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Assessing suitable sites for Falcata (*Paraserianthes falcataria* Nielsen) plantation in Bukidnon, Philippines using GIS

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Abstract

This study was conducted to determine sites that are suitable for the establishment of Falcata (*Paraserianthes falcataria* (Nielsen) plantations in Bukidnon, Philippines using Geographic Information System (GIS). GIS layers of variables such as soil, topography, climate and land use/land cover (lulc) were combined to generate the desired suitability map. A total of 2,076 Falcata plantation occurences distributed across the 22 municipalities needed for the validation of results were also collected. Results have indicated that among the 22 municipalities, the greatest number of occurrences (393) was found in Impasugong, while Kalilangan had the least with only 1 occurrence. Restricted areas (unsuitable) constitute 301,187 hectares or 33% of the total area of the province. These sites include protected areas, roads, built-up areas, lakes, rivers, and forests. Highly suitable, moderately suitable and marginally suitable constitute 22%, 44% and 1% respectively. It was also found that majority of the occurrence points coincide with highly and moderately suitable sites.

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Introduction

Forests are a vital resource a country like the Philippines possesses. It plays an important part in the different biogeochemical cycle such as nutrient and water, provides a habitat to different macro and micro flora and fauna and provides a wide resource base for the necessities of life such as food, clothing, shelter, medicine and timber. Forests also provide a viable option for climate change mitigation through carbon sequestration (Paquit & Mindaña, 2017). As population continues to increase, anthropogenic activities that lead to deforestation and forest degradation are also being done to clear more lands for food production and settlement. In industrial countries, forests are destroyed by air pollution, acid rain, drought, wind, snow, pests and diseases putting more demand on the forests as a resource (Chalupa 1990). More have also been used up to support the need for more forest products beyond its sustainable capacity. As forests are destroyed wood becomes scarce, but it remains to be the most economically important forest product and its demand continues to increase despite its declining supply. With the growing demand for wood and the halt of logging in natural and residual forests in the Philippines, there is now a need to strengthen the industrial tree plantation industry in order to meet the growing demand for wood. Tree plantation establishment is one of the best options to alleviate the burgeoning pressures on the remaining natural forests.

Wood from Falcata is one of the prime sources of pulpwood and plywood. The pulpwood and plywood industry contributes significantly to the national economy and in improving the condition of lives of the Filipino people (Subarudi 2003). Today, plantation forestry in the Philippines is by far the best way to legally produce marketable timber. Plantation forestry satisfies wood demands in the country and thus reducing resource exploitation in natural forests. The establishment of plantations also results to rehabilitation of degraded lands for the benefit of future generations (Parrotta 1995). In the Philippines, species such as *Gmelina* spp., *Swietenia* spp., and *Paraserianthes* spp., are the commonest cultivated tree plantation species. The latter is widely cultivated in the CARAGA region and it is of high demand both in local and international markets. Mini-sawmills and plywood processing companies are mainly supplied with logs of Falcata that is mostly grown by smallholder farmers. Falcata has a ready market in Caraga and in Cagayan de Oro, and its low wood density favors efficient transport and loading. Falcata is cultivated mainly for pulpwood but in some cases for sawlog. The economic maturity for pulpwood is relatively shorter which is at 6-8 years depending on location. As a result, higher revenue is generated as compared with other tree crops.

The presence of a ready market for falcata has enticed many farmers to engage in its establishment. However, as with other tree species, it has to be established in its ideal bioclimatic range to attain optimal growth. The productivity of an area is directly correlated with climate (Paquit *et al.*, 2017) and Bukidnon is one of the provinces that have an ideal climate for Falcata. The province also has ideal topography and soils that are very well suited for the species. Moreover, the province being away from the coast and landlocked is rarely affected by destructive typhoons. Despite these facts, there are areas in Bukidnon where conditions are not suitable.

GIS has been used in many studies due to the fact that it is an effective tool for data visualization, database management, data analysis, modeling and cartography. Geographic Information System (GIS) is an organized collection of computer hardware and software designed to create, manipulate, analyze efficiently, and display all types of geographically or spatially referenced data. A GIS allows complex spatial operations that ranges from simple to difficult ones (Chang 2004). A GIS- based site suitability assessment will therefore help determine whether a piece of land is suitable or unsuitable for planting tree species and will aid in the optimal use of land (Mokarram and Amin- zadeh, 2010).

It is therefore the aim of this study to use GIS technology in the identification of suitable sites for the benefit of farmers and policy makers.

Materials and mathods

Study Area

This study was conducted in Bukidnon, Philippines. It is a landlocked province in Northern Mindanao and the only province that does not have a coast line. It extends geographically from 7°20' – 8°40' N to 124°30–125°30' E, with land area of 910,462 hectares (calculated in GIS) representing 2.76% of the country's total land area.

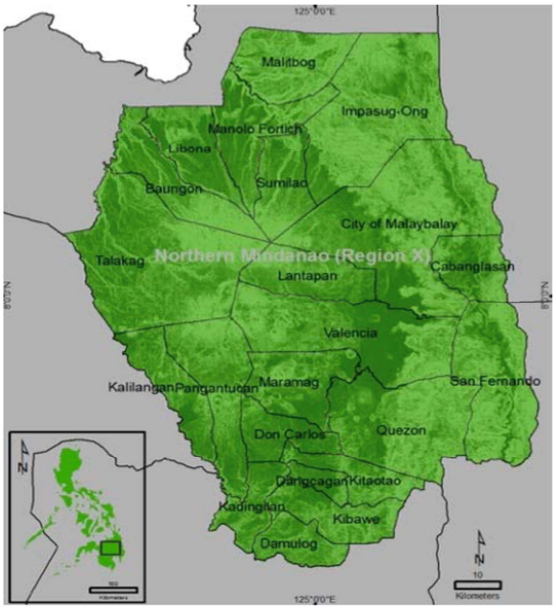

Fig. 1. Map of the Study Area (source: Paquit & Rama, 2018).

The province is composed of 20 municipalities and 2 component cities. Although the province has lofty mountains, the greater part is a gently rolling grassland plateau cut by deep and wide canyons of the Cagayan, Pulangui and Tagoloan rivers and their tributaries, and other rivers. Observations by the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) from 2006 to 2011 have shown that Bukidnon has two prevailing types of climatic variations existing between the northern and southern sections. The northern part falls under the third or intermediate A type while the southern part beginning from Malaybalay, falls under the fourth type or intermediate B type.

Data Collection

The needed data were collected from government agencies. The coordinates of Falcata plantations were gathered from the Provincial Environment and Natural Resources Office (PENRO), Community Environment and Natural Resources (CENRO) and various Municipal Environment and Natural Resources Offices (MENRO). For climate data, the website www.worldclim.org/bioclim.html was the source for bioclimatic variables such as mean annual temperature (bio1) and annual precipitation (bio12) (Hijmans *et al.*, 2005). IfSAR DEM was acquired from PhilLiDAR 2 project, and vector datasets of municipal boundaries, protected areas, and soil of Bukidnon were gathered from other credible sources. Finally, the data for land use/land cover (lulc) were obtained from ESSC.

Suitability Parameters

Topographic, climatic and edaphic factors are known to influence plant growth, development and survival (Benner *et al.* 2010). The topographic factors considered include aspect, elevation, and slope. Slope is the rate of change in elevation while aspect is the direction where slope faces and is generally categorized as northern, eastern, western, and southern. Aspect has some implications on the exposure of plants to solar radiation while slope relates with soil development. The development of soils occurs slowly on steeper slopes (Akinci *et al.* 2013). East facing slopes are known to be more suitable in terms of solar radiation received by plants (Paquit *et al.* 2017). South facing slopes are considered marginally suitable since they are generally drier and exposed to sunlight for a longer period. The three topographic parameters have corresponding weights that were determined through pairwise comparison (Saaty 1980). Fig. 2 shows the topographic parameters used. Soil type has a corresponding weight equal to 22 (Fig. 3b). Soil type influences site productivity and are differentiated based on texture, drainage, fertility, and depth (Holloway, 2013. Furthermore, soil is categorized into three groups: sand, silt, and clay. The climate of the area is classified as shown in Fig. 4 and has an assigned weight of 24 for mean annual temperature and 12 for annual precipitation. Land cover is the observed physical cover including the vegetation

(natural, planted and protected areas) and human constructions (buildings, roads, and the likes) that cover the earth's surface. This parameter has an assigned weight of 9 as shown in Fig. 3(a).

The classification and distribution of areas according to topography, climate, soil type, and land use are summarized in Tables 1, 2, and 3.

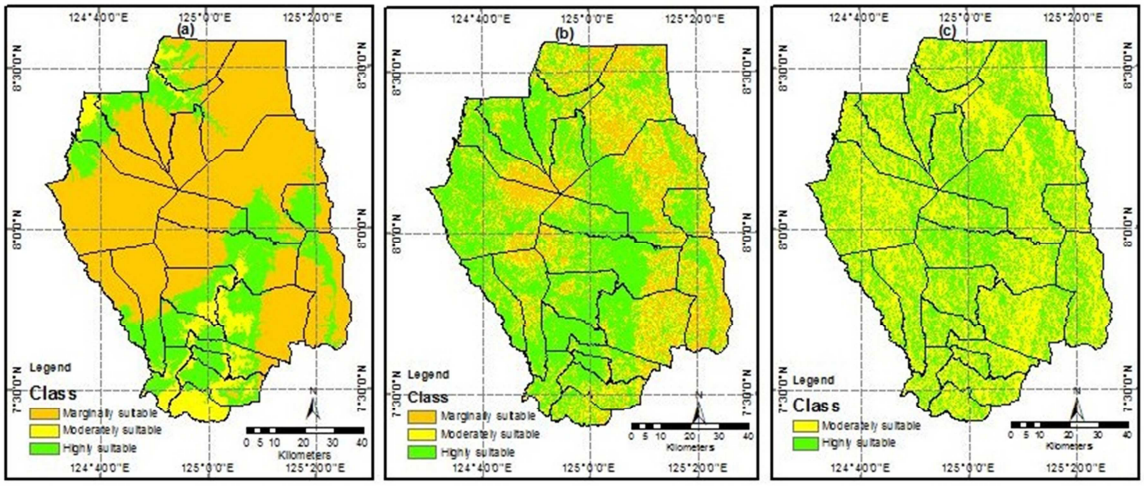

Fig. 2. (a) Elevation, (b) Slope, and (c) Aspect Map of Bukidnon.

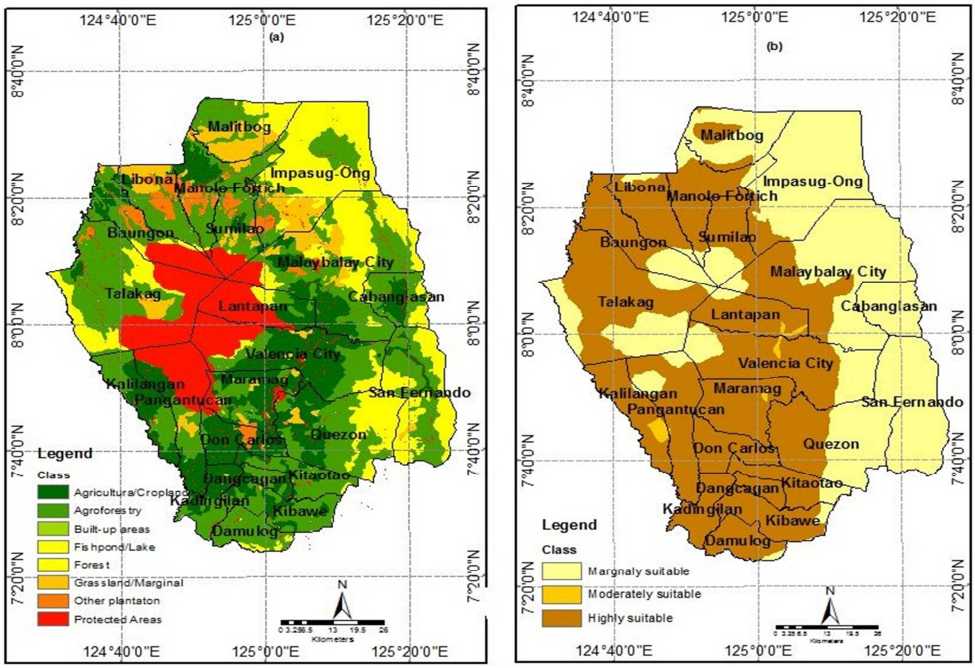

Fig. 3. (a) Land use/landcover (lulc) and (b) Soil Map of Bukidnon.

Table 1. Areal and percentile distributions of elevation, slope and aspect.

Elevation	Area (ha)	Area (%)	Source
11 – 300	599,326	66	Prawirohatmodjo (1994)
300 – 500	88,287	10	
500 – 2,921	222,850	24	
Slope	Area (ha)	Area (%)	Nguyen (1998)
0 – 10	225,361	25	
10 – 18	215,374	25	
18 – 79	469,727	50	
Aspect	Area (ha)	Area (%)	Davis *et al.* (2012)
22.5 – 157.5	513,307	56	
157.5 – 360	397,155	44	

Table 2. Areal and percentile distributions of lulc and soil.

Land-Use	Area (ha)	Area (%)	Source
Agricultural/crop land	178,103	20	ESSC (2005)
Agroforestry	350,421	38	
Buitup areas	1,184	0	
Fishpond/lakes	17	0	
Forest	176,768	19	
Grassland/marginal	54,842	6	
Other Plantation	23,887	3	
Protected areas	123,851	14	
Soil	Area (ha)	Area (%)	Source
Sandy, undifferentiated	397,130	44	Orwa *et al.*(2009)
Silt	4,755	1	
Clay, Clay loam	508,558	55	

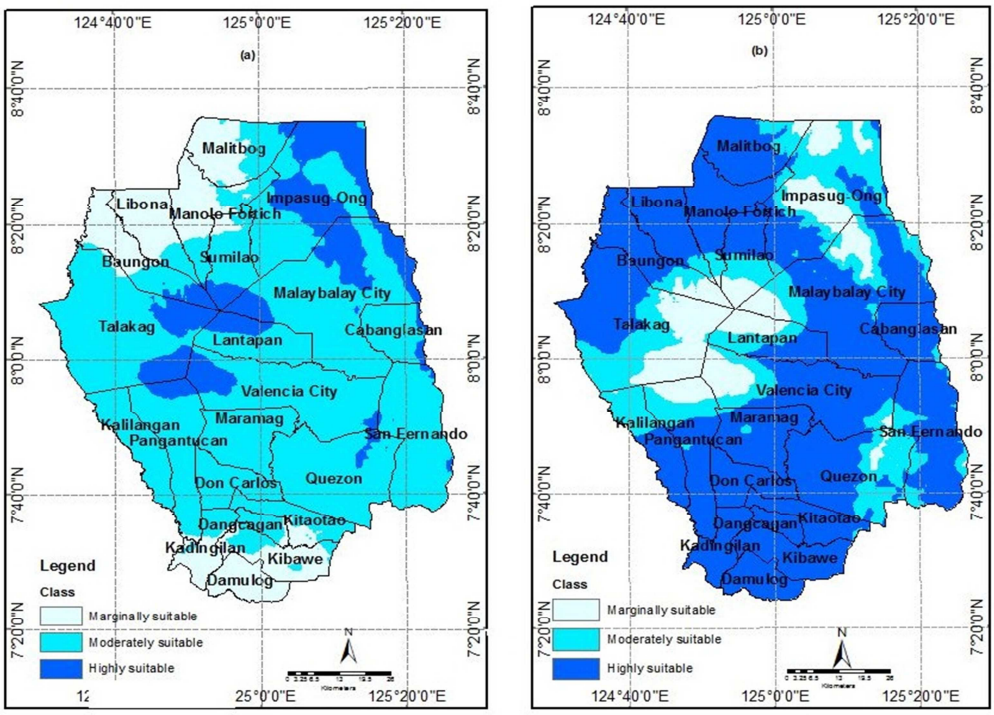

Fig. 4. (a) Annual Precipitation and (b) Mean Annual Temperature maps.

Table 3. Areal and percentile distributions of the main and sub-criteria parameters in the study area.

Annual Precipitation (mm)	Area (ha)	Area (%)	Source
2,001 –2,400	142,546	16	Orwa *et al.* (2009)
2,400 – 2,800	633,296	70	
2,800 – 3,285	134,620	14	
Mean Annual Temperature (°C)	Area (ha)	Area (%)	Source
126 - 201	117,211	13	Orwa *et al.* (2009)
201 – 221	190,473	21	
221 – 268	602,779	66	

Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a multi-criteria decision-making approach introduced by Saaty (1980). Being one of the most widely known and used multi-criteria analysis approaches, the AHP method enables users to determine the weights of the parameters in the solution of a multi-criteria problem (Saaty, 2001). The process was used in the study to determine the weight of each parameter based on the opinion of three experts. Solving a problem through AHP is carried out using the weights or priorities of the criteria subjected to pairwise comparison.

The generated weights for each expert were averaged to obtain the final weights. All seven environmental variables were reclassified into values of 1,2,3 to generate a raster that conforms to the final main classes of suitability. Results were classified into three: marginally suitable, moderately suitable, and highly suitable, with corresponding values of 1, 2, and 3 respectively.

Data processing

For soil data, clipping and subsequent conversion to raster was done. The DEM was used to generate slope and aspect with units that are expressed in degrees. All environmental variables were made uniform in terms of cell size and extent. All were then resampled to 10 x 10 meter spatial resolution and set to uniform extent. The projection for all environmental variables was then set to UTM zone 51N.

Weighted Overlay

The Weighted Overlay tool was applied to generate the final suitability map. Restricted areas were carefully factored in the map by identifying lulc that could either be temporarily or permanently restricted from tree plantation establishment such as Protected area, water bodies, roads and urban areas. The weight of each of the criterion in the overlay analysis were based on the result of the AHP analysis.

Validation of Results

The GPS points of existing *Falcata* plantations were used to validate the accuracy of the generated map. Analysis was done to determine whether the occurrence points of *Falcata* coincide with the location of highly and moderately suitable areas.

Table 4. The fundamental scale of pairwise comparison (Saaty, 1980).

Intensity importance	*Definition*	Explanation
1	Equal importance	Two activities contribute equally to the objectives
3	Weak importance of one over another	Experience and judgment slightly favor one activity over other
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is strongly favored and its dominance demonstrated in practice.
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation.
2, 4, 6, 8	Intermediate values between the two adjuscent judgements	When compromise is needed
Reciprocals	If activity i has one of the above number assigned to it when compared with activity j, then j has a reciprocal value when compared with i.	

Results and discussion

Actual Location of Paraserianthes Falcataria Nielsen

A total of 2,076 Falcata plantation occurences were observed in the study area. As shown in Fig. 5., these points are unevenly distributed across the 22 areas of interest and where found to occur mostly in the lowlands. The central part of the province is blanketed with immense mountain ranges that are considered area protected areas. As a result occurences are rarely to be found in this areas. Among the 22 municipalities, Impasug-ong obtained the greatest number of plantation points with 393 while Kalilangan had the least with only 1 (Table 5). 20 municipalities have a representative sample which means that 91% of the study site has at least 1 falcata plantation. Only Talakag and Lantapan have no sample points. As observed, the two municipalities are comprised mainly of elevated areas where the establishment of *Falcata* plantation is normally discouraged because of gall rust disease. Despite the gap in the science that relates the occurrence of gall rust and environmental factors, particularly elevation, many people have been able to document the increased incidence of the disease with elevation (Lacandula *et al.* 2017).

Relation to all Environmental Variables

In Fig. 7, the resulting suitability map of the different (*Paraserianthes falcataria* Nielsen) plantations in the study sites is shown. Some of the highly suitable sites depicted as light green color on the map are mostly distributed in the Southern part of the provinces. This areas that cover an area of 20,404 hectares fall mainly under the municipalities of Maramag, Quezon, Valencia, Don Carlos, Kitaotao, Dangcagan, and Kadingailan. These areas cover expansive lands that could fall within the 300-500 meter elevation class which is still ideal for the species. All values of environmental variables considered in this study were satisfied based on the requirements of the species.

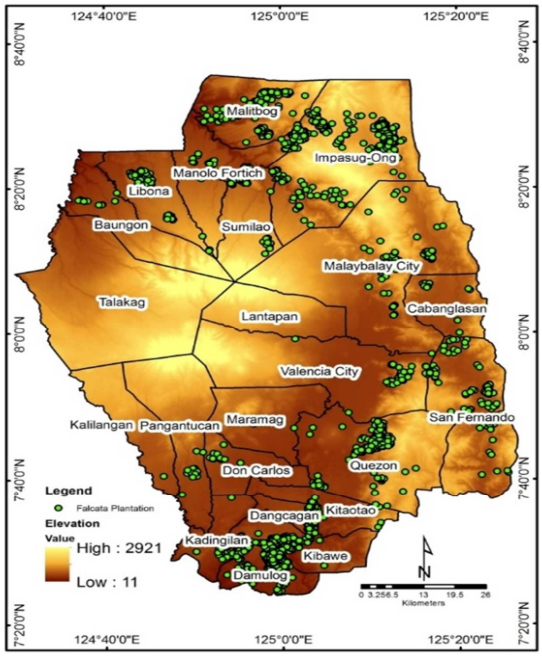

Fig. 5. Actual location of *Paraserianthes falcataria* Nielsen in Bukidnon.

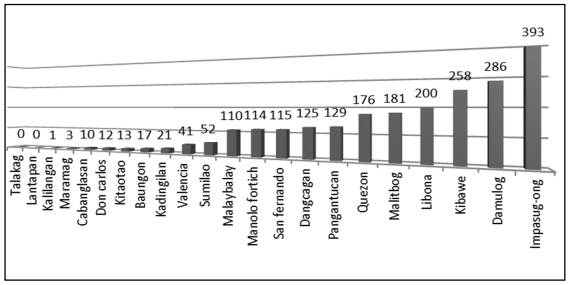

Fig. 6. Number of Falcata plantation occurences per municipality.

Suitability Distribution of Falcata Plantations in

These were areas having highly suitable elevations which are crop lands, agroforestry, and other plantation sites. Thus, *Falcata* plantations must be established in these sites for best growth performance. *Falcata* is one of the fastest growing species chosen by tree growers because of its high demand for both local and international markets.

When established, the seedlings grow fast and are not greatly affected by competing vegetation (Parrotta 1990, Bhat *et al.*, 1998). The dark green colored areas that are identified as moderately suitable are evenly distributed in all municipalities. Moderately suitable sites constitute 39,673 hectares or 44% of the total. The blue colored areas which represent a very small fraction are the marginally suitable areas. The red sites as shown in the map are areas considered as restricted covering a land area of 301,187 hectares or 33% of total. These sites include protected areas, roads, built-up areas, lakes, rivers, and forests. The dark green sites, These sites comprised the biggest land area compared to the other classified sites.

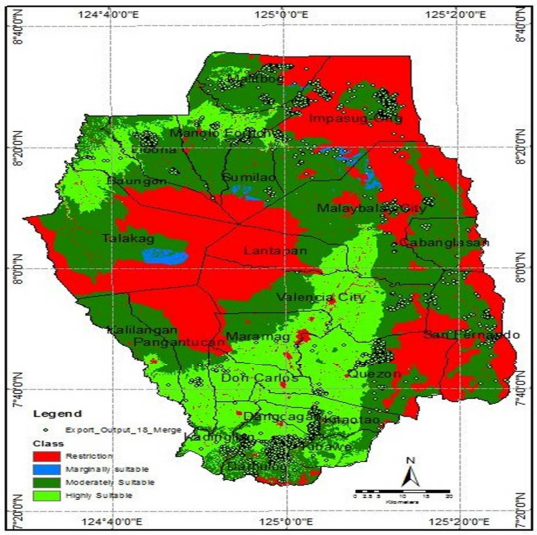

Fig. 7. Falcata (*Paraserianthes falcataria* Nielsen) suitability map.

The total areas classified by the weighted overlay analysis are summarized in Table 5. There were four classes of suitability in the final output namely: highly suitable, moderately suitable, marginally suitable, and restricted sites. As shown in Table 5, the estimated area of Bukidnon based on spatial analysis totaled to 910,462 hectares.

Table 5. Distribution of land suitability analysis based on area and percentage.

Class	Total area classified by the Weighted overlay analysis	
	Area (ha)	Area (%)
Highly suitable	204,042	22
Moderately suitable	396,738	44
Marginally Suitable	7,535	1
Restriction	301,871	33
Total	910,462	100

Suitability Model in relation with actual occurrences

The coordinates of Falcata plantations in the map coincide with the highly and moderately suitable sites. However, it should be noted that some points were found in the restricted areas as well.

This may indicate that reforestation activities such as the National Greening Program using the species have been done. However, the government should take caution in doing such activities inside protected areas since it might have disrupt balance and affect native biodiversity.

In some cases, the National Greening Program (NGP) workers lack the needed knowledge in species requirements that is required in the identification of reforestation areas. As a result, *Falcata* are often planted in almost every NGP sites that have unsuitable environmental conditions.

Conclusions

The geographic locations that covered large tracts of highly suitable sites for *Falcata* plantations were Valencia, Maramag, Quezon, Dangcagan, Kitaotao, Kibawe, and Kadingilan. In contrast, the municipalities that covered small areas of highly suitable sites were Manolo Fortich, Malitbog, Libona, impasug-ong, Lantapan, Kalilangan, Pangantucan, Baungon, Talakag, and Malaybalay. This information is of direct benefit for investors and even small-scale farmers who want to tender *Falcata* plantations. *Falcata* is a fast growing tree species with a clear end use and a ready market. Based on observations, *Falcata* is largely cultivated in Misamis oriental where truckloads are delivered to Cagayan de Oro area for processing.

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