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Research article

Identifying Niche Factors for Planting Vetiver Grass in Thailand

Yaowaret Jantakat[1*], Pongpun Juntakut[2] and Chomphak Jantakat[3]

[1] Faculty of Sciences and Liberal Arts, Rajamangala University of Technology Isan, Khonkaen, 40000, Thailand
[2] Department of Civil Engineering, Chulachomklao Royal Military Academy, Nakhonnayok, 26000, Thailand
[3] Faculty of Business Administration, Vongchavalitkul University, Nakhonratchasima, 30000, Thailand
* Correspondence: yaowaret.ja@rmuti.ac.th

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Abstract: This study aims to identify niche factors to use in mapping potential areas of vetiver grass planting in Thailand. Pak Chong district of Nakhon Ratchasima province is selected as a case study. There were 4 used datasets: existing planted vetiver data, 3 topographical data (DEM, slope, and aspect), bioclimatic data, and the modified soil data. These datasets were transformed into GIS data with WGS 1984 and Zone 48N and were processed by ecological niche factor analysis (ENFA) in BIOMAPPER. ENFA produced the habitat suitability (HS) index for planting vetiver grass and provided understanding of spatial dispersion ability and tolerance of vetiver grass ecology to the current environment. The analyzed results showed that HS-based ENM2 has the highest possibility for planting vetiver grass, with AVI 0.93 and CVI 0.07. The ENM2 included 97% marginality (the ability for spatial distribution in the study area) and 3% specialization (durability in the study area). Moreover, this ENM2 explicitly indicates the existing vetiver grasses have more highly spatial distribution than durability in the study area with niche factors such as BIO1: the mean annual temperature (25-31°C), BIO5: mean monthly maximum temperature (30-38°C), BIO6: mean monthly minimum temperature (17-27°C) and elevation (600-1,300 m), respectively. The obtained niche factor (e.g., BIO1, BIO5, BIO6, and elevation) will be implemented to map potential areas of vetiver grass in the Center for Promoting the Utilization of Vetiver Grass under the Royal Initiative Project (CPUVGRIP) of Forest Royal Department (FRD) in Nakhon Ratchasima, Thailand further.

Keywords: Vetiver grass; Habitat suitability; Ecological niche modeling; Spatial distribution

1. Introduction

King Rama IX gave the first royal initiative since 1991 to encourage the utilization of vetiver in Thailand for soil and water conservation after receiving information from the World Bank [1]. From the past to the present (about 28 years), many Thai agencies (both government and private sectors) have promoted vetiver grass use in Thailand as a suitable way for Thai society to address these problems with a simple technology that was easy to implement and cost-effective compared to other methods [2,3,4]. The government developed "The Committee to Master Plan the Development and Campaigning for the Use of Vetiver." It made the Land Development Department (LDD) a central unit responsible for breeding, propagating, and distributing vetiver varieties. The Office of the Royal Development Projects Board was responsible for distributing vetiver varieties to prevent discrepancies and usage of wrong species that may damage agricultural areas. The species Vetiveria Zizanioides was identified by the World Bank as the most effective at preventing soil erosion [2]. Thus, it was promoted for use in Thailand. These results were then expanded to Thai government agencies such as the Royal Forest Department (FRD) and the Department of Highways (DOH).

I reviewed many papers relevant to ecological modeling and assessment in this work. Ecological Niche Modeling (ENM) remains important for exploiting habitat suitability, as shown in the articles by Chen and colleagues [5] and Mathur and colleagues [6]. In ecology, the dimensions of an environmental niche vary from one species to another. The relative importance of specific environmental variables for one species may vary according to the geographic and biotic contexts [7]. A species' niche encompasses physical and environmental conditions that interact with other existing species, such as predation or competition [8,9]. The niche of a species is ancillary to environmental factors, which affect the ability of a species to survive and endure [10]. The study of ENM is worked on by software such as Maxent [11], Biomapper [12], ModEco [13], OpenModeller [14], and R [15]. This paper used ENM in the Biomapper program because Ecological Niche Factor Analysis (ENFA) proved to be a suitable method for modeling environmental species distributions, regardless of the presence-only dataset size [16]. Moreover, Biomapper is a kit of GIS and statistical tools designed to build Habitat Suitability (HS) models and maps for any animal or plant-centered on ENFA that allows computing HS models without the need for the absence of data [17].

Therefore, the objective of this study proposes the identification of niche factors for HS of vetiver grass planting to support soil and water conservation for Thai concerned agencies such as the Center for Promoting the Utilization of Vetiver Grass under the Royal Initiative Project (CPUVGRIP) in Nakhon Ratchasima province. The obtained niche factor will use to generate a map for potential vetiver grass planting areas further.

1.1 Ecology and environment of vetiver grass

Vetiver grass has grown over various sites and in various environmental conditions. However, Grimshaw [18] and Truong [19] explicitly the ecological characteristics of vetiver grass are based on three main environmental factors: climate, topography, and soil, and more details as follows:

1. Climate factor: vetiver grass can tolerate temperatures up to 40°C [18].
2. Topographic factor: vetiver grass can be planted and survive from 200 to 2000 m. [19].
3. Soil factor: there are many experiments such as vetiver tolerates high levels of salinity and shows a 50% dry matter yield reduction [20]; the tolerance of vetiver to a range of soil pH has been carried out and demonstrates the tolerance of vetiver to pH levels as low as 3.3 with soil Al toxicity levels of 68% - indications are that vetiver may be one of the most tolerant crops and pasture species to Al toxicity [21].

1.2 Study area

The study area is the Pak Chong district of Nakhon Ratchasima province, northeastern Thailand. The study area has 1,825.20 km2 and is situated approximately between latitudes from 14° to 15° N and longitudes from 100° to 102°E, as shown in Figure 1. For common physical data of the study area, topography includes a series of complex mountains that range in elevation from 200 m to 1,300 m above mean sea level (MSL); climatic data is dominantly affected by the monsoon that is measured and monitored by meteorological stations of the Thailand Meteorological Department (TMD); soil data is mainly classified as slope complex by Land Development Department (LDD) of Thailand.

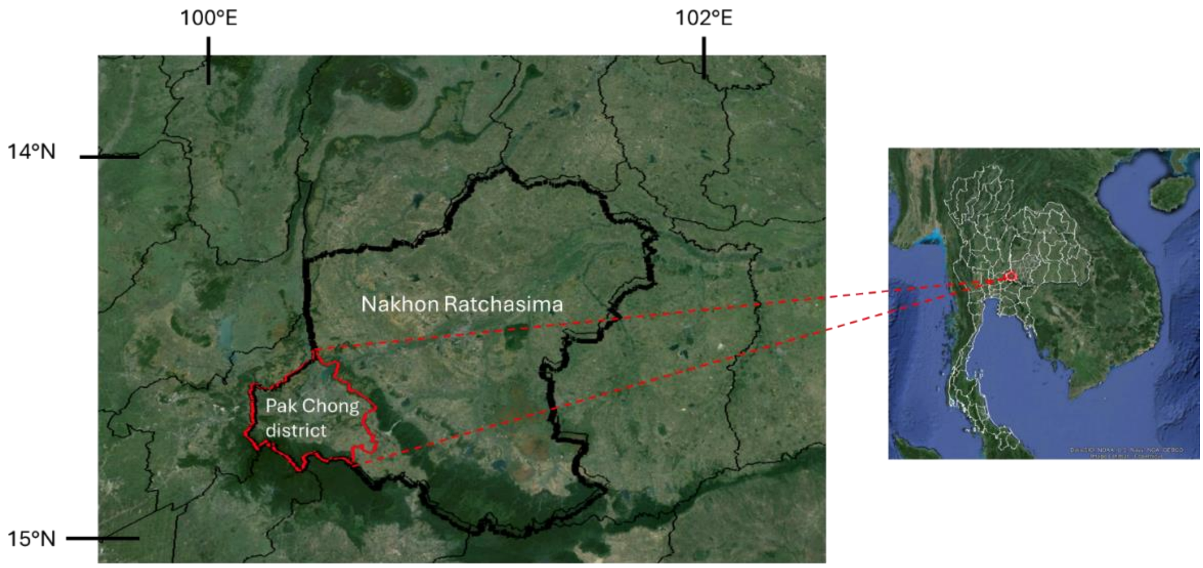
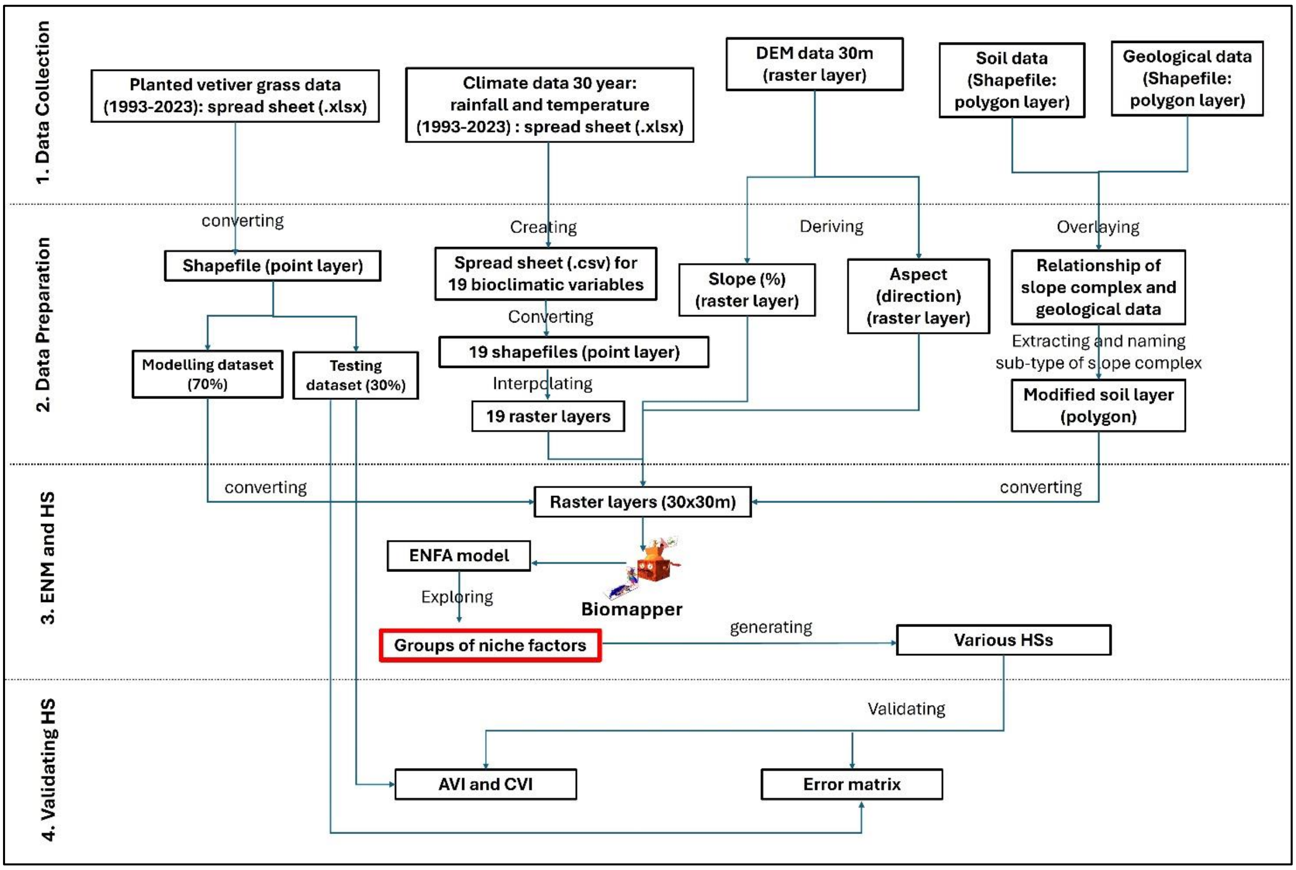


Figure 1. Location of study area.

2. Materials and Methods

This study requires the identification of niche factors for planting vetiver grass in Thailand. Pak Chong district of Nakhon Ratchasima province is the case study. A group of niche factors were identified by ENFA modeling in Biomapper and then generated HS for planting vetiver grass. Therefore, the framework of methodological steps in this study can be presented in Figure 2, and more details of each step are below.



Remark: The red shows the purpose of this study

Figure 2. The framework of the study's methodological steps

2.1 Data collection

This study collected datasets: 1) the planted vetiver grass data (1991-2023), 2) rainfall and temperature data (1991-2023), 3) Digital Elevation Model (DEM) 30 m, 4) soil data and 5) geological data, were summarized as Table 1. This study used the vetiver data between 1991 and 2023 (the latest data) because it was begun by the first royal initiative in 1991 to study the utilization of vetiver in Thailand for soil and water conservation until the present. Therefore, other data would be collected during the same time as well.

Table 1. Data collection for this study

Environmental data	Characteristics of available data	Sources
1. Vetiver and soil	- Vetiver Data was in spreadsheet data (.xlsx) and digital reports. - Soil data was in the form of vector-based GIS (polygon layer) and digital reports	Land Development Department (LDD)
2. Rainfall and temperature	Data was in monthly mean rainfall, and temperature was in spreadsheet data (.xlsx) and digital reports.	Thailand MeteorologicalDepartment (TMD)
3. DEM 30 m	Data was in raster-based GIS with a 30 x 30 m cell size and digital reports.	Department of National Parks, Wildlife and Plant Conservation (DNP)
4. Geology	Data was in vector-based GIS (polygon layer) and digital reports.	Department of Mineral Resources (DMR)

2.2 Data preparation

In this step, the collected data were checked the attribute data and then were prepared in the form of GIS, all the same as the geographical system of WGS 1984 and Zone 48N in QGIS program version 3.28.1 as follows:

2.2.1 The vetiver dataset

The vetiver data were collected from LDD 1991-2023. They focused on the 100 currently implemented points, which were then converted into shapefile (point layer). These vetiver points were divided into 2 datasets: one for creating ENM and HS (70 vetiver points or 70 percent) and another for validation (30 vetiver points or 30 percent). The 70/30 percent (modeling/testing) was chosen because it emphasizes the lowest accuracy assessment that the model can accept as the research paper of Gholamy et al. [22] and Tuan et al. [23]. Moreover, this study did not only regard the mentioned concept of ratio above but also considered the existing land use type of the vetiver grass locations for dividing modeled and validated datasets, as in Table 2 and Figure 3.

Table 2. The existing land use types of the vetiver grass points for dividing modelled and validated sets

Land use types	Modelling points	Validating points	Total
1. Agricultural area	35	15	50
2. Forest area	12	5	17
3. Roadside a steep slope	9	4	13
4. The edge of the water sources	14	6	20
Total	70	30	100

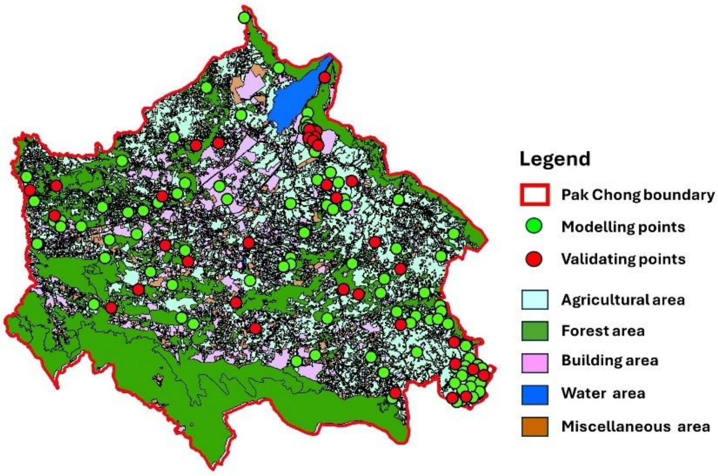


Figure 3. The existing land use types of the vetiver grass points for dividing modelled and validated sets

2.2.2 The rainfall and temperature dataset

These climatic data were characterized by using the monthly mean rainfall and temperature data from 33 climatological stations of TMD 1991-2023 that cover the study area (e.g., Nakhonsawan, Takfa Agromet., Chainat Agromet., Ayuttaya, Pathumthani, Suphanburi, Lopburi, Buachum, Pilot station, Samutprakarn, Suvarnabhumi Airport, Bangkok metropolis, Bangkok port (Klong Toei), Bang Na Agromet., Don Muang airport, Chachoengsao, Prachinburi, Aranyaprathet, Sakaew, Chonburi, Kosichang, Laemchabang, Mahasarakham, Chiyaphum, Nakhonratchasima, Pakchong agromet., Chok chai, Surin, Surin agromet., Burirum, Nang rong, Wichian buri). Then these two climatic data were used for calculating 19 bioclimate variables (as Figure 4) based on paper of O'Donnell et al. [24] (e.g., BIO1: Annual Mean Temperature; BIO2: Annual Mean Diurnal Range; BIO3: Isothermality; BIO4: Temperature Seasonality (Standard Deviation); BIO5: Max Temperature of Warmest Month; BIO6: Min Temperature of Coldest Month; BIO7: Annual Temperature Range; BIO8: Mean Temperature of Wettest Quarter; BIO9: Mean Temperature of Driest Quarter; BIO10: Mean Temperature of Warmest Quarter; BIO11: Mean Temperature of Coldest Quarter; BIO12: Annual Precipitation; BIO13: Precipitation of Wettest Month; BIO14: Precipitation of Driest Month; BIO15: Precipitation Seasonality (CV); BIO16: Precipitation of Wettest Quarter; BIO17: Precipitation of Driest Quarter; BIO18: Precipitation of Warmest Quarter; BIO19: Precipitation of Coldest Quarter).

This study used bioclimate data because it better represents the types of seasonal trends pertinent to the physiological constraints of different species based on evidence from PRISM Climate Data from Oregon State University [25]. The output of the calculated bioclimate was stored in an Excel program and then saved as .csv to convert into a shapefile (point layer) and interpolated as a raster layer.

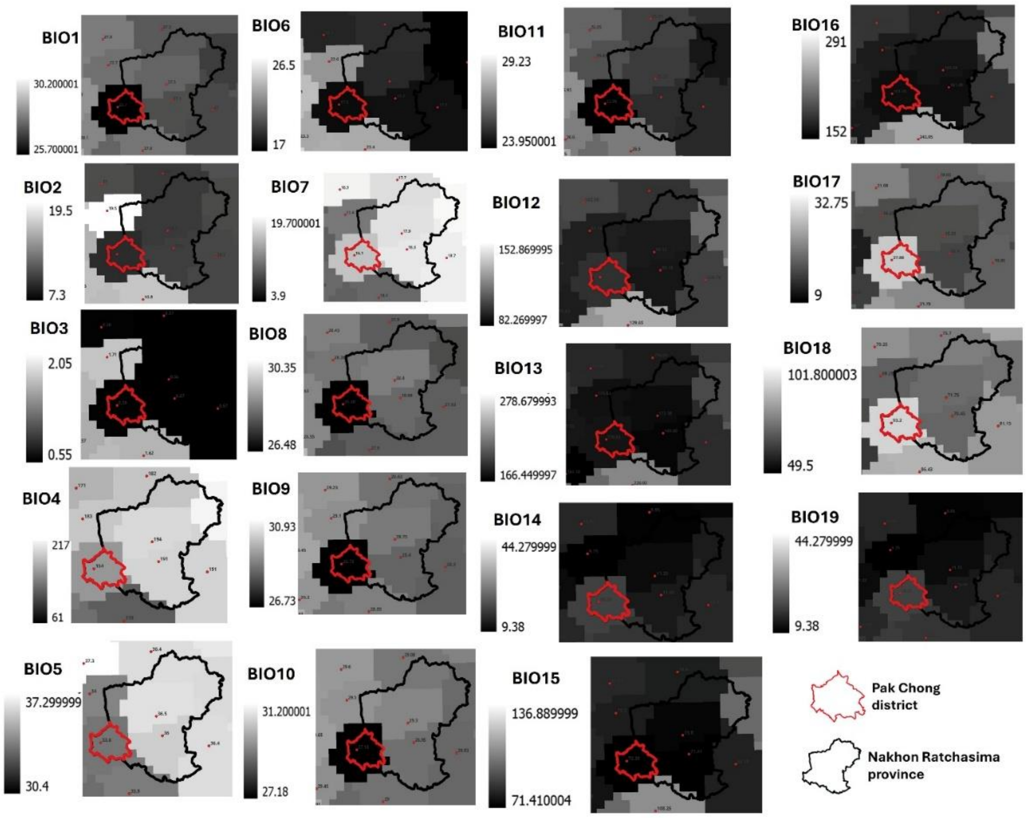


Figure 4. 19 bioclimatic layers for this study

2.2.3 The topographical dataset

The courtesy of DNP gained DEM with a cell size of 30 x 30 m. Elevation data (m) was directly extracted from DEM, while slope (degree) and aspect (direction) were also derived from DEM, as shown in Figure 5.

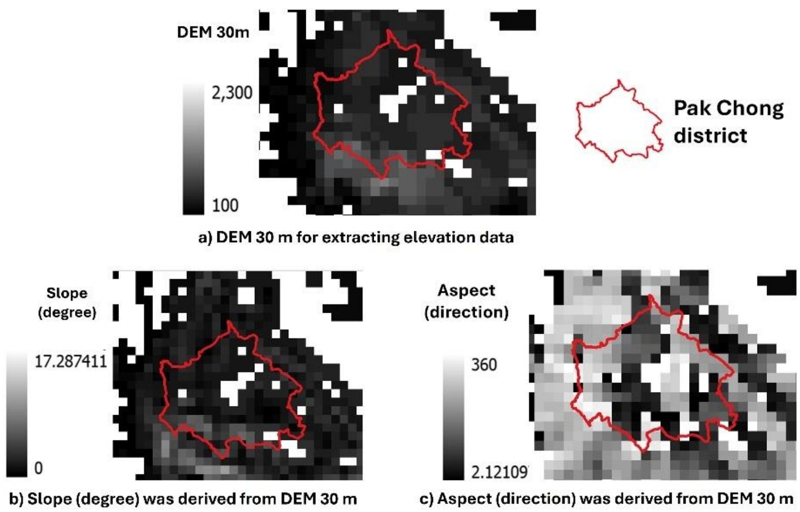


Figure 5. Three topographical layers (DEM 30m, slope, and aspect) for this study

2.2.4 The modified soil data

Some areas where soil data were classified as slope complex in the study area. Therefore, the modified soil data in this study was produced by overlaying between a layer of soil data from LDD and a layer of geological data from DMR. Here, soil data were analyzed using the characteristics of geological formation to classify subtypes of modified soil data, as shown in Figure 6.

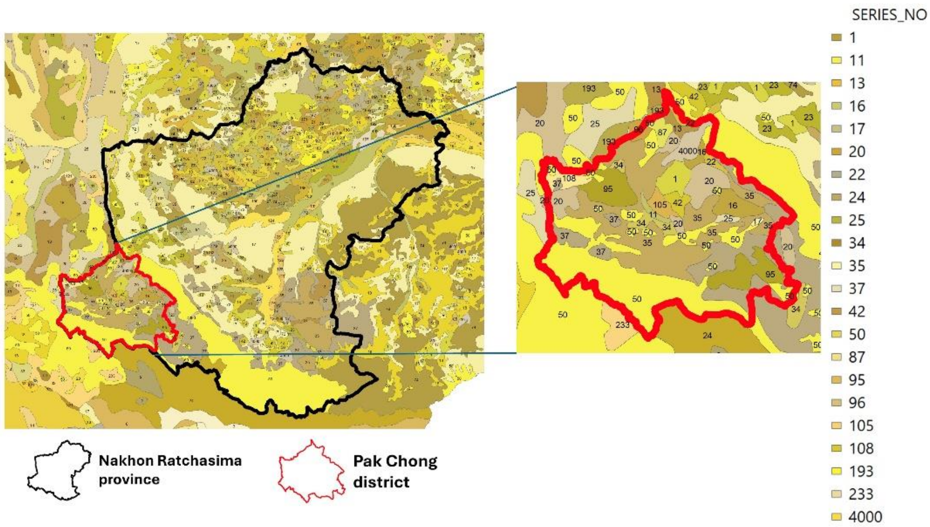


Figure 6. The modified soil data for this study

2.3 ENM and HS

In this step, we produced many ENMs-based ENFA to identify a group of niche factors for potential areas of vetiver grass planting, which were then generated as various HSs. These processes were operated in Biomapper 4.0, developed by Hirzel and colleagues [11].

In this study, all prepared data in 3.2 were converted into raster data. For ENM, raster data input ENM included 70 vetiver points' layers, 19 bioclimatic (variables) layers, 3 topographic layers (DEM, slope, and aspect), and the modified soil data. In the process, ENFA was used to produce the HS index, providing an understanding of spatial dispersion ability and tolerance of vetiver grass ecology to the current environment. ENM and validation included steps as follows:

1. Checking discrepancies: The datasets were transformed into raster format with 30 x 30 m. resolution and checked for discrepancies (they were simultaneously overlaid to verify discrepancies (same area, same spatial unit, and cell value).

2. Producing ENM: The raster-based GIS of 4-dataset was computed (in each cell) by marginality coefficient (it measured how vetiver grasses disperse with the mean environmental conditions of the study area) and specialization coefficient (it measured how vetiver grasses tolerate environmental variations of the study area). The equation of ENM production from Hirzel and colleagues [11] can be modified for this study as follows:

Marginality coefficient (m_i):

$$m_i = \frac{|m_G \mp m_s|}{1.96\sigma_G} \quad (1)$$

Where m_G is mean of overview spatial dispersion ability in the study area

m_s is mean of vetiver grass distribution

σ_G is a variation of overview spatial dispersion ability in the study area

Specialization coefficient (s_i):

$$s_i = \frac{\sigma_G}{\sigma_S} \quad (2)$$

Where σ_G is the standard deviation of overview spatial dispersion ability in the study area

σ_S is the standard deviation of the focal vetiver grass distribution

3. Computing HS: The median algorithm was used to compare the distribution of physical factors based on total marginality and specialization with a distribution of vetiver grass in the study area. The niche value varies between 0 and 100 or 0 and 1, from unsuitable to optimal niche. The equation of HS computation from Hirzel and colleagues [11] can be modified for this study as follows:

$$H(c) = \frac{1}{\sum w_i} \sum_{f=1}^{N_f} W_f \, Hm(f,c) \tag{3}$$

Where *H(c)* is the total niche index for vetiver grass distribution in the study area
Hm(f,c) is a partial niche for each factor (*f*)
W_f is automatically weighted for each factor (*f*)

2.4 Validating HSs

The testing dataset (30 vetiver points or 30 percent) was used for HS validation. Two evaluators in Biomapper were the Absolute Validation Index (AVI) and the Contrast Validation Index (CVI). The AVI checked the accuracy between the assessed and actual values, which was determined by varying from 0 to 1. The CVI is the AVI minus wrongly assessed value. If AVI and CVI values are preferred by 1, HS will be a better HS.

3. Results and Discussion

3.1 Identifying niche factors for the potential area of vetiver grass planting-based analysis of ENM and HS

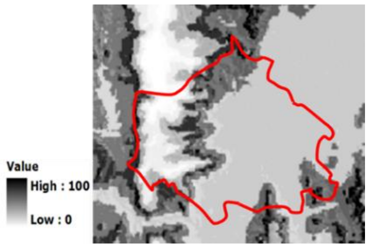
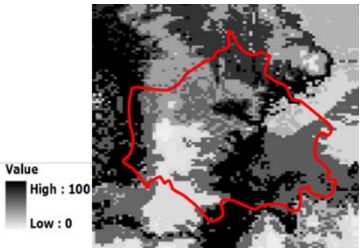
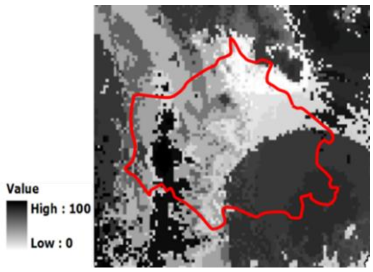
In niche factors' identification for planting vetiver grass, HS indices were produced by ENM in Biomapper, then analyzed to determine relationships between the studied environmental variables and find combinations of niche factors to produce the best HS index of vetiver grass. In this study, ENM in Biomapper, also called, 'ENFA' was explained by marginality and specialization coefficients of the studied environmental variables for vetiver grass, was computed and combined to generate a global HS-based median algorithm with the HS index varied from 0 to 100 as shown in Table 3.

The first niche model (ENM1) included 4 niche factors: BIO14, BIO15, BIO2 and BIO7. The proportion of explainable information preferred 92% of marginality, indicating that the distribution of HS for vetiver grass in the study area was greater than the species variation. Moreover, BIO14 and BIO15 were more statistically significant than BIO2 and BIO7 in ENM because they had a high coefficient of marginality.

The second niche model (ENM2) included 4 niche factors: BIO1, BIO5, BIO6 and elevation. The proportion of explainable information preferred 97% of marginality, indicating that the distribution of HS for vetiver grass in the study area was greater than the species variation. Moreover, BIO1 and BIO5 were more statistically significant than BIO6 and elevation in ENM because they had a high coefficient of marginality.

The third niche model (ENM3) included 3 niche factors: BIO4, BIO12 and BIO13. The proportion of explainable information preferred 79% of marginality, indicating that the distribution of HS for vetiver grass in the study area was more significant than the species variation. Moreover, BIO4 was more statistically significant than BIO12 and BIO13 in ENM because BIO4 had a high coefficient of marginality.

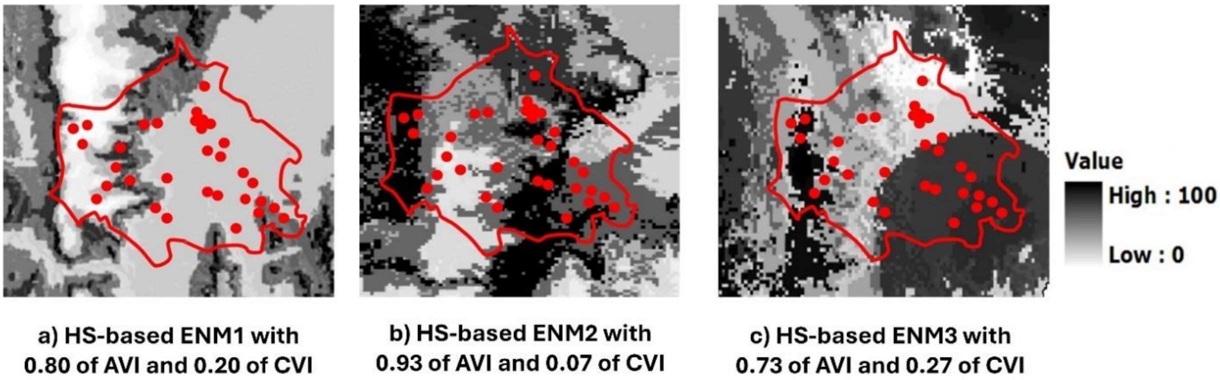
Table 3. Identifying niche factors and HS for planting vetiver grass

ENMs	Niche factors	Marg.	Spec. 1	Spec. 2	Spec. 3	HS for planting vetiver grass
1. ENM1	BIO14 (mm)	0.718	0.244	-0.379	0.643	
	BIO15 (SD)	0.620	-0.362	0.708	-0.748	
	BIO2 (°C)	0.243	0.690	-0.582	0.111	
	BIO7 (°C)	-0.204	0.577	0.124	0.123	
	Overall	0.085	6.475	0	0	
	percent of explanation	92	6	1	1	
HS1 (ENM1) = [1/(0.725+0.268+0.007+0.001)] x [0.725H(marg.,c) + 0.268H(spec.1,c) + 0.007H(spec.2,c) + 0.001H(spec.3,c)						
2. ENM2	BIO1 (°C)	-0.667	0.378	0	0	
	BIO5 (°C)	0.561	0.639	0	0	
	BIO6 (°C)	0.327	-0.617		0	
	Elevation (m)	0.364	0.263		0	
	Overall	0.187	13.277	0	0	
	percent of explanation	97	3	0	0	
HS2 (ENM2) = [1/(1.968+0.027)] x [1.968H(marg.,c) + 0.027H(spec.1,c)						
3. ENM3	BIO4	1.000	-0.050	-0.080	0	
	BIO12	0.000	-0.830	-0.460	0	
	BIO13	0.090	0.560	0.890	0	
	Overall	0.132	3.437	0	0	
	percent of explanation	79	17	4	0	
HS3 (ENM3) = [1/(1.787+0.169+0.444)] x [1.787H(marg.,c) + 0.169H(spec.1,c) + 0.444H(spec.2,c)						

Remark: - BIO1: mean annually temperature (°C); BIO2: mean monthly temperature range (°C); BIO4: mean annually temperature seasonality (SD); BIO5: mean monthly maximum temperature (°C); BIO6: mean monthly minimum temperature (°C); BIO7: mean annually temperature range (°C); BIO12: mean annually precipitation (mm); BIO13: mean monthly maximum precipitation (mm); BIO14: mean monthly minimum precipitation (mm); BIO15: mean annually precipitation seasonality (SD); Elevation (m);
- Marg. = Marginality and Spec. = specialization
- Positive and negative signs of marginality and specialization coefficient indicate each ecological model prefers higher or lower than the global distribution in each variable of the environment.
- SD is the standard deviation

3.2 Validating HS

This study used AVI and CVI in Biomapper to validate the HS of vetiver grass-based ENM. AVI provided an overall assessment of HS, and CVI defined the difference between AVI and CVI. Thus, all derived HS-index-based ENM was validated by AVI and CVI based on the prepared testing dataset of vetiver grass locations (30 points), as shown in Figure 7. The distribution of the testing dataset evaluated the 3-obtained HS of vetiver grass, which were here computed by AVI and CVI (if the testing dataset was randomly fallen in value of HS index equal to or higher than 70, was recommended as the suitable HS for planting vetiver grass) and then were validated to identify the best HS for the potential area of vetiver grass planting.



Remark: if the testing dataset randomly fell in value of HS index equal to or higher than 70, it was recommended as the suitable HS for planting vetiver grass.

Figure 7. HS Validation-based AVI and CVI

Figure 7 shows that HS-based ENM2 has the highest possibility for the best HS for planting vetiver grass in this study, with AVI 0.93 and CVI 0.07. The ENM2 included 97% marginality (the ability for spatial distribution in the study area) and 3% specialization (durability in the study area). Moreover, this ENM2 explicitly indicates the existing vetiver grasses have more highly spatial distribution than durability in the study area with niche factors such as BIO1: the mean annual temperature (25-31°C), BIO5: mean monthly maximum temperature (30-38°C), BIO6: mean monthly minimum temperature (17-27°C) and elevation (600-1,300 m), respectively. These niche factors are related to the research of Grimshaw and Faiz [26] and Truong and colleagues [27], who mentioned that the ecology of vetiver grass can tolerate drought or high temperatures.

4. Conclusions

This study identified niche factors for planting vetiver grass to implement in soil and water conservation areas in Pak Chong district, Thailand. Therefore, the HS-based ENM2 has the highest possibility of being the best HS for planting vetiver grass in the study area. This HS was derived by using 4 niche factors: BIO1 (25-31°C), BIO5 (30-38°C), BIO6 (17-27°C) and elevation (600-1,300 m). In the best HS of vetiver grass, the proportion of explainable information preferred marginality coefficients that revealed the distribution of HS for vetiver grass in the study area was more significant than the species variation. Moreover, BIO1 and BIO5 were more statistically significant than BIO6 and elevation in ENM because they had a high coefficient of marginality. The obtained niche factor (e.g., BIO1, BIO5, BIO6, and elevation) will be implemented to map potential areas of vetiver grass in the Center for Promoting the Utilization of Vetiver Grass under the Royal Initiative Project (CPUVGRIP) of Forest Royal Department (FRD) in Nakhon Ratchasima, Thailand further.

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