BIODIVERSITAS
Volume 23, Number 7, July 2022
Pages: 3619-3629

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d230739

Spatial model of forest area designation and function based on multi-criteria in dry land and mangrove forest ecosystems, Central Sulawesi, Indonesia

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Manuscript received: 22 May 2022. Revision accepted: 26 June 2022.

Abstract. *Akhbar, Naharuddin, Arianingsih I, Misrah, Akhbar RK. 2022. Spatial model of forest area designation and function based on multi-criteria in dry land and mangrove forest ecosystems, Central Sulawesi, Indonesia. Biodiversitas 23: 3619-3629.* Along with the dynamics of rapid social change and the need for land for economic development, land and climate parameters on changes in the designation and function of forest areas, it is time to integrate with socio-economic parameters and government policies while still paying attention to the condition of existing forest vegetation cover. This study aimed to develop a spatial analysis model of changes in the designation and function of forest areas based on multi-criteria in dry land and mangrove forest ecosystems. The research used a descriptive-spatial method with a multi-criteria-based decision-making technique for changes in the designation and function of forest areas. The data analysis utilizes Geographic Information System. The motivation for the proposed forest area change is the target to be achieved in the multi-criteria decision analysis. This research resulted in a spatial analysis approach that integrates scoring techniques and multi-criteria-based decision-making techniques. In Locus BL_010, a change in the function of forest area can be generated, while in Locus TL_003 a decision is made to change the allocation and function of forest area. The achievement of multi-criteria-based spatial analysis on changes in the designation and function of forest areas is quite flexible in decision making because each proposed motivational target will be achieved if it is in accordance with the established criteria and field facts.

Keywords: Forest area, locus, motivation, multi-criteria, spatial

INTRODUCTION

Forest areas in Indonesia are certain determining areas by the Government to maintain the existence as permanent forests into the conservation forest, protection forest and production forest. Any changes to their function and designation are also regulated by the Government. Changes in the function of forest areas are changes in a part or all of forest functions in one or several forest groups into other forest area functions, while changes in the allocation of forest areas are changes in forest areas to non-forest areas.

Changes in the designation and function of forest areas in Indonesia are performed through integrated research activities by the team created by Minister. At the provincial level, the changes to the allocation and function of forest areas are carried out every five years in reviewing the provincial spatial plan that aims to meet the needs of land for residents, public facilities, social facilities and investment interests.

In integrated research, the changes in the allocation and function of forest areas need a comprehensive study that integrates biophysical, climate and socio-economic aspects, as well as investment policies so that the dynamics of development and community aspirations are fulfilled so that the problem of land conflicts can be reduced. The effort to protect the done by optimizing the distribution of functions and benefits sustainably with a minimum area of 30% of the area of a watershed or island with a proportional distribution as stipulated in Forestry Law Number 41 of 1999. Consensus models can be developed to address conflicts between stakeholders in the land use allocation process, while spatial conflict resolution strategies can be developed to help stakeholders and planners consider specific land-use proposals (Zhang et al. 2012).

A comprehensive study of the spatial decision-making process on changes in the allocation and function of forest areas that involve many criteria (multi-criteria), is generally carried out using geographic information systems (GIS) technology. The multi-criteria-based decision-making approach belongs to the category of very complex data usage, but it is widely used in site selection analysis on specific problems. Such conditions require effective models and analytical techniques to handle the complexity and intensity of data in identifying the best alternative. Meanwhile, GIS has spatial analysis capabilities that function to acquire, store, retrieve, manipulate, analyze, and display geographic information that can support decision-making (Zhang et al. 2012; Rikalović et al. 2013; Fataei et al. 2015).

Decision-making is the act of selecting between two or more actions. In the decision-making process, a decision is formulated from several alternatives. In the broader problem-solving process, decision-making involves selecting several possible solutions to a problem, and the decision can be made through an intuitive or reasoned process, or a combination of both. Meanwhile, very rarely can problems be solved with a sequential and linear approach but through a complex process (Andreis 2020). The quality of the decision-making process can be achieved by considering environmental factors, organizational strategy, ethics, empowerment, information and feedback, programs, choices, risk aversion, resources and opportunities (Negulescu and Doval 2014). Furthermore, in the multi-criteria-based decision-making process, there are several terms that need to be understood such as decisions, criteria, factors and constraints, attributes, and multi-attribute decision-making methods. The data-oriented multi-attribute decision-making method requires a choice to be made between alternatives explaining that the object attribute relationship is assumed to be the objective and decision variable (Rikalović et al. 2014).

The integration between GIS and Analytic Hierarchy Process (AHP) introduced by Thomas Saaty using a multi-criteria-based decision-making approach can produce a synergistic effect with the contribution of efficient and quality spatial analysis. Furthermore, it is also expected to solve problems in making complex spatial decisions in site selection. AHP is an effective tool for dealing with complex decision-making processes, it can help decision-makers to set priority decisions (Rikalović et al. 2013; Rikalović et al. 2014).

Multi-criteria decision-making procedures, on the other hand, are frequently employed in a variety of study domains. Analyzing choice problems is made much simpler with AHP. Using these two strategies together is an effective strategy for solving problems. It's common to employ multi-criteria decision-making in situations when there is a high degree of uncertainty and ambiguity. Multi-criteria decision-making necessitates a qualitative review of more than one criterion. Additionally, the AHP technique is commonly employed in the fields of education, industry, and engineering to address multi-criteria problems (Waris et al. 2019; Govindan et al. 2014; Mangla et al. 2012; Bouzon et al. 2016). As a result, AHP has the advantage of making complex problems more manageable, but its nature is highly dependent on experts, making it highly subjective (Widiatmaka et al. 2016).

Geographic information systems (GIS) are increasingly being used in location analysis due to recent advancements in decision-making. According to the results of the study, two methods must be followed: the multi-criteria procedure for attribute data and the multi-object technique for GIS location analysis. To help with decision-making, GIS-based multi-criteria decision analysis, as described by Malczewski and Rinner (2015), brings together various techniques for merging geospatial and preference data.

For the past two decades, multi-criteria decision analysis has been utilized with GIS to study spatial problems. However, the method's complexity prevents those who are not trained from using it (Greene et al. 2011). GIS decision-making uses a prescriptive strategy that is difficult for decision-makers to understand since it involves sophisticated computations (Milutinovi et al. 2021).

Due to the complexity of the previously described multi-criteria-based analysis framework that integrates GIS and AHP, it is necessary to develop a multi-criteria spatial analysis approach in a simpler and easier decision-making framework when making changes to the allocation and function of forest areas accessible to researchers and practitioners alike. This study aimed to develop a spatial analysis model of changes in the designation and function of forest areas based on multi-criteria in dry land and mangrove forest ecosystems. A multi-criteria spatial science and technology that is accessible in the identification and decision-making process on changes in the designation and function of forest areas, as well as stimulating new and innovative research ideas in the forestry industry, is predicted to benefit from this research.

MATERIALS AND METHODS

Study area

The study was conducted in a conversion production forest area with dryland forest ecosystem type in the Pogogul Forest Management Unit area of Buol District, and in a Protection Forest area with a mangrove forest ecosystem in the Gunung Dako Forest Management Unit area, Tolitoli District, Central Sulawesi Province, Indonesia. The research was conducted from May to November 2021.

This research used the descriptive-spatial method. In the application, the forest area was analyzed for its condition using maps and satellite imagery, conducting studies and analyses of each proposed location (Locus) of forest areas based on the motivation of the proposal. Locus is the location of a forest area proposed by the District Governments to the Provincial Government to analyze the feasibility of the change according to the motivation of the proposal, either for designation and function change of forest area. In this study, two Locus were used, namely Locus BL_010 (forest area in Buol District) and Locus TL_003 (forest area in Tolitoli District). In Figure 1, a map of the research location and the Locus is presented.

Research procedures

The research process started with the preparation of work materials and equipment, coordination with the Forest Management Unit, preparation of the Locus map, team mobilization-demobilization, data collection (site surveys and interviews), processing and analyzing data/maps, compiling reports and map layout results of the analysis of changes in the designation and function of forest areas. Direct observations at the location were carried out at each Locus using work equipment such as a base map (map of Indonesia's earth), thematic maps (map of forest area, map of slope class, map of soil type, map of regional infrastructure, map of government administration, map of watershed), and satellite imagery (Landsat 8 and SPOT 7 recording 2018-2020), Global Positioning System (GPS), drones, digital cameras, tally sheets, and writing equipment. Interviews were conducted directly with Forest Management Unit officials and smallholders at the location by asking about their motivations/hopes for the proposed Locus change in the designation and function of the forest area. In the spatial data analysis, Arc-GIS software version 10.4.1 was used.

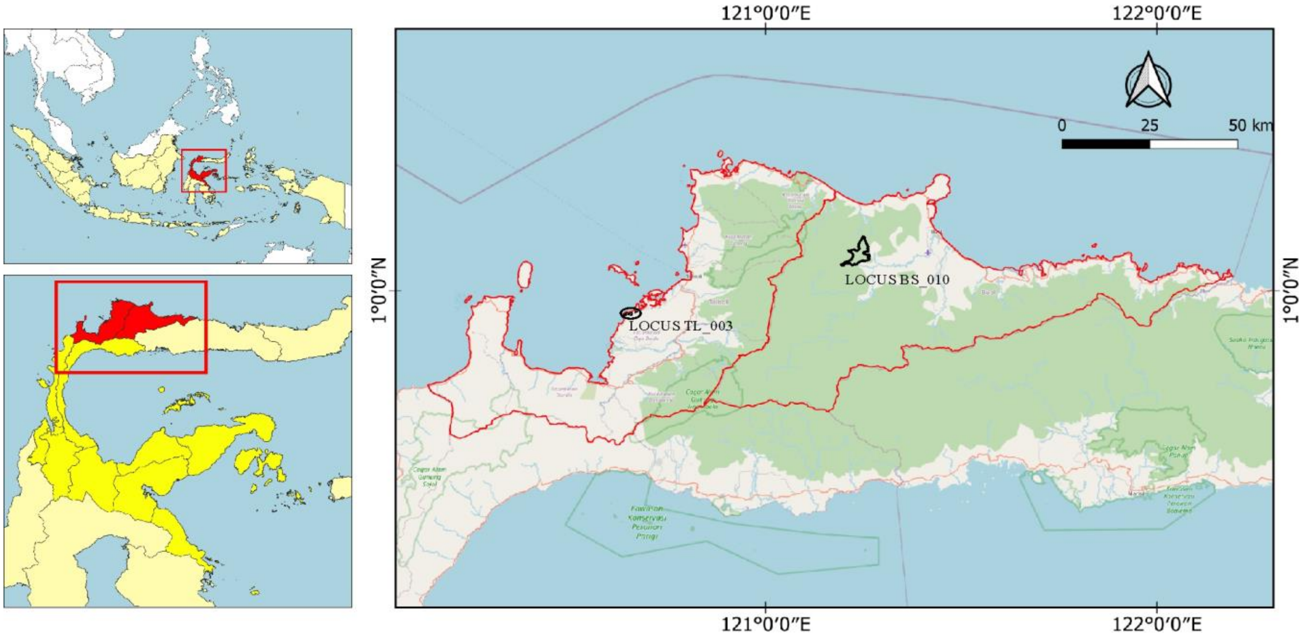

Figure 1. Research location map in Buol District (BL_010) and Tolitoli District (TL_003), Central Sulawesi Province, Indonesia

Multi-criteria-based spatial analysis on forest area designation and function change using spatial and non-spatial data based on general criteria and specific criteria. Multi-criteria spatial analysis consisted of: Attribute data analysis (tabular); layer overlap (spatial data query); distance analysis; network analysis; and non-parametric techniques. Decision analysis based on multi-criteria, problems were classified into main components that include: multi-object decision analysis and multi-attribute analysis; group and individual problem solving; decision certainty and uncertainty. The decision-making is classified into evaluation criteria into attributes and objectives of changes in the designation and function of forest areas.

Determining the change in the designation and function of forest areas is a spatial problem, the decisions have chosen generally involve a large number of feasible alternatives. In the process there were two stages, namely the screening stage and the evaluation/assessment stage, so as to reduce the time required, improve the efficiency and quality of the decision-making process (Rikalović et al. 2014). Furthermore, based on the results of the Locus filtering, an evaluation of the Locus was carried out. The screening of Locus was included in the general criteria while site evaluation was included in the specific criteria.

The general criteria consist of: (i) the locus is not indicated to have legal problems; (ii) the permit of the borrow-to-use forest area has paid non-tax state revenue (if there is a permit); (iii) the location of the research team findings outside the locus is directed at the interests of the community; (iv) accommodate national strategic interests. Specific criteria with existing conditions consist of: (i) settlements; (ii) public facilities and social facilities; (iii) arable land (food crop farming, gardens, ponds, etc.); (iv) regional investment development in the form of industrial/mining/plantation/tourism areas; (v) transmigration; (vi) green open space. Referring to the specific criteria, the standard criteria for the decision-making process on changes to the designation and function of forest areas are shown in Table 1.

Data analysis

The forest area scoring value in Table 1 is obtained from the results of multiplying and adding land and climate parameters with the formula:

$$\sum SV_{ff} = (SV_{sc} + SV_{st} + SV_{ri}) \qquad (1)$$

Where:

SVsc = 20 x weight value for each slope class (5 classes). SVst = weight value 15 x each class of soil type (5 classes) (ii); SVri = weight value (10) x each class of rain intensity (5 classes). SVff = the sum of the forest function scores (ii) ; Slope class: 1 = flat (slope <8%); 2 = sloping (slope 8-<15%); 3 = rather steep (slope 15-<25%); 4 = steep (slope 25-<45%); 5 = very steep (slope 45%) (iii) ; Soil type class: 1 = not sensitive to erosion (alluvial, glei, planosol, gray hydromof); 2 = slightly erosion sensitive (latosol); 3 = less sensitive to erosion (brown forest soil, non-calsic brown, mediteran); 4 = sensitive to erosion (andosol, lateritic, grumusol, podsol, podsolic); 5 = very sensitive to erosion (regosol, litosol, organosol, renzina) (iv) ; Rain intensity class: 1 = very low (1-13.6 mm/rainy day); 2 = low (13.6-20.7 mm/rainy day); 3 = moderate (20.7-27.7 mm/rainy day); 4 = height (27.7-34.8 mm/rainy day); 5 = very high (≥34.8 mm/rainy day) (v). (Source: Government Regulation number 104 in 2015).

The motivation for the proposed forest area change is the target in the multi-criteria decision analysis. At the final stage of the study, a qualitative analysis of the achievement of the decision-making process was carried out on each motivation for the proposed Locus changes to the designation and function of forest areas. The suitability and incompatibility of the motivation of the proposed Locus with the target of achieving changes in the designation and function of the forest area that was evaluated starting from the screening stage of the Locus, scoring of the area land to evaluation/assessment of the decision on the change in the designation and function of the forest area by considering any limiting factors encountered during the process decision-making. At the end of the analysis, a decision will be made in the form of decision-making rules for each Locus of forest area change.

Table 1. The parameters of special criteria in the decision-making process on the designation and function of forest areas change

Exitsing condition	Status/function	Conditions for the proposed location (locus)		Recommendation
Settlement	Conservation forest/ Protection forest / limited production forest/ permanent production forest/ Conversion production forest	No negative impact on the existence of biological and physical natural resources as well as the socio-economic environment of the surrounding community Not a disaster zone (flood, landslide, fault, liquefaction)		Other Landuse (Non-forest Area)
Public and Social Facilities		There are highways, village roads, environmental roads, recreation and sports parks, cemeteries, waste water and garbage disposal facilities, drainage. There are educational facilities, worship facilities, health facilities, socio-cultural facilities, government facilities		Other Landuse (Non-forest Area)
Community arable land	Conservation forest/ Protectiedforest/ limited production forest/ permanent production forest	Authorization with good intention No dispute		Social forestry / Fixed forest area according to its function
	Protected forest/ limited production forest/ permanent production forest/ Conversion production forest	Have a Certificate of Land Tenure from the Village Head known to the Subdistrict head or that land tenure has been long/frome generation to generation Land is not for sale No dispute Meet the the limit of ownership area.		Other Landuse (Non-forest Area)
Regional Investment Development in Industrial Estates	Limited production forest/permanent production forest/ Conversion production forest	It is contained in the draft regional regulation on regional spatial planning Provincial Government policy support (will be pushed into a national Strategic Area) Approved Master Plan by the Regent Have environmental study No dispute.		Other Landuse (Non-forest Area)
Regional Investment Development in Plantations		There is cultivation right Have environmental study No dispute.		Other Landuse (Non-forest Area)
Investment Development in Mining	Conservation forest	Mining Business Permit or Contract of Work and has an environmental study Settlement of gold mining conflicts without permission (unscrupulous miners) Have environmental study No dispute	Area scoring > 174 and or has a field slope class of 45% and or an altitude of 2,000 meters above sea level.	Degradation of forest area function to Protection Forest : Closed mining permit
	Protection forest	No endemic and rare flora species (Conservation forest).	Area scoring 125- 174	
	Limited production forest/permanent production forest/ Conversion production forest	Not the protection of life support systems to regulate water systems, prevent flooding, control erosion, prevent sea water intrusion, and maintain soil fertility (For Protection Forests). Not productive in producing forest products (for Limited Production Forest/Permanent Production Forest/Conversion Production Forest).	Area Scoring <125	Degradation of forest area function to Permanent Production Forest and/or Conversion Production Forest: Open-pit mining permit
	Conservation forest/ Protection forest/ limited production forest/ permanent production forest/ Conversion production forest		The main function of the forest area is heavily damaged	Other Landuse (Non-forest Area)

Note: The existing condition to be selected is based on the motivation of the proposed locus to be analyzed. Source: Akhbar et al. (2021)

RESULTS AND DISCUSSION

Land biophysical conditions, climate, socioeconomic and motivation for the proposed locus

The results of surveys and interviews in two Locus, namely BL_010 in conversion production forest area in Buol District and TL_003 in Protection Forest area in Tolitoli District each had different forest area conditions. The results of the analysis of each forest area are described as follows:

Locus BL_010:

Locus BL_010 is located in the Lakea Sub-district and Tiloan Sub-district, Buol District. The locus is located in seven village areas, namely Bukaan Village, Lakea 2, Ngune in Lakea Sub-district, and Monggonit Village, Airterang, Lomuli, Kokobuka in Tiloan Sub-district. This location is at coordinates 121°11'50.01”E-121°16'17.32”E and 1°4'31.47”N-1°9'15.37”N, it is located in the watershed area of the Buol and Lakea.

Locus BL_010 with an area of 2,524.89 Ha has land cover still in the form of primary and secondary dryland natural forest with wood potential in natural forest (medium-high) reaching 100%. The slope conditions with very steep grades reach an area of 35.67%; steep slope 7.43%; rather steep slope 43.18%; gentle slope 13.62%; 0.10% flat slope, red-yellow podzolic soil type reaches 100% area, rainfall 1,600.30 mm/year with very low rainfall intensity (7.69 mm/day) that also reaches 100% area. Rainfall data is obtained from the Lalos Meteorological Station, Tolitoli District for the 2015-2019 period.

In dryland natural forest there are types of woody forest trees such as: Meranti (*Shorea* sp.), Palapi (*Heritiera* sp.), Bayur (*Pterospermum* sp.), Bintangur (*Calophyllum* sp.), Binuang (*Octomeles* sp.), Jambu-jambu (*Eugenia* sp.), Cempaka (*Elmerillia* sp.), Matoa (*Pometia* sp.), Kume/Nantu (*Palaquium* sp.), Dara-dara (*Myristica* sp.), Langori (*Haplolobus* sp.), Kenanga (*Cananga* sp.), Ketapang (*Terminalia* sp.), Waru (*Hibiscus* sp.), Pulai (*Alstonia* sp.), Dao (*Dracontamelon* sp.), Jabon (*Anthocephalus* sp.), Pangi (*Pangium* sp.), and others. While the types of non-timber vegetation that exist include: Rattan (*Calamus* sp.), Bamboo (*Bambusa* sp.), Aren (*Arenga* sp.), types of palms, and other understorey plants.

Primary forest naturally regenerates with native plant species and there is no disturbance from human activities. Therefore, the primary forest must be a global concern to maintain its role as a carbon store and as a natural carbon cycle (Mackey et al. 2013). Special policies are needed in the management and protection of primary forests, because without policies the ecosystem services provided by forests will continue to be eroded, such as the values of biodiversity and their unique ecosystems (Mackey et al. 2015).

The socioeconomic conditions of the community around the forest area of Locus BL_010 are explained as follows: In 2021, Lakea Sub-district has a population of 11,040 people while Tiloan Sub-district has a population of 9,384 people. The types of land use around the area consist of dry land agriculture and settlements, and a mini ranch belonging to the Buol District Government. Around the forest area, there is a road with quite high activity of residents in cultivating the land around the Locus. However, accessibility in the forest area of Locus BL_010 is not available for farming roads (Akhbar et al. 2021). Furthermore, the Locus BL_010 has a problem with the motivation of the proposed provision of agricultural land for the community and settlements.

Locus TL_003:

Locus TL_003 is located in the Ogodeide Sub-district, Tolitoli District. Locus TL_003 is located in three village areas, namely Sambujan, Labuanlobo, and Bilo villages. It is Located at coordinates 120°38'15.63”E-120°41'12.23”E and 0°56'0.16”N-0°57'5.37”N, it is in the watershed area of the Sage, Labuanlobo, Baramban Bay and Basiang.

Locus TL_003 with an area of 60.58 Ha has land cover in the form of settlements, social facilities and roads that reach an area of 23.75%, clove gardens covering an area of 46.96%, open land and shrubs covering an area of 1.44%, and mangrove forests with a very low wood potential of 28.71%. The condition of the slopes with a flat class reaches an area of 63.44% and a bit steep 36.56%, alluvial soil types with an area of 28.70% and podzolic red yellow 71.29%, as well as 1,600.30 mm/year rainfall with very low rainfall intensity. (7.69 mm/hh) that reaches 100% area. Rainfall data is obtained from the Lalos Meteorological Station, Tolitoli District for the 2015-2019 period.

The types of mangrove vegetation that can still be found in areas that are still in the form of forests with fairly good growing conditions, starting from the seedling level to the tree level are dominated by the following types: *Rhizophora apiculata, Rhizophora mucronata, Avicennia alba, Avicennia marina, Avicennia lanata, Sonneratia alba, Bruguiera gymnorhiza, Bruguera seangula, Xylocarpus molucensis, Xylocarpus granatum.*

Human activities and the environment each play an important role in the diversity of vegetation in the mangrove ecosystem. Human activities affect land use and thus have an impact on mangrove diversity (Alavaisha and Mangora 2016; Gillerot et al. 2018).

The socioeconomic conditions of the community around the forest area Locus TL_003 are explained as follows: In 2021, it will have a population of 12,339 people. Types of land use in and around the area consist of dryland agriculture, clove plantations, roads and settlements. Most of the Locus TL_003 (forest area) has been residential and agricultural land/plantation of local residents for decades, as well as roads (Akhbar et al. 2021). Furthermore, Locus TL_003 has a problem with the motivation for the proposed provision of land for the benefit of public facilities (roads), social facilities (houses of worship, sports fields), agricultural land and settlements.

Mangrove forests continue to be disturbed as a consequence of human and environmental impacts such as land cover changes which will increase vulnerability to climate change impacts (sea-level rise and ecosystem degradation) (Akbar et al. 2017). Meanwhile, the loss of mangrove forests will reduce forest biomass and release carbon into the atmosphere (Eid and Shaltout 2016; Perez et al. 2018). The mangrove ecosystem which is decreasing in size every year is quite worrying, because the mangrove ecosystem is important in providing local environmental services, as well as mitigating global climate change (Barbier 2012; Wiwatthanapornchai et al. 2014).

Selection results of locus

Locus BL_010:

Selection for Locus BL_010 was analyzed based on general criteria. From the results of the analysis, it is known that the Locus BL_010 did not indicate a legal problem; there is no lease-to-use forest area permit; there is no location found by the research team outside the locus for the benefit of the community; and there is no national strategic development interest.

Locus TL_003

Selection for Locus TL_003 analyzed on general criteria. From the results of the analysis, it is known that the Locus TL_003 did not indicate a legal problem; there is no lease-to-use forest area permit; there is no location found by the research team outside the locus for the benefit of the community; and there is no national strategic development interest.

Analysis results of locus using a scoring technique

Locus BL_010:

The forest area in the Locus BL_010 with the original function of conversion production forest with area of 2,524.89 Ha according to the Decree Letter of the Minister of Forestry Number 869/Menhut-II/2014. From the results of the scoring, the function of the conversion forest area had changed into Protection Forest covering an area of 900.54 Ha (35.67%), limited production forest covering an area of 1,277.85 ha (50.61%) and permanent production forest covering an area of 346.50 ha (13.72%). The change of forest function into limited production forest and permanent production forest is caused by the location that is on a flat to flat slope class steep, red-yellow podzolic soil type (erosion sensitive soil type) and very low rainfall intensity. Meanwhile, the change in function to a Protection Forest is due to the location on a very steep slope class, red-yellow podzolic soil type (erosion sensitive soil type) and very low rainfall intensity. In accordance with the provisions, for slope class 45% (very steep) even though the total land score is <174 then the land is included in the function of Protection Forest. Figure 2 shows the results of the change in the function of the forest area scored in the Locus BL_010.

Locus TL_003:

The forest area in the Locus TL_003 with the original function of Protection Forest has an area of 60.58 Ha according to the Decree Letter of the Minister of Forestry Number SK.869/Menhut-II/2014. From the results of the scoring, the function of the Protection Forest area had changed into a Limited Production Forest covering an area of 12.68 Ha (20.93%) and a permanent production forest covering an area of 47.90 Ha (79.07%). The change of forest function in limited production forest is caused by its location on a rather steep slope class, red-yellow podzolic soil type (erosion sensitive soil type), and very low forest intensity. Meanwhile, the change of function into production forest is still caused by the location on flat slope class, alluvial soil type (erosion sensitive soil type) and red-yellow podzolic soil type (erosion sensitive soil type), and very low rainfall intensity. Figure 3 shows the results of the change in the function of the forest area scored at Locus TL_003.

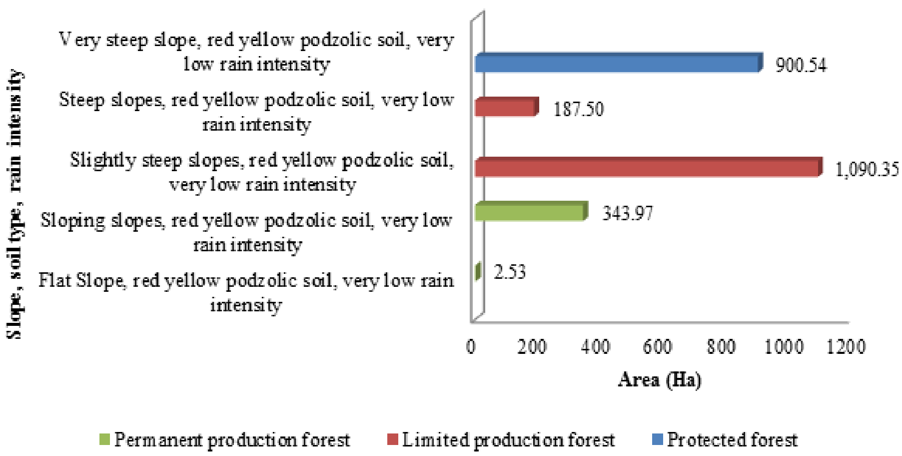

Figure 2. Forest function based on scoring results in Locus BL_010

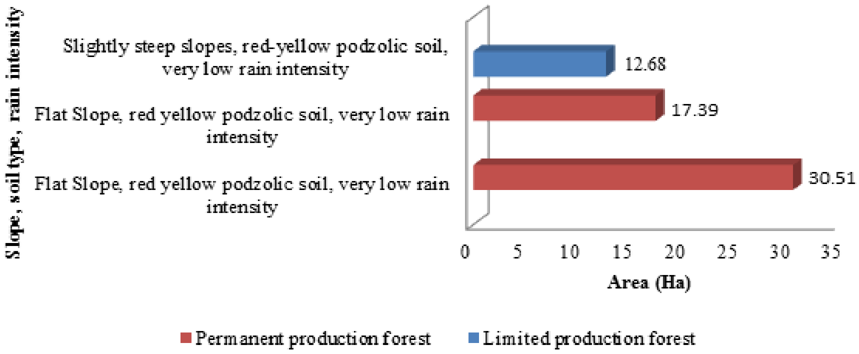

Figure 3. Forest functions scored in Locus TL_003

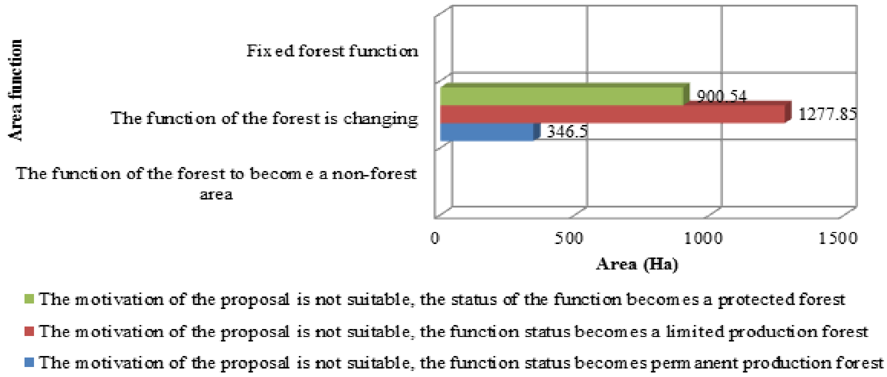

Figure 4. Designation and functions change of forest areas in Locus BL_010

The results of multi-criteria-based locus

Locus BL_010:

The results of the multi-criteria-based spatial analysis on the changes in the designation and function of forest areas in the Locus BL_010 with a total area of 2,524.89 Ha, the motivation for the proposal was not appropriate so the results obtained are not changes in area designation but changes in forest functions. The function of conversion production forest changed to Protection Forest with an area of 35.67%, limited production forest with an area of 50.61% and permanent production forest with an area of 13.72%. Figure 4 shows the results of changes in the designation and function of multi-criteria-based forest areas at Locus BL_010.

Figure 4 shows the results of a multi-criteria-based spatial analysis in the Locus BL_010. It showed that there was no change in the designation of forest areas, namely the change in forest areas to non-forest areas due to the motivation of the proposed change of forest areas into community agricultural land and settlements that are not in accordance with facts on the ground. Based on field survey results, it was not found that there were agricultural activities and human settlements in the proposed locus, the condition of the land was still densely forested, the topography of the mountains with a rather steep to very steep slope class, erosion sensitive soil types, and natural forest cover was still dominated by dense tree vegetation with potential medium to tall wood. Locus BL_010 includes forest areas located in the upper Lakea and Buol watersheds so it has an important role as a water supplier for surrounding agricultural land. Furthermore, accessibility is classified as difficult to enter into the Locus BL_010 because it is dominated by mountainous topography with steep to very steep slope conditions.

Ecosystem processes that occur in tropical rain forests are very complex due to the interaction between high biodiversity and natural abiotic elements, making them very vulnerable to disturbance. However, it is important to note that ecosystems continue to be under threat of deforestation as a result of human pressure. Meanwhile, deforestation and degradation of tropical rainforests will increase the vulnerability of billions of people with various impacts (Brandon 2014; Lewis et al. 2015; Miller and Spoolman 2016; Turubanova et al. 2018).

The motivation for the proposed change in forest area designation in non-forestry utilization plans (such as agricultural land and settlements) is important to be supported by data from land evaluations conducted through land quality assessments and indicators of land characteristics in terms of physical, economic, social, and environmental aspects. The assessment results are used to predict land potential, while land selection is important for land-use suitability, because inappropriate land use will have implications for low production and inefficient resource use (Manna et al. 2009; Pilvere et al. 2014). In land-use planning, land suitability needs to be considered, it is also important to analyze land availability. The results of land suitability analysis can be used as material to determine land availability by considering the status of forest areas and land use in spatial planning (Widiatmaka et al. 2014; Widiatmaka et al. 2016). Figure 5 shows the results of mapping changes in the designation and function of forest areas in Locus BL-010 using a multi-criteria-based decision-making facility in Arc-GIS.

Locus TL_003:

The results of a multi-criteria-based spatial analysis on the changes in the designation and function forest areas in the Locus TL_003 showed that all reached an area of 60.58 Ha, the motivation for the proposals is most appropriate so that the results obtained were changes in the designation of the area to other use areas (non-forest areas), with an area of 71.29%, and the function of Protection Forest must be maintained its existence with an area of 28.71%. Figure 6 shows the results of changes in the allocation and function of forest areas based on multi-criteria in Locus TL_003.

Figure 6 shows the results of a multi-criteria-based spatial analysis at the Locus TL_003. It showed a change in the designation of forest areas to other land use areas, and the existence of Protection Forest functions is maintained. There is a change in the designation of forest areas in the Locus TL_003 because the motivation for the proposal is in accordance with the ground facts. From the survey results, it is known that the existing conditions in the Locus TL_003 were residential land, agricultural land cultivated by the community, public facilities (roads), and social facilities (houses of worship, schools, markets, sports fields, etc.). The people who live and cultivate the land in the Locus TL_003 have been using the forest area for decades, while the road has existed since the people live in this area.

There is a Protection Forest that must be maintained in the Locus TL_003 with an area of 17.39 Ha (28.71%) because the land cover is still in the form of mangrove forest with dense vegetation cover. It is important to maintain mangrove forests that are still forested, because their existence has an important function and role in protecting coastal ecosystems from abrasion, tsunamis, and as breeding grounds for fish, shrimp, birds and other aquatic animals. The existence of mangrove ecosystems is very important because they are able to provide a variety of ecosystem services, and also contribute to significant carbon sequestration and storage (Alongi et al. 2016; Murdiyarso et al. 2015; Harefa et al. 2022). Mangrove forest is a productive ecosystem and has complex functions (physical function, biological function, and socioeconomic function), meanwhile it is very productive as a fishery resource because it is a natural habitat for various types of fish, shrimp and crabs (Eddy et al. (2016).

The following Figure 7 shows the results of mapping changes in the designation and function of forest areas in Locus TL_003 using a multi-criteria-based decision-making facility in Arc-GIS.

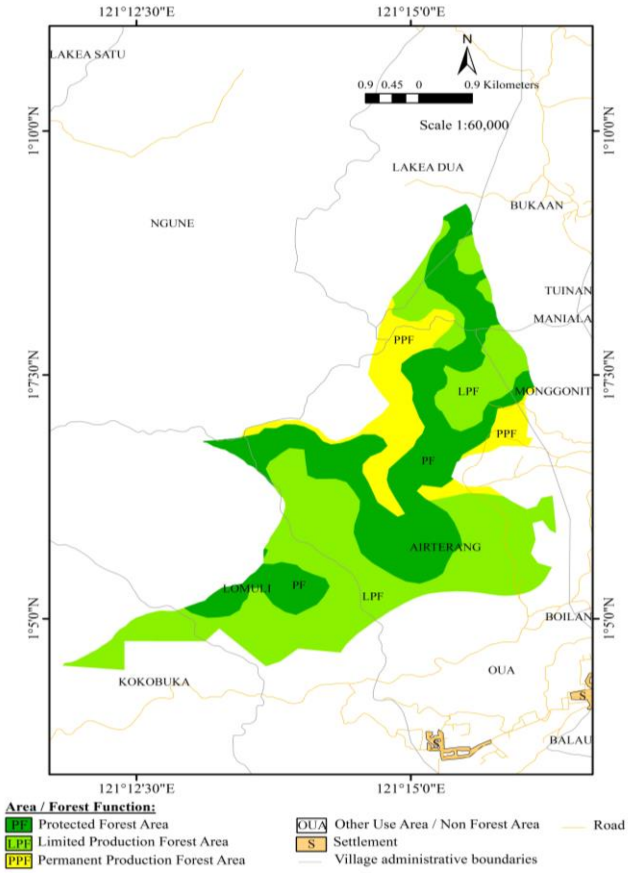

Figure 5. Map of results of analysis of changes in designation and function of forest area at Locus BL_010

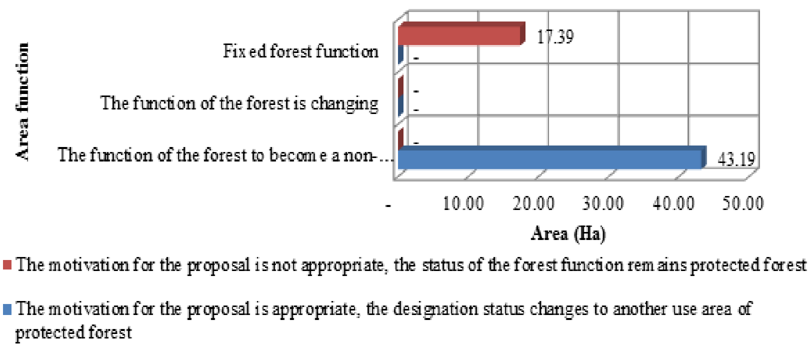

Figure 6. Designation and functions change of forest areas in Locus TL_003

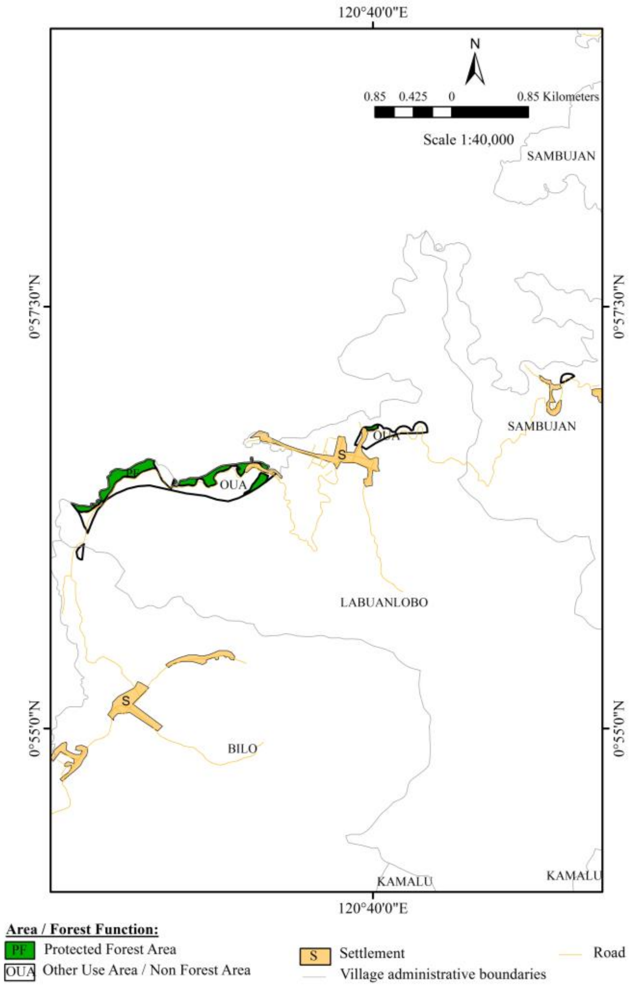

Figure 7. Map of results of analysis of changes in designation and function of forest area at Locus TL_003

Analysis of the decision-making process on the change of designation and functions of multi-criteria-based forest areas

In accordance with the decision-making stages for changes in the designation and function of forest areas based on multi-criteria, decisions are made for each locus, some locations are in accordance with the motivation of the proposal and some are not according to the motivation of the proposal. Negulescu and Doval (2014), the quality of the decision-making process can be achieved by taking into account environmental factors, organizational strategy, ethics, empowerment, information and feedback, programs, choices, risk avoidance, resources and opportunities. Furthermore, in the following description, the results of the multi-criteria decision achievements for each locus are analyzed.

Locus BL_010:

In the multi-criteria-based spatial analysis of changes in the designation and function of forest areas in the Locus BL_010 with the motivation of the proposal for community agricultural land and settlements, as described in the results of the locus screening, there were no problems found so that it can be continued with the evaluation/assessment of the locus.

In the evaluation/assessment of the locus (scoring analysis and multi-criteria analysis), using specific criteria for the existing condition of the forest area, it can be explained that the motivation for community agricultural land and settlements proposal had not met as a result of the inappropriateness of the motivation of the proposal with the ground fact. The motivation for the proposal was not supported by data showing that there were activities for cultivating agricultural land and settlements in forest areas, while the limiting factors for topography and accessibility of the area as well as soil types that were sensitive to erosion and prone to landslides make this area unfit to be converted into a non-area.

The motivation for the proposed change in forest area designation in Locus BL_010 is not in accordance with field facts. It explains the need for an in-depth study of each locus that will be proposed by stakeholders in order to prevent new conflicts in land use. Zhang et al. (2012) state that conflict in land use planning can be viewed from two perspectives, namely conflicts between land use types and between stakeholders. This conflict can be resolved by balancing the interests of environmental conservation with economic development.

The research findings of Rangga et al. (2020) provide a new perspective on the perspective of local communities and forests in relation to forest conservation. The local community has the opportunity to be the party that can protect the forest and vice versa, so reasonable efforts and regulations are needed to empower local communities in forest conservation.

Furthermore, by following the stages of the multi-criteria-based decision-making process, three decision-making rules have resulted in changes to the function of forest areas in Locus BL_010: IF status of area “Conversion Production Forest” AND slope class “flat-sloping” AND soil type “podzolic red-yellow” AND rainfall intensity “very low” AND land cover “natural forest” AND motivation for proposal “not suitable” THEN status of area “ Permanent Production Forest” (i). IF status of area “Conversion Production Forest” AND slope class “ rather steep ” AND soil type “podzolic red-yellow” AND rainfall intensity “very low” AND land cover “natural forest” AND motivation for proposal “not suitable” THEN status of area "Limited production forest" (ii). IF the status of the area is “Conversion Production Forest” AND the slope class is “very steep” AND the land cover is “natural forest” AND the motivation for the proposal is “not suitable” THEN the status of the area is “Protection Forest ” (iii).

Locus TL_003:

In a multi-criteria-based spatial analysis of changes in the designation and function of forest areas in Locus TL_003 with the motivation of the proposal being for settlements, community agricultural land, public facilities (roads), social facilities (houses of worship, schools, markets, sports fields), as described in the results of the locus filtering, no problems were found so that it can be continued with the evaluation/assessment of the locus. In the evaluation/assessment stage of the locus (scoring analysis and multi-criteria analysis), the use of specific criteria for the existing condition of the forest area, it can be explained that the motivation for the proposal in the Locus TL_003 is mostly fulfilled because of the coherence between the motivation of the proposal and the ground fact. The motivation for the proposal is supported by data that there are activities for cultivating agricultural land and settlements, the existence of roads and social facilities in the forest area, while the Protection Forest area is maintained because the land cover is still in the form of mangrove forest that has an important function and role in protecting coastal ecosystems.

The decision to change the designation and function of forest areas is expected to accommodate various interests to reduce land-use conflicts in Locus TL_003. Rikalović et al. (2014), in the context of decision making, problems are often encountered in the form of subjective influences; uncertainty in formulating the relationship between facts and decisions to be made; the existence of varying degrees of the trade-off between the criteria for evidence-gathering procedures (facts); there are problems with objective decision-making procedures, namely in the resolution and/or prevention of conflicts. Zhang et al. (2012) state that conflict resolution can be solved by balancing the interests of environmental conservation with economic development. Musa et al. (2020), various mangrove management schemes have been implemented in Indonesia (Java, Sumatra and other islands) such as rehabilitation, silvofishery systems, social forestry and agrarian reform object land.

Furthermore, by following the stages of the multi-criteria-based decision-making process, two decision-making rules are produced on the changes to the designation and function of forest areas in Locus TL_003: (i) IF status of area “Protection Forest ”AND slope class “flat- rather steep ” AND soil type “podzolic red yellow” OR “alluvial” AND rainfall intensity “very low” AND land cover “road” OR “settlement” OR “garden people” AND the motivation for the proposal is “appropriate” THEN status of the area “Other Landuse Areas”. (ii) IF the status of the area is “Protection Forest ”AND land cover is “mangrove forest” AND the motivation for the proposal is “not appropriate” THEN status of the area is “Protection Forest”.

Generally, it can be explained that in the decision-making process on a multi-criteria-based spatial analysis of changes in the designation and function of forest areas, every stage needs to be considered. At the locus screening stage, researchers/planners are required to filter out any problems to prevent conflicts, while the locus evaluation/assessment stage at least two stages were carried out, namely the locus scoring stage and the determination stage for changes to the designation and function of forest areas.

Based on the analysis, it was found that there was a discrepancy between the scoring results in the acquisition of new forest functions and the change in the designation of forest areas to non-areas. Meanwhile, a scoring technique is needed in determining new forest functions when the target for designation change of forest areas is not achieved. So that in order to achieve the target of efficient and effective forest area designation changes, the scoring technique will remain a consideration as the initial stage in the process of evaluating/assessing forest area designation changes.

The model of spatial analysis of changes in the designation and function of multi-criteria-based forest areas in dry land and mangrove forest ecosystems is quite flexible in decision making. These results are indicated by the motivational target of the proposal in each locus, it will be achieved if it is in accordance with the established criteria and also the ground fact.

In conclusion, a spatial analysis model is produced that integrates scoring techniques and decision-making techniques based on multi-criteria changes in the designation and function of forest areas in dry land and mangrove forest ecosystems. At Locus BL_010 produced three decision-making rules on changes in forest area function (from the function of conversion production forest covering an area of 2,524.89 Ha to protected forest covering an area of 35.67%, to limited production forest covering an area of 50.61%, to permanent production forest covering an area of 13.72%). Meanwhile, at Locus TL_003 two decision-making rules were made on changes to the allocation and function of forest areas (from a protected forest function covering an area of 60.58 ha to an area of other uses covering an area of 71.29% and remaining protected forest covering an area of 28.71%).

ACKNOWLEDGEMENTS

Thank you to the Institute for Research and Community Service of Tadulako University, Indonesia the Pogogul Forest Management Unit (FMU) and Gunung Dako FMU, Central Sulawesi Provincial Forestry Service, Faculty of Forestry, Tadulako University and ESRI Indonesia, and all parties related to the research implementation.

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