BIODIVERSITAS
Volume 25, Number 10, October 2024
Pages: 3510-3520

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d251013

Diversity and spatial distribution of Lauraceae tree species in Lower Montane Forest at Doi Suthep-Pui National Park, Northern Thailand

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Manuscript received: 15 August 2024. Revision accepted: 9 October 2024.

Abstract. *Srisuwan S, Sungkaew S, Wachrinrat C, Asanok L, Kamyo T, Thinkampheang S, Kachina P, Hermhuk S, Phumphuang W, Yarnvudhi A, Marod D. 2024. Diversity and spatial distribution of Lauraceae tree species in Lower Montane Forest at Doi Suthep-Pui National Park, Northern Thailand. Biodiversitas 25: 3510-3520.* Montane forests are characterized by high plant diversity, including a notable representation by the Lauraceae family, which offers a variety of ecological and economic benefits. This study aimed to assess the species diversity, spatial distribution, and habitat suitability of the Lauraceae family in the Doi Suthep-Pui National Park, Northern Thailand. A Generalized Linear Model (GLM) was employed to determine the spatial distribution of the dominant Lauraceae species, whereas the Maximum Entropy (MaxEnt) model was used to assess habitat suitability for key species. A total of 24 species across 10 genera were found. The most species-rich genera were *Cinnamomum* and *Litsea*, followed by *Cryptocarya*, *Machilus* and *Phoebe*, and *Actinodaphne*, *Persea*, *Beilschmiedia*, and *Neocinnamomum*. Habitat suitability for important Lauraceae species was categorized into low-, medium-, and high-potential areas. The elevation and soil organic matter were the most significant factors influencing species abundance. Additionally, soil properties also played a role in species distribution. The spatial distribution of Lauraceae species was primarily influenced by elevation. However, this distribution is also influenced by the interplay between elevation, soil properties, climate, and human activity. Thus, a comprehensive knowledge of these determinants can inform conservation strategies and ensure the long-term viability of Lauraceae populations in montane forests.

Keywords: Ecological niche, forest dynamic plots, Generalized Liner Model, habitat suitability, long-term ecological research

INTRODUCTION

Tropical regions, which cover approximately 40% of the Earth's surface, host more than two-thirds of the world's biodiversity (Ang et al. 2016; Stork 2020), and are home to the most diverse ecosystems on the planet, including rainforests, mangroves, and coral reefs. These ecosystems support an immense variety of life forms, making them biodiversity hotspots critical for global ecological health (Giam 2017), and crucial for their intrinsic value and the vital ecosystem functions and services they provide, ranging from carbon sequestration and climate regulation to water purification and soil fertility (Levin et al. 2020). Despite their importance, tropical ecosystems are severely threatened by human activities. Deforestation, driven by agricultural expansion, logging, and infrastructure development, is the most significant threat. According to recent studies, tropical forests are being cleared at an alarming rate, with millions of hectares lost each year (Curtis et al. 2018). Rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events have already affected species distribution and ecosystem dynamics (Shivanna 2022). Relationships between species and environmental factors that influence species distribution can also be called 'spatial distribution' (Xie et al. 2022). Many environmental factors influence the distribution of tree species, including climatic factors (elevation, slope, and aspect), soil factors (physical and chemical properties of soil), and factors related to human impacts on the ecological niche for each species (Sri-Ngernyuang et al. 2003; Nguyen et al. 2015). Spatial distribution of trees also provides insights into the adaptations strategies (Lim et al. 2018; Soriano-Redondo et al. 2019; Marod et al. 2022).

Tropical montane forests, found at higher elevations in tropical regions, are distinctive ecosystems known for their cool temperatures, high humidity, and significant levels of endemism. These forests experience a unique climatic regime with persistent cloud cover and frequent mist, creating specialized habitats for various plants and animals (Salinas et al. 2021; Tiwari et al. 2024). In Thailand, mountain ecosystems are primarily found in the northern part of the country, generally at elevations of approximately 1,000 meters above sea level (m a.s.l.), and are characterized by two subtypes: Lower Montane Forest (LMF) and Upper Montane Forest (UMF) (Marod et al. 2022). These forests exhibit high species diversity, with notable dominance by plant families, such as Fagaceae and Lauraceae, contributing to their distinct characteristics. Consequently, these forests are often called 'oak-laurel forests' due to their prominent vegetation types (Ohsawa 1991; Tagawa 1995). Oak-laurel forests are known to reach the upper canopy layers of montane forests in Southeast Asia (Ashton and Zhu 2020). However, these ecosystems are susceptible to climate change and are increasingly vulnerable to degradation due to human activities. These factors negatively affect mountain ecosystems' biodiversity (Pullaiah et al. 2015; Gao et al. 2021). The Lauraceae family, a dominant component of tropical and subtropical evergreen forests, is also experiencing a decline in these areas (Sri-Ngernyuang et al. 2003; Yahara et al. 2016; Plant et al. 2020).

The family Lauraceae is abundant in montane forests across tropical and sub-tropical forests of Asia, Australia, the Pacific islands, and others (Tan et al. 2023). This family is globally distributed, with approximately 2,500-3,000 species classified into 44 genera worldwide (Chen et al. 2020). In Thailand, 159 species are distributed across 19 genera (De Kok 2023). Many Lauraceae species have significant ethnobotanical interest that serve as medicinal plants or food resources (Van Hop et al. 2020; Chaisoung et al. 2023). The products from Lauraceae plants include timber, nutritious fruits, spices, and perfumes (Li et al. 1982; Su and Ho 2016). Despite their ecological and economic importance, the taxonomy of Lauraceae in the region remains unclear (De Kok 2023), and documentation of their distribution is limited. To address these gaps, we utilized a 16-hectare permanent plot in LMF at Doi Suthep-Pui National Park, Northern Thailand, to investigate the spatial distribution of Lauraceae species based on their ecological niches. We also employed line transects along existing natural trails to observe species diversity and applied the MaxEnt modeling approach to assess habitat suitability for various Lauraceae species. This approach aims to support the conservation of vulnerable species and provides a foundation for future research and conservation efforts.

MATERIALS AND METHODS

Study area

A 16-ha Forest Dynamics Plot (FDP) was established in 2010 at approximately 1,350 m altitude in Doi Suthep-Pui National Park, Chiang Mai Province, Northern Thailand, which covered an area of approximately 261 km^2. The highest mountain is Doi Pui, which ranges from 330 to 1,685 m a.s.l. (Figure 1). The average temperatures in the region range between 2 and 23°C, and annual rainfall varies from 1,350 to 2,500 mm. These unique environmental factors, including the topographic and climatic conditions, contribute to the cool climate of the area (Marod and Duengkae 2019). The forest types include Deciduous Dipterocarp Forest (DDF), Mixed Deciduous Forest (MDF), Dry Evergreen Forest (DEF), and Lower Montane Forest (LMF). Soil properties also vary among these forest types, with sandy soil and sandy clay loams found at elevations below 1,000 m above sea level and predominantly sandy clay loams and clays at higher elevations (Arunyawat and Shrestha 2016; Hermhuk et al. 2020). Due to its varied forest types and high elevation, Doi Suthep-Pui National Park is an important source of biodiversity for both plants and wildlife (Gardner et al. 2000).

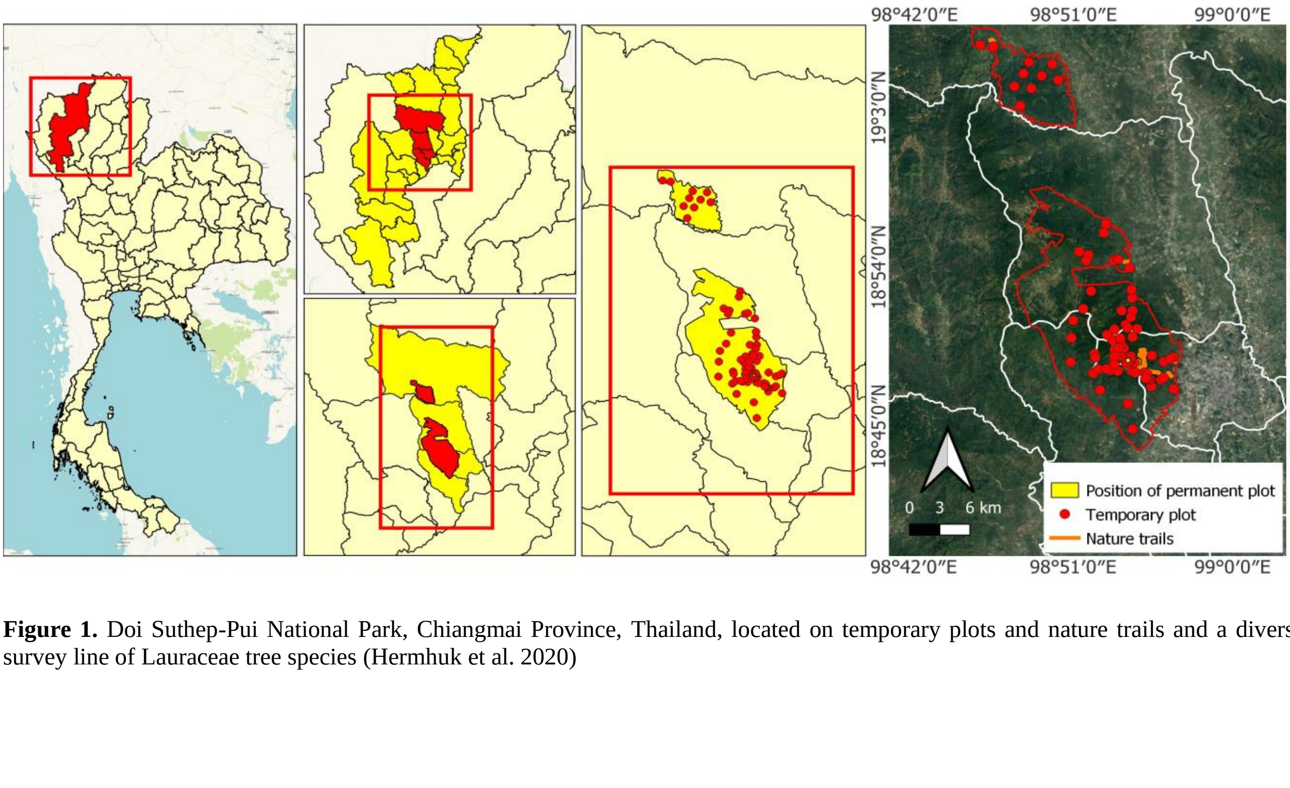

Figure 1. Doi Suthep-Pui National Park, Chiangmai Province, Thailand, located on temporary plots and nature trails and a diversity survey line of Lauraceae tree species (Hermhuk et al. 2020)

Data collection

Species diversity

The primary data were collected using the line-transect method. Ten survey lines were established along nature trails in Doi Suthep-Pui National Park. These lines were chosen based on the criterion that they covered all major forest types (LMF, DEF, MDF, and DDF). Each transect extended 10 m on either side of the trail (Krebs 2014). All Lauraceae species encountered within these transects were identified.

Secondary data were collected from 50 temporary sample plots, each measuring 30 m × 30 m, established within Doi Suthep-Pui National Park. These plots covered various forest types, including DDF (1 plot), MDF (2 plots), MF (40 plots), pine forest (6 plots), and an agricultural area (1 plot). Each plot was further divided into 10 × 10 m subplots, and all tree species with a Diameter at Breast Height (DBH) larger than 4.5 cm were measured and identified (Hermhuk et al. 2020). Moreover, all tree species of the Lauraceae family from the 16-ha FDP, established in the Huai Kog Ma watershed area, were used for species diversity analysis (Marod et al. 2022).

Habitat suitability

Species presence data were obtained from 50 temporary plots that recorded Lauraceae species data (Hermhuk et al. 2020) and surveys conducted along natural trails. Environmental factors included topographic data (Digital Elevation Model (DEM), elevation, and slope) and climatic data (temperature) downloaded from the Google Earth engine (https://earthengine.google.com/). Additionally, the Normalized Difference Vegetation Index (NDVI) was calculated. Soil factor data, including the percentages of clay and sand, soil pH, and soil organics carbon, were downloaded from OpenLandMap (https://opengeohub.org/) in ASCII (.asc) file format. These data were used as input files for MaxEnt modeling, and the resulting maps were visualized using QGIS (Phillips et al. 2006; Ding et al. 2024).

Spatial distribution of Lauraceae

A 16-hectare FDP established in 2010 was used in this study. Subplots of 10 × 10 m were delineated, and all trees with a Diameter at Breast Height (DBH, 1.3 meters above the soil surface) greater than 1 cm were tagged, measured, and their position (X, Y) recorded and species identified (Marod et al. 2022). Tree monitoring was done every 2-yr during the first 10-yr period and then expanded into 5-yr intervals, with the latest monitoring completed in 2020. The tree nomenclature was followed (Smitinand 2014). This study used data from 2020 to analyze the spatial distribution.

Environmental factors were recorded by determining the position of the permanent plot using an RTK GNSS network. Kriging interpolation was performed using QGIS (Pereira et al. 2022). Data from the four corners of the permanent plot were used to analyze and determine the elevation of each point within the subplots. This method facilitated the analysis of the spatial distribution of Lauraceae tree species in relation to environmental factors.

Soil samples were collected by dividing a 16-ha permanent plot into 50 × 50 m subplots. Then, they were taken from the surface (depth between 0-15 cm) at five locations within each subplot, one from each of the four corners and one from the center. These samples were combined into a single composite sample for each subplot, resulting in 64 samples. Physical and chemical properties, such as silt and clay percentages, were tested. Soil pH was analyzed using a pH meter (soil:water ratio of 1:1) (Natural Soil Survey Center 2014) at the Laboratory of Soil Science, Faculty of Agriculture, Kasetsart University, Thailand.

Data analysis

Habitat suitability of Lauraceae

The habitat suitability data for Lauraceae were divided into two groups using stratified random sampling. 80% of the data were used to validate the map. The initial dataset was inputted into the MaxEnt model (Phillips et al. 2006). Ten replicates were conducted (Trisurat et al. 2015). The results produced a probability of presence value ranging from 0 to 1; values close to 1 indicated high model reliability of the Lauraceae family distribution, following the methodology outlined by Vale et al. (2014).

Spatial distribution of Lauraceae

The spatial distribution of the Lauraceae family within the permanent plot was analyzed using a Generalized Linear Model (GLM) to determine the relationships between environmental factors and tree species. Topographic factors and soil properties were assigned as independent variables, and the number of individuals in each tree species was the dependent variable. The model with the lowest Akaike Information Criterion (AIC) was selected using stepwise AIC from the MASS package (Ripley et al. 2024) in the R program.

RESULTS AND DISCUSSION

Species diversity of Lauraceae

The results revealed 24 Lauraceae species in 10 genera from Doi Suthep-Pui National Park (Table 1). The most abundant genera based on the number of species was *Litsea*, each containing approximately seven species. These were followed by *Cinnamomum* with five species, *Cryptocarya* with three species, *Machilus*, and *Phoebe*, each with two species, and *Actinodaphne*, *Persea*, *Beilschmiedia*, and *Neocinnamomum*, each with one species. Notably, *Cinnamomum* is one of the most ecologically valuable genera in the Lauraceae family. Several members of this species are used as spices and medicines by utilizing their bark, flowers, and fruits, whereas others serve as ornamental landscape trees (De Kok 2019; Wang et al. 2020). Notably, *Cinnamomum iners* is distinguished by its unique leaf venation pattern, which is a critical characteristic for genus identification (Figure 2.B) (De Kok 2019). *Litsea* species in Thailand are predominantly medium-sized with a spiral leaf arrangement and considerable variation in leaf size and shape, making them ecologically and botanically significant (Figure 2.A)

(Yahara et al. 2016). *Persea* found in Thailand as three species, was identified by specific leaf and petiole characteristics. *Actinodaphne* characters of leaf and natural pubescence was important for identified this genus (Figure 2.C) (Chakrabarty et al. 2021). *Cryptocarya* and *Beilschmiedia* together placed in the *Cryptocarya* group as one of the early divergent clades within the family but with the molecular data make its classification clearer (De Kok 2016a, 2016b) diversity of Lauraceae species in the LMF of Doi Suthep-Pui National Park was consistent with previous studies that have documented high species richness in this forest (Sri-Ngernyuang et al. 2003; Brockelman et al. 2011; De Kok 2015; Marod et al. 2022; Chaisoung et al. 2023; De Kok 2023). This high diversity underscores the ecological importance of forests and the need for ongoing conservation efforts.

The results indicated that species diversity along the natural trails was higher than at other sites. This increased diversity may be attributed to the accessibility of these trials, which allowed the exploration of areas where temporary plots could not be placed. Additionally, factors such as slope inclination and convexity significantly influence species distribution, contributing to the observed variability (Sri-Ngernyuang et al. 2003). Furthermore, expanding the sampling area could facilitate the discovery of rare and endemic species requiring specific habitats (Pacifici et al. 2016; Becker et al. 2022).

Habitat suitability of Lauraceae tree species

To predict habitat suitability in the study area, dominant species were selected based on more than 100 individuals or those classified as vulnerable by the IUCN (2024). Nine environmental factors were considered in the MaxEnt model. The results categorized the habitat suitability of Lauraceae tree species at different potential levels. The various factors influencing dominant species are listed below.

Litsea martabanica: The important factors affecting its distribution were soil organic carbon (30.8%), followed by elevation and temperature (24.8% and 18.6%, respectively). This species is commonly found on LMF at elevations ranging from 600-1,650 m a.s.l. For habitat suitability, the low potential area was 268.16 km^2, the medium potential area was 8.73 km^2, and the high potential area was 6.13 km^2 (Figure 3.A).

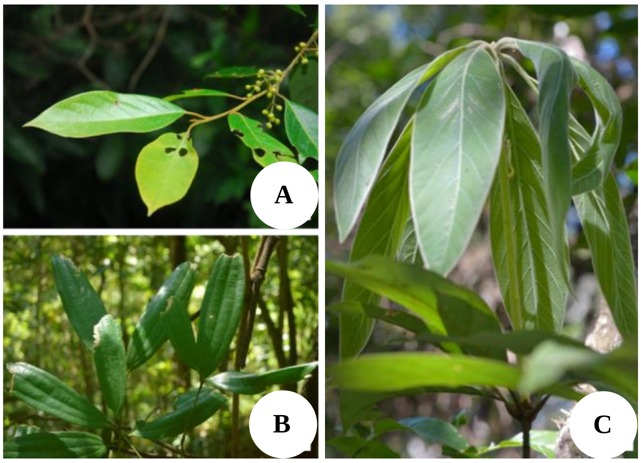

Figure 2. The characteristics of some dominant genera of the Lauraceae family. A. *Litsea martabanica*; B. *Cinnamomum iners*; and C. *Actinodaphne henryi*

Table 1. Species diversity of Lauraceae family in Doi Suthep-Pui National Park, Thailand

Botanical name	Temporary plot	Nature trails	Permanent plot	Status (IUCN 2024)
Actinodaphne henryi Gamble	+	+	+	LC
Beilschmiedia gammieana King ex Hook.fil.	+	+	+	-
Cinnamomum bejolghota (Buch.-Ham.) Sweet	+	-	-	LC
Cinnamomum iners (Reinw. ex Nees & T.Nees) Blume	+	+	+	LC
Cinnamomum mollissimum Hook.fil.	-	-	+	-
Cinnamomum porrectum (Roxb.) Kosterm.	-	+	+	LC
Cinnamomum tamala (Buch.-Ham.) T.Nees & Eberm.	-	+	+	LC
Cryptocarya pallens Kosterm.	+	-	-	VU
Cryptocarya albiramea Kosterm.	-	+	-	-
Cryptocarya amygdalina Nees	-	+	+	-
Lindera caudata (Nees) Hook.fil.	-	+	+	-
Litsea beusekomii Kosterm.	+	+	+	VU
Litsea cubeba (Lour.) Pers.	-	+	-	LC
Litsea glutinosa (Lour.) C.B.Rob.	+	+	+	LC
Litsea grandis (Wall. ex Nees) Hook.fil.	+	+	+	LC
Litsea martabanica (Kurz) Hook.fil.	+	+	+	LC
Litsea monopetala (Roxb. ex Baker) Pers.	-	-	+	LC
Litsea pierrei Lecomte	-	+	+	LC
Neocinnamomum caudatum (Nees) Merr.	-	+	+	LC
Persea americana Mill.	-	+	-	LC
Machilus declinata (Blume) de Kok	-	+	+	-
Machilus gamblei King ex Hook.fil.	+	+	+	LC
Phoebe paniculata (Nees) Nees	+	+	+	LC
Phoebe lanceolata (Nees) Nees	+	+	+	LC

Note : + and-for the presence and absence of a species, respectively

Cinnamomum iners: The important factors for its distribution were elevation (62.4%), followed by temperature and soil pH (11.3% and 7.1%, respectively). This species is found in various types of forests. For habitat suitability, the low potential area was 271.08 km^2, the medium potential area was 8.56 km^2, and the high potential area was 3.39 km^2 (Figure 3.B).

Machilus gamblei: The important factors for its distribution were elevation (58%), followed by temperature and soil organic carbon (12.7% and 10.5%, respectively). This species is mostly found at high elevations. For habitat suitability, the low potential area was 274.93 km^2, the medium potential area was 5.35 km^2, and the high potential area was 2.76 km^2 (Figure 3.C).

Actinodaphne henryi: The important factors for its distribution were soil organic carbon (27.7%), followed by the percentage of sand and temperature (20.1% and 19%, respectively). This species is found above 800 m a.s.l. in the DDF to LMF. For habitat suitability, the low potential area was 271.25 km^2, the medium potential area was 6.92 km^2, and the high potential area was 4.86 km^2 (Figure 3.D).

Phoebe lanceolata: The important factor affecting its distribution was temperature (24.9%), followed by soil organic carbon and percentage of sand (21.0% and 17.8%, respectively). This species is mostly found in LMF on the ridge. For habitat suitability, the low potential area was 257.58 km^2, the medium potential area was 15.26 km^2, and the high potential area was 10.19 km^2 (Figure 3.E).

Litsea cubeba: The important factor for its distribution was elevation (97.7%), followed by percentage of clay and soil organic carbon (1.5% and 0.5%, respectively). This species was found only in one natural trail in the LMF at high elevations. For habitat suitability, the low potential area was 282.90 km^2, the medium potential area was 0.09 km^2, and the high potential area was 0.04 km^2 (Figure 3.F).

Litsea beusekomii: The important factor affecting its distribution was temperature (69.9%), followed by soil pH and elevation (10.4% and 9.2%, respectively). This species is rarely found but has been found in many sites in LMF. For habitat suitability, the low potential area was 242.42 km^2, the medium potential area was 21.50 km^2, and the high potential area was 19.12 km^2 (Figure 3.G).

Our findings indicate that the habitat suitability for Lauraceae varies among species, with environmental factors such as elevation, soil organic carbon, and temperature having significant effects on their distribution. Specifically, elevation and temperature were the most influential factors (De Andrade Kamimura et al. 2017; Fadhila et al. 2023; Tan et al. 2023). Elevation is correlated with various environmental factors such as temperature, soil nutrient, and light intensity (De Andrade Kamimura et al. 2022). It is also associated with proximity to streams, which reflects hydrological conditions of area that influences the distribution of Lauraceae (Sri-Ngernyuang et al. 2003). According to Fadhila et al. (2023), Increasing of light intensity that related directly to the rise of altitudinal can influences variation in growth physiologically, morphologically, and anatomically such as *C. iners* have different cell types at different altitudinal. For *L. martabanica*, *C. iners*, *M. gamblei*, and *L. cubeba*, with *L. cubeba*, being particularly constrained to specific high elevation areas, and it prefers sunny, warm conditions with high light intensity, and tolerant of poor soil due to its shallow root system (Shi et al. 2023). However, different altitudes also affect yields such as essential oil content, and leaf size (Liao et al. 2023), which is consistent with previous studies (e.g., Marod et al. 2015; Anh et al. 2021; Thammanu et al. 2021), which confirmed that these studies have reported that these species are widely distributed at high elevations and low temperatures. In contrast, *P. lanceolata* and *A. henryi* showed sensitivity to the percentage of sand and were found in the LMF to DDF at an elevation of 600-1,400 m a.s.l. (Li et al. 1982; Marod et al. 2015). The *L. beusekomii*, a rare species endemic to Thailand (Ngernsaengsaruay et al. 2011), was found at various sites but in low populations, indicating that this species requires specific environmental factors for establishment (Papuga et al. 2018). Other environmental factors influence tree distribution at different levels, reflecting their ecological niches under current and future environmental conditions (Alkishe et al. 2022).

Spatial distribution of Lauraceae tree species

Environmental factors within the 16-ha FDP were 1,320 to 1,420 m a.s.l. and a slope between 5.0% and 41.4%. The predominant soil textures were sandy clay loam, clay loam, silt loam, loam, and clay, varying from lowland to upland areas. In addition, organic matter content ranged from 7% to 34% (Figures 6.A-6.D).

The spatial distribution of the number of individuals and their relationship with environmental factors for the ten species with the highest tree density were analyzed using a GLM. The results showed that soil properties and elevation strongly influenced their distribution, whereas the effects of other environmental factors varied among the species (Table 2). Based on the GLM, the relationships between the Lauraceae family and environmental factors could be divided into two groups. The first group included species that showed a positive association with elevation, such as *Cinnamomum mollissimum* (Figure 4.A), *Litsea grandis* (Figure 4.B), *Beilschmiedia gammieana* (Figure 4.C), and *Litsea monopetala* (Figure 4.D). Elevation played a critical role in determining the distribution of these species (Xie et al. 2024). This distribution is typically found at high elevations and mostly exists in the LMF, which is consistent with previous reports (De Andrade Kamimura et al. 2017; Ashton and Zhu 2020; Van Hop et al. 2020; Anh et al. 2021; Marod et al. 2022). These species thrive under cooler and more humid conditions, which are characteristic of higher altitudes. The second group comprised species that showed negative associations or exhibited no significant relationships with elevation, such as *M. gamblei* (Figure 5.A), *C. iners* (Figure 5.B), *L. martabanica* (Figure 5.C), *A. henryi* (Figure 5.D), *Cryptocarya amygdalina*, and *Phoebe paniculata*. The GLM indicated that these species were not significantly elevated. Other environmental factors, such as soil properties (e.g., the percentage of sand, silt, and clay, as well as soil nutrients), also play a crucial role in spatial distribution (Zhang et al. 2016).

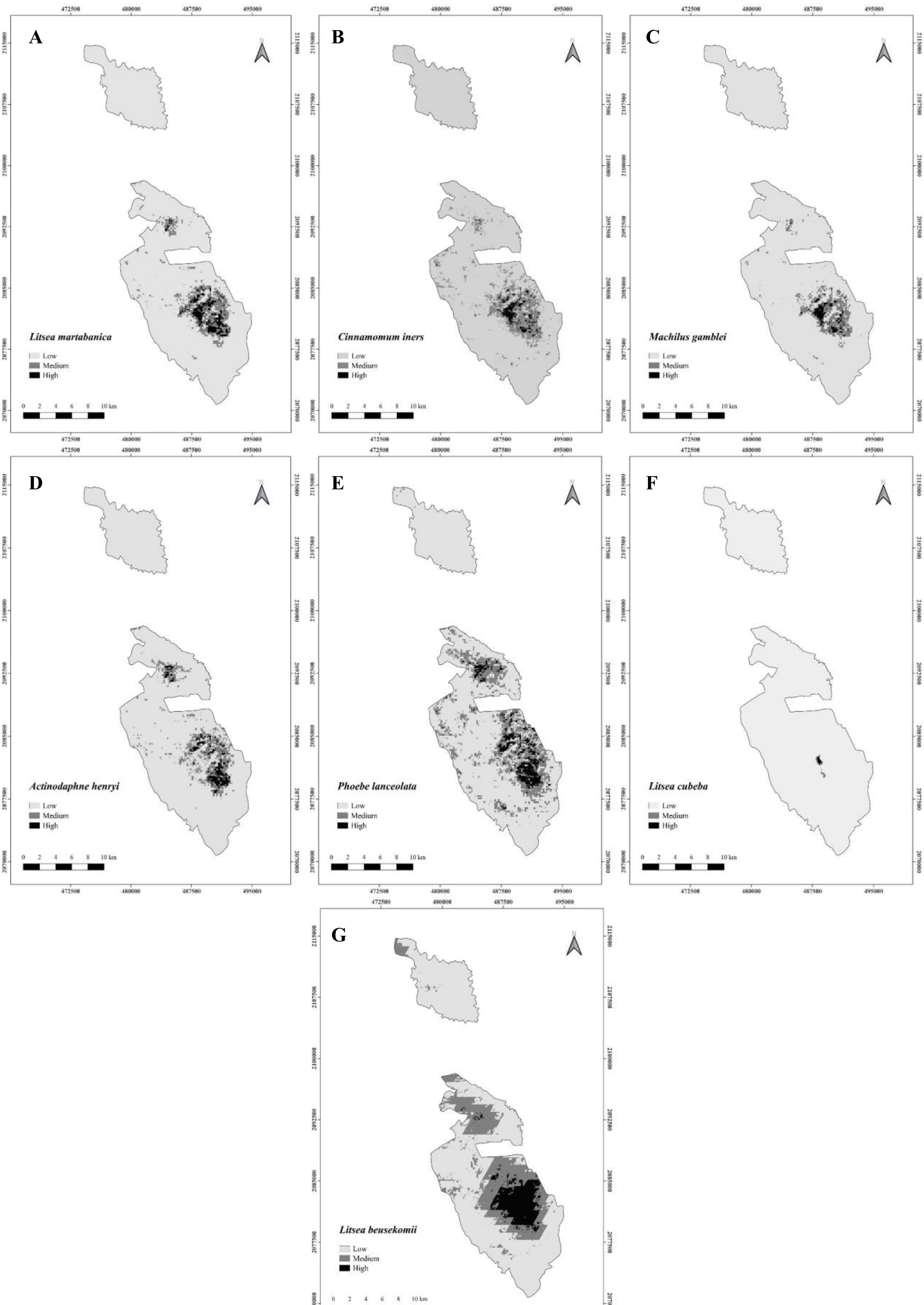

Figure 3. Habitat suitability maps for the Lauraceae family. A. *Litsea martabanica*; B. *Cinnamomum iners*; C. *Machilus gamblei*; D. *Actinodaphne henryi*; E. *Phoebe lanceolata*; F. *Litsea cubeba*; and G. *Litsea beusekomii*

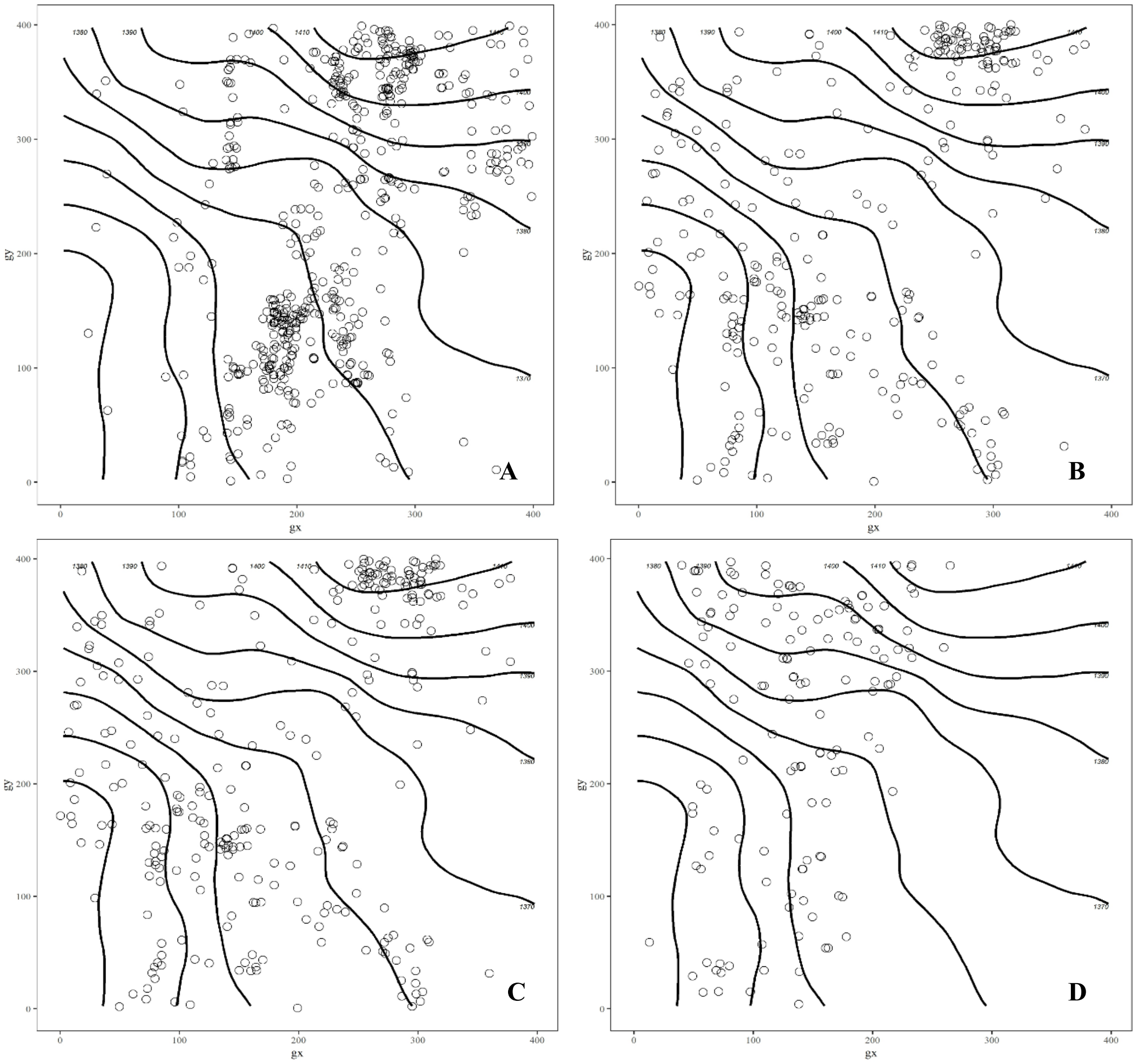

Figure 4. Distribution of the first group species that have a positive association with elevation. A. *Cinnamomum mollissimum*; B. *Litsea grandis*; C. *Beilschmiedia gammieana*; and D. *Litsea monopetala*

Table 2. GLM analysis showing the relationship between selected Lauraceae tree species and environmental factors. The values represent the model regression coefficients, which were selected from the lowest AIC

Species	Intercept	Environmental factors								
		elevation	slope	%sand	%silt	%clay	pH	OM	P	K
L. martabanica	18.1170***	-0.0072***	0.0491***	-0.0351***	-0.0762***	-0.0601***		-0.0160**	-0.0059***	-0.0021***
M. gamblei	4.7349***		0.0133***	-0.0354***	-0.0601***	-0.0349***	0.4273		0.0052*	0.0006.
C. iners	6.7477***		-0.0625***		-0.0102***	-0.0671***		-0.0494***		
C.mollissimum	-8.2045**	0.0108***	-0.0994***		-0.0161***	-0.0707***		-0.0379***	0.0123*	0.0012*
L. grandis	-10.2045***	0.0062***	-0.0317***	0.0465***	0.0452***			0.0457***		
B. gammieana	5.3966	0.0046*	-0.0475***	0.0241***		-0.1902***	-0.6679***	-0.0945***	-0.0691***	-0.0040***
A. henryi	8.1349*	-0.0038				-0.0419**			-0.0304**	-0.0068***
L. monopetala	-43.7216***	0.0208***		0.1231***	0.1504***	0.0640*		0.1725***		0.0047***
C. amygdalina	14.5376***	-0.0028		-0.0166**		-0.1421***	-0.5458*	-0.0811***	-0.0708***	-0.0060***
P. paniculata	-6.8359***			0.1124***	0.1172***				-0.0240*	-0.0049***

Note: *: p<0.05; **: p<0.01; ***: p<0.001

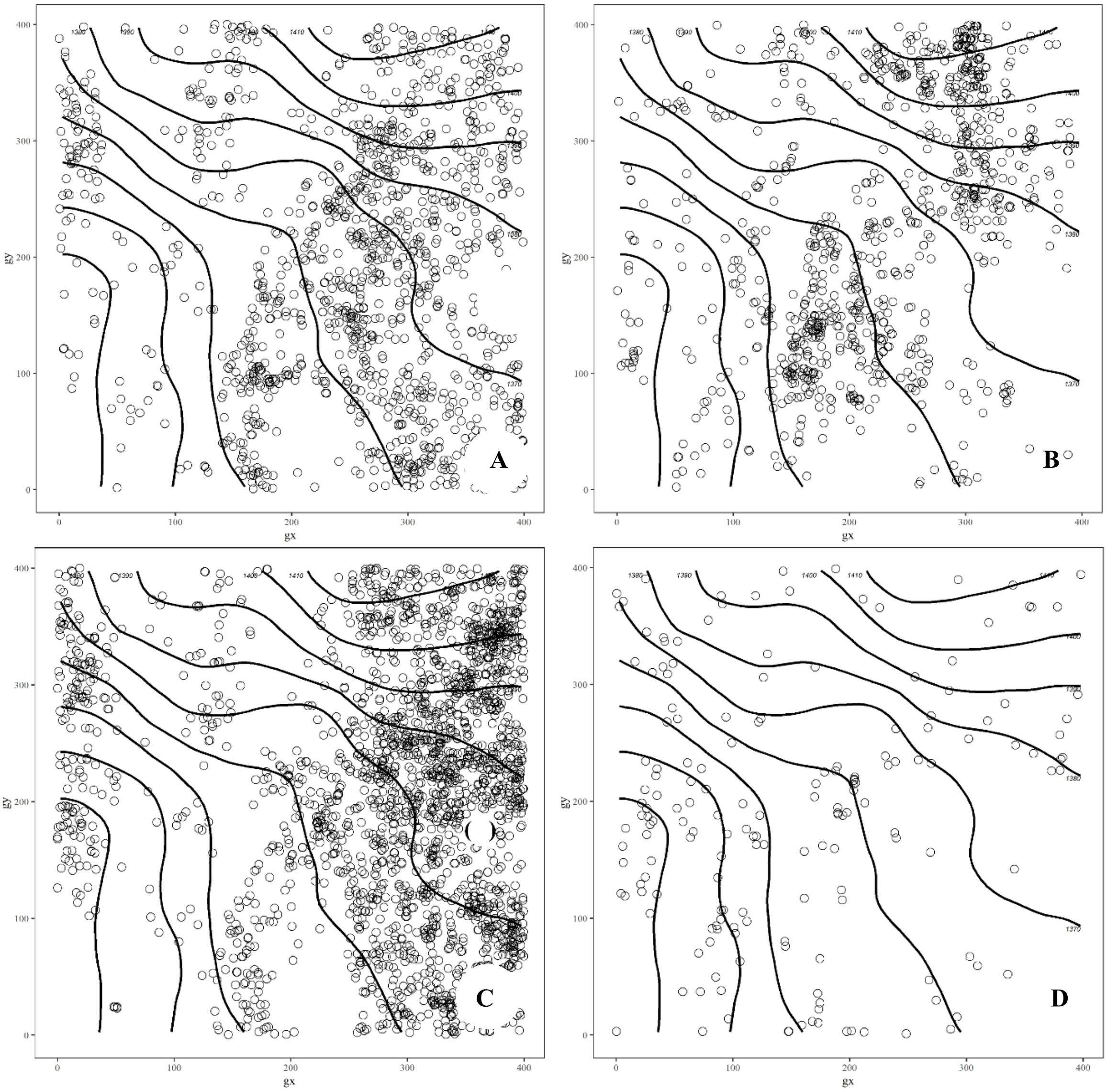

Figure 5. Distribution of the second group species that had a negative association or exhibited no significant relationships with elevation. A. *Machilus gamblei*; B. *Cinnamomum iners*; C. *Litsea martabanica*; and D. *Actinodaphne henryi*

Variations in soil composition, such as sand, silt, and clay percentages, create diverse habitats that support different Lauraceae species (Sri-Ngernyuang et al. 2003). In addition, the organic matter contents ranging from 7% to 34% enhance soil fertility and structure, further influencing species distribution. Climate factors, such as temperature and precipitation, along with other environmental variables, such as slope and aspect, shed light on the microclimatic conditions under which Lauraceae species thrive amidst human activities, including deforestation and land-use change, which significantly impact these species by fragmenting and degrading their habitats (Alkishe et al. 2022). Notably, many areas exhibit varied distributions of Lauraceae tree species, even if the species themselves are identical (Zhu et al. 2015; Okabe et al. 2021). Understanding these environmental factors is crucial for the conservation and management in montane forest (Tan et al. 2023). The impacts of climate change are intensified by elevation, severely affecting montane forests. The resulting loss of biodiversity in these forests leads to the decline of valuable ecosystems, including Lauraceae species (Mata-Guel et al. 2023; Tan et al. 2023), which are both ecologically and economically important (Giraldo-Kalil et al. 2023). This makes certain species of Lauraceae more threatened, particularly those with small populations or specific environmental factors for establishment (Tan et al. 2023).

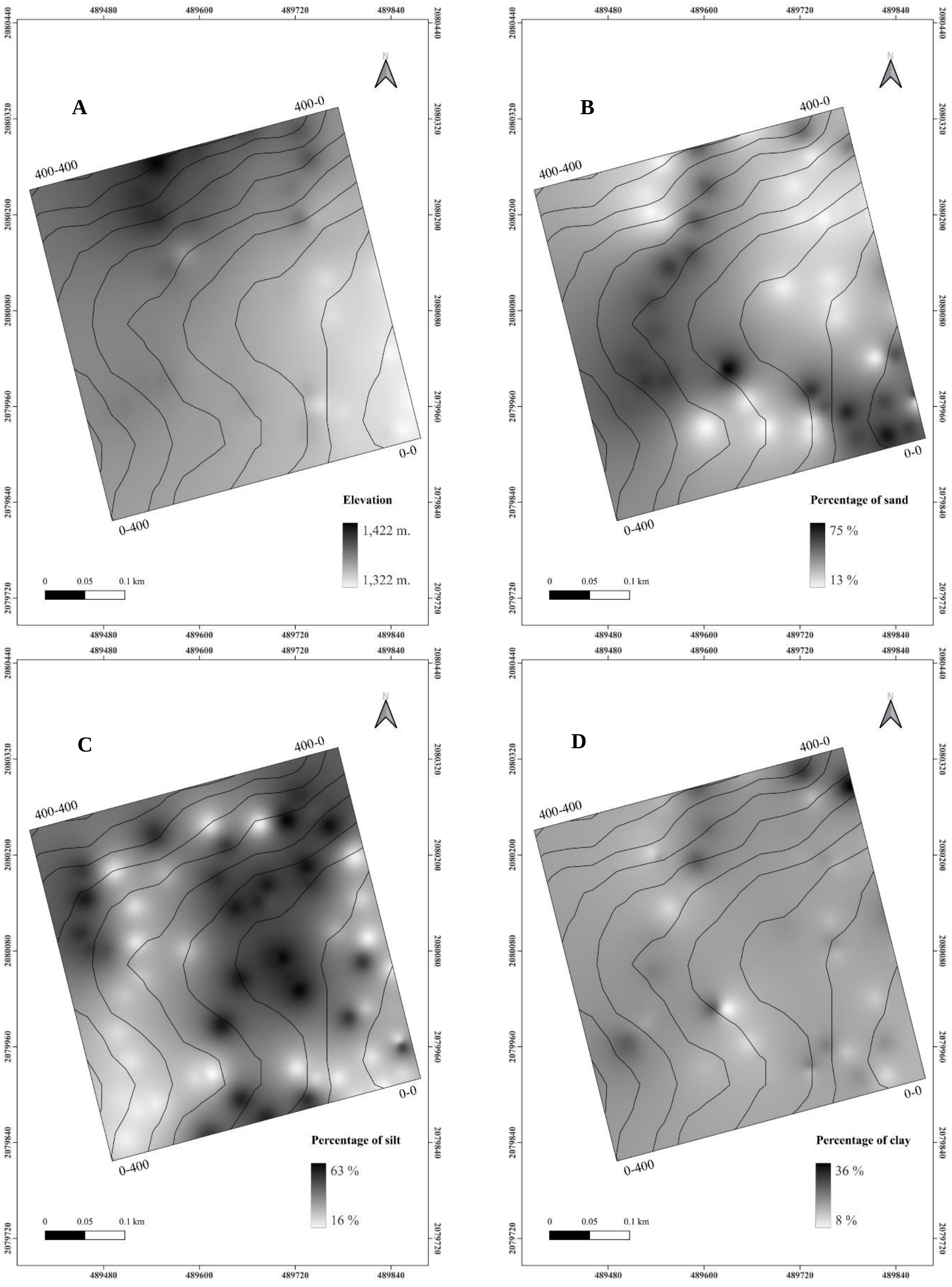

Figure 6. Map of the environmental factors in the 16-ha permanent plot in Doi Suthep-Pui National Park, Thailand. A. Elevation; B. % sand; C. % silt; and D. % clay

In conclusion, the species diversity of the Lauraceae family in Doi Suthep-Pui National Park comprises 24 species from 10 genera. The genera *Cinnamomum* and *Litsea* were the most species-rich within this family. The habitat suitability for Lauraceae species varies significantly among species. The altitudinal gradient emerged as the most influential factor in determining the spatial distribution of Lauraceae tree species. However, this distribution is also influenced by the interplay between elevation, soil properties, climate, and human activity. Future research should focus on investigating the potential impacts of climate change on Lauraceae distribution or conducting long-term monitoring to observe population dynamics to develop effective conservation strategies. This approach will help to ensure the preservation of Lauraceae species and the ecological balance of montane forests in Southeast Asia.

ACKNOWLEDGEMENTS

This research is funded by Kasetsart University, Thailand through the Graduate School Fellowship Program. We would like to thank the Head of Doi Suthep-Pui National Park, Chiang Mai Province, Thailand, for facilitating and assisting with the field data collection. We also thank all members of the Thai Forest Ecological Research Network.

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