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Habitat Suitability of Lapnisan (*Aquilaria* spp.) Under Various Climatic Projections for Reforestation in Negros Oriental, Philippines

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Abstract
Aim: This study aimed to assess the habitat suitability of *Aquilaria* species in Negros Oriental, Philippines, in response to projected climate change scenarios Representative Concentration Pathway (RCP) 2.6 and RCP 8.5 in 2050. Specifically, it sought to determine the area (km^2) and location for suitable Aquilaria reforestation sites.
Methodology: The study employed purposive sampling and data mining to determine the actual location of *Aquilaria* species. The coordinates of *Aquilaria* were used to evaluate the model's performance through the Area Under the Curve (AUC), assessing its ability to distinguish between suitable and unsuitable habitats. Key input layers—including climatic variables (temperature and rainfall), environmental factors (land cover, soil type, elevation, and slope), and a Digital Elevation Model (DEM)—were reclassified and weighted based on their relevance to *Aquilaria* growth. These layers were integrated in ArcGIS to generate habitat suitability maps under climate scenarios RCP 2.6 and RCP 8.5, projecting potential suitable areas for *Aquilaria* by the year 2050.
Results: Under the extreme RCP 8.5 scenario, no areas remained classified as highly suitable. However, moderately suitable habitats expanded significantly from 6.79% to 4,559.329 km^2 (93.44%), while marginally suitable areas increased from 3.20 km^2 (0.06%) to 319.90 km^2 (6.56%). Despite a reasonably strong model performance (AUC = 0.79), ecological compatibility for *Aquilaria* declined—likely due to its dependence on stable moisture conditions and limited thermal tolerance. Additionally, habitat fragmentation and reduced connectivity, particularly in climate-impacted barangays, exacerbate risks to the species' survival.
Conclusion: Highly suitable areas may vanish entirely, with the species being forced into less favorable, moderately to marginally suitable zones. The RCP 8.5 climate scenario marks a critical ecological turning point for *Aquilaria* spp., with suitable habitats in Negros Oriental projected to shift from low elevations (<300–400 m) to mid elevations (600–900 m), particularly under this high-emissions pathway.
Keywords: *habitat suitability, Aquilaria species, reforestation, climate change adaptation*

INTRODUCTION

Identifying climatically suitable areas is crucial for forest restoration in the face of rapid environmental change. Climate change is increasingly destabilizing Earth's fundamental environmental systems, driving extreme weather patterns such as intensified heatwaves, erratic rainfall, and extended droughts (van Dijk et al., 2025). Year 2024 was officially recorded as the hottest on record, with widespread flooding and drought wreaking havoc across regions including Southeast Asia (van Dijk et al., 2025). These climatic disruptions threaten forest species globally—particularly those dependent on narrow ecological niches or sensitive to microclimatic shifts in temperature and moisture (Haesen et al., 2023). In Southeast Asia, *Aquilaria* spp.—valued for agarwood—face mounting pressure from these stressors, with habitat suitability declining as microclimates warm and moisture regimes shift (Hazarika et al., 2023).

In Negros Oriental, central Philippines, remnant forest patches support *Aquilaria* spp., a genus increasingly threatened by deforestation, timber poaching, habitat fragmentation, and climate change. Unsustainable harvesting

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for agarwood, combined with the absence of large-scale cultivation systems, has left wild populations highly vulnerable. Climate stressors—such as rising temperatures and erratic rainfall—further reduce regeneration and seedling survival, particularly under high-emission scenarios like Representative Concentration Pathway (RCP) 8.5, which projects significant habitat contractions.

Broader ecosystem challenges—soil erosion, invasive species, and watershed degradation—compound these threats, undermining the integrity of forest ecosystems. Regionally, modeling under RCP 2.6 and RCP 8.5 suggests habitat shifts upslope, with some species potentially gaining new suitable areas in higher elevations (Liu et al., 2023). Similar trends have been observed in coconut, oil palm, and mangroves.

Species distribution models (SDMs), particularly Maxent, have been employed in Philippine-based research to evaluate how climate change influences the spatial patterns and habitat viability of native flora and fauna (Xu et al., 2025). Mancera and Lapuz (2021) projected upslope migration for Melastome trees, while Ranius et al. (2023) reported dipterocarp habitat losses up to 27% under RCP 8.5, often outside existing protected zones. Although few species distribution modeling (SDM) studies have focused specifically on *Aquilaria* spp. in Negros Oriental, Ceniza et al. (2022) identified key ecological constraints—such as low-nutrient soils and overharvesting—in their study of *Aquilaria* in Leyte. Rauf et al. (2020) utilized geographic information system to map the suitability of Hevea brasiliensis and *Aquilaria malaccensis* at Simpang Kuta Buluh, and propagation studies conducted from 2023–2025 on *A. crassna* (Li et al., 2024) show potential using coconut fiber substrates.

These findings suggest that by 2050, suitable habitats for *Aquilaria* spp. in Negros Oriental may shift from low (<300–400 m) to mid elevations (600–900 m), especially under RCP 8.5. However, climate suitability alone is insufficient; factors such as soil quality, harvesting pressure, land tenure, and socio-economic conditions must be integrated into restoration efforts.

Through spatial analysis integrating ArcGIS and species occurrence records, this study projects the potential distribution of *Aquilaria* under future climate scenarios (RCP 2.6 and RCP 8.5). The resulting habitat maps provide targeted insights to inform conservation planning. By pinpointing zones with projected climatic stability, the findings contribute to adaptive reforestation pathways—including assisted migration, locally led planting initiatives, and ecologically sound propagation practices—crucial for safeguarding *Aquilaria* populations and reinforcing forest resilience across ecologically sensitive Philippine landscapes.

Objectives

This study aimed to assess the habitat suitability of Lapnisan (*Aquilaria* spp.) in Negros Oriental, Philippines, in response to projected climate change scenarios RCP 2.6 and RCP 8.5 in 2050. Specifically, it sought to determine the following:

1. Habitat suitability maps
2. Sensitivity analysis of the model
3. area (km^2)
4. locations suitable for *Aquilaria* spp. reforestation sites.

METHODS

Data Preparation and Analysis Overview

Environmental variables (climate, soil, land cover, slope, elevation) and *Aquilaria* spp. occurrence (survey, data mining) were standardized to a common spatial reference (WGS 1984, UTM Zone 51) and cleaned for consistency. All datasets were reclassified into suitability classes (1–5) based on ecological thresholds.

Habitat Suitability Modeling

A weighted overlay analysis was conducted in ArcGIS, assigning weights to each variable based on literature and expert input. To produce habitat suitability maps, this study integrated reclassified spatial layers corresponding to present-day environmental conditions and projected climatic scenarios (RCP 2.6 and RCP 8.5). This methodological approach enabled spatial assessment of ecological viability under varying climate trajectories.

Sensitivity and Scenario Analysis

Python-based sensitivity testing, including Monte Carlo simulations, assessed the influence of key variables (temperature and precipitation) on model outputs. Scenario comparisons identified areas of habitat loss, stability, or gain, informing climate-adaptive conservation planning.

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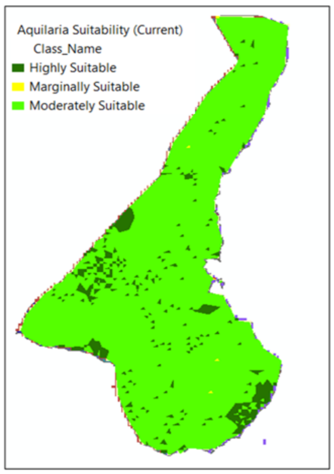
RESULTS and DISCUSSION

Suitable Habitat of *Aquilaria* species Across Different Climatic Scenarios (RCP 2.6 & RCP 8.5)

The study's habitat suitability model combines climatic (rainfall, temperature), topographic (elevation, slope), edaphic (soil texture, moisture, nutrients), and landscape (land cover/use) factors. Following Rabgay et al. (2020) and Ebale et al. (2023), rainfall and temperature receive the highest weights (25% each), reflecting their strong correlation with agarwood (*Aquilaria* spp.) distribution. Soil and vegetative cover are weighted at 15% reflecting their ecological importance without diminishing the dominant influence of climate factors (Wu et al, 2022). This balanced approach aligns with literature and realistically represents *Aquilaria's* environmental suitability across climate scenarios



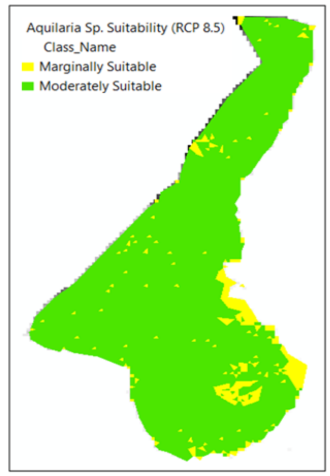


Figure 1. Suitability for *Aquilaria* RCP 2.6 Figure 2. Suitability for *Aquilaria* RCP 8.5

Under RCP 8.5, rising temperatures and rainfall variability may worsen soil drying and erosion, especially on steep slopes, leading to habitat contraction unless mitigated. Conversely, under RCP 2.6, minimal land cover change is expected with ongoing forest conservation, allowing stable or expanding suitable areas.

Slope and elevation, assigned 10% each, showed weaker or negative correlations with species distribution in Negros Oriental but may still influence habitat viability.

Under RCP 2.6, substantial highly suitable areas remain where climatic and topographic factors stay within species tolerance, supporting a stable conservation baseline (Srivastava et al., 2018). In contrast, RCP 8.5 projections indicate marked declines and fragmentation of highly suitable habitats due to increased temperatures, rainfall variability, and extreme events (Opdam et al., 2006; Xu et al., 2025; Yanahan & Moore, 2019). Areas like Manjuyod and Bindoy may shift toward marginal suitability, threatening population strongholds (Barras et al., 2021; Britnell et al., 2023; Fischer & Lindenmayer, 2007).

This habitat contraction highlights *Aquilaria's* vulnerability to climate stressors. Without timely adaptive management—such as assisted migration, ecological corridors, and microclimate buffering—populations risk range compression, genetic isolation, or extinction (Stark & Fridley, 2022). Models also suggest an upslope or riparian habitat shift toward cooler microclimates, though migration may be limited by soil, pollinator, and forest community availability.

Srivastava et al. (2018) stress that habitat suitability models are vital for climate-resilient biodiversity planning when integrated with field monitoring and ecological knowledge, aiding conservation prioritization and adaptation strategies. Under RCP 8.5, *Aquilaria's* suitable habitats contract and shift, reflecting species-specific tolerances and adaptive limits. According to Cheng et al. (2025), different scenarios require targeted conservation efforts in specific regions sensitive to biodiversity loss, habitat loss, and fragmentation, emphasizing the need for conservation (Abedin et al., 2024; Opdam et al., 2006).

The shrinking highly suitable habitat signals a narrowing climatic niche and greater vulnerability to rapid environmental changes. Soil moisture, rainfall reliability, and thermal limits may fall below *Aquilaria's* physiological needs, reducing population health and recruitment without intervention. The findings highlight the critical importance

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of integrating forward-looking climate scenarios into conservation strategies to ensure long-term ecological resilience and adaptive management. While habitat models offer valuable forecasts, inherent uncertainties—like spatial resolution, omitted biotic factors, and dispersal assumptions—require field validation, multi-model comparisons, and scenario analyses.

Translating these insights into actionable policy frameworks, ecological restoration efforts, and land-use zoning strategies is essential for promoting the long-term sustainability of *Aquilaria* spp*.* and other ecologically valuable forest species within Negros Oriental and comparable landscapes.

Sensitivity Analyses for *Aquilaria* species for 2050 across different scenarios (RCP 2.6 - RCP 8.5)

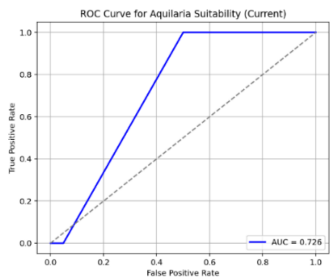

Figure 3**.** AUC for *Aquilaria* RCP 2.6

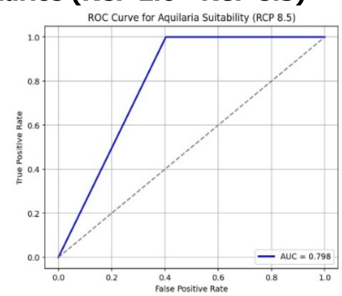

Figure 4**.** AUC for *Aquilaria* RCP 8.5

Variations in the ecological response of the species under contrasting climate scenarios—RCP 2.6 and RCP 8.5—illustrate divergent pathways of environmental change anticipated under low and high greenhouse gas emissions, respectively (Arnell et al., 2019). Model sensitivity, measured by Area Under Curve (AUC) from Receiver Operating Characteristics (ROC) analysis (Figures 5 and 6), showed moderate accuracy at 0.72 under RCP 2.6 and higher accuracy at 0.79 under RCP 8.5.

The stronger environmental gradients in RCP 8.5 enhance model performance by clarifying ecological thresholds, as noted by Stark and Fridley (2022). In contrast, stable conditions in RCP 2.6 create subtler habitat shifts, limiting model sensitivity and indicating a need for finer data or additional variables.

Intensifying climatic stressors—particularly rising temperatures and altered precipitation patterns—may surpass the physiological tolerances of *Aquilaria* spp., potentially resulting in habitat contraction and reduced ecological stability (Tomanek, 2008; Grossman, 2023). As Wuldo and Zeleke (2025), Hooper and Vitousek (1998), and Franklin and MacDonald (2024) suggest, such thresholds of environmental stress signal potential disruptions to forest composition and species viability, especially in biodiversity-rich regions vulnerable to accelerated climate change.

While the model outputs offer valuable spatial insights into *Aquilaria* habitat suitability, their interpretive power remains constrained by several methodological limitations. Key challenges include coarse spatial resolution, uncertainties in input datasets, and simplified assumptions regarding how species respond to climatic variables. These constraints may hinder the precision and ecological realism of habitat projections. To enhance future predictive accuracy, studies should integrate long-term ecological monitoring and mechanistic modeling approaches that account for species-specific physiology, dispersal capacity, and adaptive thresholds under varying climate trajectories.

Table 1. Identified Suitable Areas (km^2) in Negros Oriental for *Aquilaria* Species Under RCP 2.6 and RCP 8.5 Climate Scenarios in 2050.

Target Reforestation Areas for *Aquilaria spp*. Cultivation			
Scenario	**Suitability Criteria**	**Area (km^2)**	**Percent (%)**
RCP 2.6	Marginally Suitable	3.201201	0.06
	Moderately Suitable	331.39718	6.79
	Highly Suitable	4547.462336	93.15
RCP 8.5	Marginally Suitable	319.900491	6.56
	Moderately Suitable	4559.329245	93.44

As presented in Table 1, projected *Aquilaria* spp. habitat suitability under RCP 2.6 reveals extensive ecological viability across Negros Oriental, with approximately 93.15% (4,547.46 km²) of the area classified as highly suitable. In

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contrast, only 6.79% falls within the moderately suitable range, and a minimal 0.06% is deemed marginally suitable. These proportions underscore the potential of low-emission scenarios to sustain favorable conditions for *Aquilaria* growth and persistence in the region. Under RCP 8.5, highly suitable habitat disappears, with 93.44% (4,559.33 km²) shifting to moderately suitable and marginally suitable areas expanding to 6.56% (319.90 km²), reflecting a decline in optimal conditions.

Temperature, elevation and altered precipitation patterns are increasingly breaching ecological and physiological thresholds essential for *Aquilaria* species persistence, leading to diminished habitat suitability and suppressed growth and reproductive outcomes—as highlighted across multiple ecological studies (see Pugnaire et al., 2019; Shi et al., 2021; Grossman, 2023) and in thermal sensitivity mechanisms (cf. Tomanek, 2010). Furthermore, fragmentation linked to climate-induced stressors poses additional threats to ecosystem function, interfering with biotic interactions such as pollination, seed dispersal, and genetic connectivity—processes extensively examined by landscape ecologists including Muralidharan (2025), Siddiqui (2024), Opdam et al. (2006), and Fischer and Lindenmayer (2007).

While moderately suitable areas persist, they may require adaptive management to support *Aquilaria* (Srivastava et al., 2018). The absence of highly suitable zones under RCP 8.5 warrants caution, as models may overlook microclimates, soil variation, and species plasticity. Future studies should include fine-scale data and physiological thresholds to refine conservation strategies.

Table 2. Reforestation and Afforestation Areas Potential for Aquilaria Under RCP 8.5 in 2050.

AREAS SUITABLE FOR LAPNISAN (*Aquilaria spp.*) REFORESTATION for 2050 (RCP 8.5)				
	SUITABILITY	**LOCATION**		**AREA (Square Kilometers)**
		CITY/ MUNICIPALITY	**BARANGAY**	
Aquilaria spp.	Moderately Suitable	Canlaon City	Portion of barangay Pula, Bayog, Malaiba, Binalbagan and Budlasan, and entire of barangays Ninoy Aquino, Masulog, Mabigo, Linothangan, Bucalan and Lumapao	4559.32
		Vallehermoso	Portion of barangays Bagawines, Poblacion, and Macapso, and entire of barangays Maglahos, Tagbino, Bairan, Cabulihan, Pinocawan, Guba, Malangsa, Puan, Don Esperidion Villegas, Tabon and Molobolo	
		Guihulngan City	Portion of barangays Hibaiyo, Bulado, Calamba, Poblacion and Mabunga, and entire area of the remaining barangays	
		La Libertad	Portion of barangyas Pisong and Mambulod, entire area of the remaining barangays	
		Tayasan	Portion of barangays Tanlad, Pindahan, Pinalubngan, Saying, Matuog and Tamao, entire area of remaining barangays	
		Jimalalud	Portion of barangays Apanangon, Eli, Buto, Lacaon Cabang and Agutayon, and entire area of the remaining barangays	
		Ayungon	Portion of Carol-an and Nabhang, and entire of are of the remaining barangays	
		Bindoy	Portion of barangays Nalundan, Tinaogan, Balaas and Nagcasunog, and entire area of the remaining barangays	
		Manjuyod	Portion of Barangays Balaas, Campuyo, Maaslum and Mandalupang, entire area of the remaining barangays	

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		Mabinay	Portion of barangays Tara, Malingay, BUgnaya Pantao Himocdongon, Poblacion Bulibulihan Paniabonan and Mayaposi, and the entire area of the remaining barangays	
		Bais City	Portion of barangays Lonoy, Calasga-an, Cambagiuo, Basak, La Paz, Valencia, Tangculogan, Cambanjao Tamisu, Binohon, and the entire of barangays of Tagpo, Sab-ahan, Cambangahan, Mabunao, Panala-an, Tagpo, Manilipac, DAnsulan, Katacgahan, Panamangan, Mansangaban and Cabanlutan	
		Tanjay City	Portions of barangays Sta. Cruz Viejo, San Jose, Azagra, Polo, and entire of the remaining barangays	
		Pamplona	Portion of barangays SanIsidro, Banawe, Balayong Magsusunog, Sta. Agueda, Simborio, Mangoto, Poblacion, Malalangsi, and the entire area of the remanings barangays	
		Amlan	Portion of barangays Bio-os, Jantianon, Silab, Jugno, Tambojangin, and Tandayag	
		San Jose	Portion of barangays San Roque, Jilocon, Basiao, Basak, Cancawas, Cambaloctot, Sr. Ascion, and the entire area of the remaing barangays	
		Sibulan	Portion of barangays Enrique Villanueva, Maningcao, Ajong, Lo-oc, San Antonio, Calabnugan and Balugo	
		Dumaguete City	Portion of barangays Camanjac, Balugo, Talay, and Cantil-e	
		Valencia	Portion of barangays Dobdob, Malaunay, Puhagan Caidiocan, Malabo, Sagbang, Lunga, Mampas, Cambucad, Pulangbato, Palinpinon, Balili, East Balabag and the entire area of the remaining barangays	
		Bayawan City	Portion of San Jose, Bugay, Dawis, banaybanay, Tabuan, Kalumboyan, Tayawan, Minaba, San Roque, Malabugas and Narra, and entire area of the remaining barangays	
		Basay	Portion of baranbgays Bongalonan, Cabalayongan and Nagbo-alao, and the area of the remaining barangays	
		Sta. Catalina	Portion of barabgays Caranoche, población, CAwitan, Alangilan, Manalongon,, Milagrosa, San Francisco, San Pedro, and Fatima, and entire of the area of the remaining barangays	
		Siaton	Portions of barangays Giliga-on, Cabangahan, Datag, Si-it, Bonbonon, Albiga, Malabuhan, Sumaliring, Napacao, Caticugan, Sandulot, Canaway, Inalad, San Jose, Poblacion I 7 II, Mantuyop and entire of the remaining barangays	
		Zamboanguita	Portion of barangays Najandig, Malongcay Diot, Lotuban, Mayabon Poblacion and Maluayand Basac, and entire of barangays Nasig-id, Nabago, and Calango	
		Dauin	Portion of barangays Baslay, Boloc-boloc, Lipayo, Masaplod Norte, Bulak, Masaplod Sur, Maayong tubig and entire are of the remaining barangays	

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		Bacong	Portion of barangays Soludpan, Banilad Combado, Lutao, Buntis, South Poblacion, Saksak, Noth and West Poblacion, and the entire area of the remaining barangays	
	Marginally Suitable	Canlaon City	Portion of barangay Pula, Bayog, Malaiba, Binalbagan and Budlasan	319.90
		Vallehermoso	Portion of barangays Bagawines, Poblacion, and Macapso	
		Guihulngan City	Portion of barangays Hibaiyo, Bulado, Calamba, Poblacion and Mabunga	
		La Libertad	Portion of barangyas Pisong and Mambulod	
		Tayasan	Portion of barangays Tanlad, Pindahan, Pinalubngan, Saying, Matuog and Tamao	
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		Ayungon	Portion of Carol-an and Nabhang	
		Bindoy	Portion of barangays Nalundan, Tinaogan, and Nagcasunog	
		Manjuyod	Portion of Barangays Balaas, Campuyo, Maaslum and Mandalupang	
		Mabinay	Portion of barangays Tara, Malingay, BUgnaya Pantao Himocdongon, Poblacion Bulibulihan Paniabonan and Mayaposi	
		Bais City	Portion of barangays Lonoy, Calasga-an, Cambagiuo, Basak, La Paz, Valencia, Tangculogan, Tamisu, Binohon, Lo-oc, Cambuilao, Canlargo Capinahan, and Barangays I & II, and the entire barangays of San Isidro, Hangyad, Consolacion, Tamogong, Tanculogan, Rosario, San Isidro and Cambanjao	
		Tanjay City	Portions of barangays Sta. Cruz Viejo, San Jose, Azagra, Polo	
		Pamplona	Portion of barangays SanIsidro, Banawe, Balayong Magsusunog, Sta. Agueda, Simborio, Mangoto, Poblacion, Malalangsi	
		Amlan	Portion of barangays Bio-os, Jantianon, Silab, Jugno, Tambojangin, and Tandayag	
		San Jose	Portion of barangays San Roque, Jilocon, Basiao, Basak, Cancawas, Cambaloctot, Sr. Ascion, Tapon Norte, Sto. Nino and Poblacion	
		Sibulan	Portion of barangays Enrique Villanueva, Maningcao, Ajong, Lo-oc, San Antonio, Calabnugan, and entire area of barangays Boloc-boloc, Agan-an, Maslog, Tubtubon, Magatas, Poblacion, Cangmating	
		Dumaguete City	Portion of barangays Camanjac, Balugo, Talay, and Cantil-e and the entire area of the remaining barangays	
		Valencia	Portion of barangays Dobdob, Malaunay, Puhagan Caidiocan, Malabo, Sagbang, Lunga, Mampas, Cambucad, Pulangbato, Palinpinon, Balili, East Balabag	
		Bayawan City	Portion of San Jose, Bugay, Dawis, banaybanay, Tabuan, Kalumboyan, Tayawan, Minaba, San Roque, Malabugas and Narra	

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		Siaton	Portions of barangays Giliga-on, Cabangahan, Datag, Si-it, Bonbonon, Albiga, Malabuhan, Sumaliring, Napacao, Caticugan, Sandulot Canaway, Inalad, San Jose, Poblacion I 7 II, Mantuyop	
		Zamboanguita	Portion of barangays Najandig, Malongcay Diot, Lotuban, Mayabon Poblacion and Maluay	
		Dauin	Portion of barangays Baslay, Boloc-boloc, Lipayo, Masaplod Norte	
		Bacong	Portion of barangays Soludpan, Banilad Combado, Lutao, Buntis, South Poblacion	

The table above outlines areas projected to remain suitable for Aquilaria cultivation by 2050. RCP 8.5 represents a high-emission scenario associated with more intense warming—projected to reach approximately 4°C by 2100—and is widely regarded as a realistic worst-case climate pathway. This scenario incorporates severe and variable environmental stressors, such as extended droughts, extreme heat, and erratic rainfall patterns, all of which significantly impact *Aquilaria*, a species highly sensitive to microclimatic shifts and water availability (Rubenstein et al., 2023). Additionally, climate zone boundaries are expected to shift, meaning areas currently suitable under milder scenarios like RCP 2.6 may become unstable, facing soil moisture deficits or heightened pest risks.

Using RCP 8.5 as a basis for site selection helps reduce maladaptation risks, such as establishing plantations in municipalities/barangays that may become unsuitable in the future—potentially leading to high mortality rates and financial losses. Prioritizing this scenario ensures long-term resilience and promotes ecological stability, thereby supporting the sustainable survival of Aquilaria in a changing climate.

Conclusion

The contrasting climate scenarios of RCP 2.6 and RCP 8.5 reveal differing ecological responses of *Aquilaria* spp., with higher model accuracy under more extreme conditions highlighting the challenges and limitations in predicting habitat suitability amid intensifying climate stressors, underscoring the need for refined data and mechanistic approaches to improve future projections.

Under both RCP 2.6 and RCP 8.5 scenarios, the majority of target reforestation areas for *Aquilaria* spp. cultivation are classified as highly to moderately suitable, indicating strong potential for successful cultivation despite climate variability.

Prioritizing site selection based on the high-emission RCP 8.5 scenario ensures greater long-term resilience and reduces maladaptation risks for *Aquilaria* cultivation by anticipating future climate stressors and shifting environmental conditions.

Recommendations

To enhance the effectiveness of *Aquilaria* spp. reforestation efforts, it is recommended to integrate refined ecological data and mechanistic modeling approaches that account for species-specific responses to climate variables, thereby improving the precision of habitat suitability projections. Given the significant differences observed between RCP 2.6 and RCP 8.5 scenarios, site selection should prioritize areas identified under the more extreme RCP 8.5 scenario to mitigate maladaptation risks and ensure long-term resilience against anticipated climate stressors. Additionally, continuous monitoring and adaptive management strategies should be implemented to respond proactively to environmental changes and support sustainable cultivation in both current and future suitable habitats.

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