Research Article

Application of Geographic Information Systems and Analytical Hierarchy Process for Coastal Land Use in Palu

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Abstract.
Palu City, a coastal city in Eastern Indonesia, holds significant potential for development due to its abundant natural resources. However, the 2018 earthquake and tsunami caused extensive damage to both land and marine environments, necessitating a strategic approach to environmental restoration and economic recovery. This study aims to guide coastal land use in Palu City by applying the Analytical Hierarchy Process (AHP) technique and Geographic Information System (GIS) technologies. Remote sensing and GIS tools are employed to analyze land cover and process spatial attribute data. The methodology includes field surveys, AHP analysis, and spatial integration using GIS. The results show that land use planning in Palu's coastal areas should prioritize biophysical, economic, and social considerations. Key recommended uses include residential development, tourism, and trade zones. The study also highlights the importance of incorporating disaster vulnerability data into the planning process, given the city's susceptibility to natural hazards. Careful mapping and land designation, informed by past disaster impacts, are essential to ensure sustainable resilient coastal development in Palu.

Keywords: AHP, GIS, land use, social-economic

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1. Introduction

Coastal regions facilitate activities such as fishing, aquaculture, tourism, and transportation. These activities are vital for local economies and provide livelihoods for millions of people (1)–(4). (5) mentions coastal areas in Indonesia have certain characteristics that are spread unevenly. It is influenced by geological conditions, genesis (formation process), geomorphological processes, vegetation, and human activities in coastal areas. In Indonesia, some cities and towns are located in the Bay Area, so the Gulf region is a gateway and a transportation hub for the mobility of people and goods (6). Thus, Palu City, which is geographically located in the Bay, has the potential to be developed into a strategic area to support the development of Palu City. Central Sulawesi Provincial

Government (Government of Palu and Donggala regency government) to develop a Palu Bay region, namely: construction of the Palu Bay Growth Center, waterfront city, and special economic area (7). In its implementation, it creates conflicts in the community, especially the existence of reclamation. Also, the post-earthquake on September 28, 2018, which was followed by the tsunami and liquefaction, destroyed vital objects, public facilities, and residential areas.

Remote Sensing and Geographical Information System (GIS) provides computer-based technology to facilitate monitoring of land change as well as improve decision-making for future land management (8), (9). The combination of AHP and GIS methods is a powerful combination to be applied for land use suitability analysis [10], [11]. Land use suitability assessment is a key determinant in any planning and decision-making process in cities and suburbs. The assessment of conformity is carried out through the AHP model using a set of criteria involving geophysical and socio-economic variables (12)–(14).

(11) stated that applying GIS can overcome the problem of inconsistency in expert opinion when trying to assess and assign relative importance to each criterion. Moreover, data and information on biophysical and coastal land as a basis for evaluating socio-economic potential. Thus the integration of AHP and GIS is one of the approaches used for planning, and regional management as well as for accelerating development in terms of exploiting potential natural resources in coastal areas.

The AHP-GIS combination has been carried out by several previous researchers related to the direction of land use as well as the development of coastal areas (11), (15)–(17). Coastal studies are needed to support regional development that not only increases economic growth and welfare but also maintains a balanced carrying capacity and environmental quality towards sustainable development. This research aims to apply AHP and GIS techniques for the direction of coastal land use in the city of Palu.

2. Research Methodology

The research process for land use directions using AHP and GIS is shown in **Figure 1.**

The location of the study was carried out on the coast of Palu City, located between 0°, 36”-0°,56” latitude, and 119°,45”-121°,1” east longitude, with an area of 395.06 km2 located in the plains of the Palu valley and Palu bay. There are 6 districts which are located in coastal areas as in **Figure 2.**

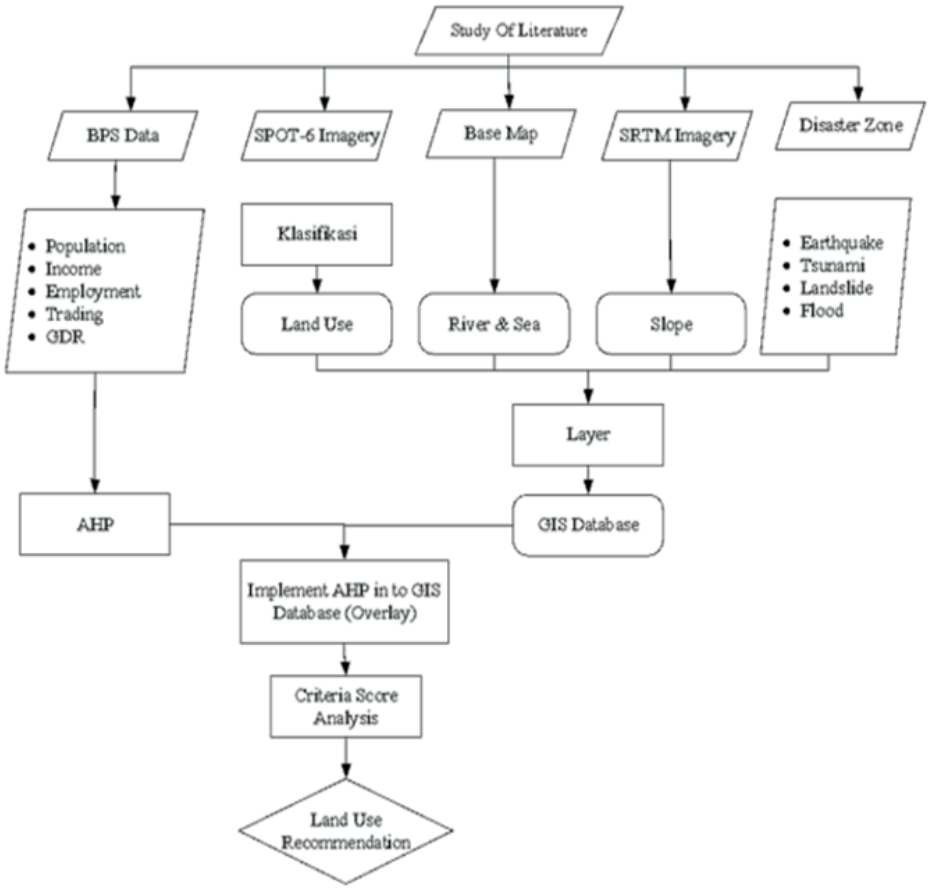

Figure 1: Flowchart of the research stage (source: research team).

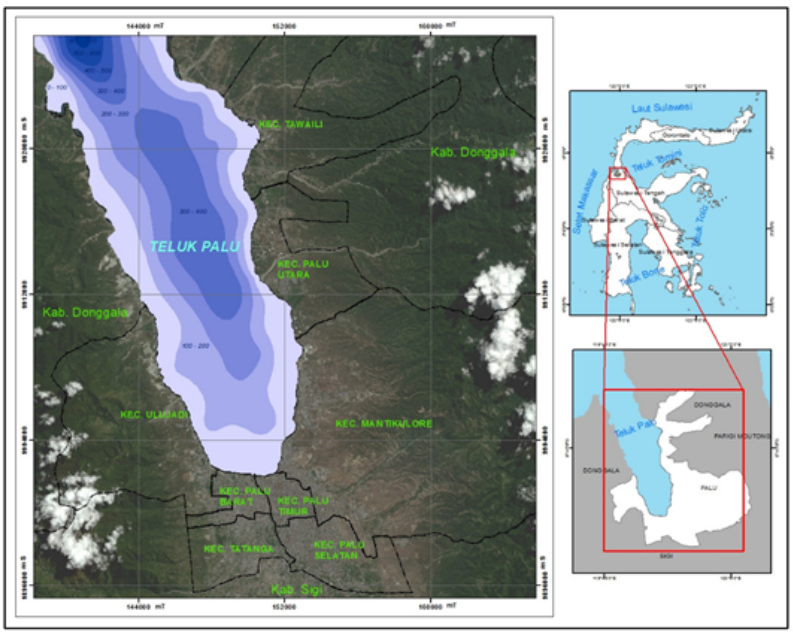

Figure 2: Research Location.

AHP is used as a tool to assist in the development of this strategy requires the preparation of a hierarchy in the process. The activity begins with the stage of the decision-making problem identification and definition of the problem. Followed by the design and modelling of various alternative solutions, and finally the establishment of solutions that will be implemented (arranged in a hierarchy) (11). Hierarchy is the beginning of objectives, criteria, sub-criteria, and alternatives. AHP technique to assess the important criteria that are converted to weighted criteria (wi). The scores for each criterion (xi) on each land mapping unit are then determined. A weighted linear combination of wi and xi gives a suitability index for each land mapping unit—the following AHP diagram in **Figure 3.**

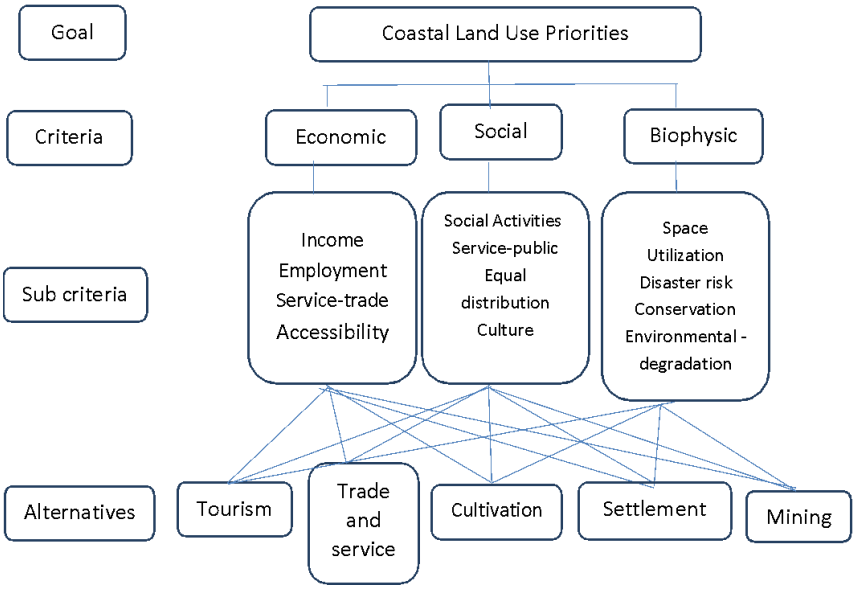

Figure 3: The land use hierarchy uses AHP.

Structured questionnaire to obtain data and information on the socio-economic conditions, local knowledge, institutional development of tourism, coastal infrastructure, phenomena of degradation, protected areas, management and utilization of coastal areas of environmental space.

GIS is a set of processing systems capable of data storage, spatial manipulation, analysis, and representation, conducted in GIS is used to generate new information. In this case, including the base map, topographic, land cover, and other thematic. GIS is a very useful technique for mapping, analysis, and modelling for a very good ability to store, analyze, and display spatially distributed data according to user-defined

specifications (18). Fieldwork is required to check the accuracy of interpretation (classification), sampling, measurement, and data collection related to the research objectives. Fieldwork carried out on the sample points has been determined. Questionnaires are instruments in data collection in the field.

In this process, SPOT-6 imagery, SRTM imagery, and Earth Map as data sources to produce data on slopes, roads, rivers/sea, and land use types. Socio-economic data were obtained from the Central Bureau of Statistics (BPS) of Palu City in 2018. Furthermore, the Palu City Regional Spatial Plan (RTRW) and Disaster Hazard Map are part of the screening of land use requirements. Each land use requirement can be arranged in one map layer in GIS. A land mapping unit is an area that has the same land use characteristics. Evaluation of directions for sustainable land use needs to evaluate not only natural physical conditions but also socio-economic and environmental conditions. To determine which criteria (and to what degree or weight) influence the direction of land use for each land use type, experts are consulted to provide an assessment of the importance of the criteria.

The determination of the criteria weight for each stakeholder is carried out using a pairwise comparative analysis of the criteria on the Expert Choice. After that, look at the inconsistency value (IC). Weighted priority data are implemented in GIS to produce land use direction maps. This process is carried out in GIS through a composite map that has two components. The spatial component is used to indicate the location and shape of the land mapping unit. The attribute component, represented as a table, is used to input and store the criteria score. The GIS function is used to perform calculations based on the above equation as well as the criteria scores and weights. The calculated conformity index is stored in one column. Integrating the spatial component and the suitability index produces a continuous suitability map.

3. Research Result and Discussion

3.1. Tabel

Land cover data generated from the image extraction SPOT6 was subsequently classified to produce a layer of land use. The same thing for the slope layer obtained from SRTM imagery, while the appearance of the earth map information is obtained by the waters and administration. A disaster vulnerability map is also part of the layer that is taken into consideration. The results are as in **Figure 4.**

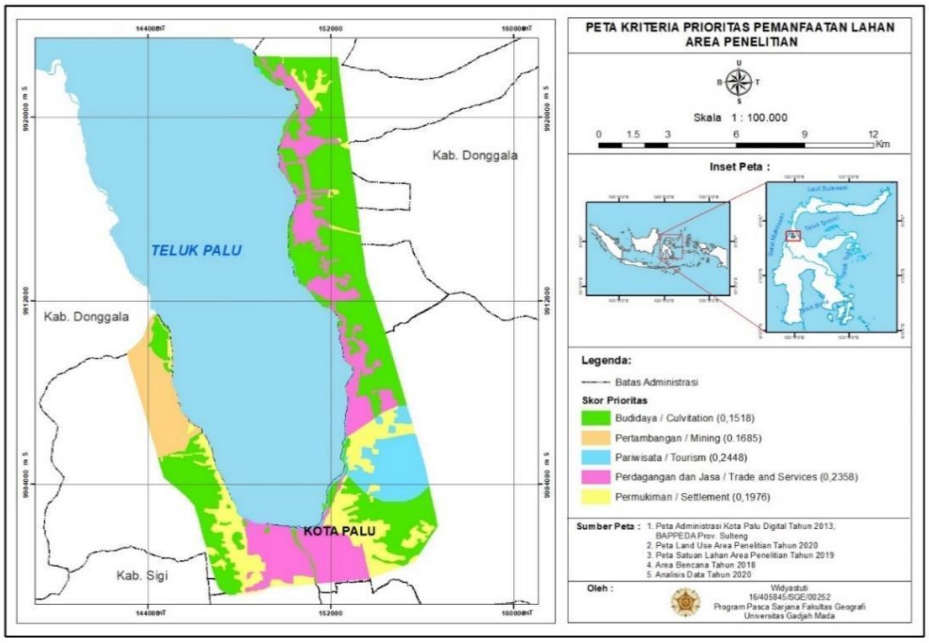

Figure 4: Land utilization priority.

Based on the results of using Expert Choice AHP processing, utilization of land in the city of Palu has to pay attention to three aspects: biophysical, economic, and social. Alternative strategies and priorities of each aspect of perception are sorted by a combination of five stakeholders. The results are presented in **Table 1**.

TABLE 1: Data Tingkat Pendidikan Penduduk Desa X.

Goal	**Land use**			**Total weight**
Criteria	**W1**	**Sub criteria**	**W2**	**Wi = w1 x w2**
Economy	0,307	Income	0,289	0,089
		Employment	0,165	0,05
		Service-trade	0,246	0,075
		Accessibility	0,298	0,091
Social	0,293	Social activities	0,234	0,068
		Service-public	0,347	0,102
		Equal distribution	0,174	0,051
		Culture	0,255	0,075
Biophysics	0,4	Space utilization	0,166	0,066
		Disaster risk	0,27	0,108
		Conservation	0,325	0,13
		Environment degradation	0,237	0,095

Source: AHP data analysis, 2020

Analysis of the combined opinion of respondents on land-use priorities in the Palu Bay area put on each criterion achievement of objectives. Furthermore, the calculation of scores and weights is very important in the processing of SIG-AHP (19). It is obtained from the combined opinion of all respondents (government, university, and community. Terms AHP analysis one inconsistency: if the ratio is more significant than 0.1 (Figure 5), the revised opinion, but if the ratio of inconsistency is very significant, then the respondent is removed.

Figure 5: Priority for land-use direction (source: analysis data, 2020).

AHP analysis using Expert Choice helps in data filling and value execution. Whether it's to see individual or pair comparisons. In the study, it was found that respondents with an odd number had a better chance of getting a better result than an even number. The AHP analysis results are strongly influenced by the perceptions of the respondents, the more objective the respondents are in expressing their opinions, the closer the AHP results will be to the truth. However, the objectivity of the respondents is challenging to measure because, in AHP, there is no level of significance. The choice of respondents can also affect the results of AHP. In this study, a sample of 15 respondents was used, but 5 experts were used in the analysis. This can be seen from the assessment of the questionnaire with inconsistencies below or equal to 0.1. In several reviews of existing research, in combining AHP and GIS, there are different criteria with various considerations, so the results of this study are alternative.

AHP is widely used in land use suitability assessments due to its ability to handle various criteria and combine qualitative and quantitative data. A pair comparison is done to determine the relative weight of each criterion based on its importance. Integrating weighted criteria into Geographic Information Systems (GIS) to generate conformance maps (12), (20)–(23).

4. Conclusion

According to the joint perception of stakeholders based on the processed AHP biophysical a top priority is to improve post-disaster conditions in Palu. Namely handling priority on housing, tourism, services and trade as a driver of local economic improvement.

GIS helps in combining quantitative data in spatial attributes, making it easier to collate spatial information that can be concentrated input in the management plan.

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