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GIS-Based Spatial Model for Habitat Suitability of Babirusa (*Babyrousa celebensis*), in Gorontalo Province

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Abstract. Babirusa (*Babyrousa celebensis*) is an endemic animal from Gorontalo Province whose population is declining day by day due to poaching, land clearing, and selling babirusa meat in traditional markets in Gorontalo Province. Since 1931 this species has begun to be protected in Indonesia, and since 2008, International Union for Conservation of Nature (IUCN) named the babirusa species as a vulnerable category. This study aims to determine the suitability of babirusa habitat areas (*Babyrousa celebensis)* in Gorontalo Province with a Geographic Information System (GIS) approach and to determine the relationship of physical characteristics for the habitat of the babirusa habitat in Gorontalo Province. The variables are land use, slope, and elevation. The method used is GIS spatial modeling with overlay analysis. From the results of the analysis, it has concluded that a suitable area as a babirusa habitat is only about 33% of the total area of Gorontalo Province and there are types of land use in the wilderness and swamps at an elevation of 0-500 msl with sloping 0-8%. The validation test shows that Coefficient kappa is 0.16 and overall accuracy is 58%. Therefore, further research is needed by adding other variables to delineate the spatial distribution of babirusa.

Keywords*: babirusa, habitat, GIS, suitability area*

1. Introduction

Babirusa (*Babyrousa celebensis*) is a Sulawesi endemic animal whose population is decreasing due to poaching and lack of conservation control and management. To support conservation, IUCN in 2008 included babirusa species as a vulnerable category. Besides, Babirusa is a type of animal that has been included in CITES Appendix I since 1982.

The decline in the Babirusa population caused by hunting and trading of babirusa meat in traditional markets in the provinces of Gorontalo and North Sulawesi, to be consumed by the local non-Muslim community (Macdonald et al., 2008). Other factors that can also reduce the population and habitat of Babirusa are illegal logging practices, land clearing for fields and illegal mining (Macdonald et al., 2008). These factors can be a threat to forest sustainability and the level of biodiversity in Gorontalo Province Forest.

Babirusa has protected in Indonesia since 1931 ((Macdonald, 1993). Because this species is vulnerable and limited, thus allowing the extinction of several threats, such as hunting, habitat loss, and the possibility of natural disasters. Therefore it is necessary management and conservation in order to maintain and supervise babirusa populations in a sustainable manner both genetically, independently,

and freely (Manansang et al., 1996). Regulation of the Minister of Forestry of the Republic of Indonesia Number: P.55 / Menhut-II / 2013 concerning the Strategy and Action Plan for Conservation of Babirusa (*Babyrousa celebensis*), in general, there are two strategies listed in the efforts of Pelestrian Babirusa (*Babyrousa celebensis*), namely conservation efforts in natural habitats (in-situ) and conservation efforts outside their natural habitat (ex-situ).

Geographical Information System (GIS) is a tool for collecting, storing, displaying, and connecting spatial data from (partial) earth surface phenomena to be analyzed and the results communicated to users of information, especially for decision making (Supriatna, 2018). GIS Provides Tools for Ecologists to Analyze Environmental Effects of Ecological Processes (Wastoni, 2010). Habitat suitability can be determined by multivariable analysis using GIS (Guissan and Zimmermann, 2000). spatial analysis of habitat suitability can do using parameters that are processed and weighted according to the size of the influence on the carrying capacity of animal habitats.

This research carried out in Gorontalo Province, which is one of the provinces with babirusa species in addition to North Sulawesi. Gorontalo Province has the Nantu Nature Reserve which is home to a large population of babirusa (Ministry of Forestry, 2013). This study uses the application of Geographic Information Systems by using spatial overlay analysis to determine the suitability of babirusa habitat so that it can be monitored, preserved, and further studies of babirusa species in Gorontalo Province. The spatial location of ecologically sensitive areas is fundamental for wildlife conservation (Wong and Fung, 2015). Therefore, raising awareness and law enforcement is an effective strategy to reduce hunting and trafficking in babirusa by utilizing spatial data and Geographic Information Systems (GIS) because wildlife habitat planning requires detailed information relating to the spatial distribution and abundance of species to understand the ecology and development of management plans (Singh et al., 2009).

This study aims to determine the suitability of the habitat of the Babirusa (*Babyrousa celebensis*) habitat in Gorontalo Province and to determine the relationship of physical characteristics for the habitat of the Babirusa habitat (*Babyrousa celebensis*) in Gorontalo Province. It has hoped that the resulting map can be a reference to keep off poaching and illegal trade so that the natural habitat of Babirusa is not threatened and protected from extinction.

2. Methodology

2.1. Study Area

Gorontalo Province located in the northern part of Sulawesi Island, located at 0 ° 19 ′ 00 "- 1 ° 57 ′ 00" LU (North Latitude) and 121 ° 23 ′ 00 "- 125 ° 14" 00 "BT (East Longitude)) Location Gorontalo Province is very strategic because it was flanked by two territorial, namely Gorontalo Bay and Tomini Bay in the South and Sulawesi Sea in the North, Gorontalo province 0.63% consisting of 5 (five) districts and 1 (one) city, that is Boalemo Regency, Gorontalo Regency, Pohuwato Regency, Bone Bolango Regency, North Gorontalo Regency, and Gorontalo City (Central Bureau of Statistics, 2017).

Gorontalo Province has a topography mostly in the form of plains, hills and mountains. Gorontalo City Region located at the lowest elevation, from 0 to 500 meters above sea level. Gorontalo Regency consists of plains and mountains with varying elevations, from 0 to 2,065 meters above sea level. Boalemo Regency consists of areas with flat to mountainous topography located at elevations with variations from 0 to 2,100 m above sea level. Pohuwato Regency located at an elevation of 0 to 1,920 m which found in the border area with Central Sulawesi. Bone Bolango Regency has a topography with variations between 0 and 1,954. North Gorontalo District has a topography with different elevations, with variations in elevation from 0 to 1,970 m above sea level (National Development Plant Board, 2013).

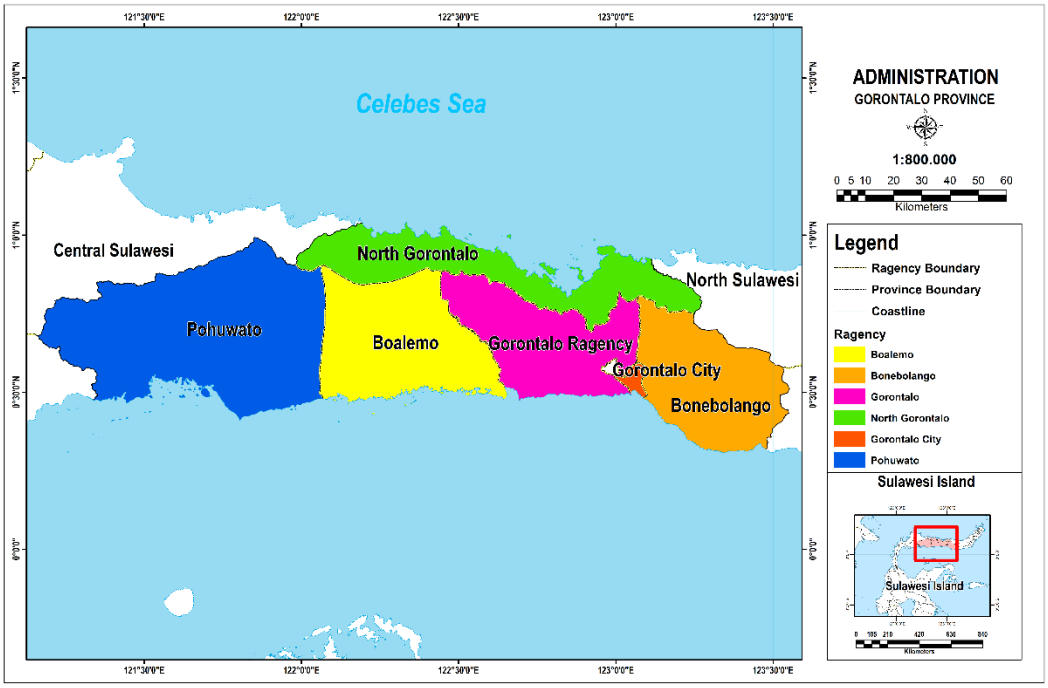


Figure 1. Study Area

2.2. Research Variable

In this study, there are three variables to determine the suitability of babirusa habitat areas that are used based on living conditions, behavior, threats, and characteristics of Babirusa's food place, that land use, slope, and elevation.

Landuse influences human threats related to the sustainability of the babirusa habitat. In determining the suitability of babirusa habitat areas, some areas are not suitable for babirusa habitat, that is areas with high intensity of human activities land use, such as settlements, plantations, agriculture, rice fields, and fields. Whereas, a suitable area is Forest and swamp of land use.

Table 1. Landuse assessment parameters (Manansang J. et al., 1996; IUCN, 2008)

Landuse	Class	Score	Explanation	Weight
Forests, Swamps	Suitable	2	The babirusa is omnifora animals, so food supplies in tropical rain forests are abundant, some babirusa foods are leaves, roots, and fruits. Babirusa also needs to supply a source of water and minerals (salt) to survive by eating wood larvae found in swampy areas	40
Settlements, Plantation, Paddy Field, Grassland, Cultivate Land	Not Suitable	1	Associated with disturbances such as the threat of land clearing for fields, hunting, illegal mining, illegal logging and all human activities that threaten babirusa habitat and the other biodiversity.	

A slope is a form of the earth's surface that has a certain angle to the horizontal plane of the earth's surface. Based on the home range, babirusa tends to look for places with terrain that is not too steep or rocky, because babirusa tends to live in areas that are mostly flat and sloping, especially areas around the swamp (Macdonald & Johansson, 2017). Suitable slopes for babirusa habitat are flat to sloping areas with slope classification based on the van Zuidam in 1985. However, for the slope class is not suitable, the slope is slightly steep until steep on a determination of weight and score based on the tendency of babirusa habitat based on literature.

Table 1. Slope Parameter Scoring (Macdonald & Johansson, 2017)

Slope	Explanation	Class	Score	Weight
0%-2%	Flat	Suitable	2	30
2%-8%	Sloping	Slightly Suitable	2	
>8%	Steep	Not Suitable	1	

The elevation is the vertical position of an object concerning a certain point. The Classification of habitat suitability with elevation based on babirusa feed growing sites. According to Leus (1998) and the Ministry of Forestry (2013), some babirusa foods are tubers, bamboo shoots, mushrooms and fruits such as Dongi fruits (*Dillenia ochrea*), Rao fruits (*Dracontomelon Rao*) and Sengkuang fruits (*D. mangiferum*). Babirusa's favorite food sources are Pangi fruit that lives at an elevation of 10-1000 meters above sea level (Arini, 2012), Rao plants and Sengkuang fruits at an elevation of 0-500 m, and bamboo around 0 - 00 m, 2000 meters above sea level, strong fangs and teeth can easily destroy hard peas (Leus and Macdonald, unpublished observations), as well as grains such as walnuts (*Canarium (Burs.*), Oaks (*Lithocarpus (Burs*.)) and chestnut seeds (*Castanopsis Burs*). These seeds live at an elevation of 150-1200 msl (Pratiwi et al., 2012).

Table 2. Elevation Parameter Scoring (Ministry of Forestry, 2013; Arini, 2012; Pratiwi et al., 2012)

Elevation	Class	Score	Weight
0-500	Suitable	2	30
500-2000	Slightly Suitable	1	
>2000	Not Suitable	1	

2.3. Data Collection and Processing

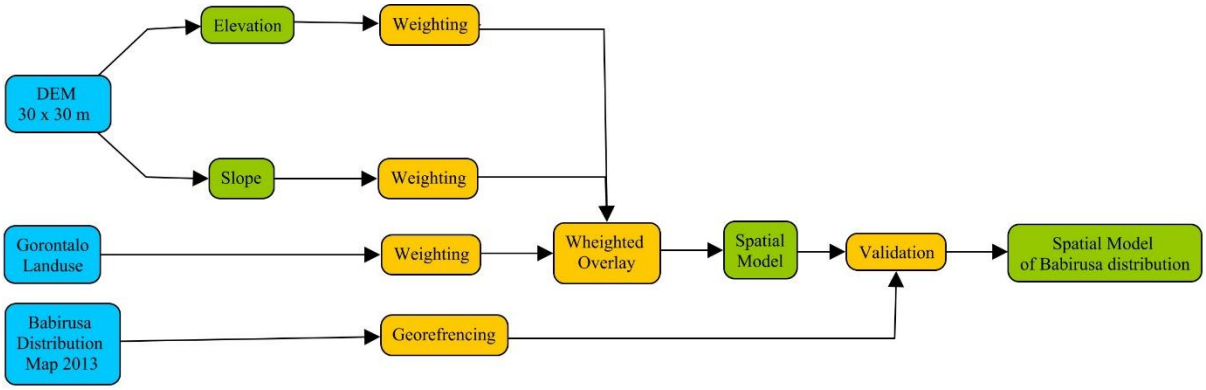
The research was conduct using the weighted overlay method. The methods are used or apply a measurement scale of universal values to diverse and different inputs to make integrated analyzes (Belay et al., 2015). The data needed in this study is secondary data in the form of data or information obtained from literature study sources and institutions related to the data needed.

Table 4. Data Sources

Daa types	**Year**	**Source**
Landuse	2013	RBI Map (Geospatial Information Agency)
Slope	2010	DEM (Geospatial Information Agency)
Elevation	2010	DEM (Geospatial Information Agency)
Distribution Map of Babirusa in Sulawesi Island	2013	Ministry of Forestry

All data that have spatial information can visualize in the form of maps with ArcGIS 10.1 software. In processing each variable, the analysis applied is the Weighted Overlay analysis. Such analysis used raster baseline data. A raster GIS used to store, manage, and analyze the data needed in suitability analysis and also to display the results of the analysis (Store & Jokimäki, 2003). Next is model validation. Model validation did use a confusion matrix compared to the reference map for babirusa habitat distribution from the Ministry of Forestry. Reference maps from the ministry of forestry must

be georeferenced following reference shapefile data. The RMS error value for the georeferenced process must be less than 1 (Moses and Devadas, 2012). The model has done to minimize errors from the coordinate matching process. This process can explain in the flowchart diagram (figure 2).



Gambar 2. flow chart Diagram

2.4. Data Analysis

In this study, the overlay analysis used is the raster overlay with the weighted overlay method. This method uses a spatial data raster data format of several variables by ranking each parameter (Waikar & Nilawar, 2014). Each variable is given a weight according to previous research (Table 5). This overlay analysis constructed from land use, slope, and elevation variables. The variable that has the lowest suitability class is land use with suitable and not suitable classes. Determination of the weight of each variable based on the size of its effect on the suitability of the babirusa habitat. The resulting output is in the form of a raster that has a new value on each pixel that represents a suitable and not suitable region.

Table 5. Babirusa Habitat Suitability Matrix

Suitability Classes	Slope	Landuse	Elevation (msl)
Suitable	0 – 8 %	Forests, Swamps	0-500
Not Suitable	>8 %	Settlements, Water Body, Plantation, Paddy Field, Grassland, Cultivate Land	>500
Reference	Macdonald & Johansson (2017)	Manansang J. et al., (1996; 2008)	Ministry of Forestry, (2013), Arini D. I. D. (2012), Pratiwi et al., (2012)
Weight	30	40	30

2.5. Data validation

Data validation used with matrix confusion. According to Stahler (2006), this matrix presents a cross-tabulation in a class that is predicted by image classification analysis of what observed in the base data for the test location. The confusion matrix usually used to validate land cover classifications, but in this study, the confusion matrix used for validation by testing the accuracy of the model with the georeferenced babirusa distribution map from the forestry ministry. The total sample points used were 50 from each suitability class. The sample point determined by a stratified random sampling method. This study has limitations in validating the model; the data used for validation is a reference map from the Ministry of Forestry as a comparison of the map model.

3. Results and Discussion

3.1. Landuse Suitability Area

Landuse in Gorontalo Province is dominated by wilderness in the middle to the south. Land use in the form of wilderness or tropical rain forests and swamps is a Suitable area for babirusa habitat because it has a lot of food and feed and low intensity of human disturbance. Whereas the not suitable areas, by settlements, rice fields, plantations, rice fields, rice fields, bushes, and water bodies.

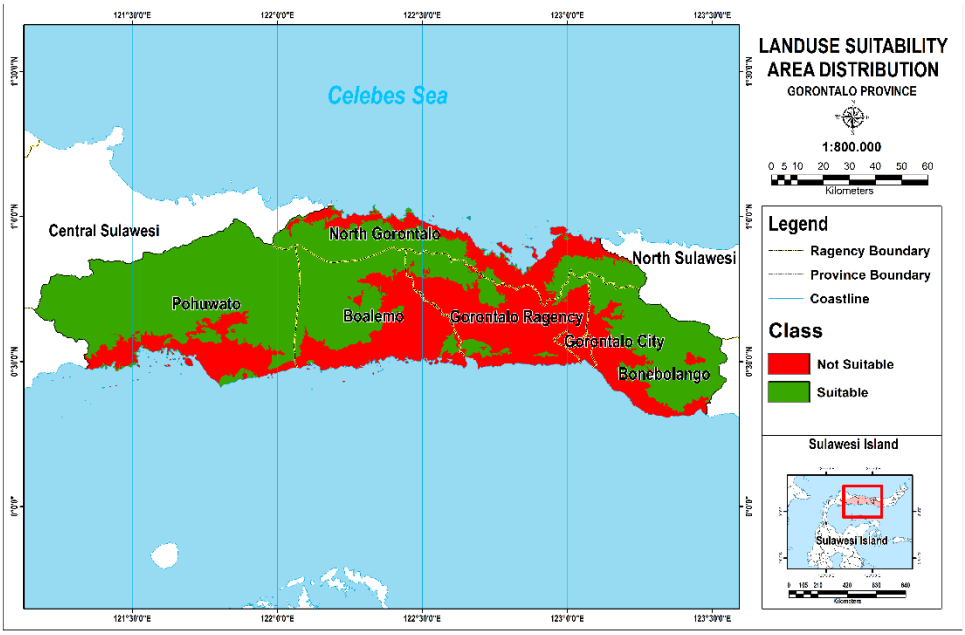


Figure 3. Landuse Suitability Distribution

Based on Figure 3, the suitable areas dominated by wilderness forest in the southern region, which is in the Pohuwarto Regency to North Gorontalo Regency and Boalemo Regency. Areas that are not suitable /not suitable are in Gorontalo City, East Gorontalo Regency, North Pahuwato Regency, North Gorontalo Coastal Regency, and South Bonebolango Regency.

3.2. Slope Suitability area

Based on the analysis of suitability based on slope variables, it was found that the flat relief has a suitable class with a slope of 0-2%, a Slightly suitable area that has a slope of 2-8% with a sloping relief, and a not suitable /not suitable area has a rather steep to very steep relief with slope> 8%.

Based on Figure 4, the area in suitable conditions is spread in the southern, western and central Gorontalo regions because it has a flat to sloping terrain. A small portion of this region is suitable in the northwest and eastern Gorontalo regions. However, most of the Gorontalo region consists of not suitable slope areas because the central part of Gorontalo Province consists of hills that have a slope of more than 8% with a rather steep to very steep relief.

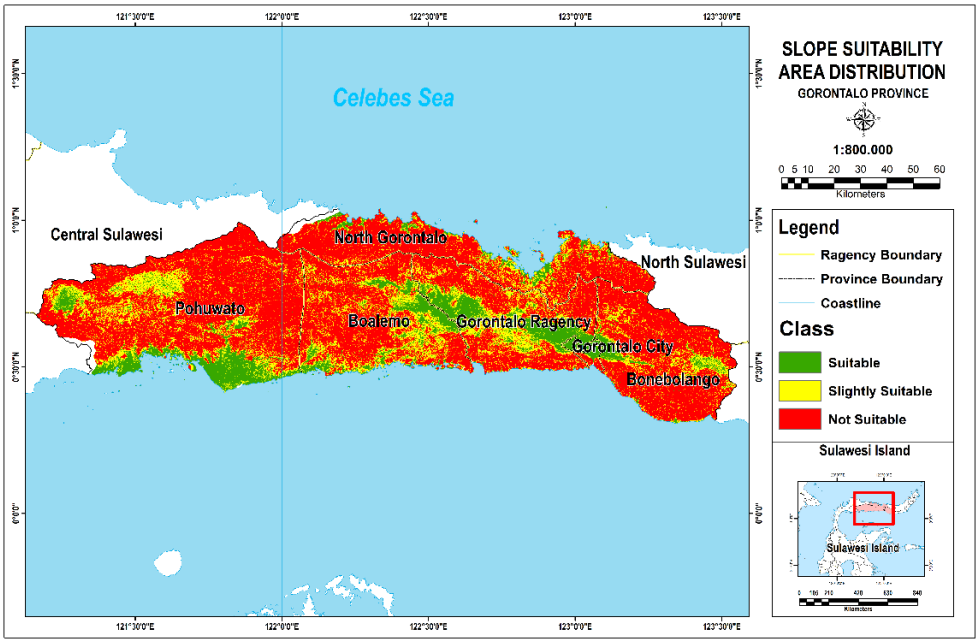


Figure 4. Slope Suitability Area Distribution

3.3. Elevation Suitability Area

Based on the results of the analysis of the Suitability area to elevation variable, the suitable babirusa habitat is mostly located at an elevation of 0-500 msl, while a Slightly suitable area located at an elevation of 500-2000 msl, and areas that are not suitable /not suitable area located at an elevation of more than 2000 msl.

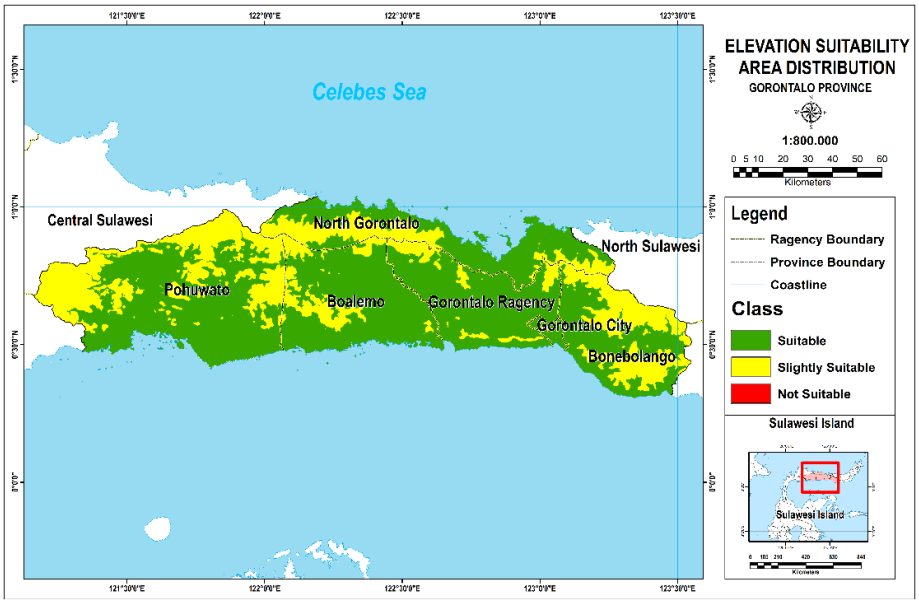


Figure 5. Elevation Suitability Area Distribution

Based on Figure 5, most of the Gorontalo area have classes suitable for babirusa habitat. Areas of suitable elevation are in the southern, western, and central Gorontalo provinces precisely in Boalemo Regency, Gorontalo City, and Pahuwato Regency. While the areas that are Slightly suitable and not suitable for babirusa habitat are scattered randomly following the shape of hilly land in Gorontalo Province.

3.4. Overlay Analysis

Based on the results of weighted overlay processing, areas suitable for babirusa habitat distributed in the western part of Gorontalo Province. The results obtained are two habitat suitability classes that are suitable and not suitable/not suitable classes. The suitable class is in an area with an elevation 0 to 500 meters above sea level, and a slope range is 0% to 8% in the type of land use is wilderness forests and swamps. As for the type of class that is not suitable/not suitable is in an area with elevation of more than 500 meters above sea level (> 500 msl), with a slope of more than 8% or relief in the form of steep to very steep, with land use in the form of settlements, rice fields, plantations, rice fields, bushes, rice fields, and bodies of water.

Most of the suitable areas are in the Puhowato Regency and northwest of Gorontalo Regency, in the east of Bonebolango Regency, and a small portion in North Gorontalo Regency. Only Gorontalo City is not suitable for Babirusa habitat

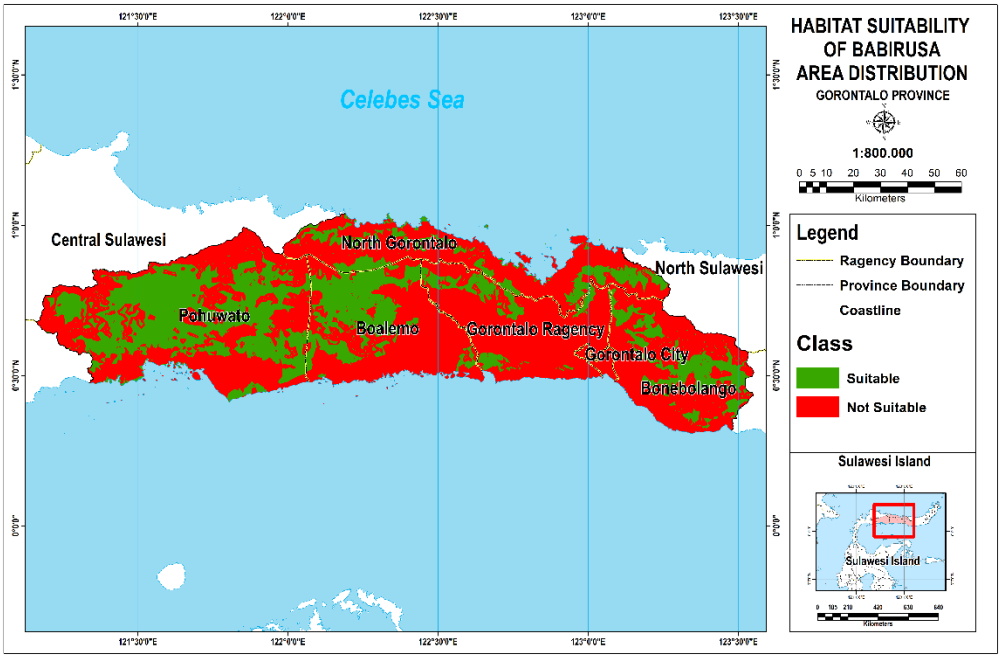


Figure 6. Babirusa Habitat Suitability Map in Gorontalo Province

3.5. Percentage of an area of Suitability Classes

Weighted overlay process produces polygons with suitable area categories and is not suitable for babirusa habitats. Polygon areas can identify by calculating geometry methods for each habitat suitability class. The area of each class defined in units of hectares (Ha).

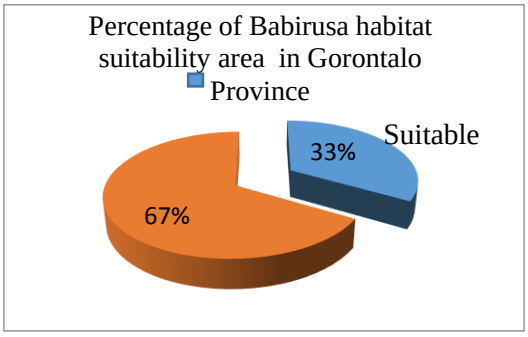


Figure 7. Graph Percentage of Suitability Area of Babirusa Habitat in Gorontalo Province (Data Processing, 2019)

Tabel 6. Percentage of Suitability Areas (Data Processing, 2019)

Class	Total Area (ha)	Percentage
Suitable	404917,24	33%
Not suitable	809681,42	67%

From not-suitable class category, there is the highest area of 809,681.42 hectares or 67% of the total area of Gorontalo Province. As for the suitable class category, an area of 404917.24 hectares obtained, or about 33% of the total area of Gorontalo Province. The results show that the area suitable for the babirusa habitat has a small area in Gorontalo Province.

3.6. Model Validation

Data validation is done using a confusion matrix. The matrix used to determine the accuracy of the suitability model compared to the georeferenced map of babirusa distribution from the Ministry of Forestry.

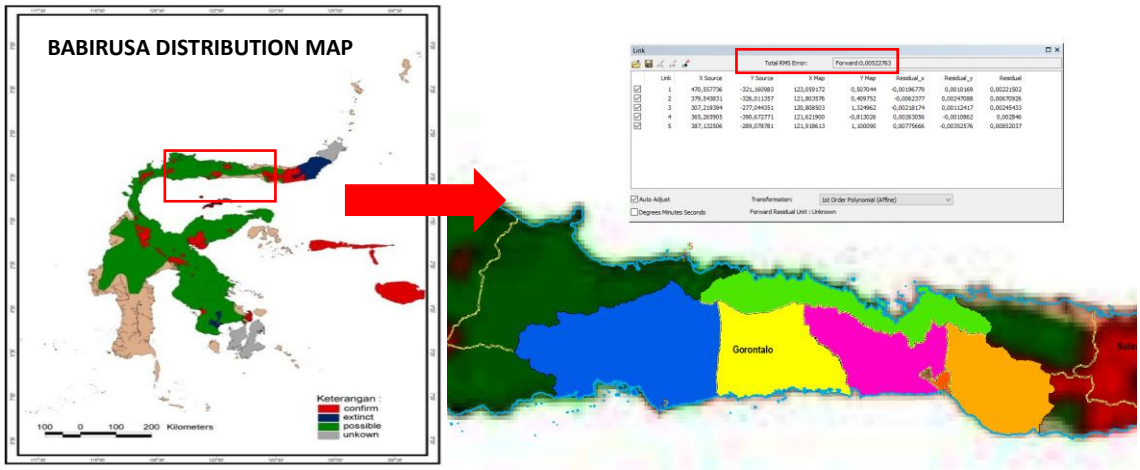


Figure 8. Distribution Map of Babirusa in Sulawesi Island (Ministry of Forestry, 2013)

RMS error value is 0.00522763, this shows that the map reference conversion has a low error rate. Fifty samples based on suitability class used to see accuracy by considering the overall accuracy and coefficient kappa. comparison between the suitability model and the babirusa distribution map from the forestry ministry in 2013 can see in figure 8.

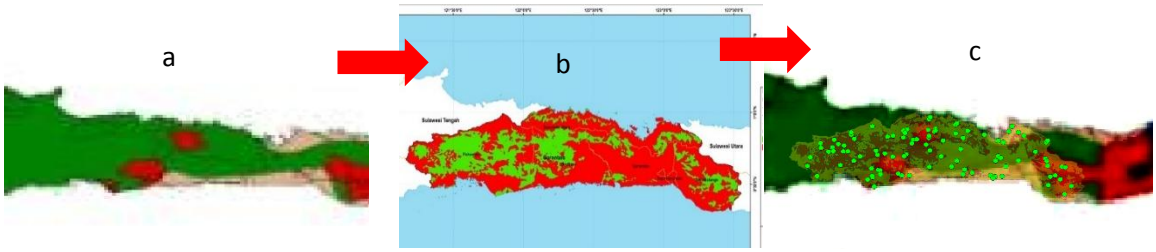


Figure 9. (a) Distribution map of babirusa (Ministry of forestry, 2013), (b) habitat suitability model (2018), (c) distribution of stratified random sample point.

"Red area" on the babirusa distribution map from the Ministry of Forestry is the "confirmed" area of babirusa, and the "green" area is the "possible" babirusa habitat area, while the "gray" area is the area where babirusa habitat "is not suitable or unknown" area for babirusa habitat. On the Suitability model of babirusa habitat, the red color is an area that is "not suitable" with the babirusa habitat, while the area with the green color is the area that is "suitable" for the babirusa habitat in Gorontalo.

For the "Confirm" and "Possible" class areas on the map from the Ministry of Forestry, it assumed to be the same as the “suitable” class from a model. For areas classified as "Unknown," and others assumed to be the same as “not suitable” class on the model. The level of validity of the model results can obtain by calculating the kappa coefficient from the parameters of the correct number of sample points, the total number of samples, user accuracy and producer accuracy in the confusion matrix.

Tabel 6. Confusion matrix

	(Reference map) Babirusa distribution map from a forest of ministry, 2013			
Suitability Model of Babirusa Habitat	Suitable (Confirmed and Possible)	Not Suitable (Unknown & Others area)	Total	User Accuracy (%)
Suitable	45	5	50	90%
Not Suitable	37	13	50	26%
Total	82	18	100	
Producer's Accuracy (%) :	54,88%	72,22%		
Overall Accuracy :		58%		
Kappa Coefficient :		0,16		

The overall accuracy of the model has a value of 54%, and this value indicates that the model has a low level of accuracy. Based on the kappa coefficient, the accuracy of the model results on the reference map has a value of 0.16. The kappa coefficient has a range of 0 to 1. The high kappa coefficient value indicates that the more valid and accurate the resulting conformance model. Low kappa coefficient values indicate that the suitability model is invalid and inaccurate. Based on a comparison of reference maps and model maps, most of the babirusa habitat areas with suitability models have the same location as the babirusa distribution according to the Ministry of Forestry. However, the level of accuracy of the user's accuracy in the class area suitable for the babirusa habitat shows the highest value of 90%. Shows that the area in a suitable class in the model has a high level of validity.

4. Conclusions

Gorontalo Province is one of the provinces that have the Babirusa species (*Babyrousa celebensis*). The variables used in the process of determining the babirusa habitat area are slope, height and land use. The habitat area suitable for babirusa is around 33% of the total area of Gorontalo Province less than the area that is not suitable. Most suitable habitat areas in the western part of Gorontalo Province located in the Puhowato Regency and western Gorontalo District. The result shows that a suitable area for the babirusa habitat has a small area in Gorontalo Province. This suitable area is at an elevation of 0-500 meters above sea level with a slope of 0-8% in the use of forest and swampland. Based on the kappa coefficient and overall accuracy, the spatial model of the babirusa habitat produced has a low level of accuracy and accuracy of the reference map of the ministry of forestry. Only suitable areas have high accuracy. The research due to limited data to validate the results of the spatial model suitability of the babirusa habitat. However, the resulting model can still be developed by adding other variables or parameters to determine suitable habitats for babirusa species in Gorontalo province

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