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Short communication

Land suitability classifications in response to ecological requirements of *Panax notoginseng* in Vietnam

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Panax notoginseng (Burk.) F. H. Chen, commonly known as Sanqi in China and Tam Thất bắc in Vietnam, is a perennial herb from the *Araliaceae* family and *Panax* genus. *Panax notoginseng* is cultivated in cool, rainy hillside environments with deciduous trees (Liu *et al.*, 2025). In China, *Panax notoginseng* is primarily cultivated in mid to high-altitude regions ranging from 1200 to 2200 meters above sea level, around 23.5°N latitude and 104°E longitude (Liu *et al.*, 2025). In Vietnam, *Panax notoginseng* cultivations are mainly distributed in the northern highlands, including Cao Bang, Tuyen Quang, Ha Giang, and Lao Cai (Tran *et al.*, 2024). However, this region has a wide range of geological, topographical, and climatic features coupled with significant variations in altitude (Tan *et al.*, 2023; Nguyen *et al.*, 2024).

The analysis of suitability classification are useful to planners for better management of natural resources as well as to concentrate on the specific area of interest (Lanie, 2018). Jamidi *et al.*, (2025) identified suitable locations within North Aceh Regency of Indonesia for the cultivation of oil palm plants using rainfall and temperature data of past period (2014-2023) and also for future periods (2026-2045) by employing projected climate data. Current studies on *Panax notoginseng* have primarily concentrated on its ecological parameters (Tan *et al.*, 2023), which include topography, climatic conditions, soil conditions (Shi *et al.*, 2021), water, and soluble organic fertilizer (Mu *et al.*, 2023), with little attention paid to distribution and suitability studies. In this study, the habitat distributions and quality of *Panax notoginseng* are combined to investigate the suitable cultivation conditions under different planting techniques and ecological conditions using GIS and MCDA approaches. This study aims to (1) investigate the suitable areas for *Panax notoginseng* growth and (2) examine the growth and

quality of *Panax notoginseng* under different suitable conditions in northern Vietnam.

The study was implemented in Lao Cai, Ha Giang, and Cao Bang provinces, which are geographically located in northern Vietnam and share international borders with China. They are characterized by the Hoang Lien Son mountain range, which includes Fansipan mountain, the highest peak in Indochina (Fig. 1). The region has a tropical monsoon climate, but conditions vary with altitude and location. In northern Vietnam's mountains, the coldest season is from January to March, with temperatures dropping below 0°C, causing frost and occasional snow at high elevations. The hottest period, from April to July, brings high temperatures and heavy rainfall, especially between May and October. This intense rain often leads to landslides and flash floods, disrupting transport and daily life in mountainous areas.

We used 23 years (2000–2022) of historical climate data of monthly maximum and minimum temperature, precipitation, humidity, wind speed, and sunshine hours from five weather stations across the study area, sourced from Vietnam's Meteorological Administration. Terrain data (elevation, slope, aspect) were derived from a 12.5m ASTER DEM, and five soil factors (pH, OM, CEC, texture, type) were obtained from provincial Agriculture Departments. To validate the climate data, on-site agrometeorological measurements (Lanie, 2018) near three *Panax notoginseng* experimental sites were used. Additionally, 90 soil samples were analyzed to verify the soil dataset.

Selection criteria

Based on ecological requirements (literature cited), 13

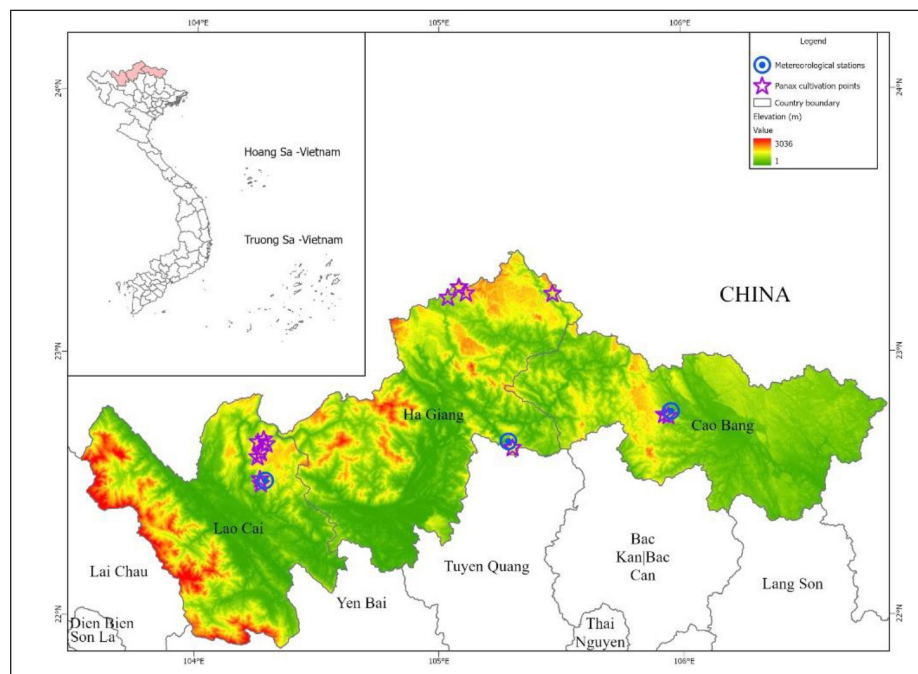
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Table 1: Suitability classification thresholds criteria and weights of criteria for *Panax notoginseng* cultivation

Criteria	Highly suitable	Moderately suitable	Not suitable	Relative weight of main group (0-1)	Relative weight of sub-criteria (0-1)
Climate					
Mean annual temperature (°C)	15 - 18	14 - 15, 18 - 20	>20, <15	0.545	0.333
Max temperature in hot seasons (°C)	22 - 24	24 - 25	>25		0.120
Min temperature in cold seasons (°C)	11 - 13	13 - 14	>14		0.120
Annual precipitation (mm)	1000 - 1400	1400 - 1500	>1500		0.333
Annual precipitation in hot seasons (mm)	600 - 750	750 - 900, 490 - 750	>900, <490		0.094
Terrain					
Elevation (m)	1200 - 1800	1000-1200, 1800 - 2000	>2000, <1000	0.273	0.648
Slope (degree)	10 - 15	5 - 10, 15 - 20	>20, <5		0.230
Aspect	67.5 – 112.5, 157.5 - 292.5	112.5 - 157.5, 292.5 - 337.5	0 - 67.5, 337.5 – 360		0.122
Soil properties					
PH	≥ 4.0 - <6.0	≥ 6.0 - ≤ 7.0	< 4.0 or > 7.0	0.182	0.545
OM	< 2.0	≥ 2.0 - < 4.0	≥ 4.0		0.273
CEC	< 10	≥ 10 - < 25	≥ 25		0.182
Soil type	Humic ferrasols	Plinthic Ferrasols			0.600
Soil texture	Medium silt soils	Light/heavy silt soils	Sandy soils		0.400

**Fig. 1:** Study area, locations of the experimental sites and related climatic weather stations (Lao Cai, Ha Giang, and Cao Bang provinces).

critical criteria for *Panax notoginseng*, growth were identified by experts and farmers. For Multi-Criteria Decision Analysis (MCDA), these criteria layers were standardized to a common 0-1 scale using linear min-max transformation to prevent scale bias. Subsequently, each standardized layer was classified into three suitability levels based on thresholds adjusted for local conditions, Table 1, generating 13 individual criterion suitability maps. The thresholding values for suitability classes are defined as numerical thresholds such as: 80-100 for S1 (Highly Suitable), 60-79 for S2 (Moderately Suitable), 40-59 for S3 (Suitable), 0-39 for N (Not suitable) based on the FAO framework. The Analytic Hierarchy Process (AHP) employs the

pairwise comparison method to evaluate the relative importance of the criteria. The weights for the main criteria and their respective sub-criteria, derived from pairwise comparisons based on expert opinions and provided by the user, are presented in Table 1.

Suitability classification

Panax notoginseng thrives in areas with high rainfall and low winter temperature variation, but high summer temperatures pose a challenge. In Lao Cai, annual rainfall ranges from 1,163 to 1,565 mm, peaking in June–August. Ha Giang and Cao Bang also meet the plant's rainfall needs (1,000–1,400 mm/year). To protect

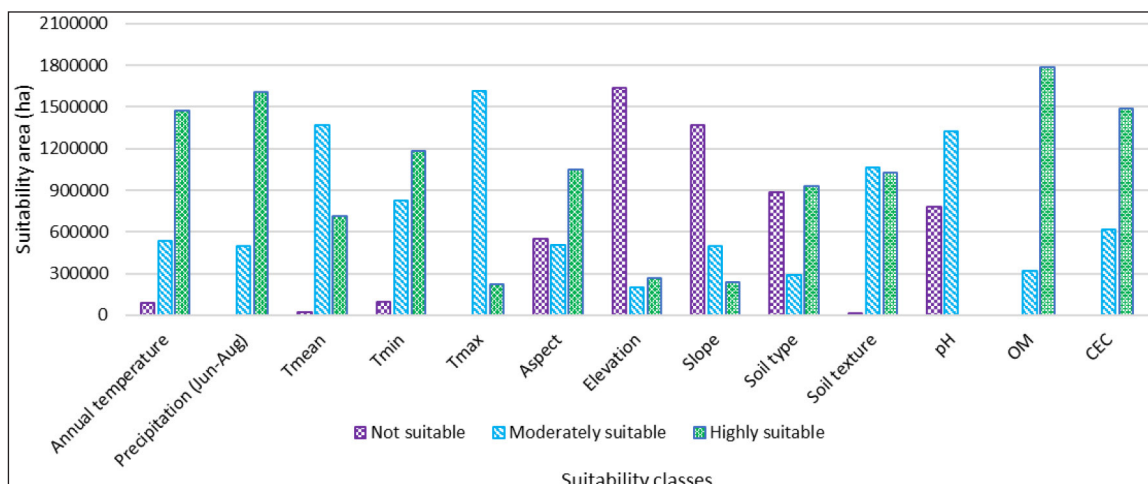


Fig. 2: Area under different suitability classes for *Panax notoginseng* in northern Vietnam.

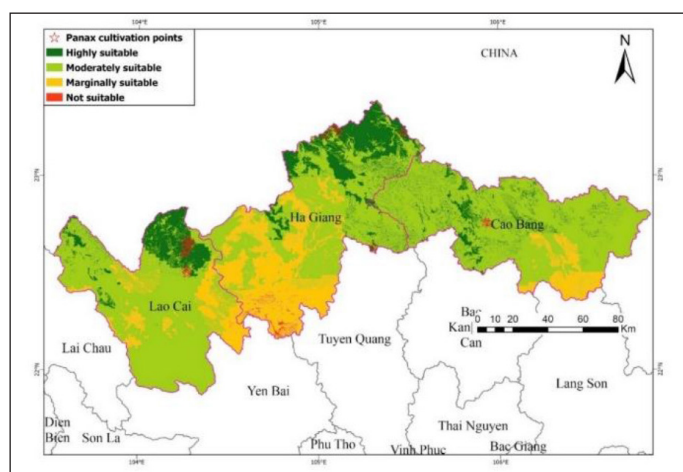


Fig. 3: Spatial distribution of land suitability and validation of suitability map for *Panax notoginseng* in the study area.

against summer heat, cultivation under shade nets is recommended. However, much of the region is unsuitable due to low elevation, steep slopes, and poor soil quality (low pH, OM, and CEC). While ferralsols are common, they are not ideal. More suitable soils include humic ferralsols and fluvisols, typically found in forests or near rivers. The area under different suitability classes for *Panax notoginseng* is presented in Fig. 2.

The analysis identifies 287,239 ha (13.65%) as Highly Suitable (S1) for *Panax notoginseng*, mainly in high mountainous areas of Lao Cai, Cao Bang, and Ha Giang, offering ideal conditions like stable temperatures and fertile soil. Moderately Suitable (S2) land covers 1,393,415 ha (66.24%), though issues like steep slopes and variable rainfall require improved management. Marginally Suitable (S3) areas span 416,797 ha (19.81%), facing challenges such as poor soil and rugged terrain, but can be improved with technical interventions. Only 6,212 ha (0.30%) are Not Suitable (S4) due to extreme conditions, where alternative land uses are recommended (Fig. 2).

The locations of *Panax notoginseng* plantation farms were documented through extensive field surveys conducted in the study area. These surveys involved on-site inspections, GPS data

collection, and interviews with local farmers to verify the accuracy of the recorded locations. Fig. 3 presents a visualization of these farm locations alongside the suitability map.

The suitability map aligns well with existing farm locations, as the majority of *Panax notoginseng* plantations fall within highly suitable (S1) zones, which validates the model. A notable exception is a farm in Bac Ha District, Lao Cai Province, situated outside the S1 area, possibly explained by unique microclimates, soil variations, or human interventions overcoming natural limitations. The strong alignment between farm locations and the suitability map confirms the model's reliability in identifying optimal planting areas for *Panax notoginseng*. The high validation accuracy supports its use in future land-use planning. This study outlines a detailed methodology using GIS and Multi-Criteria Decision Analysis (MCDA), including AHP for weighting criteria. It recommends cultivation in high-altitude areas above 1,200 meters in northern Vietnam—particularly Lao Cai, Ha Giang, and Cao Bang—where cool, humid climates prevail. The suitability map, created through GIS overlay analysis, shows that over 80% of the region meets the environmental requirements for *Panax notoginseng* cultivation.

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