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GIS-Aided Suitability Assessment of Mt. Mayapay Watershed in Butuan City, Agusan del Norte

Roger T. Sarmiento[1,*] *and Jupiter V. Casas*[2]

[1] Department of Natural Resources, Caraga State University, Butuan City, Philippines
[2] College of Forestry and Environmental Science, Central Mindanao University, Valencia City, Philippines

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ABSTRACT

The recent depleting forest resources of the Philippines prompted national and local government agencies, NGO's, private sectors and academic institutions to develop reforestation strategies to conserve and protect the remaining resource. In recent years, the Philippine government promoted the Community Based Forest Management Agreement (CBFMA), Integrated Forest Management Agreement (IFMA) among others to fast track reforestation. However, several reforestation programs undertaken by government agencies were generally assessed as poorly implemented due to several factors. The improper species-site suitability matching of reforestation species used is one of the issues recognized causing poor results in reforestation programs. A powerful tool used nowadays aid improve species-site suitability matching is a Geographic Information System (GIS). This research explored the use of GIS in developing site suitability maps of Mt. Mayapay for the three primary reforestation species namely *Acacia mangium* Willd., *Swietenia macrophylla* King., and *Spathodea campanulata* Beauv. These site suitability maps were overlaid to develop species suitability maps for economic and environmental forestry purposes. The general area of study site was determined to be moderately suitable (S2) for the three selected species. For most of the site, the species recommended for forest production purposes was *Acacia mangium* Willd. The species recommended for forest protection purposes on the other hand was *Spathodea campanulata* Beauv. This study suggest that through GIS, the species-site suitability matching can be improved and to forestry planners to develop better land use pattern and make reasonable decisions for forest land use. The site suitability maps developed are useful to identify suitable areas for

* Corresponding Author
Email:rtsarmiento@carsu.edu.ph

effective conservation, efficient income generation and sustainable forestland management in Mt. Mayapay, Butuan City, Agusan del Norte, Philippines.

Keywords: GIS, production, protection, reforestation, species-site matching, suitability

1 Introduction

Tropical forests are still used as renewable resources. However, with the pressure due to increasing population, more agriculture lands and urban areas are required to provide for the basic needs for food and housing. As a result, forest areas have been converted resulting to a decline at a very alarming rate (Department of Environment and Natural Resources, 2009). Because of the continuously decreasing forest cover in the Philippines, aggravated by the impacts of climate change, the Department of Environment and Natural Resources (DENR) and other government agencies, private sectors, religious groups and academic institutions spearheaded reforestation strategies to restore forest cover in degraded areas. This aimed also to conserve and protect the remaining forest. However, several reforestation projects undertaken by government agencies were generally regarded as poorly implemented (Chokkalingam et al., 2006). Some government officials have even connived with logging companies and poachers which impaired the progress of rehabilitation projects. This resulted to failure in fully attaining sustainable development. Success rates of government reforestation projects are very low when compared with reforestation projects contracted by PO, NGOs, and the private forest entities (Chokkalingam et al., 2006). Unsatisfactory projects are wasting government's financial resources. Thus, proper planning is imperative to ensure project success. In Butuan City, the "Mt. Mayapay Rehabilitation Project" was launched. It was laid out with the key intention of reviving Mt. Mayapay as green as it was decades ago and to conserve the watershed's soil and water resources.

Mt. Mayapay is the tallest mountain in the Butuan-Buenavista mountain range with an elevation of 675 meters above sea level. The watershed has a total land area of 18,642 hectares (Calo and Lasam, 2006). It was once the primary source of water for domestic and irrigation purposes. However, due to rampant illegal logging in the early 80's, the watershed was devastated. A small portion of the mountain was declared as a military reserve. The larger portion of the mountain, evaluated as a degraded and a disaster area, was the target of the rehabilitation effort of DENR and other sectors. In the "Mt. Mayapay Rehabilitation Project", fast growing forest species like Large-leafed mahogany (*Swietenia macrophylla*), Mangium(*Acacia mangium*), and African tulip (*Spathodea campanulata*) are the primary reforestation species used. In promoting this, monthly tree planting activities have been organized.

According to Kartawinata (1994), rehabilitation of deforested lands requires urgent and serious attention in order to (1) outpace the rate of deforestation, (2) restore biological diversity, (3) diversify the products and increase the productivity of deforested lands, (4)

provide socio-economic benefits to both government and rural community, and (5) supply raw material to the wood industry so that the pressure on remaining primary forests can be reduced and even eliminated. Thus, the Philippine government strongly promotes reforestation to rehabilitate degraded watersheds.

Efforts in the rehabilitation of degraded areas have gone wasted because of factors of poor species-site suitability matching and socio-political reasons (Galang, 2010). While there is sufficient knowledge and experience that can be used as basis for trial programs, further research is needed, particularly on the use of locally and economically valuable fast-growing species.

Geographic Information System (GIS) is now recognized as a powerful decision-support tool. It involves the capturing, storing, management, analysis and presentation of spatial data for identifying and mapping areas with specific characteristics, or fulfilling defined criteria such as those required for forestry production. Maps produced through GIS provide managers with previews of potential opportunities for the expansion of existing forest. The use of GIS technology ensures that forest lands are not degraded and it should be used according to its capacity to satisfy human needs for present and future generations.

Many tropical countries have achieved economic growth by reviving their forests. However, some of these countries remain impoverished despite rehabilitation program for their forests. In the Philippines, forest rehabilitation is no longer a new experience. Nonetheless, as the remaining forest conversion continues to be unabated, rehabilitating degraded landscapes is likely to become more and more important. The rehabilitation of Mt. Mayapay has become a major concern for all sectors, thus in 2008, the "Mt. Mayapay Rehabilitation Project" was launched as a means to rehabilitate degraded areas and protect the remaining forest cover. However, in the course of its implementation, the project encountered several problems (budget constraints, uncooperative partner agencies, unpredictable weather conditions).The lack of information on species-site matching is also one of the major issues in reforestation. This problem can be minimized if proper profiling of the site is done prior to implementation with the aid of new techniques such as GIS.

The main outcome of this study is the provision of information that will enhance the success and sustainability of forest rehabilitation efforts in the Philippines through species-site suitability of the primary reforestation species used in the Philippines. Similarly, the findings of this study will be the basis for recommendations on implementing similar projects in the future. In addition, this will provide information to the public to give feedback regarding questionable rehabilitation efforts of the government.

The general objective of this research is to assess the Mt. Mayapay Watershed for site suitability to forestry interventions and plantation expansions using GIS modeling. Specifically, the study aims to (a) identify suitable sites for production and protection forest of Mt. Mayapay Watershed using GIS tools, (b) develop GIS based suitability maps for three selected tree species for reforestation, and (c) determine potential lands for new forest plantation with purposes.

2 Methodology

Characteristic of the Study Area

Mt. Mayapay is a prominent natural landmark in Butuan City. Its plateau formation, the predominant feature serves as backdrop of the City. It is considered as the highest peak of the Butuan City-Buenavista mountain ranges with an elevation of 675 meters above sea-level (Figure 1), which render vulnerable to landslides if the denuded areas are not replanted.

The mountain lies between 8°57′36″ and 8°48′0″ latitude and 125°24′0″ and 125°34′48″ longitude. It is bounded by the Butuan-Cagayan de Oro Highway in the North, Bugabus River and Calaitan River in the South, Agusan River in the east, and Barangays Otao and Rizal in the municipality of Buenavista in the West (Figure 2). However, the study was confined on the 929.43 hectare immediate periphery of the mountain situated in the Barangay Nong-nong and Tungao in Butuan City, and Barangay Alubijid in the Municipality of Buenavista.

Climatic Type

The entire province of Agusan del Norte falls under Type II. In Corona System of Classification it is characterized to have no distinct dry season with pronounced rainy season during the month of November to March. It has a mean annual rainfall of 1950 mm, monthly mean temperature of 28.20° Celsius, and relative humidity of 81.0% to 88.10%.

Topography and Slope

The northern portion of Butuan City and the municipality of Buenavista are generally flat to gently sloping with an elevation range from 1 to 200 meters and slope range varying from 1 to 8% and 6 to 18%.

Mt. Mayapay has a slope ranging from rolling to very steep. The very steep slope is located in the mid to top portions of the mountain with a slope of more than 45% and at an elevation of approximately 675 meters.The areas with steep slopes are found in the Butuan City side of the watershed with slope range of 25%-60% while the rolling slope can be found in the Buenavista aside with slope range of 18%-25%.

Duration of the Study

The study was conducted for five months from October 2010 to February 2011 within the 929.43 hectare immediate periphery of Mt. Mayapay.

Data Collection

Using GIS tools, the study site was divided into grid cells of 400 m x 400 m and generated a grid map. Using the generated map in the field, 5 cores randomly selected in a zigzag pattern were collected within each cell and mixed up to constitute the sample. Depending on the site identified such as slope, vegetation and open areas, two or more samples were collected. The central point of the five cores was used as the reference point of the sample and its location was recorded using a GPS receiver. The locations were then used reference in developing soil thematic maps using GIS software.

The soil samples were taken from 0-15 cm below the soil surface for top soil and another 15-30 cm for the subsoil sections. Samples were mixed and air dried for 2 days. Approximately 400 - 500 grams per sample were placed in sample containers, labeled, and analyzed in soil laboratory. Routine soil analysis method was used to determine soil pH, NPK, organic matter content while feeling method was used to determine soil texture.

Using ArcGIS9.3 spatial analysis tools, sampling points were interpolated using Inverse Distance Weighting (IDW) method to generate surface thematic maps of the different soil properties namely: soil pH, soil depth, soil types, soil textures, soil fertility and soil organic matter content. These thematic maps were rasterized and used as map layers for suitability analysis.

Geological information was derived from geological maps, while slope and elevation were derived from a Shuttle Radar Topography Mission - Digital Elevation Model (SRTM DEM) downloaded from www.philgis.org. The climatic information was derived from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) Station of Butuan City, Agusan del Norte. A ten (10) year observation period (2001 to 2010) for rainfall and temperature was collected and used as reference for thematic map preparation. In addition, the forest policies, problems, accomplishment reports and literatures related to assessing forestry land use potential were obtained from the National Economic and Development Authority Caraga Regional Office XIII (NEDA Reg. XIII) and the Department of Environment and Natural Resources Caraga Regional Office XIII (DENR Reg. XIII).

Information on the characteristics of the selected species was obtained through available literatures and journals both online and in research library of Central Mindanao University in Bukidnon and Caraga State University in Butuan City. Some information was also obtained from the office of the Ecosystems and Research Development Services of the DENR in Caraga Region.

Land Potential Suitability Assessment

As this study was based on spatial analysis to assess land suitability for 3 selected species using GIS technology, the methodology used was based on the FAO (1984) approach for land evaluation for forestry. The main steps are the following: (a) Selection of the

forest species, (b) Determination of ecological criteria, (c) Determination of classes for each ecological criterion, (d) Determination of weight and score of land suitability for selected species, and (*e*) Assessment of the land potential suitability for establishing forest plantation. The final score of the land suitability in each site is given by the formula below.

$$S = \sum W_i X_i,$$

where S is the suitability index/final score, W_i weight of criterion i and X_i score of class i.

The formula was applied in a 10 meter grid cell size. The higher the value in the cell, the more suitable it is for the forest species. The final score/suitability index was converted to a suitability class, as shown in the Table 1.

The next step was to develop the map of preliminary land suitability for forestry plantation. All physical land suitability maps of 3 selected tree species were superimposed in order to get the final suggestion based on priority matrix (Table 2).

3 Results and Discussion

Site Suitability Map of Selected Forest Tree Species

Table 3 shows the physical site suitability for growing *Acacia mangium* within the 929.43 hectare study area. About 784.33 ha or comprising about 84.39% of the site was determined to be Moderately Suitable (S2) for growing *A. mangium*. Only 145.10 ha or 15.61% of the entire area was determined to be Marginally Suitable (S3). There were no areas identified as Highly Suitable (S1) as well as Not Suitable (N) for growing the species.

Moderately suitable locations for growing *A. mangium* almost cover the entire study site. In these areas, the soil characteristic is mostly sandy loam and the soil pH was acidic with pH levels of 4.5 to 5.5. Mostly, all areas are gently sloping to undulating (15-25%).

In the central part of the study site most areas have sandy soil in small open patches and trenches created from excessive surface runoff. These areas are assessed as marginally suitable for *A.mangium*, due to the prevailing soil and ecological conditions. *A. mangium* grows best on sandy clay soils with good drainage. It also tolerates soils of low fertility and impeded drainage. Since the prevailing soil type of the site is sandy loam, majority of the area are classified as moderate suitable for this species with no areas determined to be highly suitable.

Table 4 showed large area of the study site were found to have moderate suitability (S2) for growing mahogany species covering an area of 872.05 hectares or 93.83% of the entire study site. Moderately suitable sites are located on gently sloping sites with slope ranging from 8-25% and elevations less than 500 meters above sea level.

The location of marginally suitable areas for *S. macrophylla* practically overlapped in the hilly northern part of the mountain. Most of the marginally suitable sites are located within the Butuan City portions of the mountain. Examining the suitability map of *S. macrophylla* (Fig. 3b), the whole study area is classified into two classes only; the

Moderately Suitable (S2) and Marginally Suitable (S3) classes with no areas identified as Highly Suitable (S1) and Not Suitable (N). This can be explained by the fact that large portion of the study area have some limitations for forest plantation, notably very shallow layer, steep and very steep soils in the mountains and acid. The acidic sandy soils and very poor soil fertility are other characteristics that hinder proper growth of *S. macrophylla*.

Result showed that about 61.20% of the entire area or 568.83 hectares is moderately suitable for growing *S. campanulata*. Only 38.8% or 360.60 hectares has marginal suitability for the species. Similar to *A. mangium* and *S. macrophylla*, there are no areas identified to be Highly Suitable (S1) and Not Suitable (N) for growing *S. campanulata* (Table 5). The moderately suitable sites for *S. campanulata* were found on relatively flat areas with elevation lower than 450 m above sea level. The high adaptability of this tree is related to its low elevation requirement. The soil characteristics of highly suitable class were mostly loamy sand with slightly acid soil pH. In steep to very steep slopes, the predominant lands are marginally suitable for almost all 3 species, but having medium value for *S. campanulata*. Most of the highly mountainous and inland sandy areas were ranked as marginally suitable because of high elevation, steep slopes and very low soil pH. Areas with very thin layer of topsoil and crag portions were considered as not suitable to grow *S. campanulata* due to limitations on soil depth (Fig. 3c).

Site Suitability of Mt. Mayapay for Economic Forestry (Forest Production)

The site suitability for "economic forestry" was determined in the priority matrix by considering the ordinal preference on species based on economic analysis and consultations from forestry experts. The species were ranked 1st, 2nd and 3rd order priority over the same tract of land. Rank 1 was given significant priority for establishment on the site. *A. mangium* was given highest priority, followed by *S. macrophylla* and then *S. campanulata* having the least priority (Table 2).

Of the selected species, *A. mangium* was considered the most important for economic purposes because it is fast growing and most appreciated species in wood production. It produces wood with high utility value, making it economically more feasible. Studies indicate that they have high crude protein content but low in vitro dry matter digestibility. As a fuel with a calorific value of 4,800-4,900 kcal/kg, *A. mangium* provides good quality charcoal and is suitable for the manufacture of charcoal briquettes and artificial carbon. The pulp is readily bleached to high brightness levels and is excellent for paper making. The neutral sulphite semi-chemical pulping of *A. mangium* gives yields of 61-75%. The wood also makes excellent particleboard. As timber, it is an important source of wattle timber; in which the wood is used for construction, boat building, furniture and cabinet making, and veneer. It makes attractive furniture and cabinets, mouldings, and door and window components. Conversion into veneer and plywood is feasible with no specific processing requirements.

S. macrophylla also played an important role in economic forestry and is given 2nd priority rank. It is one of the most important tropical timbers on the world market. In the Philippines, most *S. macrophylla* traded are planted trees, although small quantities are available from natural stands. It is used in multi-storey systems in the Philippines, boat and ship building and pattern making. Logs are used for the manufacture of veneers and for paneling. It is also used as shade for coffee and cacao.

S. macrophylla is regarded as the world's finest timber for high-class furniture and cabinet work. Its popularity is especially due to its attractive appearance in combination with ease of working, excellent finishing qualities and dimensional stability. The species is often used for interior trim such as panelling, doors and decorative borders. It is sometimes applied for precision woodwork such as models and patterns, instrument cases, clocks, printer's block and parts of musical instruments; were uniform straight-grained material is used. Other minor uses include burial caskets, wood carvings, novelties, toys and turnery.

S. campanulata is next in importance and is given 3rd priority in rank for economic forestry. In its original habitat, the soft, light brownish-white wood is used for carving and making drums. In many parts of the country, *S. campanulata* has been planted as an ornamental plant. The flowers bloom with great profusion, and the trees can be seen from great distances. It is not browsed by domestic animals and although a popular decorative tree for avenues it has shallow roots and a tendency for branches to break off in a storm.

Table 6 presented the site suitability for economic purposes of the study area for three selected species. Result shows that *A. mangium* is preferred to cover an area of about 744.03 hectares or 80.05% of the entire study site. *A. mangium* was given 1st order priority in economic forestry. Areas regarded as marginally suitable for *A. mangium* were assigned to the 2nd order species *S. macrophylla*.

S. macrophylla as given 2nd order priority for establishment was assessed to cover an area of 168.32 hectares or 18.11% of the entire study site. Looking at Figure 3d, it shows that locations suitable for mahogany are the same locations classified as marginally suitable for *A. mangium*. Using ordinal assignment, sites classified having higher values for a species is assigned to the first order species and lower values assigned to the next order species. The second order species was then assigned on the next higher value while the next order species assumes the lower value, so on and so forth until the last order species is assigned over an area.

S. campanulata was assessed to be suitable only in 17.08 hectares comprising only 1.84% of the entire study site. Being in the last order of priority, the species is assigned in areas which are least suitable for the first and second order species. The above suitability resulted because in economic forestry, experts and local people regarded *S. campanulata* to have the least concern species in the market.

Site Suitability of Mt. Mayapay for Environmental Forestry (Forest Protection)

Mt. Mayapay's geography is particularly prone to natural calamities. This therefore,requires attention to prioritize environmental protection, especially in steep to very steep slopes of the mountain. According to Calo and Lasam (2006), Mt. Mayapay had a greater probability of landslide if exposed to severe rainfall as what happened in Guinsaogon, Leyte in 2006. Storms, flood, soil erosion, droughts and intrusion are frequent events in Butuan City,thus, appropriate tree species to fast track restoration of forest cover is imperative.If all degraded areas are fully restored, soil erosion and rapid surface runoff will be prevented hence flooding and vulnerability of landslides on the lowland areas will be eliminated.

The site suitability classes for environmental forestry were determined by considering the ordinal preference based on environmental analysis. Unlike the site suitability assessment for economic forestry, suitability assessment for environmental protection takes the value of the highest scoring tree species overlaying the suitability maps of the other selected species.

Table 7 showed that of the 3 selected species, *S. campanulata* has the highest suitability on the site. About 479.89 hectares or 51.63% were classified as more suitable for growing African tulip than any of the other 2 selected species. African tulip is native in Africa and can be considered for reclamation work, they can grow under the most difficult condition, especially eroded soil. They grow fast, however they have a shallow root systems and is not adaptable for areas having steep to very steep slopes. The tree reproduces aggressively, so it is a popular choice in rehabilitating degraded forest lands such as poorly vegetated areas of Mt. Mayapay.

A. mangium was assessed to be suitable in 393.38 hectares or 42.32% of the entire study site. According to Le Dinh Kha (2001), the species creates a more favorable environment for many other soil microorganisms, and thus improves the physical and chemical soil properties. In addition, *A. mangium* plantations have the potential to provide several other environmental benefits. They have been used to allow agro-forestry to be practiced on steep land where previously cultivation would have caused excessive soil erosion and to stabilize hill slopes. The *Acacia* species plantations also play an important role in reducing greenhouse gases and are also expected to reduce the pressure on native forests as a source of industrial raw material. This will help to preserve the environmental integrity of native forests. However, they are not suitable as windbreaks because of the tendency of trees to snap in high winds. It grows best on more fertile sites with good drainage and very deep soil depth.

S. macrophylla is a drought-tolerant tree (Orwa et al., 2009). This species is one of the principal tree species planted on bare or bushy hills in the Philippines, having the function of protecting against erosion and land-deformation. Young trees are fast growing compared to other tree species such as *Acacia* and *Spathodea* species.

S. macrophylla has several physiological and morphological characteristics that may contribute to its ability to adapt to environment of acid, shallow and poor soil, in particular on thin layer soil of the study area. Table 7 shows that only about 56.16 hectares or 6.04% of the study area is suitable for growing *S. macrophylla*. In comparison with *A. mangium*, *S. macrophylla* is firmer for windbreak however not very adaptable for very steep sites ranging from 25-50% slopes.

4 Conclusion

Using GIS tools, site suitability maps were developed for the tree selected species. Suitable sites for growing *Acacia magium* Willd., *Swietenia macrophylla* King., and *Spathodea campanulata* Beauv. were identified for forest production and forest protection purposes. Accordingly, it can be concluded that the suitable species recommended for most of the sites was *A. mangium* for economic forestry and *S. campanulata* for environmental forestry purposes.

Incorporating environmental and economic aspect into site suitability assessment for the selected tree species will allow forestry planners to develop better land use pattern and make reasonable decisions for forestland use. This study shows that the site suitability assessment model developed here is useful to identify suitable areas for forest plantation in terms of effective conservation, efficient income generation and sustainable forestland management in Mt. Mayapay, Butuan City, Agusan del Norte, Philippines.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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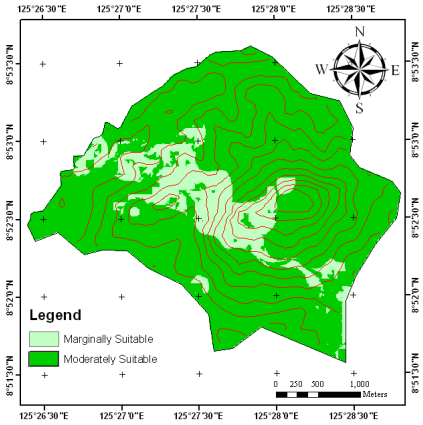
Fig. 1: View of Mt. Mayapay as seen from the North-Eastern part, the Butuan City side of the mountain. (Source: NEDA-Region XIII Accomplishment Report, 2010)

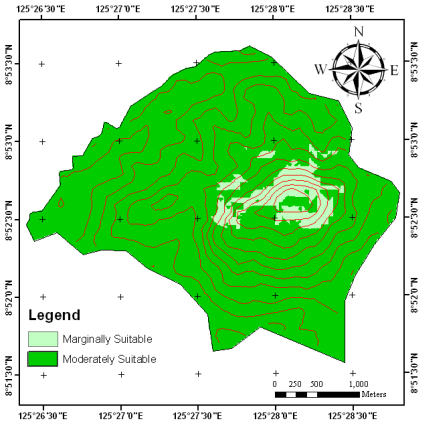
Fig. 2: Map showing the location of Mt. Mayapay Watershed and the study area.

Fig. 3: Site suitability maps of Mt. Mayapay developed through GIS modellling.

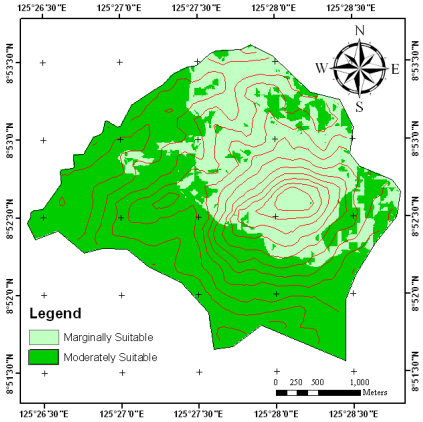
(a) *A. mangium*



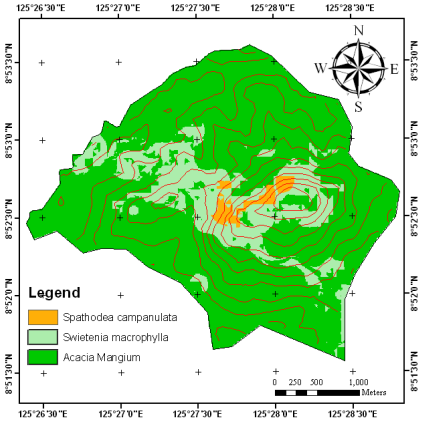
(b) *S. macrophylla*



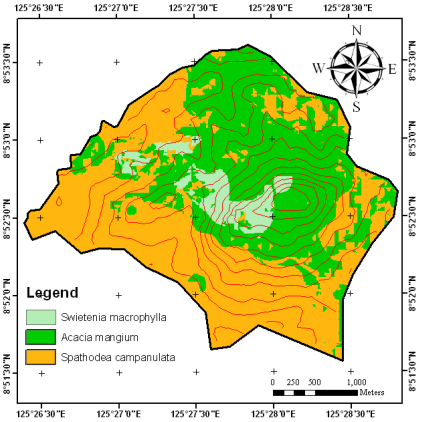
(c) *S. campanulata*



(d) economic forestry



(e) environmental forestry



(f) Sample Points

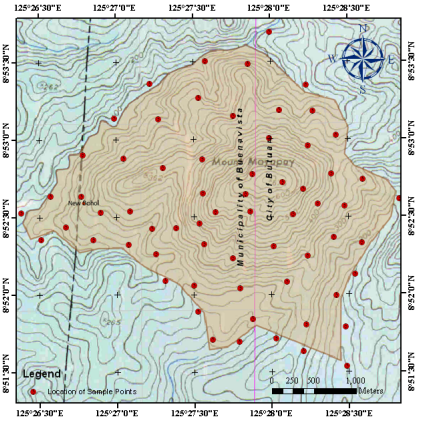


Table 1: **Site suitability classes**

Score	**Suitability Classes**
> 3.5	Highly Suitable (S1)
$2.5 - 3.4$	Moderately Suitable (S2)
$1.5 - 2.4$	Marginally Suitable (S3)
< 1.4	Not Suitable (N)

Table 2: **Priority matrix for final site suitability classification**

Scenarios for Forestry Purposes	***A. mangium***	***S. macrophylla***	***S. campanulata***
Economic Forestry	1st	2nd	3rd
Environmental Forestry	2nd	3rd	1st

Table 3: **Site suitability classification for *Acacia mangium***

Suitability Class	**Area in Hectares**	**Percentage of Total Area** (%)
Highly Suitable	0.00	0.00
Moderately Suitable	784.33	84.39
Marginally Suitable	145.10	15.61
Not Suitable	0.00	0.00
Total Area	929.43	100.00

Table 4: **Site suitability classification for *Swietenia macrophylla***

Suitability Class	**Area in Hectares**	**Percentage of Total Area** (%)
Highly Suitable	0.00	0.00
Moderately Suitable	872.05	93.83
Marginally Suitable	57.38	6.17
Not Suitable	0.00	0.00
Total Area	929.43	100.00

Table 5: **Site suitability classification for *Spathodea campanulata***

Suitability Class	**Area in Hectares**	**Percentage of Total Area** (%)
Highly Suitable	0.00	0.00
Moderately Suitable	568.83	61.20
Marginally Suitable	360.60	38.80
Not Suitable	0.00	0.00
Total Area	929.43	100.00

Table 6: **Site suitability of Mt. Mayapay for forest production**

Species Name	**Area in Hectares**	**Percentage of Total Area** (%)
A. mangium	744.03	80.05
S. macrophylla	168.32	18.11
S. campanulata	17.08	1.84
Total Area	929.43	100.00

Table 7: **Site suitability of Mt. Mayapay for forest protection**

Species Name	**Area in Hectares**	**Percentage of Total Area** (%)
A. mangium	393.38	42.32
S. macrophylla	56.16	6.04
S. campanulata	479.89	51.63
Total Area	929.43	100.00