

Suitability assessment of Kalantas (*Toona calantas* Merr. & Rolfe) and Supa (*Sindora supa* Merr.) in the Quezon Protected Landscape using weighted overlay analysis

Giorjia Mae L. Veran^{1*}, Romnick S. Baliton¹, Marco A. Galang¹

¹Institute of Renewable Natural Resources, College of Forestry and Natural Resources, University of the Philippines Los Baños, College, Laguna, Philippines

ABSTRACT. One of the most cited reasons behind the failure of reforestation activities in the country is the lack of species-site matching, especially for Philippine native tree species. This, among other reasons, resulted in the extensive use of exotics for local forest rehabilitation activities, which may pose a serious threat to the country's native biodiversity if not appropriately addressed. This study provides future reforestation programs with information regarding the suitable areas for two threatened native tree species, namely Kalantas (*Toona calantas* Merr. & Rolfe) and Supa (*Sindora supa* Merr.), within the Quezon Protected Landscape (QPL). Brush/shrub lands, grasslands, and open forests within the QPL were identified as potential reforestation sites. The silvical requirements of the species from secondary sources were matched with the characteristics of the identified reforestation sites using Geographic Information System (GIS) and Analytic Hierarchy Process (AHP) indices developed by Dolores *et al.* (2020). The study revealed that both *T. calantas* and *S. supa* are highly suitable for all the identified potential reforestation sites within the QPL. The identified potential reforestation sites cover 864 ha (8.64 km²) or approximately 92% of the landscape. Therefore, the present study's findings are useful for future reforestation programs in the QPL and the utilization of *T. calantas* and *S. supa* for such forestation initiatives.

Keywords: Integrated analytic hierarchy process, reforestation, species-site matching

Article Information

Received 20 September 2022

Accepted 26 May 2023

Published online 16 October 2023

*Email: glveran@up.edu.ph

INTRODUCTION

The Quezon Protected Landscape (QPL), traversing the municipalities of Atimonan, Pagbilao, and Padre Burgos in Quezon Province, is recognized as a biologically important zone by virtue of Proclamation No. 394 following the National Integrated Protected Areas Systems (NIPAS) Act of 1992. Although under the protection and management of the Department of Environment and Natural Resources-Protected Area Management Board (DENR-PAMB), QPL is not completely safeguarded from anthropogenic

threats. A significant portion of the landscape serves rural residential purposes, making these areas and the entire landscape vulnerable to invasive human activities (Conda & Buot, 2016; Villanueva & Buot, 2017; Paclibar & Tadosa, 2020). One threat worth noting is the presence and patronage of invasive alien plant species (IAPS). Therefore, any effort to restore and reforest the degraded segments of the QPL must carefully consider the species selection, primarily the use of suitable native species, thus, this research.

Both species are native to the Philippines and are classified as threatened by either or both the International Union for Conservation of Nature (IUCN 2021-3) and the Philippine National Red List (DENR DAO 2017-11). *Toona calantas* Merr. & Rolfe is yet to be assessed by the IUCN as it is presently under the “Data Deficient” category (Barstow, 2018). However, it was once locally deemed as Critically Endangered (DENR DAO 2007-01) before its current classification as a “Vulnerable” species (DENRDAO 2017-11). On the other hand, the IUCN classifies *Sindora supa* Merr. as a Vulnerable species, while the same species were categorized in the Philippine National Red List as endangered (EDC, 2020a; EDC, 2020b). In this light, propagating and conserving these two species within their native and suitable habitats is important. Interestingly, previous studies have documented the natural occurrence of *T. calantas* in the QPL (Tadosa *et al.*, 2016; Paclibar & Tadosa, 2020). Although no recent studies have yet accounted for the existence of *S. supa* in the QPL, it was found as a dominant species in another karst formation in the country located in Palawan (Tolentino *et al.*, 2020). Hence, the karst forest of the QPL can potentially be a suitable site for *S. supa*. Moreover, the common names of the species, including supa, pania, and parina, are widely attributed to the vernaculars of the Quezon province (ERDB, 2018).

Geographic Information System, or GIS, is a contemporary method of visualizing geospatial data. With this technology, physiographic features can be organized into a map that, in this case, matches the site characteristics with the silvical requirements of the selected species. Like GIS, the AHP is a tool that aids decision-making. AHP is more widely applied in multi-criteria decision-making situations wherein the relative strength of each criterion against the others in a system is reflected in ratio scales (Saaty, 1987). Although species-site matching is inherently a multi-criteria decision-making process, AHP had only been formally used in this discipline by Dolores *et al.* (2020) as they evaluated the suitability of *Albizia acle* (Blanco) Merr., *Alstonia scholaris* (L.) R. Br., and *Agathis philippinensis* (Warb.) to the Pantabangan-Carranglan Watershed in Luzon. In that same

study, the authors were able to establish, albeit only fundamentally, the reliability of the use of GIS and AHP in future species-site suitability assessments, like this present study.

Despite being done ever since the early 1900s, most reforestation programs in the country had always been described as “of little success, or worse as “failed” endeavors (Lasco *et al.*, 2006; Tolentino, 2008; Le *et al.*, 2013; Schneider *et al.*, 2014). The same authors recognize the need for more species-site matching studies and using indigenous tree species in its suitable grounds as one of the promising ways forward for both forest rehabilitation and plantations. This research follows such recommendations and consequently aims to assess the suitability of *T. calantas* and *S. supa* to the degraded and potential reforestation sites within the QPL using GIS and AHP indices. Before the suitability assessment, the authors identified the degraded areas within the QPL and determined the silvical requirements of the selected native species using secondary sources.

METHODOLOGY

Description of the study site

The QPL, formerly known as Quezon National Park, covers approximately 938 ha of land. It traverses three municipalities of Quezon Province, namely, Atimonan (Brgy. Santa Catalina and Brgy. Malinao Ilaya) in the northeastern side, Padre Burgos (Brgy. Sipu) in the southeastern portion, and Pagbilao (Brgy. Silangan Malicboy) in the western region of the landscape (**Figure 1**). It is located between 13°58'00" and 14°01'00" latitudes and between 121°47'00" and 121°50'00" longitudes around 160 km southeast of the City of Manila. QPL is considered a part of the Sierra Madre Mountain range, with its highest elevation of 380.4 m asl and its lowest point of 12.5 m asl (**Figure 2**).

The site has a Type II Climate, characterized by the absence of a dry period but with a pronounced wet season from November to February. Based on the data of PAGASA from 2009 to 2019, the mean annual temperature in the entire QPL ranges from 26.9°C to 27.1°C, while the area received an

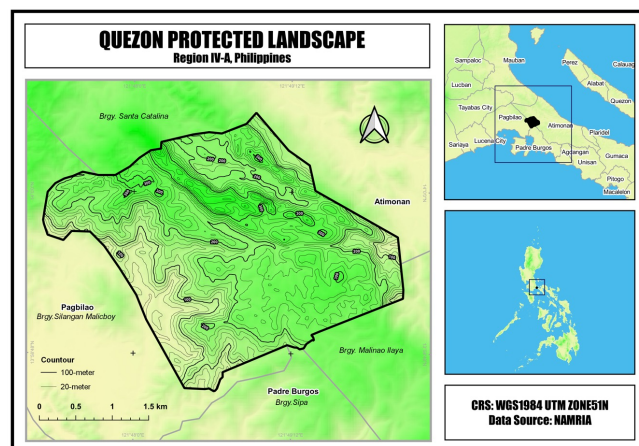


Figure 1. Location map of the Quezon Protected Landscape.

average annual rainfall of 3,027 to 3,043 mm. The soil of the entire landscape belongs to the soil series known as Bantay clay. According to Carating *et al.* (2014), Bantay soils have limestone origins and are usually cultivated if not covered with grasses or secondary growth forests. The soil textural class of the Bantay clay ranges from clay-to-clay loam with a pH ranging from 5.5 to 7.5 (Descalsota *et al.*, 2005; Carating *et al.*, 2014).

Species selection

Both species selected for this study are threatened Philippine natives (Table 1). *Sindora supa* is even an endemic species of the Philippines. *Toona calantas* was selected for the study because recent studies reveal its natural occurrence in the site (Tadiosa *et al.*, 2016; Paclibar & Tadiosa, 2020). While *S. supa* was recently found to be a dominant species in a karst forest of Palawan, it has not been found existing in the QPL, whose karst formations are located around the popular Pinagbanderahan Peak with elevation ranging from 249 to 342 m asl (Paclibar & Tadiosa, 2020; Tolentino *et al.*, 2020). Several common names of the *S. supa*, including supa, pania, and parina, are also attributed to the vernaculars of Quezon Province (ERDB, 2018). Due to these, the present study explored the potential of the QPL as a suitable site for *S. supa*.

The silvical requirements of the selected species were gathered through secondary data gathering such as but not limited to published articles, theses, and online databases. All sources consulted

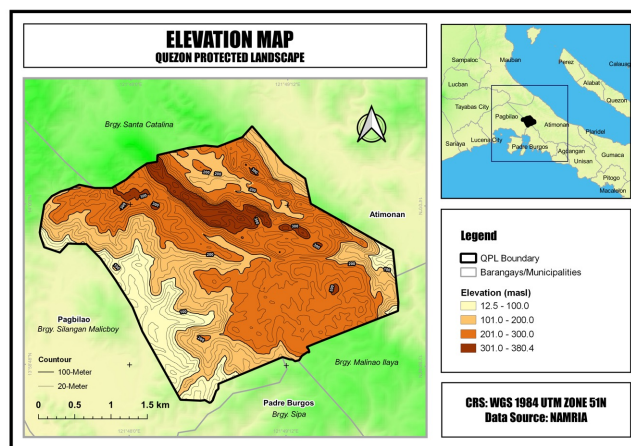


Figure 2. Elevation map of the Quezon Protected Landscape.

in determining the requirements of the selected species are enumerated in Table 2.

The temperature and rainfall requirement of the species were derived from publicly available climate information of PAGASA and climatedata.org. The average annual rainfall and average annual temperature of the sites where the species naturally occur, as reported by the ERBD (2014, 2018) and Quisumbing (1978), was regarded as the actual range required for the growth and survival of the species.

According to the Bureau of Soils and Water Management (BSWM) soil map and Carating *et al.* (2014) descriptions, the soil textural class in the species' natural distribution areas was considered the species' preference. All soil pH values of the identified soil profiles required by the two (2) species were then derived from the study of Descalsota *et al.* (2005). Since the study of Fernandez (2015) revealed that *S. supa* grew better in Makiling soil with a soil textural class under the silty clay classification and pH of 7.14, it was used as an additional basis for the reported soil textural class and soil pH preference of *S. supa*.

Since the ERDB only reported "low to medium" elevations as the site requirements of the species, other studies were sought for the preferred elevation ranges. The elevation features of St. Paul's Bay in Palawan, where *S. supa* was reported as a dominant species, and that of Sitio Dicasalarin

Table 1. Conservation status of the selected native species based on the Philippine National Red List (DAO 2017-11) and the International Union for Conservation of Nature (IUCN 2021-3).

Selected native species	DAO 2017-11	IUCN 2021-03
<i>Toona calantas</i>	Vulnerable	Data deficient
<i>Sindora supa</i>	Endangered	Vulnerable

Table 2. Secondary sources consulted to determine the site requirements of Kalantas (*Toona calantas*) and supa (*Sindora supa*).

Site feature	<i>Toona calantas</i>	<i>Sindora supa</i>
Average annual rainfall (mm yr ⁻¹)	ERDB PAGASA climatedata.org	ERDB PAGASA climatedata.org Fernando <i>et al.</i> (2008)
Soil textural class	BSWM	BSWM Fernandez (2015) Coracero & Malabrigo (2020)
Soil pH	BSWM Descalsota <i>et al.</i> (2005)	BSWM Fernandez (2015) Coracero & Malabrigo (2020) Descalsota <i>et al.</i> (2005)
Elevation (m asl)	ERDB Lapitan <i>et al.</i> (2015)	ERDB Coracero & Malabrigo (2020) Fernando <i>et al.</i> (2008)
Average annual temperature (°C)	ERDB Fernando <i>et al.</i> (2008)	ERDB Fernando <i>et al.</i> (2008)

in Brgy. Zabali, Baler, Aurora were ranked 21st out of the 139 surveyed species in terms of carbon stock were considered. On the other hand, the elevation requirement of the *T. calantas* was also derived from the study of Lapitan *et al.* (2015), which assessed the spatial distribution of the species within the Mt. Makiling Forest Reserve (MMFR).

Thematic mapping of site characteristics

Using QGIS (version 3.16), an open-source GIS software developed by the Open Source Geospatial Foundation (OSGeo), thematic maps of the site characteristics (elevation, rainfall, temperature, soil textural class, and soil pH) were generated. The sources of all data used for this study are enumerated in Table 3.

Determination of potential reforestation sites

The land cover map from the National Mapping and Resource Information Authority (NAMRIA) determined the degraded areas within the QPL. The map shows the extent of forests, agricultural lands, built-up areas, and brush/shrub lands

(Figure 3). As per the mandate of the Republic Act No. 7586 or the National Integrated Protected Areas Systems (NIPAS) Act of 1992, protected areas like the QPL are set aside and managed for ecosystem protection and development. Hence, areas within the QPL that are no longer densely forested, *i.e.*, brush/shrublands and open forests, were identified as degraded sites.

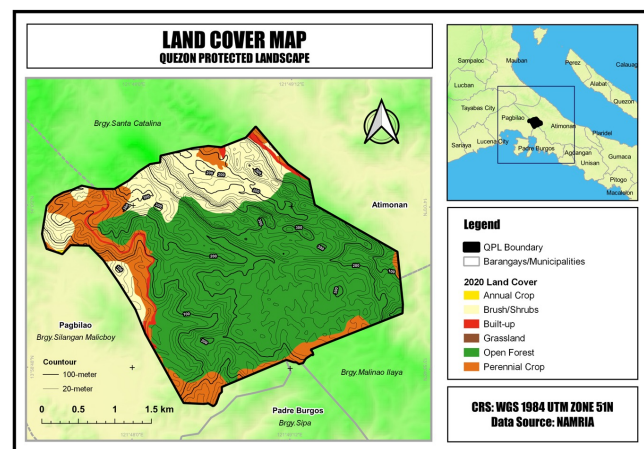
**Figure 3.** Land cover map of the Quezon Protected Landscape.

Table 3. Summary of data sources used for the thematic maps of the Quezon Protected Landscape.

Data	Source	Description
Elevation	NAMRIA	Interferometric Synthetic Aperture Radar (IfSAR)-Digital Terrain Model (DTM) at 5-meter by 5-m resolution in raster format
Mean annual precipitation	ClimDatPh (DOST-PAGASA)	2009-2019 Annual rainfall (mm) data in CSV file format
Mean annual temperature	ClimDatPh (DOST-PAGASA)	2009-2019 Annual average temperature (°C) data in CSV file format
Soil textural class and pH	Department of Agriculture-BSWM	Soil textural classes in shapefile format
Land cover	NAMRIA	2020 Philippine land cover in shapefile format

Factor suitability scoring

The different site factor values, *viz.*, number of meters above sea level (m asl) for the elevation, millimeters (mm) of mean annual rainfall, degrees in Celsius (°C) for the mean annual temperature, soil textural type, and soil pH, were reclassified into suitability scores. The site factors included in this analysis were those used by Dolores *et al.* (2020), whose developed AHP weights were adopted for the present study. Suitability scores vary from 1 to 3, where 1 denotes marginal suitability, 2 is moderate, and 3 means high suitability. Reclassification is based on the requirement or preference of the species – the closer the site factor is to the species requirement, the higher the potential suitability of the species to the site. The requirement or preference of the species is the range of site characteristics wherein the species naturally grows. Such was derived from its natural distribution range and/or experimentation results; whichever literature is available. For illustration (**Figure 4**), species preferences may be viewed as the "target" site characteristics. Hence, the suitability score is considered 1 or high if the site falls within this range. Similar site characteristics, such as a similar but not exact soil textural class, are considered moderate suitability. Otherwise, the site is only of marginal suitability. This reclassification scheme for the different site factors is also defined in **Table 4**. The suitability scores of each site factor per species obtained will be multiplied by the weights acquired using AHP.

Species-site matching

The entire process followed the approach developed by the Food and Agriculture Organization (FAO, 1982) for the physical evaluation of forestry land potential. In this regard, the formula for the

suitability index shown in **Equation 1** was used to assess the suitability of the identified potential reforestation areas in the QPL for the selected forest species.

Equation 1.

$$S = \sum W_i X_i$$

Where: S = suitability index, i = each site factor,
 W = weight of each i , X = score of each class i .

The different site factors investigated in this study are the same site factors utilized by Dolores *et al.* (2020) using AHP. In lieu of this, the weights of the different site factors (W) used in obtaining the suitability index are hereby adopted from the site factor weight determination done by Dolores *et al.* (2020). The AHP weights developed in the study of Dolores *et al.* (2020) are summarized in **Table 5**.

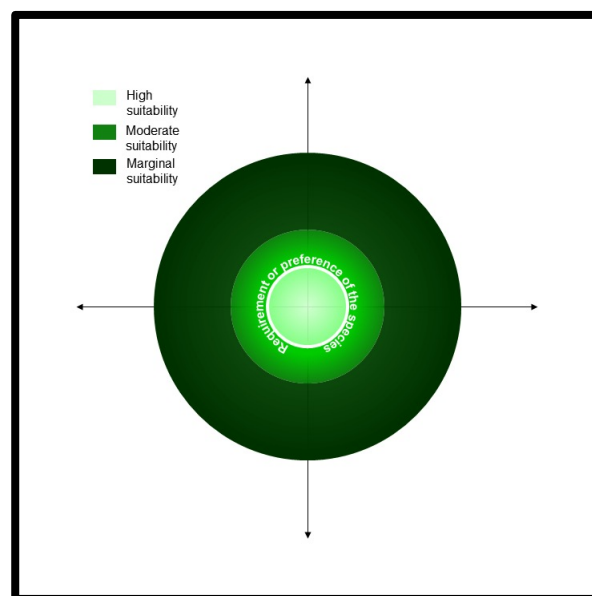
**Figure 4.** Scheme of reclassification of site factors into suitability scores.

Table 4. Reclassification of the different site factor values into suitability scores.

Site factor	Suitability score		
	Marginal (1)	Moderate (2)	High (3)
Elevation	Areas outside the elevation requirement of the species.	Areas not within the elevation requirement but with a similar elevation range.	Areas that fall within the required elevation range of the species.
Mean annual rainfall	Areas receiving less or more than the mean annual rainfall required by the species.	Areas receiving a similar amount of mean annual rainfall to that the species requires.	Areas receiving an annual rainfall within the amount preferred by the species.
Mean annual temperature	Areas with a mean annual temperature that is beyond the temperature requirement of the species.	Areas with a mean annual temperature that is not within but similar to the temperature requirement of the species.	Areas with mean annual temperatures are within the range required by the species.
Soil textural class	Areas without the same nor similar soil textural class requirement of the species.	Areas without the same soil textural class but with soil that belongs to a similar soil textural class to that required by the species.	Areas with the same soil textural class as that required by the species.
Soil pH	Areas with soil pH that is beyond that required by the species.	Areas with soil pH that is not within the range required by the species but has a similar pH.	Areas with soil pH that has or is within the species requirement.

Table 5. Site factor weights developed by Dolores *et al.* (2020) using the Analytic Hierarchy Process.

Site factor	Weight (%)
Mean annual rainfall	24.5
Soil textural class	23.04
Soil pH	22.48
Elevation	19.27
Mean annual temperature	10.71

Secondary data collected were used to reclassify the site factors' suitability values. The 2020 Land Cover data from NAMRIA was used to identify the potential reforestation sites within the QPL. The characteristics of the identified potential reforestation areas in the QPL and the species requirements were reclassified into suitability scores in **Tables 7 and 8** for *T. calantas* and *S. supa*, respectively.

Raster analysis in QGIS was done for every site factor to determine the extent of suitable areas within the identified potential reforestation sites in QPL. After this, the AHP weights Dolores *et al.* (2020) developed were applied to the obtained suitability scores. The obtained suitability indices, *i.e.*, the summation of the products of the site factor weights and their suitability scores, were again reclassified into marginal (≤ 1.00), moderate (1.01 - 2.00), and high (≤ 2.01). The raster analysis

mainly included using the following tools: reclassify by table and raster calculator. All the weighted site factor maps for each selected species were integrated using the analysis above and tools in QGIS (version 3.16), and the overall extent of suitability in hectares was determined for each species.

RESULTS AND DISCUSSION

Potential reforestation sites in the Quezon Protected Landscape

Areas within the QPL that are no longer densely forested were identified as degraded sites. Since the forests in the land cover map have no closed canopies, areas with open forests were identified as potential reforestation sites with brush/shrub lands (**Figure 5**). The assumption is that these areas will need some reforestation in the future.

Table 6. Site characteristics of the Quezon Protected Landscape, site requirements of *Toona calantas*, and the reclassified suitability scores for each site factor.

Site factor	Quezon Protected Landscape	<i>Toona calantas</i>	Score
Average annual rainfall (mm yr ⁻¹)	3,027 - 3,043	950 - 4,100	3
Soil textural class	Clay - Clay loam	Loam	2
Soil pH	5.5 - 7.5	5.0 - 6.7	2
Elevation (m asl)	12.5 - 380.4	100 - 500	2 for 0-100 3 for 100-500
Average annual temperature (°C)	26.9 - 27.1	25 - 30	3

Table 7. Site characteristics of the Quezon Protected Landscape, site requirements of *Sindora supa*, and the reclassified suitability scores for each site factor.

Site factor	Quezon Protected Landscape	<i>Sindora supa</i>	Score
Average annual rainfall (mm yr ⁻¹)	3,027 - 3,043	1,500 - 3,500	3
Soil textural class	Clay - Clay loam	Silty clay - Clay loam	3
Soil pH	5.5 - 7.5	6.0 - 7.3	2
Elevation (m asl)	12.5 - 380.4	300 - 1,000	2 for 0-300 3 for >300
Average annual temperature (°C)	26.9 - 27.1	25 - 30	3

Silvical requirements of the selected species

Various publications and databases were sought to complete the silvical requirements of *T. calantas* and *S. supa* because primary experimentation nor data collection could not be done in this study. The silvical or site requirements of the species usually include a range of characteristics summarized per site factor in **Table 8**.

Suitability of the selected species

Tables 6 and **7** present the suitability scores assigned for every site factor for *T. calantas* and *S. supa*, respectively. The site factors were presented according to their respective AHP weights (**Table 5**). The suitability scores were based on the reclassification criteria – wherein areas outside the species requirement are marginally suitable (score = 1), areas with similar features to that preferred by the species were moderately suitable (score = 2), and ultimately, the sites with characteristics that are the same or within the species requirement are highly suitable areas (score = 3).

All the identified potential reforestation sites within the QPL were highly suitable for both *T. calantas* and *S. supa*. **Figures 6** and **7** show that no marginal nor moderately suitable areas were found for both species and that 858.13 ha, or 100% of the identified potential reforestation sites, are highly suitable for *T. calantas* and *S. supa*.

Toona calantas obtained an overall suitability index ranging from 2.35 to 2.54 across potential reforestation sites. This index falls under the high suitability class. *S. supa*, on the other hand, garnered a suitability index of 2.58 to 2.78 – an index also classified under the high suitability class. The QPL is a relatively small and uniform site with little considerable variations in soil, climate, and elevation. Results further shows that the requirements of the species are well-fitted in the characteristics of the QPL as the suitability scores ranged from 2 (moderate) or 3 (high).

Table 8. Site requirements of Kalantas (*Toona calantas*) and supa (*Sindora supa*).

Site feature	<i>Toona calantas</i>	<i>Sindora supa</i>
Average annual rainfall (mm yr ⁻¹)	950 - 4,100	1,500 - 3,500
Soil textural class	Loam	Silty clay - Clay loam
Soil pH	5.0 - 6.7	6.0 - 7.3
Elevation (m asl)	100 - 500	300 - 1,000
Average annual temperature (°C)	25 - 30	25 - 30

The results of this study are outliers when viewed side by side with previously conducted species-site suitability assessments in the country. No recent studies for various local sites and species have obtained 100% high suitability. None has obtained even 100% low nor 100% moderate suitability results. To cite, only one of the three selected species examined by Dolores *et al.* (2020) obtained high suitability for the Pantabangan-Carranglan Watershed (PCW). This high suitability was observed for 53% of the identified potential reforestation sites. Sarmiento & Casas (2015) found no highly suitable areas for their selected species in the Mt. Mayapay Watershed of Butuan City, Agusan del Norte. Lastly, Galang (2010) found that only a small percentage of the MMFR is highly suitable for narra.

Nonetheless, the previous literature is consistent with the findings of this study and vice versa. None of the previously evaluated sites were as small and relatively uniform as the QPL. The QPL only has 983 ha or 9.83 km² of area, while the PCW is more than 133,000. Mt. Mayapay Watershed is more than 18,000 ha, while the MMFR exceeds 4,000 ha. All the previously examined sites are many times bigger than the QPL. Following Tobler's First Law of Geography, the variation of site characteristics increases as the area of the site increases. Therefore, larger sites would have more sources of variation in terms of site factors. Consequently, larger sites would yield more varied suitability results like other studies' findings.

Another way to confirm variations in the site characteristics is through primary data collection, especially for the soil characteristics which textural class and pH have a weight of 23.04%

and 22.48%, respectively. Soil textural class ranked second, while soil pH ranked third in the adopted AHP weights developed by Dolores *et al.* (2020). Unfortunately, the present study could not conduct primary data collection nor any actual experimentation due to constraints brought about by the pandemic.

It is important to note, however, that despite being valid, the findings of this study do not ensure 100% survival of the species to the QPL, nor will it ensure 100% success of reforestation programs in the QPL if *T. calantas* and *S. supa* are used. Apart from the site characteristics, there remain to be other factors that affect the survival of the species, such as the quality of the germplasm used, silvicultural practices, and the presence of pests or pathogens, among others (Tolentino, 2008; Schneider, 2014). Proper species-site matching is likewise only one component or a single driver among many other drivers that facilitate the success of forest rehabilitation endeavors in the Philippines (Le *et al.*, 2013). Other components of the technical/biophysical driver identified by Le *et al.* (2013) were site preparation, planting activity timing, technical capacity, and silviculture. Species-site suitability assessments cannot solely address these other components. Other reforestation success drivers are enabling socio-economic, institutional, political, and management conditions.

CONCLUSIONS AND RECOMMENDATIONS

The study determined that there are around 864 ha of potential reforestation sites within the QPL. This is around 92% of the entire site and comprises areas with open forests and brush/shrublands, according to the 2020 Land Cover Map of NAMRIA. Most importantly, both species

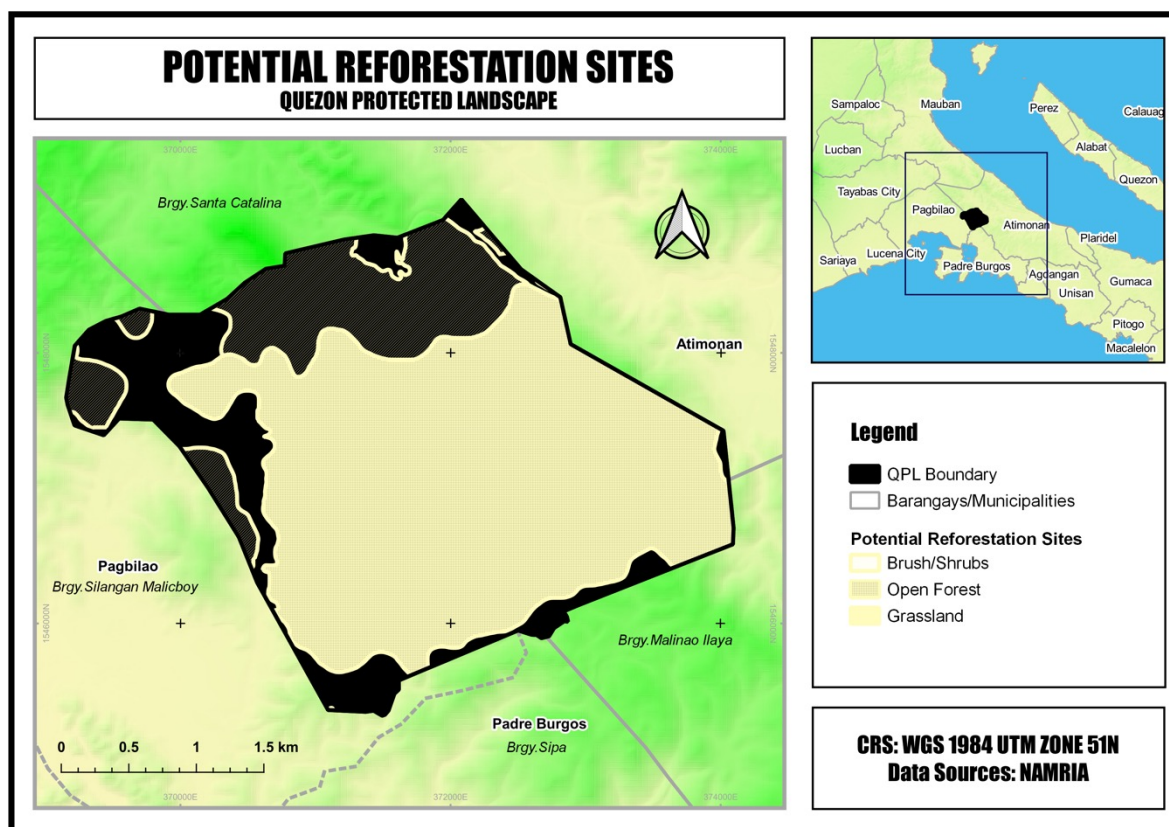


Figure 5. Land cover map of the potential reforestation sites in Quezon Protected Landscape.

are highly suitable in all the identified potential reforestation sites. The site requirements of *T. calantas* and *S. supa* were found to highly match the site characteristics of the QPL.

Toona calantas and *Sindora supa* were highly suitable for all the identified potential reforestation sites within the QPL. The site uniformity can explain the small variation in the suitability results obtained. QPL also belongs to a single soil series with minimal variations in climate and elevation. Belonging to a single soil series meant having the same soil textural class and soil pH – site factors that rank second and third in AHP weights.

While the study provided practical information on the utilization of *S. supa* and *T. calantas*, it remains limited by the availability and quality of secondary sources used. Field validation to verify the site characteristics and requirements remain important activities to execute. Primary data collection and analysis, especially of the soil characteristics and site lithology, are crucial because the characteristics

of this site factor, namely, textural class and pH, all together weigh 45.52%. Not only do soil characteristics have a considerably large weight, but the variations in the soil characteristics are also high. Therefore, it is suggested that primary soil analysis must be done and future research must consider selecting different species mixes and/or other critical and key biodiversity sites.

ACKNOWLEDGMENTS

This study was made possible by the valuable contributions of the following institutions: financial support from the Department of Science and Technology-Science Education Institute (DOST-SEI) and data inputs from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), National Mapping and Resource Information Authority (NAMRIA), Bureau of Soils and Water Management (BSWM), and Ecosystems Research and Development Bureau (ERDB).

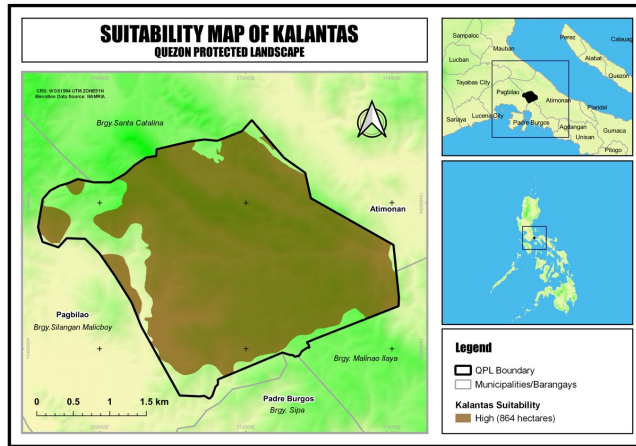


Figure 6. Suitability map of Kalantas to the identified potential reforestation sites with the Quezon Protected Landscape.

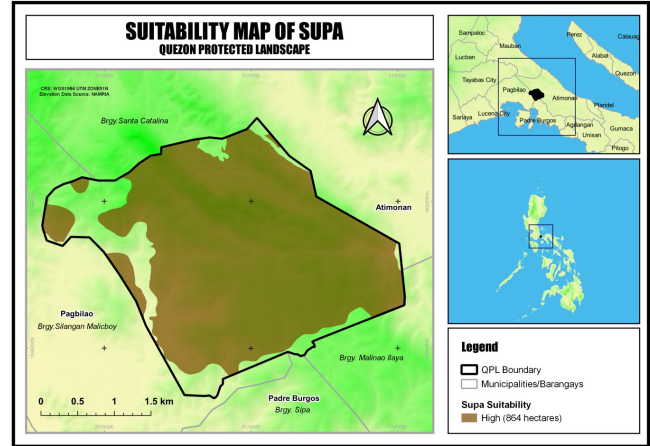


Figure 7. Suitability map of Supa to the identified potential reforestation sites with the Quezon Protected Landscape

LITERATURE CITED

- Barstow, M. (2018). *Toona calantas*. The IUCN Red List of Threatened Species 2018: e.T32122A68105077. Retrieved on April 24, 2022, from: <<https://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T32122A68105077.en>>.
- Carating, R. B., Galanta, R. G., & Bacatio, C. D. (2014). The soils of the uplands. In: *The Soils of the Philippines. World Soils Book Series*. Springer, Dordrecht. DOI: 10.1007/978-94-017-8682-9_3. pp. 107–147.
- Conda, J. M. & Buot, I. E. Jr. (2016). Biodiversity assessment and conservation status of some pteridophytes in the northeastern portion of Quezon Protected Landscape, Philippines. *The Thailand Natural History Museum Journal*, 10(1), 15–31.
- Coracero, E. E. & Malabrigo, P. (2020). Carbon storage potential of the tree species along the ultramafic forest in Sitio Dicasalarin, Barangay Zabali, Baler, Aurora, Philippines. *AIMS Environmental Science*, 7(6), 589–601.
- Descalsota, J. P., Mamaril, C. P., & San Valentin, J. O. (2005). Fertility status of selected rice soils in the Philippines. *Philippine Journal of Crop Science*, 28, 45–57.
- Dolores, J. C. R., Galang, M. A., & Dida, J. J. V. (2020). Species-site suitability assessment of native species in Pantabangan-Carranglan watershed using Geographic Information System (GIS) and Analytic Hierarchy Process (AHP). *Philippine Journal of Science*, 149(3), 529–537.
- EDC [Energy Development Corporation]. (2020). *Sindora supa*. The IUCN Red List of Threatened Species 2020: e.T32809A67803839. Retrieved on 24 April 2021, from <<https://dx.doi.org/10.2305/IUCN.UK.2020-1.RLTS.T32809A67803839.en>>.
- ERDB [Ecosystems Research and Development Bureau]. (2014). Compilation of selected forest species from Vol. 2 No. 1-12, 1990. Ecosystems Research and Development Bureau. *Research Information Series on Ecosystems (RISE)*, 26(1–2), 50–59.
- ERDB [Ecosystems Research and Development Bureau]. (2018). Threatened Philippine forest tree species: Kamatog (*Sympetalandra densiflora* (Elm.) Steenis) and Supa (*Sindora supa* Merr.). Ecosystems Research and Development Bureau. *Research Information Series on Ecosystems (RISE)*, 30(3).
- Fernandez, R. A. M. F. (2015). Effects of EM-1 Application on the growth of Supa (*Sindora supa* (Merr.)) seedlings planted in Caliraya (Luisiana Clay Loam) and Makiling (Macolod Clay Loam) soils [Thesis Manuscript]. College, Laguna: UPLB-CFNR.
- Fernando, E. S., Suh, M. N., Lee, J., & Lee, D. K. (2008). Forest formation of the Philippines. ASEAN-Korea Environmental Cooperation Unit, Seoul National University, Seoul, Republic of Korea. 232 p.

- Galang, M. A. (2010). GIS-Aided suitability assessment of Mt. Makiling Forest Reserve (MFR), Philippines for smooth Narra (*Pterocarpus indicus* Willd.). *University of Southern Mindanao Research and Development Journal*, 18(1), 67–72.
- Lapitan, P., Castillo, L., Balatibat, J., Castillo, M., & Bantayan, N. (2015). Spatial distribution of Kalantas (*Toona calantas* Merr. & Rolfe) in the Molawin –Dampalit Watershed, Mount Makiling Forest Reserve, Philippines. *Ecosystems & Development Journal*, 5(3), 33–42.
- Lasco, R. D., Carandang, A. P., Chokkalingam, U., Pulhin, J. M., Razal, R. A., Acosta, R. T., Natividad, M. Q., & Peras, R. J. J. (2006). One century of forest rehabilitation in the Philippines: approaches, outcomes and lessons. In: Chokkalingam, U., Carandang A. P., Pulhin, J. M., Lasco, R. D., Peras, R. J. J., & Toma, T. (eds.), *One Century of Forest Rehabilitation in the Philippines: Approaches, Outcomes and Lessons* (pp. 107–121). Center for International Forestry Research (CIFOR). <https://doi.org/10.17528/cifor/002025>.
- Le, H. D., Smith, C., & Herbohn, J. (2013). What drives the success of reforestation projects in tropical developing countries? The case of the Philippines. *Global Environmental Change*, 24(1), 334–348.
- Paclibar, G. C. B., & Tadosa, E. R. (2020). Plant species diversity and assessment in Quezon Protected Landscape, Southern Luzon, Philippines. *Philippine Journal of Systematic Biology*, 14(3), 1–19.
- Quisumbing, E. (1978). Medicinal plants of the Philippines. Forest Research Institute. Katha Pub. Co., Quezon City, Philippines. 1262 p.
- Saaty, R. W. (1987). The Analytic Hierarchy Process-What and how it is used. *Mathematical Modelling*, 9(3–5), 161–176.
- Sarmiento, R. T. & Casas, J. V. (2015). GIS-aided suitability assessment of Mt. Mayapay Watershed in Butuan City, Agusan del Norte. *Annals of Studies in Science and Humanities*, 1(1), 46–60.
- Schneider, T., Ashton, M. S., Montagnini, F., & Milan, P. P. (2014). Growth performance of sixty tree species in smallholder reforestation trials on Leyte, Philippines. *New Forests*, 45(1), 83–96.
- Tadosa, E. R., Santos, J. M., Cudiamat, M. A., Cruzate, S. M., Arma, E. J. M., Hilapo, D. C., Biscocho, H. H., Saldo, L. A. & Pagadora, R. S. (2016). Analysis of the forest and grassland vegetation at southwestern side of Quezon Protected Landscape, Southern Luzon, Philippines. *IAMURE International Journal of Ecology and Conservation*, 19(1), 53–69.
- Tolentino, E. L. Jr. (2008). Restoration of Philippine native forest by smallholder tree farmers. *Smallholder Tree Growing for Rural Development and Environmental Services: Advances in Agroforestry*, 5, 326–346.
- Tolentino, P. J. S., Navidad, J. R. L., Angeles, M. D., Fernandez, D. A. P., Villanueva, E. L. C., Obeña, R. D. R., & Buot, I. E. (2020). Review: Biodiversity of forests over limestone in Southeast Asia with emphasis on the Philippines. *Biodiversitas*, 21(4), 1597–1613.
- Villanueva, E. L. C. & Buot, I. E. Jr. (2017). An enumeration of Hoyas in Quezon Province, Luzon Island, Philippines. *Thailand Natural History Museum Journal*, 11(1), 23–33.