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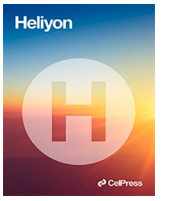

Suitability of bamboo to the ecological conditions in Ba Be district, Bac Kan province, Vietnam

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ABSTRACT

In Vietnamese culture, bamboo holds deep symbolic significance. However, in recent years, as a result of evolving usage patterns and the introduction of alternative materials in the face of a rapidly developing modern market economy, industrialisation, and urbanisation, bamboo's economic and social value has dwindled. Nevertheless, with the pressing challenges of climate change, environmental pollution, and the depletion of natural resources, bamboo is experiencing a resurgence in importance within the lives of Vietnamese people. Ba Be district, situated in Bac Kan province, stands as one of the country's most impoverished regions. Natural bamboo thrives in 14 out of 15 communes, with Dong Phuc commune being the exception. Planted bamboo is found in 14 out of 15 communes, excluding Cho Ra town, covering approximately 7.9 % of the entire district's natural area (NA). The district's vast terrain, featuring slopes exceeding 15°, presents formidable obstacles to socio-economic development. This study aims to shed light on the distribution of bamboo forests in Ba Be district and presents an assessment of bamboo's suitability within its natural surroundings. The study employs the analytical hierarchy process (AHP) method and spatial statistics, using remote sensing data supplied by the Department of Natural Resources and Environment, Ba Be district. The results demonstrate that 60 % of Ba Be district's NA is conducive to bamboo cultivation and growth. The findings of this research provide local authorities with a scientifically grounded basis for strategic planning, enabling bamboo to emerge as a pivotal resource within production forests. This approach outlines the ideal spatial distribution for bamboo cultivation and development, ultimately fostering the sustainable utilisation of local natural resources to support both immediate and long-term local socio-economic development.

1. Introduction

Bamboo has always held a cherished place in Vietnamese culture due to its enduring presence in the daily lives of its people. The resilient, flexible, and durable qualities of bamboo symbolised the Vietnamese people's unwavering resilience in the face of nature's challenges and societal changes throughout their history. Research on bamboo has garnered global interest, particularly in regions with strong traditions and natural advantages in bamboo cultivation and development. Such research has primarily focused on categorising bamboo species [1,2], assessing ecological characteristics [3–6], and examining bamboo's applications in the cultural,

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political, and economic life of specific regions [7–9]. Bamboo stands as the fastest-growing plant globally, capable of growing more than 60 cm in a single day. It belongs to the grass family, boasting a columnar shape with excellent bending and flexibility. Bamboo can reach heights up to 40 m while remaining steadfast against the elements [10].

There are 1575 species of bamboo, of which approximately 1200 are woody bamboo types, rendering bamboo a valuable afforestation resource [11,12]. Asia has the most diverse array of bamboo species worldwide [13]. Vietnam ranks 11th globally in terms of bamboo species diversity, with 79 species, trailing only behind countries such as Japan (90 species), Panama (94 India species), Colombia (102 species), India (108 species), Venezuela (115 species), the United States (130 species), Mexico (136 species), Australia (159 species), Brazil (409 species), and, notably China (approximately 700 species) [1,14] Vietnam, spanning approximately 1.4 million hectares, is renowned for its suitable growth environment suitable growth environment [15] and is ranked 16th worldwide for its wealth of bamboo-related ecosystems and endemic genetic resources [16].

Warm temperatures and high humidity foster bamboo growth [17]. In Vietnam, bamboo thrives in various soil types, with temperatures ranging from 20 °C to 30 °C and rainfall between 1000 mm and 2000 mm [2,18]. Besides natural bamboo areas, many new bamboo plantations aim for economic development. Ideal bamboo development terrain features elevations below 1000 m, slopes less than 25°, and soil with a thickness of 30 cm–50 cm, characterised by medium-light loam or sandy loam soils with effective drainage [19].

Ba Be, located in the mountainous Bac Kan province, 60 km north of the provincial capital, exhibits diverse topography, divided by rivers and streams, which poses significant transportation challenges, especially in the highland villages. The region is characterised by towering mountains interspersed with rugged limestone formations. Ba Be confronts formidable hurdles in its socio-economic development [20]. Bamboos have proven to have diverse applications in social and economic domains [21]. Consequently, our study delves into the assessment of bamboo's suitability within the natural conditions of Ba Be district.

The Analytical Hierarchy Process (AHP) method, developed in the late 1970s by Saaty [22], is a quantitative analytical method used for comparative assessments and optimised alternative selections based on an analysis of criteria. Several authors have employed the AHP method to evaluate ecological suitability [23,24]. These researchers applied the AHP method to natural or socioeconomic indicators, assessing ecological efficiency or vulnerability in specific areas. The AHP method serves as the mathematical foundation for delivering evaluation results based on multiple quantitative criteria. In our research, we have utilised the AHP method to assess the adaptability of bamboo plants. This study imparts essential scientific insights into bamboo, with the primary objective of evaluating bamboo's suitability within the study area's natural conditions. Our aim is to transform the previously challenging local conditions into a catalyst for economic and social development. The study's outcomes offer the local government a scientific basis to develop bamboo-related handicrafts, fostering both socio-economic development and the pursuit of sustainable development goals.

2. Materials and methods

2.1. Study area

Ba Be district is located in the mountainous terrain of Bac Kan province within the North-eastern region of Vietnam [25]. The district encompasses a natural area (NA) of 6,8404.9 ha. The district experiences an average annual temperature ranging from 21 °C to

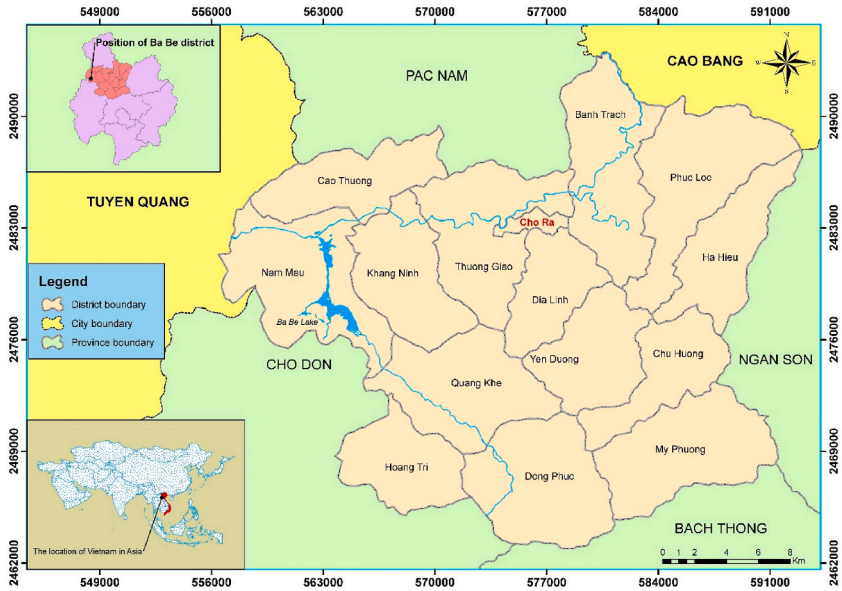


Fig. 1. Location of Ba Be district.

23 °C, with an average annual rainfall of approximately 1600 mm. Eleven soil types, including red-yellow soil on clay and metamorphic rocks (Fs) and Mumolo red-yellow soil on acid magmatic rock (Fa), collectively account for over 50 % of the district's NA. Two principal rivers, Nang River and Cho Lung River, flow through Ba Be district [20].

According to local statistics, approximately 85.1 % of the NA in Ba Be district is currently designated for forestry development [26], while agricultural production land occupies approximately 9.8 %. Special use land constitutes 1.5 % and residential land comprises only 0.6 %. Bamboo can be found throughout all 14 communes and one commune-level town in Ba Be district (see Fig. 1).

2.2. Methods

2.2.1. Research process

Fig. 2 illustrates the comprehensive procedure and methodologies undertaken in this study. A meticulous review of bamboo-related literature was conducted to precisely delineate research objectives, methods, and research directions. Simultaneously, data gathered from local authorities served as the foundation for research and analytical steps. Interviews and field surveys were conducted in parallel to evaluate bamboo's distribution, preservation, utilisation, and functional aspects in the study area. Spatial data collected from local authorities, along with map processing techniques, were employed to create assessment maps. The study's ultimate conclusion combines the suitability assessment map with an analysis of bamboo's potential for preservation, use, and function, thereby elucidating bamboo's suitability for cultivation and growth in Ba Be district (see Fig. 3).

Raw data were procured from local authorities, including the Forest Protection Department, Department of Natural Resources, and Environment in Ba Be district. Additionally, hydrological, traffic, population, and spatial data related to forest management were provided by government agencies, encompassing administrative data, topography, slope, current land use, forest status, rainfall, and temperature. Each spatial data layer was formatted as.shp files and subsequently detected and combined using ArcGIS software. ArcGIS 10.1 (ESRI - Environmental System Research Institute, USA) software was utilised to process the raw data related to Ba Be district's forest status, thus pinpointing bamboo's location and statistical distribution within the study area. Subsequently, ArcGIS 10.1 software facilitated the processing and overlaying of component map layers to construct a map evaluating bamboo's suitability within local natural conditions. Data generated by ArcGIS 10.1 software was transferred to Excel for further processing, data analysis, and spatial statistics.

2.2.2. Evaluation criteria

The suitability map of bamboo was developed by superimposing data on topography, slope, soil layer thickness, temperature, and rainfall. Each component map assigned criteria into five levels of suitability, corresponding to a 3-point scale: very suited (3 points), moderately suited (2 points), poorly suited (1 point), not suited (0 point), and not evaluated (0 point). The Ministry of Agriculture's standards for planting, caring, and exploiting bamboo as well as studies on bamboo's ecological characteristics, guided the determination and scoring of each evaluation criterion [19]. The evaluation for elevation and slope criteria was based on technical standards for bamboo planting, care, and exploitation, as well as ecological characteristics of bamboo studies, issued by the Ministry of Agriculture and Rural Development (MARD), corresponding to three types of terrain in the study area, namely valleys (<500 m), hills (500–1000 m), and mountains (>1000 m). Temperature and rainfall, as climatic criteria, were identified to influence bamboo growth. Although some bamboo species may exhibit varying suitability, most bamboo varieties generally require warm and humid conditions [27]. In conjunction with the technical standards for bamboo, as set by MARD, the study categorised temperature and rainfall into

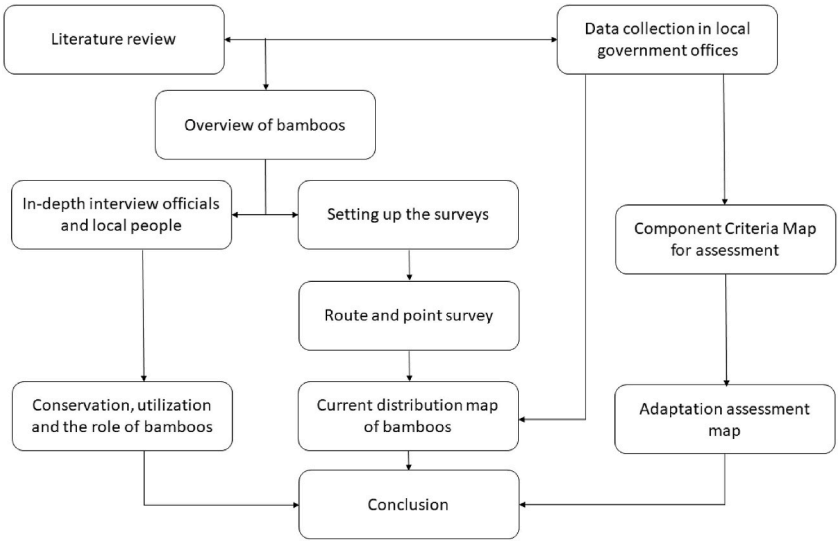


Fig. 2. The flowchart of research.

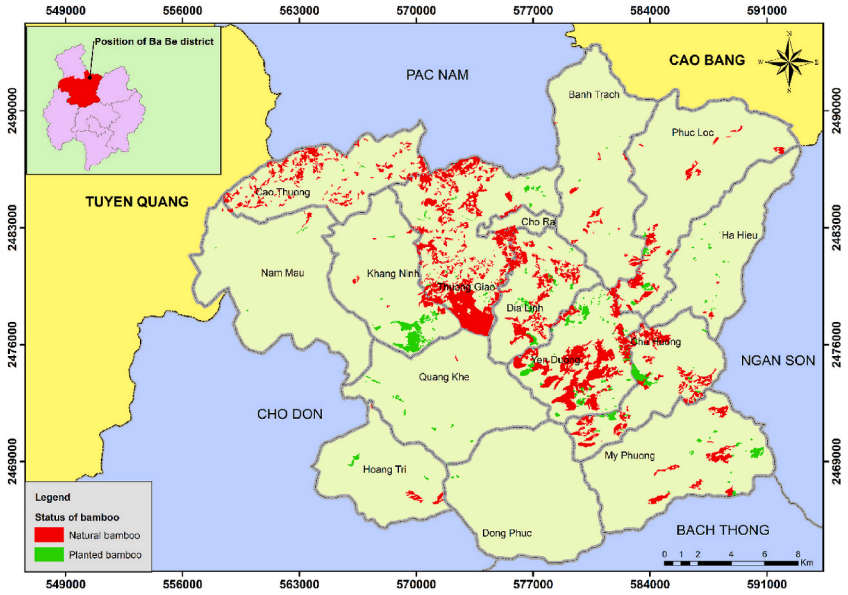
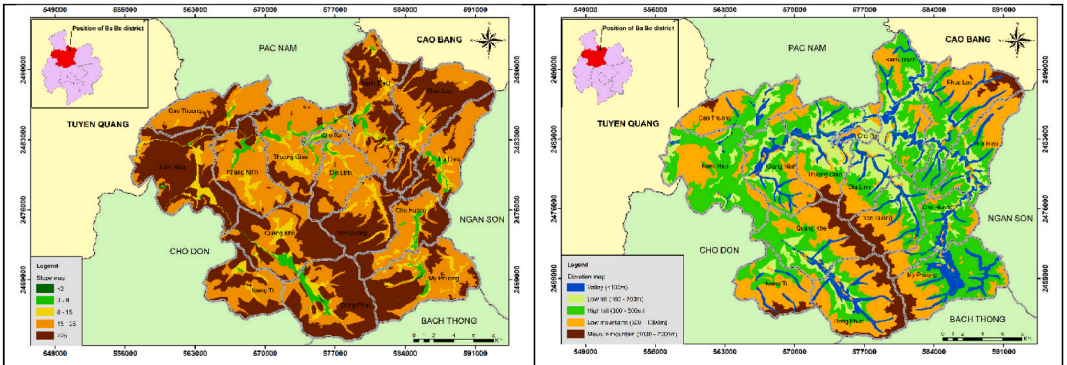


Fig. 3. Current distribution of bamboo in Ba Be district.



(a) Slope map of Ba Be district. 5 slope levels are divided as follows: Under 3°, 3-8°, 8-15°, 15-25° and above 25°

(b) Elevation map of Ba Be district. 5 levels of elevation are divided as follows: Valley, low hill, high hill, low mountain, medium mountain

Fig. 4. Topographic of Ba Be district.

three suitability levels: very suitable, moderately suitable, and poorly suited (Table 1) [19]. Soil thickness impacts root development. The length of the roots is usually 40–100 cm and then they neither grow nor thicken in diameter. This is the basis for the classification of soil thickness criteria [14]. Ba Be district is divided into five levels of suitability assessment including: very suitable (S1), moderately

Table 1
Criteria for assessing the adaptability of bamboo.

Adaptive assessment criteria	Very Adaptable (3 points)	Moderately adaptive (2 points)	Poorly adapted (1 point)
Slope (°)	3 - 8, 8 - 15	15–25	>25
Temperature (°C)	>22	21–22	≤ 21
Rainfull (mm)	1600–1700	, 1500 - 1600	<1500
Topographic (m)	<500	500–1000	>1000
Soil layer thickness (cm)	50–100	<50	>100

suitable (S2), poorly suitable (S3), unsuitable (N), and not evaluated (NE). N areas included those with terrain exceeding 1500 m or slopes greater than 25°. Areas categorised as NE encompassed special-use forest land, protection forest land, urban residential land, rural residential land, and water surfaces. Special-use forest land in the district primarily lies within Ba Be National Park, reserved for conservation purposes and not utilised for other activities.

2.2.3. Suitability assessment model

This study employed the AHP model [28]. In this computational approach, all evaluation criteria were assigned equal importance in terms of weighting. This choice aimed to minimise subjectivity and emphasise the impact of each criterion on bamboo suitability [29]. The sum of component points was divided by the number of evaluation criteria to determine the rating index:

$$Adaptation\ index(A_i) = \frac{\sum(component)}{e} = \frac{Topography * Slope * Layer\ thickness * Temperature * Rainfall}{e}$$

e: number of evaluation criteria.

The results yielded a range of total fitness scores, from the lowest at 18 to the highest at 30 points, corresponding to an Ai range from 3.6 to 12. The obtained dataset was categorised into four levels of fitness with equivalent values:

$$\Delta A_i = \frac{(A_i\ max - A_i\ min\ )}{n}$$

n: number of criteria.

3. Results

3.1. Current distribution of bamboo in Ba Be district

The analysis results reveal that bamboo occupies 7.9 % of the NA within Ba Be district. This district comprises one commune-level town and 14 communes, and it hosts two types of bamboo forests: natural bamboo forests and planted bamboo forests, with natural bamboo forests covering 85 % of the total bamboo area and planted bamboo forest constituting 15 %.

Natural bamboo forests are spread across 14 communes in Ba Be district, with Dong Phuc being the only exception. The commune with the largest natural bamboo forest area is Thuong Giao, covering 1482.9 ha, while the commune with the smallest area is Quang Khe, with only 2.4 ha (Table 2). Other communes with significant natural bamboo areas include Yen Duong (961.3 ha), Dia Linh (480.2 ha), Chu Huong (480.2 ha), Cao Thuong (466.6 ha), Phuc Loc (271.5 ha), My Phuong (208.3 ha), Banh Trach (88.5 ha), and Khang Ninh (70.0 ha). The remaining communes have natural bamboo areas less than 50 ha, including Hoang Tri (46.8 ha), Cho Ra (22.5 ha), Ha Hieu (14.4 ha), Nam Mau (14.4 ha), and Quang Khe (2.4 ha) (see Table 3).

Planted bamboo forests are distributed in 14 out of the 15 communes, with Cho Ra being the only place where bamboo is not cultivated (Table 2). This commune is the smallest district and serves as the economic, political, and social centre of Ba Be district, housing government offices and schools, and having the highest population density in the district [26]. Khang Ninh commune boasts the largest bamboo growing area (225.6 ha), followed by Yen Duong (165.7 ha), Chu Huong (113.5 ha), Dia Linh (67.5 ha), My Phuong (62.5 ha), and Thuong Giao (53.7 ha). The remaining communes have less than 50 ha of bamboo cultivation, including Phuc Loc (38.9 ha), Quang Khe (26.3 ha), Ha Hieu (19.9 ha), Hoang Tri (18.8 ha), Nam Mau (5.3 ha), Dong Phuc (3.9 ha), Banh Trach (3.7 ha), and Cao Thuong (3.1 ha).

Ba Be District contains Ba Be National Park, one of the 20 most beautiful natural freshwater lakes globally, recognised by UNESCO as the third Ramsar site in Vietnam [30]. This strict protection of the national park has left its natural ecosystems intact. Only 14.4 ha of natural bamboo forests are recorded within the park. The area designated for new bamboo forest planting is also minimal, with just 5.3

Table 2
Current area of natural bamboo and planted bamboo in Ba Be district.

Order	Name of commune	Natural bamboo (ha)	Cultivated bamboo (ha)	Total area (ha)
1	Cao Thuong	466.6	3.1	469.7
2	Banh Trach	88.5	3.7	92.2
3	Dong Phuc	0.0	3.9	3.9
4	Nam Mau	14.4	5.3	19.7
5	Hoang Tri	46.8	18.8	65.6
6	Ha Hieu	14.4	19.9	34.3
7	Quang Khe	2.4	26.3	28.8
8	Phuc Loc	271.5	38.9	310.4
9	Thuong Giao	1482.9	53.7	1536.6
10	My Phuong	208.3	62.5	270.8
11	Dia Linh	480.2	67.5	547.6
12	Chu Huong	461.7	113.5	575.2
13	Yen Duong	961.3	165.7	1127.1
14	Khang Ninh	70.0	225.6	295.5
15	Cho Ra	22.5		22.5

Table 3
Area of suitability.

Name of commune	N	NE	S1	S2	S3	Area by commune
§ång Phóc	49,1	3615,1	154,8	1201,1	877,5	5897,6
§þa Linh	19,1	531,1		1957,3	617,5	3125
Bµnh Tr[1]ch	34	1192,9	137,6	1806,4	2796,7	5967,6
Cao Thîng	126,9	595,6		853,8	2330,4	3906,7
Chu H¬ng		513,5	34,4	1118,7	1817,9	3484,5
Hµ HiÖu		955,7		299,3	2751,3	4006,3
Hoµng TrÜ		1677,9		488,3	1360,7	3526,9
Khang Ninh	10,6	1610	57,4	909,5	1845,3	4432,8
Mü Ph¬ng		994,8	16,4	2794,9	1898,7	5704,8
Nam MÉu		6392,6	10,3	49	26,7	6478,6
Phóc Léc	330,2	1665,5		336,3	3960,7	6292,7
Qu¶ng Kh[a]	312,2	3193,1	75,1	870,3	997,7	5448,4
Thîng Gi¸o	108,1	2250,7	1373	1668,2	292,5	5692,2
TT. Chî R·		117,7	55,2	287,6		460,5
YÔn D¬ng		870,5		972,5	2137,3	3980,3
Area by assement	990,2	26177	1914	15613	23711	68404,9

ha. The focus is on preserving special-use forest to ensure the sustainability of the natural ecosystem. A small part of the national park located west of Khang Ninh commune, bordering Nam Mau, is also strictly preserved. The area of newly planted bamboo forest in Khang Ninh is concentrated in the southeast region of the commune, bordering Quang Khe and Thuong Giao communes (Table 2).

The distribution map highlights that most natural bamboo forests are located in low-lying areas, primarily in Thuong Giao, Dia Linh, Yen Duong, Chu Huong, Phuc Loc, and My Phuong communes. These communes are situated in valleys, low hills (100–300 m), and high hills (300–500 m). Few areas are in low mountains (500–1000 m) and medium mountains (1000–2000 m). In practice, lower terrain areas are more suitable for bamboo growth, whereas high terrain areas are less suitable.

3.2. Topographical features of Ba Be district

Ba Be district in Bac Kan province exhibits a prominent feature: the steep slope of its terrain. Cho Ra is the only area where the slope does not exceed 25° and areas with slopes below 15° account for only 47 % of the NA. The remaining 14 communes have area with slopes greater than 15°, covering more than 85 % of the NA. Notably, Cao Thuong commune has 97 % of its NA with slopes exceeding 15°. Ba Be district is divided into three distinct topographical types: valleys, hills, and mountains, with the area distribution being 11 %, 50 %, and 39 %, respectively. These topographical features shape the district's character but also pose challenges to its socio-economic development (see Fig. 4).

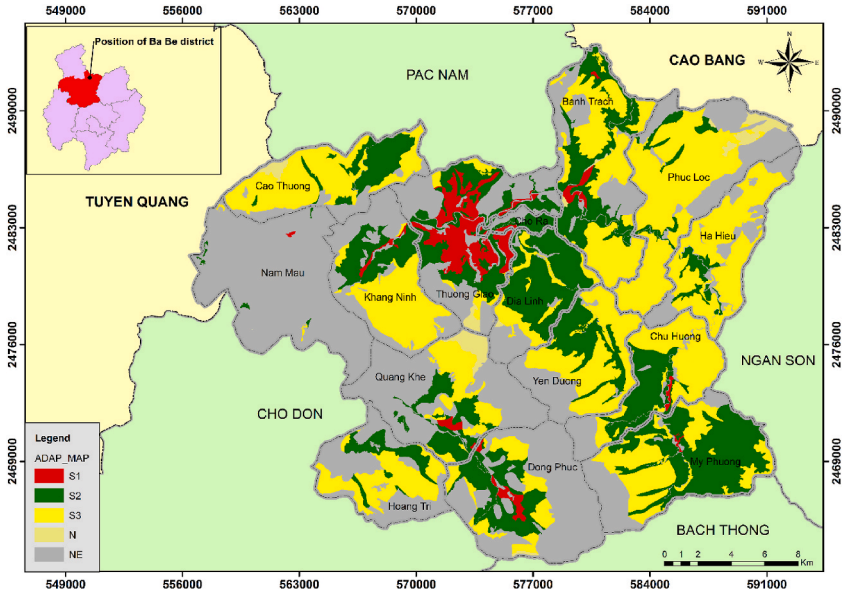


Fig. 5. Adaptation assessment map of bamboo in Ba Be (S1, very suitable; S2, moderately suitable; S3, poorly suitable; N, not suitable; NE, not evaluated).

3.3. Suitability assessment results

The results of the assessment of bamboo suitability in Ba Be district were derived from data on topography, slope, soil layer thickness, temperature, and rainfall. Although temperature and rainfall are relatively stable in the study area due to its size, the remaining factors, including topography, slope, and soil layer thickness, have direct effects on bamboo suitability. The spatial statistical method, utilising the suitable distribution map of bamboo, provided the following results.

Fig. 5. Suitability assessment map of bamboo in Ba Be (S1, very suitable; S2, moderately suitable; S3, poorly suitable; N, not suitable; NE, not evaluated).

Out of the total NA of 68,404.9 ha, approximately 41,159.8 ha, equivalent to 60.2 % of the district's NA, are suitable for bamboo cultivation, distributed across all 15 communes.

Banh Trach commune is the area with the most suitable bamboo cultivation, covering 4740.7 ha, which constitutes 79.4 % of its NA. Banh Trach features a combination of hills (3757.2 ha), valleys (984.4 ha), and mountains (1226 ha). Despite its steep terrain, with 89.7 % of the commune's NA having slopes exceeding 15°, the presence of valleys and hilly areas makes Banh Trach an ideal location for bamboo growth. The S1 area in Banh Trach spans 137.6 ha, S2 covers 1806.4 ha, and S3 encompasses 2796.7 ha.

My Phuong commune has S1, S2, and S3 areas of 16.4 ha, 2794.9 ha, and 1898.7 ha, respectively. The total suitable area of the commune accounts for 82.6 % of its NA. Phuc Loc commune has a suitable area of 4287.6 ha, corresponding to 68.1 % its NA, with suitability classes of S2 (336.3 ha) and S3 (3951.3 ha).

Although Thuong Giao commune's total suitable area ranks fourth in the district, covering 3333.4 ha (accounting for 58.6 % of its NA), it boasts the largest S1 area in the district, spanning 1372.7 ha (accounting for 71.7 % of the total S1 area in the district). The S2 area in Thuong Giao is 1668.2 ha, while S3 encompasses 292.5 ha. This commune is exceptionally suitable for bamboo development and accounted for 28.5 % (1536.6 ha) of the total bamboo area in the whole district at the time of the study.

Cao Thuong is the fifth largest commune in terms of bamboo suitability area, featuring S2 and S3 areas of 853.8 ha and 2330.4 ha, respectively. Although Cao Thuong's topographic elevation is not high, its terrain has a steep slope, with 97 % of the mountainous sloping above 15°. This makes Cao Thuong the commune with the steepest terrain in the district and the reason it lacks an S1 area.

Yen Duong is the commune with the second largest bamboo area in the district, covering 1127.1 ha, which account for 20.9 % of the total bamboo area in the district. The total suitable area of this commune is 3100.3 ha, with S2 spanning 972.5 ha and S3 covering 2127.8 ha. Yen Duong has steep terrain, with over 92.4 % of the commune's NA having slopes exceeding 15°.

Ha Hieu has S2 and S3 areas of 299.3 ha and 2692 ha, respectively, and the total suitable area accounts for 74.7 % of the commune's NA. Chu Huong has a total suitable area comprising 85.3 % of the commune's NA (3484.5 ha), with S1 covering 34.4 ha, S2 spanning 1118.7 ha, and S3 encompassing 1817.9 ha. Khang Ninh commune boasts S1, S2, and S3 areas of 57.4 ha, 909.5 ha, and 1845.3 ha, respectively. The total area suitable for bamboo accounts for 63.4 % of the commune's NA. This is an area with a slope exceeding 15°, constituting 87.6 % of its NA, and the terrain is evenly distributed among valleys, hills, and mountains.

Dia Linh only features S2 and S3 areas of 1957.3 ha and 617.5 ha, respectively. Dong Phuc commune has a total suitable bamboo area of 2233.4 ha, which corresponds to 37.9 % of its NA, with S1 covering 154.8 ha, S2 spanning 1201.1 ha, and S3 encompassing 877.5 ha. Dong Phuc is characterised by its high terrain, hills, and mountains, with a steep slope of 89.7 % of its NA.

Quang Khe and Hoang Tri are two communes with similar total suitable areas of 1943.1 ha (35.7 % of the NA) and 1849.0 ha (52.4 % of the NA), respectively. Both communes have steep terrains with slopes exceeding 15° and primarily comprise high hills and mountains.

Commune-level town Cho Ra serves as the economic, political, and social centre of Ba Be district, housing government offices. The area assessed as suitable for bamboo covers 460.5 ha, equivalent to 74.4 % of the commune's NA. Cho Ra centre includes topographical features of valleys (93.9 ha), hills (253.8 ha), and medium mountains (112.8 ha). It is the only area in the district where the slope across the entire commune is below 25°. However, this is the area where the economic, political, and social development of the district is concentrated, so the assessment level for the development of bamboo focuses on the suitability level S2.

Nam Mau has the smallest area assessed as suitable for bamboo cultivation in the district, with just 1.3 % of the commune's natural area evaluated. This result stems from the fact that Nam Mau commune lies entirely within the core area of Ba Be National Park. In 2004, Ba Be National Park was recognised as an ASEAN Heritage Park [31]. Consequently, the focus is on preservation to protect the diverse flora in the park [32]. This is why the entire area of Nam Mau commune was not assessed in this study.

3.4. Utilisation of bamboo

For a region facing multiple challenges, both natural and socio-economic, such as Ba Be district, bamboo has emerged as a valuable option for poverty alleviation, thanks to its immense potential and economic value. Bamboo offers great potential in reviving traditional weaving villages, generating local employment, and preserving local cultural products, including baskets, shelves, tables, chairs, household items, and even bamboo buildings. Furthermore, bamboo plays a crucial role in preventing soil erosion, conserving water, improving soil quality, and carbon absorption, all of which hold significant value for the locality's sustainable development. Bamboo also serves as an eco-friendly building material and provides inspiration for contemporary architectural design.

Notably, the current land usage status in Ba Be district can often change due to a range of factors, both objective (e.g. weather, natural disasters) and subjective (e.g. human impacts.). This implies that data layers like topography, slope, and soil layer thickness may change over time. Therefore, ongoing research is necessary to monitor these changes and provide updates for bamboo cultivation and development in Ba Be district.

4. Conclusions

This study provides an in-depth analysis of the current distribution of bamboo in Ba Be district, Bac Kan province, while also establishing the suitability of bamboo cultivation based on key components, including topography, slope, soil thickness, temperature, and rainfall. It utilises official data as a foundation for evaluating the economic potential of bamboo and its role in preserving and enhancing sustainable natural environment development in Ba Be district. The findings reveal that the suitable area for bamboo cultivation in Ba Be district encompasses 41,159.8 ha, equivalent to 60.2 % of the district's NA. This is approximately 7.6 times larger than the actual current distribution of bamboo in the district, which spans 5.399.9 ha, equivalent to 7.9 % of the district's NA. The suitable areas for bamboo cultivation are primarily concentrated at altitudes below 1000 m and on slopes with gradients less than 25°. A distinctive topographical characteristic of Ba Be district is the prevalence of steep slopes, with up to 90.3 % of the district's NA featuring slopes exceeding 15°. This study underscores that the natural conditions in Ba Be district are conducive to bamboo cultivation. For a region facing economic challenges, characterised by a high risk of landslides, and predominantly inhabited by ethnic minorities, this research serves as a scientific foundation to assist Ba Be district in developing its economy using bamboo as a sustainable and locally relevant resource, leveraging the technical capabilities of its residents, and harnessing its internal strengths.

Data availability statement

Data included in article/supp. material/referenced in article.

CRediT authorship contribution statement

Van Thanh Do: Software, Formal analysis, Data curation. **Van Hoan Kieu:** Validation, Methodology, Formal analysis. **Quyet Chien Nguyen:** Software, Investigation, Formal analysis. **Thi Loi Duong:** Software, Formal analysis, Data curation. **Hoang Duong Dinh:** Writing – original draft, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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