (Ha)	Development direction
Class A	Earthquake and landslide	21,41	Cannot do development
	Tsunami	767,98	
	Not vulnerable	75,46	
Class B	Flood	342,96	Cannot do development
	Earthquake and landslide	3360,91	
	Not vulnerable	4179,45	
Class C	Flood	1608,38	Conditional development can be carried out
	Earthquake and landslide	16875,2	
	Tsunami	13590,4	
	Not vulnerable	9240,48	
Class D	Tsunami	48,27	Conditional development can be carried out
Class E	Tsunami	221,71	Conditional development can be carried out

C. Development Direction in Sulabesi Island

Land capability can be one of the benchmarks in planning the future development of Sulabesi Island. This is because, as a small island, land resources are very limited, so it is important to determine the direction of development *under* land capability. Classification of land capability can support the sustainability of land use as well as efforts to reduce the negative impact of human activities on natural ecosystems [20], [25], [49]. Thus, in the development direction *of* Sulabesi Island, it is necessary to look at the distribution of built-up land cover at very low land capability and consider natural disaster risk factors.

Based on the result of the analysis, there are still built-up lands in areas with very low land capability, so it needs to be a concern of the local government. The arrangement of built-up areas in the future may no longer be included in the classification of land capability for low development (class A and B). Land conditions with low land capability should be more designated for non-built-up land cover. Besides, the development of Sulabesi Island should also be directed at high and very high land capability classes (class D and E), thereby increasing its sustainability, both for housing, trade, and services, soon. Restrictions on land cover change activities must be carried out because this can affect land quality and community activities [50]. It can also affect the commodities of small island communities [51].

Development on the island of Sulabesi should be more directed at high and very high land capability classes (classes D and E), thereby increasing its sustainability for housing, trade and services, and so on. Therefore, it is crucial to plan for the island of Sulabesi, especially related to land use, according to the availability and capabilities of the land. Sustainable land management must combine geographical, biophysical, economic, social, and political conditions [52]. In general, coastal communities depend on coastal resources, so if land management is not carried out properly, it can impact community food security [53], [54]. Even small islands are vulnerable to food insecurity caused by their geographical conditions [55]–[58].

Furthermore, from the aspect of the disaster, as a small island vulnerable to natural disasters, the development of Sulabesi Island must pay attention to disaster-prone areas. Based on the analysis results, development on Sulabesi Island can be carried out on class C land capabilities because only that class is not included in the disaster risk area. However, on high land capacity, development can also be carried out by considering the type of disaster and increasing efforts to reduce the impact of disasters.

Land arrangements built with the condition of island land capability and disaster risk can be interpreted as an effort to mitigate natural disasters and increase the resilience of the island of Sulabesi as a small island. This effort is categorized as passive mitigation by optimizing appropriate land use planning [59]; however, active mitigation can also be carried out or referred to as physical ease [60]. The condition of the island of Sulabesi has a risk of disasters such as earthquakes, floods, landslides, and tsunamis. However, this risk continues to increase with climate change. This phenomenon challenges people on small islands [61], [62]. Threats to water scarcity and food vulnerability are impacts faced by small island communities due to climate change; moreover, the high dependence on the mainland has exacerbated the situation [56], [63], [64]. Maintaining the island's coastal ecosystems, such as mangroves, can mitigate the impacts of climate change; besides, it can provide services to the community's economy [65], [66].

Proper land use is the key to the future development of the island of Sulabesi. The arrangement of built-up lands according to their capabilities and the risk of disaster must be a concern in the planning and spatial planning policies of the island of Sulabesi. In addition, land cover change activities must be controlled, especially in vital coastal areas such as mangrove forests, to reduce coastal disaster risk.

IV. CONCLUSION

Sulabesi Island has a land capability condition dominated by moderate development capacity (class C) of 48%, but high land capability (class E) is only 10%; this island also faces the threat of disasters such as floods, landslides, and tsunamis. With these conditions, future development must be integrated with land capabilities and the threat of disasters it faces as a small island. In the last 20 years, the built-up land on Sulabesi Island has increased, from 823,877 ha in 2000 to 51322,3 ha. Even built-up land cover has spread to areas with deficient land development capability (class A), even though these areas should be free from development. The areas with high development capabilities (class E and class D) are included in high disaster-risk areas. Class E areas are prone to tsunamis, earthquakes, and landslides; class D dams are included in tsunami-prone areas. With these conditions, on the island of Sulabesi, it is crucial to pay attention to land capabilities and look at disaster risk indicators. Even though the land capacity is high in development, it is still at disaster risk and needs to be a concern in future planning development. The area that can be built as a growth center for Sulabesi Island in the future is included in class C because it has the moderate land capability and is not a disaster-prone area.

The focus of this research is still limited to physical adjustments because it only looks at changes in land cover and disaster risk with land capabilities. A more specific analysis can be carried out for further research regarding land use for settlements. In addition, the disaster aspect in this study is still about disasters in hinterland areas due to limited data, so further research can more specifically relate to coastal erosion and sea-level rise, which continue to threaten small islands.

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