THAI NGUYEN UNIVERSITY
UNIVERSITY OF AGRICULTURE AND FORESTRY
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DO VAN HAI

ASSESSMENT OF THE QUALITY AND POTENTIAL OF AGRICULTURAL LAND FOR MEDICINAL PLANT CULTIVATION IN LAO CAI PROVINCE

Industry: Land Management

Code: 9.85. 01.03

SUMMARY OF DOCTORAL THESIS ON LAND MANAGEMENT

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LIST OF PUBLISHED WORKS RELATED TO THE THESIS

1. **Do Van Hai**, Hoang Van Hung, Dam Thi Hanh (2024), *Application of GIS and AHP in Evaluating Land Suitability for Platycodon Grandiflorus Cultivation in Lao Cai Province*, Vietnam Journal of Agricultural Sciences (VJAS), 2024, Vol. 22(10): 1323–1336.

2. **Do Van Hai**, Hoang Van Hung, Dam Thi Hanh (2024), *Assessment and selection of potential medicinal plants in Lao Cai province: a multi-criteria analysis*, Vietnam Journal of Agriculture and Rural Development, October 2024, pp. 13–22.

3. **Do Van Hai**, Hoang Van Hung, Dam Thi Hanh (2024), *Application of GIS Technology to Develop Land Unit Maps for Land Evaluation of Medicinal Plants in Lao Cai Province*, TNU Journal of Science and Technology, Vol. 230(13): 480–488.

4. **Do Van Hai**, Hoang Van Hung, Dam Thi Hanh (2023), *Application of AHP and GIS Methods in Evaluating Agricultural Land Suitability for Medicinal Plants in Bat Xat District, Lao Cai Province*, Proceedings of the 2nd National Scientific Conference for Young Scientists of National and Regional Universities, 2023, pp. 16–23.

5. **Do Van Hai** (2020), *Study on Land Suitability Classification for Panax notoginseng (Tam that) Cultivation in Lao Cai Province*, TNU Journal of Science and Technology, Vol. 225(08): 428–435.

SUPERVISION OF UNDERGRADUATE THESES

- Graduation thesis: *Evaluation of Land Use Efficiency for Medicinal Plant Cultivation Towards Sustainable Agricultural Production in Bat Xat District, Lao Cai Province* – Student: Vu Quoc Dai, successfully defended in 2023.

- Graduation thesis: *Application of GIS and Multi-Criteria Analysis for Agricultural Land Suitability Assessment for Panax notoginseng in Bac Ha and Si Ma Cai Districts, Lao Cai Province* – Student: Lu Thi Anh, successfully defended in 2024.

- Graduation thesis: *Application of Multi-Criteria Analysis for Land Suitability Assessment for Shan Tuyet Tea Cultivation in*

Bac Ha District – Student: Cu Seo Senh, successfully defended in 2024.

INTRODUCTION

1. Urgency of the topic

Land is a highly valuable national resource. It serves as a unique means of production, a vital component of the living environment, and the foundation for residential settlements as well as the construction of economic, cultural, social, and defense infrastructures (Land Law, 2013). In agricultural and forestry production, land is an essential, irreplaceable asset (Nguyen The Dang et al., 2014). However, due to population growth, rapid urbanization, and land-use conversion, agricultural land is under increasing pressure. Therefore, it is necessary to use agricultural land rationally and sustainably, ensuring stable crop productivity, job creation, and improved income for rural laborers (Nguyen Ngoc Nong et al., 2020). Sustainable land management and use have thus become a national and regional strategy aimed at protecting and developing agricultural land resources.

Vietnam, located in a humid tropical monsoon climate zone, possesses a rich and diverse flora, which is highly favorable for the cultivation of various crops, including medicinal plants. According to the Department of Crop Production – Ministry of Agriculture and Rural Development, by the end of 2021, Vietnam had about 5,117 species and subspecies used as medicinal plants, belonging to 1,823 genera and 360 families of vascular plants, along with several taxa of mosses, algae, and large fungi (MARD, 2021). In Vietnam, the annual demand for medicinal materials is approximately 80,000 tons. However, domestic cultivation and harvesting currently only meet 20–25% of this demand, with the rest being imported (Tran Huu Phuoc, 2019). Each year, around 20,000 tons of medicinal materials are imported from China, with an import value of approximately 16–17 million USD (Ministry of Health, 2017).

Given its abundant medicinal plant resources and favorable soil and climatic conditions for medicinal plant cultivation, Lao Cai Province has issued several policies, including resolutions, decisions, and development plans, to promote the sustainable development of the medicinal plant sector (Government, 2013; Lao Cai Provincial People's Committee, 2021). Lao Cai has been identified as a pioneering province in planning and establishing medicinal plant

cultivation zones (Department of Agriculture and Rural Development, 2023).

Lao Cai is a mountainous border province located between the Northeast and Northwest regions of Vietnam, bordering four provinces: Ha Giang to the east, Yen Bai to the south, Lai Chau to the west, and Yunnan Province (China) to the north. The province has a total natural land area of 636,425 ha, of which agricultural land accounts for 551,690 ha, representing nearly 87% of the total (Ministry of Natural Resources and Environment, 2023). Additionally, Lao Cai's land is fertile and diverse, comprising 10 soil groups with 30 main soil types. The fragmented mountainous terrain creates mid- and high-elevation zones with a subtropical climate, offering advantages for developing medicinal plant cultivation. According to the Vietnam Institute of Medicinal Materials, Lao Cai has approximately 850 medicinal plant species out of the total medicinal flora, many of which are rare and of high pharmaceutical value (Ministry of Health, 2016).

However, due to the uneven topography and fragmented climatic sub-regions, combined with small-scale and scattered land use and a lack of centralized planning, the agricultural land potential of the province has not been fully utilized. Therefore, assessing agricultural land quality is a crucial scientific and practical foundation for guiding the rational use of land for medicinal plant cultivation, ensuring crop stability and increasing farmers' income. The research outcomes will provide significant value for policymakers in selecting and investing in the development of medicinal plant cultivation in Lao Cai Province.

From this practical need, the topic "Assessment of the Quality and Potential of Agricultural Land for Medicinal Plant Cultivation in Lào Cai Province" is both scientifically grounded and practically meaningful.

2. Topic objectives

- To assess the current status of agricultural land use and identify potential medicinal plant species;
- To evaluate the quality of agricultural land and develop Land Mapping Units (LMUs) for medicinal plant cultivation;
- To assess the potential of agricultural land for medicinal plant cultivation;

- To propose land-use solutions for medicinal plant cultivation in Lao Cai Province..

3. Scientific and practical significance

3.1. Scientific significance

+ Contributes to the improvement of multi-criteria land evaluation methods in support of land-use planning for medicinal plant cultivation, particularly in northern mountainous provinces;

+ Provides criteria and scientific foundations for determining land suitability levels for specific medicinal plant species, serving as a basis for future research on sustainable agricultural land use.

3.2. Practical significance

+ Provides scientific basis for selecting and allocating agricultural land for medicinal plants to enhance production value and increase farmers' income in the province;

+ Proposes land-use solutions for selected medicinal plants in the direction of sustainable development in Lao Cai Province and serves as reference material for other regions with similar conditions.

4. New contributions of the Thesis

+ Identified and selected four key medicinal plant species (Platycodon grandiflorus, Angelica sinensis, Cynara scolymus, and Ligusticum wallichii) based on evaluations of economic, social, and environmental effectiveness;

+ Assessed the quality and potential of agricultural land for medicinal plant cultivation in Lao Cai Province;

+ Applied GIS to create eight thematic maps (including soil type, soil depth, soil texture, soil pH, total organic carbon, elevation, slope, and rainfall) and constructed a land mapping unit (LMU) map as a scientific basis for land suitability evaluation;

+ Applied the AHP method to determine the weights of eight natural factors, integrated them into GIS, and generated detailed land suitability classification maps for the four selected medicinal plant species..

Chapter 1:
DOCUMENT OVERVIEW

1.1. Theoretical Basis for Assessing Agricultural Land Quality and Potential for Medicinal Plant Cultivation

The theoretical foundation for land evaluation, land use,

medicinal plant cultivation, and sustainable development has been clarified, including definitions of land, land use types, and land mapping units, as well as principles and criteria for sustainable land use. The research identifies groups of factors influencing the development of medicinal plants and specifies economic, social, and environmental indicators in evaluating the effectiveness of medicinal plant cultivation.

1.2. Practical Basis for Assessing Agricultural Land Quality and Potential, and the Current Status of Medicinal Plant Development in the World and in Vietnam

There are various land evaluation systems worldwide, but the FAO land evaluation framework remains conceptually sound and provides internationally recognized guidelines. The current trend is to develop modern land evaluation methods to optimize land use efficiency. However, each method has its own advantages and limitations depending on technical expertise, data availability, and the specific crop being evaluated. In Vietnam, modern land evaluation methods have recently been combined with local knowledge to improve evaluation outcomes. Based on a review of global and national practices, and considering the specific conditions in Lao Cai Province and medicinal plant requirements, this study adopts the Analytic Hierarchy Process (AHP) integrated with GIS as an effective and appropriate approach for evaluating agricultural land potential for medicinal plant cultivation in Lao Cai.

1.3. Studies on Agricultural Land Potential for Medicinal Plant Cultivation

1.3.1. International Studies

Land suitability evaluation for medicinal plants has been of interest to scientists and organizations worldwide for many years, using diverse methods. This reflects the critical role of land evaluation in the sustainable development of the medicinal plant sector. However, no single land evaluation method is universally applicable, and most studies tend to focus on natural factors while neglecting economic, infrastructure, social, and environmental aspects. This creates a gap in achieving holistic and sustainable land use goals. Therefore, in this study, prior to assessing land suitability for specific medicinal plants, the author considers economic, social, and environmental criteria to evaluate the effectiveness of land use

for medicinal plant cultivation.

1.3.2. Domestic Studies

In recent years, particularly following national policy directions for medicinal plant development, many Vietnamese studies have focused on assessing resource status, analyzing potential and advantages, identifying growth-influencing factors, and proposing development solutions and technical cultivation processes. However, in-depth studies on land suitability for medicinal plants remain limited. This gap provides a foundation and necessity for this dissertation to conduct a comprehensive and updated land suitability assessment for medicinal plants.

1.3.3. Studies on Medicinal Plant Development in Lao Cai Province

Studies in Lao Cai primarily focus on assessing the province's potential and advantages in developing medicinal plants, including zoning, conservation, production, and economic efficiency. However, land suitability evaluations are still limited, presenting an opportunity and research gap for the dissertation to address.

1.4. General Evaluation and Research Orientation

The theoretical and practical review shows that land evaluation is a crucial tool for the sustainable development of medicinal plants. While the FAO framework is widely adopted globally, many studies fail to incorporate economic, social, and environmental factors. In Vietnam, land suitability research for medicinal plants is still scarce, especially in Lao Cai—a province with approximately 1,000 medicinal plant species but currently focusing on only 7 core species.

Based on practical conditions and research gaps, the dissertation is oriented toward:

Selecting potential medicinal plant species based on evaluations of economic, social, and environmental effectiveness and the province's development plans;

Assessing land suitability using the integrated AHP and GIS method, combined with the FAO evaluation framework to identify suitable cultivation zones for medicinal plants.

The research process includes four main steps:

Identification of potential medicinal plant species;

Classification and assignment of weights to land evaluation criteria;

Calculation of land suitability indices using GIS;

Classification and development of land-use orientation maps for medicinal plant cultivation in Lao Cai Province.

Chapter 2
OBJECTS, CONTENT AND METHODS OF RESEARCH

2.1. Research Objects and Scope

2.1.1. Research Objects

- Soil quality in agricultural land in Lao Cai province;
- Land use types (LUT) for medicinal plant cultivation;

2.1.2. Research Scope

- Spatial scope: The research is carried out in Lao Cai province, focusing on two ecological sub-regions that are developing medicinal plant cultivation.
- Temporal scope: The study is conducted from 2020 to 2024.

2.2. Research Content

- Assessment of the natural and socio-economic conditions of the study area
- Current status of agricultural land use and potential medicinal plants
- Evaluation of agricultural land quality and development of land unit maps
- Assessment of the agricultural land potential for medicinal plant cultivation
- Solutions for land use in medicinal plant cultivation in Lao Cai province

2.3. Research Methods

2.3.1. Research Site Selection

Select 4 representative districts from 2 key ecological sub-regions in Lao Cai (Sa Pa, Bat Xat, Bac Ha, Si Ma Cai) based on climate, terrain characteristics, and the province's medicinal plant development policies.

2.3.2. Data Collection Methods

Secondary data: Collected from specialized agencies, thematic maps, and both domestic and international research documents.

Primary data: Interviews with 120 households cultivating medicinal plants in 4 districts and consultations with 30 experts (soil science, agronomy, agricultural extension staff).

2.3.3. Economic, Social, and Environmental Impact Assessment

Use Circular 60/2015/TT-BTNMT to evaluate three impact groups:

Economic: Value added (VA), investment efficiency (HQĐT).

Social: Labor, acceptance, planning, consumption.

Environmental: Land cover, GACP-WHO certification.

Each group is divided into three levels: High – Medium – Low.

2.3.4. SWOT Analysis Method

Analyze the strengths, weaknesses, opportunities, and threats of 7 medicinal plants, to select the most promising species.

2.3.5. Additional Survey Methods, Land Map Revision, and Thematic Map Construction

Land map revision: Collect field soil samples, analyze soil physical and chemical properties (11 indicators), and revise soil maps based on real-world observations and existing documents.

Construction of thematic maps and land units: Use GIS software (ArcGIS 10.8) to create 8 single-criterion maps (land type, slope, pH, rainfall, etc.), which are then overlaid to form the land unit map.

2.3.6. Land Suitability Assessment Methods

AHP (Analytic Hierarchy Process): Determine the weight (Wi) of criteria based on expert opinions.

Scoring (Xi): Based on the suitability of each criterion for plant cultivation.

Calculating land suitability index (Si): Calculate $Si = \sum(Wi \times Xi)$ and classify into 5 suitability levels (S1, S2, S3, N).

GIS: Integrate the indices to create a suitability map for medicinal plant cultivation.

Chapter 3
RESEARCH RESULTS AND DISCUSSION

3.1. Assessment of Natural, Economic, and Social Conditions in the Study Area

3.1.1. Natural Conditions

Lao Cai is a mountainous border province located between the Northeast and Northwest regions of Vietnam. It borders four provinces and cities: to the east is Ha Giang, to the south is Yen Bai, to the west is Lai Chau, and to the north is Yunnan Province (China), with a borderline of 182.086 km. Lao Cai lies between 21°48’ and 22°50' North latitude and between 102°32’ and 104°38' East longitude. The total natural area is 6,364.03 km², accounting for 1.9% of the national area, ranking 18th out of 63 provinces in terms

of size..

3.1.2. Economic Conditions

3.1.3. Social Conditions

3.1.4. General Assessment of Natural and Socio-economic Conditions Affecting Lao Cai's Development

3.1.4.1. Advantages

Lao Cai holds a strategic geographical position along the Kunming – Lao Cai – Hai Phong economic corridor, favorable for trade and logistics development. Its diverse terrain and climate support the growth of specialty medicinal plants and ecotourism. The province is rich in land and water resources, with an abundant labor force and vibrant ethnic culture, making it ideal for agricultural development, especially medicinal plant cultivation.

3.1.4.2. Challenges

The strongly dissected terrain hinders infrastructure development and agricultural production. Seasonal harsh weather affects farming. Transport infrastructure, particularly in highland areas, remains underdeveloped. Average income is low, and poverty rates remain high in several areas.

Despite its great potential for medicinal plant development, Lao Cai must overcome challenges through infrastructure investment, technology application, and sustainable agricultural development.

3.2. Current Status of Agricultural Land Use and Potential Medicinal Plants

3.2.1. Land Use Status and Changes in the Period 2015–2022

3.2.1.1. Current Status of Agricultural Land Used for Medicinal Plants in Lao Cai Province

As of the end of 2022, Lao Cai Province had 3,550 hectares of land used for cultivating medicinal plants, accounting for 2.67% of the province's total agricultural land. These plantations were primarily concentrated in six districts and towns: Sa Pa, Bat Xat, Bac Ha, Si Ma Cai, Muong Khuong, and Van Ban. Perennial medicinal plants (mainly Amomum longiligulare) accounted for 83.86% of the total area, while annual medicinal plants (such as Cynara scolymus, Platycodon grandiflorus, Ligusticum wallichii, Paris polyphylla, etc.) made up 16.14%.

The distribution of medicinal plants varies significantly across localities, depending on natural conditions, ecological characteristics,

and especially market demand, plant varieties, and yield potential. Some species such as Cynara scolymus and Paris polyphylla are only found in Sa Pa; Ligusticum wallichii is mainly grown in Bat Xat; Platycodon grandiflorus is common in Bac Ha and Si Ma Cai; while low-input crops such as lemongrass (Cymbopogon spp.), ginger (Zingiber officinale), and turmeric (Curcuma longa) are cultivated sporadically across the province.

3.2.1.2. Agricultural Land Use Changes in Lao Cai Province (2018–2022)

Between 2018 and 2022, the area of land used for growing medicinal plants in Lao Cai Province increased significantly from 1,579 hectares (in 2018) to 3,550 hectares (in 2022). Perennial medicinal plants (mainly Amomum longiligulare) accounted for the majority and showed steady growth. In contrast, the area of annual medicinal plants fluctuated, peaking in 2019 before declining due to the impacts of the COVID-19 pandemic and unstable market demand.

Key crop trends include:

Amomum longiligulare expanded continuously and became dominant;

Angelica sinensis, Panax notoginseng, Illicium verum, and Coix lacryma-jobi significantly declined or were phased out due to market challenges;

Cynara scolymus and Ligusticum wallichii maintained stable cultivation areas;

Platycodon grandiflorus and Paris polyphylla began to be cultivated and showed an increasing trend.

Table 3.9: Changes in the Area of Major Medicinal Plants in Lao Cai Province (2018–2022)

Unit: ha

No.	Medicinal Plant	2018	2019	2020	2021	2022
I	**Annual Plants**	**402.3**	**1,063.0**	**1,041.1**	**642.0**	**573.0**
1	Cynara scolymus	80.0	90.0	74.0	50.0	51.0
2	Angelica sinensis	105.5	148.0	85.6	67.0	7.0
3	Ligusticum wallichii	146.7	137.0	144.0	139.0	95.6
4	Coix lacryma-jobi	20.0	22.0	11.0	–	–
5	Platycodon grandiflorus	0.0	25.0	23.0	94.0	98.0
6	Paris polyphylla	0.0	11.0	81.0	48.0	48.0
7	Other medicinal plants	50.1	630.0	622.5	244.0	273.4

II	**Perennial Plants**	**1,176.7**	**1,201.0**	**2,663.1**	**2,942.4**	**2,977.0**
8	Illicium verum	37.6	40.0	40.0	–	–
9	Panax notoginseng	3.0	20.0	11.9	1.4	–
10	Amomum longiligulare	1,018.4	1,050.0	2,179.2	2,591.0	2,630.0
11	Ampelopsis cantoniensis	46.0	61.0	190.0	156.0	156.0
12	Other medicinal plants	71.7	30.0	242.0	194.0	191.0
Total		**1,579.0**	**2,264.0**	**3,704.2**	**3,584.4**	**3,550.0**

(Source: Report on medicinal plants by the Department of Agriculture and Rural Development 2018 - 2022)

3.2.2. Assessment of the Economic, Social, and Environmental Effectiveness of Some Medicinal Plants

In the period from 2018 to 2022, Lao Cai Province cultivated 8 types of medicinal plants listed in the Ministry of Health's 100 priority plants for development, with the provincial medicinal plant development project (2021–2025, orientation to 2030) identifying 6 key plants. Based on practical experience and policies, the dissertation identifies 10 main medicinal plants, including: Cynara scolymus, Angelica sinensis, Ligusticum chuanxiong, Coix lacryma-jobi, Platycodon grandiflorus, Houttuynia cordata, Illicium verum, Panax notoginseng, Amomum longiligulare, Ampelopsis cantoniensis.

However, the areas of these plants fluctuate significantly due to various factors (market, seeds, diseases, etc.), so to select potential medicinal plants, the dissertation proceeds to assess the economic, social, and environmental effectiveness of 7 types of medicinal plants that are widely cultivated in the research area.

3.2.3.1. Economic Effectiveness

Based on the household survey forms, the author has compiled the economic effectiveness of 7 types of medicinal plants in Lao Cai Province, as shown in the table below:

Table 3.10: Economic Effectiveness of Main Medicinal Plants in Lao Cai Province

No.	Medicinal Plant	Production Value (GO) (Million VND/ha)	Total Cost (IC) (Million VND/ha)	Added Value (VA)		Investment Efficiency (HQĐT)		General Evaluation
				Value (Million VND/ha)	Classification	Value (times)	Classification	
1	**Cynara scolymus**	160.0	95.0	65.0	VA3	1.7	HQDT2	H
2	**Angelica sinensis**	136.8	85.0	51.8	VA3	1.6	HQDT2	H
3	**Ligusticum wallichii**	129.6	58.0	71.6	VA3	2.2	HQDT3	H

4	**Platycodon grandiflorus**	123.2	43.0	80.2	VA3	2.9	HQDT3	H
5	**Paris polyphylla**	54.1	38.0	16.1	VA1	1.4	HQDT1	L
6	**Amomum longiligulare**	120.0	63.0	57.0	VA3	1.9	HQDT2	H
7	**Ampelopsis cantoniensis**	71.5	39.0	32.5	VA2	1.8	HQDT2	M

(Source: Compilation from household survey forms)

From the above analysis, it can be seen that Platycodon grandiflorus (Cát cánh) and Ligusticum wallichii (Xuyên khung) are the two medicinal plants with the best economic efficiency in Lào Cai due to their low production costs and high return on investment (ROI). Angelica sinensis (Đương quy), Cynara scolymus (Actiso), and Amomum longiligulare (Sa nhân tím) also show good economic efficiency with high production value and reasonable production costs. Meanwhile, Ampelopsis cantoniensis (Chè dây) shows average economic efficiency, and Paris polyphylla (Chùa dù) has lower economic efficiency.

3.2.3.2. Social Efficiency

Social efficiency is evaluated based on the following criteria: Labor demand fulfillment, land users' acceptance, alignment with economic-social development strategies and planning, and product consumption levels. After synthesizing the results of survey interviews and comparing them with the social efficiency evaluation table of medicinal plants in Lào Cai province (Table 2.3), the social efficiency results of the main medicinal plants in Lào Cai province are presented in Table 3.11 below:

Table 3.11: Social Efficiency of Main Medicinal Plants in Lào Cai Province

No.	Medicinal Plant	Labor input		Land user acceptance		Compatibility with socio-economic development strategy and planning		Product marketability		General Evaluation
		Value (labor-days)	Ranking	Value (%)	Ranking	Value (%)	Ranking	Value (%)	Ranking	
1	**Cynara scolymus**	200,0	LĐ2	80	CN3	91	PHCL3	98	TT3	H

No.	Medicinal Plant	Labor input		Land user acceptance		Compatibility with socio-economic development strategy and planning		Product marketability		General Evaluation
		Value (labor-days)	Ranking	Value (%)	Ranking	Value (%)	Ranking	Value (%)	Ranking	
2	Angelica sinensis	170,0	LĐ2	81	CN3	81	PHCL2	85	TT2	M
3	Ligusticum wallichii	220,0	LĐ3	80	CN3	83	PHCL2	86	TT2	H
4	Platycodon grandiflorus	228,0	LĐ3	91	CN3	95	PHCL3	96	TT3	H
5	Paris polyphylla	142,0	LĐ1	72	CN2	77	PHCL2	88	TT2	L
6	Amomum longiligulare	211,0	LĐ3	80	CN3	73	PHCL2	82	TT2	M
7	Ampelopsis cantoniensis	156,0	LĐ2	80	CN3	80	PHCL2	76	TT2	M

(Source: Synthesized from household survey questionnaires)

The summarized data on social effectiveness in Table 3.11 show that: Artichoke, Ligusticum wallichii, and Platycodon grandiflorus are all rated as having high social effectiveness (H). Angelica sinensis, Amomum longiligulare, and Ampelopsis cantoniensis are evaluated at a medium level (M). Meanwhile, Paris polyphylla has low social effectiveness (L) due to its limited ability to generate employment. Thus, 6 out of 7 medicinal plants assessed for social effectiveness have a positive impact on maintaining social stability.

3.2.3.3. Environmental Effectiveness

The environmental effectiveness of major medicinal plants in Lào Cai Province is assessed based on two criteria: (1) Increasing land cover capacity; and (2) Maintaining and protecting soil. The evaluation results are presented in Table 3.12 below:

The summary data on environmental effectiveness in Table 3.12 indicate that all seven medicinal plants studied in Lào Cai Province are ranked at medium (M) and high (H) environmental effectiveness levels. Notably, Angelica sinensis, Amomum longiligulare, and Ampelopsis cantoniensis are rated at medium effectiveness (M). Therefore, most of the medicinal plants studied in Lào Cai Province provide a safe level of environmental performance in land use.

Table 3.12: Environmental effectiveness of major medicinal plants in Làò Cai Province.

No	Medicinal Plant	Enhancing land cover capacity		Maintaining soil protection		General Evaluation
		Value (%)	Ranking	Value (%)	Ranking	
1	**Cynara scolymus**	81,0	TCP3	98	BVĐ3	H
2	**Angelica sinensis**	70,0	TCP2	71	BVĐ2	M
3	**Ligusticum wallichii**	56,0	TCP2	75	BVĐ3	H
4	**Platycodon grandiflorus**	55,0	TCP2	80	BVĐ3	H
5	**Paris polyphylla**	65,0	TCP2	83	BVĐ3	H
6	**Amomum longiligulare**	83,0	TCP3	0	BVĐ1	M
7	**Ampelopsis cantoniensis**	75,0	TCP2	72	BVĐ2	M

(Source: Synthesized from household survey questionnaires)

Summary of Economic, Social, and Environmental Effectiveness Evaluation Results

Based on the evaluation results, the author summarizes the overall assessment of the economic, social, and environmental effectiveness of seven major medicinal plants in Lao Cai province in the following table:

Table 3.13: Summary of the Evaluation Results of Economic, Social, and Environmental Effectiveness of Medicinal Plants in Lao Cai Province

No	Medicinal Plant	Economic Effectiveness	Social Effectiveness	Environmental Effectiveness	General Evaluation
1	Cynara scolymus (AIII)	H	H	H	H
2	Angelica sinensis (AII)	H	M	M	M
3	Ligusticum wallichii (AIV)	H	H	H	H
4	Platycodon grandiflorus (AI)	H	H	H	H
5	Paris polyphylla	L	L	H	L
6	Amomum longiligulare	H	M	M	M
7	Ampelopsis cantoniensis	M	M	M	M

3.2.3. Selection of Potential Medicinal Plants

Based on the results of the evaluation of economic, social, and

environmental effectiveness, combined with a SWOT analysis of the strengths, weaknesses, opportunities, and threats of the 7 main medicinal plants in Lao Cai province, the thesis has identified and selected the 4 most promising medicinal plants for development and soil suitability assessment for agricultural land, including:

Cynara scolymus, Angelica sinensis, Ligusticum wallichii, Platycodon grandiflorus are medicinal plants with the most clear strengths and development opportunities:

- High economic value, stable production efficiency.
- Purchased by businesses with support for seeds and cultivation techniques.
- Recognized by the Ministry of Health for their medicinal properties and sustainable development potential.
- A large and stable market for consumption both domestically and internationally.

Paris polyphylla, Amomum longiligulare, and Ampelopsis cantoniensis encounter significant difficulties and challenges in their production and development:

- Dependent on the market, especially the Chinese market.
- Lack of a standardized processing and preservation procedure.
- High investment costs and difficulty in scaling up production.
- Unstable consumption market, easily affected by trade policies and climatic conditions.

3.3. Evaluation of Agricultural Land Quality and Development of Land Unit Maps

3.3.1. Determination of Criteria for Agricultural Land Quality Assessment

Based on soil characteristics, topography, climate, and land use features, and with reference to the requirements specified in Circular No. 60/2015/TT-BTNMT, the criteria for assessing land quality in Lao Cai province are determined as follows:

Soil criteria: include 5 indicators—soil type, soil layer thickness, soil texture, soil pH, and total organic carbon.

Topographic criteria: include 2 indicators—elevation and slope.

Climatic criteria: include the indicator of rainfall.

3.3.2. Evaluation of Agricultural Land Quality by Soil Type

The agricultural land area under study covers 367,938 hectares and includes 15 soil types, categorized into 5 main soil groups.

Among them, the red and yellow soils cover an area of 223,258.60 hectares, accounting for 60.68% of the total surveyed area. The yellow-red humus soils on high mountains (900–1800m elevation) occupy an area of 111,845.62 hectares, accounting for 30.40% of the total surveyed area.

The distribution of the five main soil groups across the investigated land area is shown in Figure 3.4.

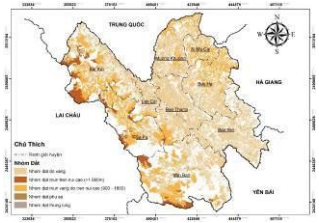

Figure 3.4: Map of the Distribution of the Five Main Soil Groups in the Study Area

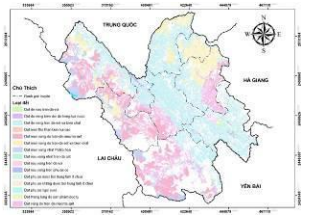

Figure 3.5: Diagram of the Distribution of 15 Main Soil Types in the Study Area

The distribution of each specific soil type is illustrated in the diagram in Figure 3.5 below.

3.3.3. Development of the Land Mapping Unit (LMU)

3.3.3.1. Factors and Classification Criteria for Developing the Land Mapping Unit Map

Based on the characteristics of soil, topography, climate, and land use, and with reference to the requirements specified in Circular No. 60/2015/TT-BTNMT, the criteria for assessing land quality in Lao Cai province are determined as follows:

Soil criteria: including 5 indicators—soil type, soil layer thickness, soil texture, soil pH, and total organic carbon.

Topographic criteria: including 2 indicators—elevation and slope.

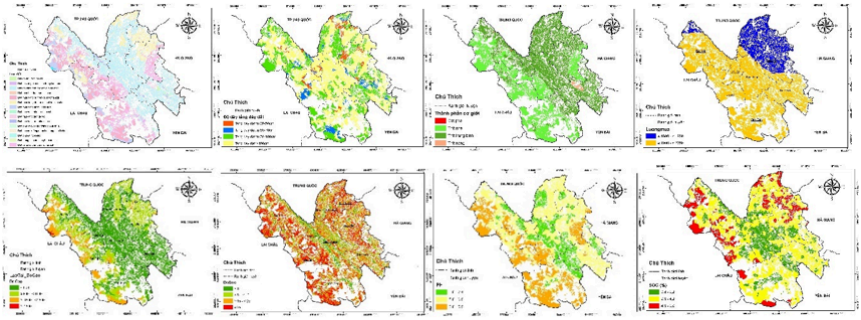

Figure 3.1: Thematic Maps of Soil Characteristics in the Study Area

Climatic criteria: including the indicator of rainfall.

Below are the results of developing 8 thematic maps for the construction of the Land Mapping Unit (LMU) map for Lao Cai province.

3.3.3.2. Development of the Land Mapping Unit (LMU)

The Land Mapping Unit (LMU) map of Lao Cai province was developed based on the overlay of 8 thematic map layers: soil type, soil layer thickness, soil texture, soil pH, total organic carbon, elevation, slope, and rainfall (details provided in Appendix 4), using the Union tool in ArcGIS.

As a result, 8,032 land parcels were delineated, corresponding to 735 land mapping units based on the 8 criteria used in land unit mapping. The table below presents the characteristics and area of each land mapping unit in the study area.

Table 3.5: Summary of 735 Land Mapping Units Based on Natural Condition Criteria

Land Mapping Unit	Land Unit Characteristics	Area (ha)	Proportion (%)
1	G1,T4,D1,Sl3,E1,P2,N2,R1	1,2	0,00
2	G1,T4,D1,Sl3,E1,P3,N2,R1	119,0	0,03
3	G1,T4,D1,Sl4,E1,P2,N2,R1	193,8	0,05
4	G1,T4,D1,Sl4,E1,P3,N2,R1	437,6	0,12
5	G1,T4,D3,Sl4,E1,P2,N2,R1	2,1	0,00
6	G1,T4,D3,Sl4,E1,P3,N2,R1	13,3	0,00

Land Mapping Unit	Land Unit Characteristics	Area (ha)	Proportion (%)
…	…	..	..
735	G9,T2,D4,Sl4,E3,P3,N2,R1	95,6	0,03
	Total	**367938**	**100**

Details of the 735 land mapping units and their characteristics are presented in Appendix 3. The distribution of these land units is linked between the attribute database and the map.

The distribution of land units according to the 8 criteria is illustrated in the following map::

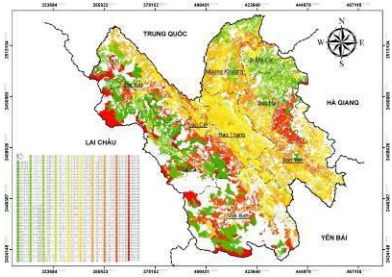

Figure 3.2: Land Mapping Unit Map Based on 8 Natural Condition Criteria

3.4. Evaluation of Agricultural Land Potential for Medicinal Plants

3.4.1. Determination of Weights (Wi) for Criteria Relevant to Medicinal Plants

Similarly, for the remaining medicinal plants, the weights of the 8 natural condition criteria were determined. The summarized results are shown in the table below:

Table 3.6: Weights of 8 Natural Condition Criteria for 4 Medicinal Plants Based on Analytic Hierarchy Process (AHP)

No.	Sub-Criteria	AI	AII	AIII	AIV
1	Soil type	0.286	0.299	0.271	0.268
2	Soil depth	0.135	0.134	0.172	0.172
3	Soil texture	0.040	0.028	0.030	0.033
4	Soil pH	0.047	0.051	0.072	0.071
5	Elevation	0.291	0.262	0.226	0.232
6	Slope	0.071	0.064	0.043	0.040

7	Total organic carbon	0.095	0.126	0.126	0.130
8	Rainfall	0.035	0.036	0.061	0.054

The table above shows the weights of the 8 natural condition criteria for the 4 medicinal plants (Platycodon grandiflorus, Angelica sinensis, Cynara scolymus, Ligusticum wallichii) based on the Analytic Hierarchy Process (AHP). From this data, the criteria that have the greatest and least influence on all four medicinal plants can be identified, as well as the specific degree of influence of each criterion on each plant.

Through analysis, it is found that "Soil type" is the criterion with the greatest influence on all four medicinal plants, reflecting the importance of having suitable soil for cultivation. In contrast, "Rainfall" is the criterion with the least impact among the eight criteria, indicating that these plants can tolerate different rainfall levels without significantly affecting their growth. However, the degree of influence of each criterion varies for each plant, showing the diversity in natural condition requirements for each medicinal plant..

3.4.2. Determining the Score Values (Xi) for the Criteria of Medicinal Plants

Scoring the subdivisions of each criterion evaluates the suitability of each medicinal plant with the specific characteristics of each subdivision. For the 8 physical criteria, scoring is based on expert consultations and published scientific literature on the 4 medicinal plants being studied in Lào Cai province. The results indicate that the PRA scoring method and the scoring based on previous studies show similarities but differ in their levels.

Table 3.39: Score Values (Xi) for Each Criterion of the Potential Medicinal Plants

No.	Value	Symbol	A-I	A-II	A-III	A-IV
I	**Soil type**					
1.1	Brown-red soil on limestone	G1	5,4	5,6	5,4	5,2
1.2	Yellow-red soil modified by paddy rice cultivation	G2	5,9	5,4	5,2	5,3
1.3	Yellow-red soil on shale and metamorphic rock	G3	7,2	7,5	7,0	6,9
1.4	Yellow-brown soil on sandstone	G4	4,3	5,2	3,8	5,2

No.	Value	Symbol	A-I	A-II	A-III	A-IV
1.5	Yellow-brown soil on limestone	G5	8,9	7,5	7,0	6,9
1.6	Yellow-brown soil on ancient alluvium	G6	5,9	5,4	5,2	5,3
1.7	Yellow-red soil on acid volcanic rock	G7	5,2	5,2	5,4	5,0
1.8	Coarse humus soil with peat on high mountain	G8	8,4	8,9	7,3	8,6
1.9	Light yellow humus soil, podzolized	G9	5,2	7,4	8,4	8,9
1.10	Yellow-red humus soil on acid volcanic rock	G10	4,3	5,2	5,3	5,1
1.11	Yellow-red humus soil on shale and metamorphic rock	G11	5,2	7,1	7,3	5,1
1.12	Neutral slightly acidic alluvial soil	G12	8,4	8,9	8,7	8,6
1.13	Non-deposited neutral slightly acidic alluvial soil	G13	5,3	7,3	5,2	7,4
1.14	Streambed alluvial soil	G14	7,5	8,6	8,4	8,9
1.15	Valley soil from slope deposits	G15	5,9	5,2	5,2	5,3
II	**Soil depth**					
2.1	> 100 cm	D1	7,5	8,4	8,5	7,4
2.2	70 - 100 cm	D2	8,7	8,3	7,3	7,1
2.3	50 - 70 cm	D3	8,8	7,0	6,7	8,7
2.4	30 - 50 cm	D4	5,2	4,2	3,2	3,4
III	**Soil texture**					
3.1	Medium soil	T1	8,5	7,2	8,6	5,3
3.2	Light soil	T2	8,0	7,0	6,9	8,0
3.3	Heavy soil	T3	3,3	3,1	3,3	3,2
3.4	Loamy sand	T4	4,1	5,3	5,0	7,4
IV	**Elevation (m)**					
4.1	< 800	E1	3,3	3,2	5,5	3,2
4.2.	≥ 800 - < 1500	E2	5,1	5,3	7,2	5,1
4.3	≥ 1500 - < 2500	E3	8,9	7,2	8,0	8,0
4.4	≥ 2500	E4	6,9	7,9	5,4	6,2
V	**Slope (^{0})**					
5.1	< 8	Sl1	8,4	8,2	8,9	8,7
5.2	≥ 8 - < 15	Sl2	4,1	4,0	4,5	5,4
5.3	≥ 15 - < 25	Sl3	3,6	3,2	3,8	4,0
5.4	≥ 25	Sl4	3,4	3,0	3,1	3,4
VI	**PH**					
6.1	6,6 - 7,4	P1	6,8	4,3	8,9	8,4

No.	Value	Symbol	A-I	A-II	A-III	A-IV
6.2	5,6 - 6,5	P2	7,1	8,6	5,3	5,5
6.3	3,9 - 5,5	P3	3,5	3,5	3,1	3,4
VII	**Rainfall (mm)**					
7.1	≥ 1900 - < 2350	R1	5,7	7,3	6,3	5,3
7.2	≥ 1600 - < 1900	R2	7,2	5,8	6,5	6,8
VIII	**Total organic carbon (%)**					
8.1	4,3 - 9,0	N1	8,4	8,6	6,9	7,6
8.2	2,3 - 4,2	N2	8,0	7,3	8,7	8,1
8.3	0,8 - 2,2	N3	3,5	3,2	3,8	4,0

3.4.3. Land Suitability Classification for Medicinal Plants on GIS

After constructing the land unit map based on 8 criteria in section 3.3.3, it is necessary to combine the weight results (Wi) of the criteria for each medicinal plant species (Table 3.37) and the score values (Xi) – which represent the suitability level of each subclass within the criteria for each medicinal plant (results in Table 3.38), in order to assess the land suitability classification for each medicinal plant species. This process is carried out with the support of ArcGIS 10.8 software to combine the land unit map with the formula for calculating the land suitability index (Si) for medicinal plants.

The land suitability index formula (Si) is applied to 8,032 land segments corresponding to 735 land units, with the specific formula as follows:

$$Si = (Wi_1 \times Xi_1) + (Wi_2 \times Xi_2) + (Wi_3 \times Xi_3) + (Wi_4 \times Xi_4) + (Wi_5 \times Xi_5) + (Wi_6 \times Xi_6) + (Wi_7 \times Xi_7) + (Wi_8 \times Xi_8)$$

For the medicinal plant Platycodon Grandiflorus, applying the suitability index formula, the calculation for this medicinal plant is as follows:

$$Si_{\text{Cát cánh}} = (0{,}286 \times Xi_G) + (0{,}135 \times Xi_D) + (0{,}040 \times Xi_T) + (0{,}047 \times Xi_P) + (0{,}291 \times Xi_E) + (0{,}071 \times Xi_{Sl}) + (0{,}095 \times Xi_N) + (0{,}035 \times Xi_R)$$

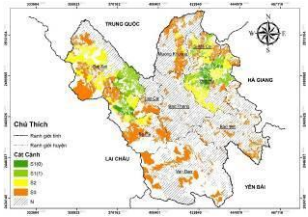

Figure 3.3: Agricultural land suitability map for Platycodon Grandiflorus medicinal plant in Lào Cai province.

The specific distribution area of the 5 levels of agricultural land suitability in Lao Cai province for Platycodon Grandiflorus medicinal plant is shown in the following table:

Table 3.9: Area of agricultural land suitability levels for Platycodon Grandiflorus medicinal plant in Lào Cai province.

No.	Suitability Level	Symbol	Area (ha)	Proportion (%)
1	Highly Suitable	S1(0)	7,285	1.98
2	Suitable	S1(1)	25,486	6.93
3	Moderately Suitable	S2	44,399	12.07
4	Low Suitability	S3	104,711	28.46
5	Not Suitable	N	186,057	50.57
	Total		367,938	100.00

Thus, the process of evaluating land suitability in Lao Cai province has used 8 natural condition criteria to assess the suitability for 8,032 land parcels corresponding to 735 land units for 4 potential medicinal plants: Platycodon Grandiflorus, Angelica Sinensis, Cynara Scolymus, Ligusticum Wallichii. The agricultural land suitable for growing medicinal plants, in general, is located at an altitude of 800 meters above sea level, with a slope ranging from 3 to 8 degrees, and soil that has a balance between sand, silt, and clay, facilitating good drainage. Such areas are concentrated in the districts of Bac Ha, Si Ma Cai, Bat Xat, Muong Khuong, and the town of Sa Pa. The specific land suitability assessment for these 4 medicinal plants by land unit is detailed in Appendix 3.

Similarly, the same process was applied to the remaining 3 medicinal plants: Angelica Sinensis, Cynara Scolymus, Ligusticum Wallichii, to determine the suitable land area and location, as shown in the land suitability map.

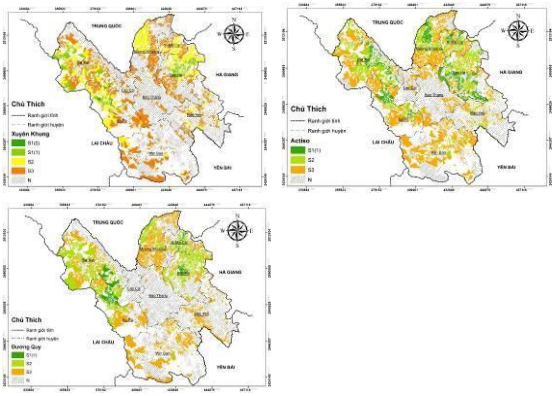

Figure 3.4: Agricultural land suitability map for the medicinal plants Angelica Sinensis, Cynara Scolymus and Ligusticum Wallichii in Lao Cai Province

The summarized results of the suitability ranking assessment for the 367,938 hectares of agricultural land for each medicinal plant are shown in the table below:

Table 3.44: Suitability ranking of agricultural land for some potential medicinal plants in Lao Cai Province.

Medicinal Plant	Highly Suitable S1(0)		Suitable S1(1)		Moderately Suitable (S2)		Low Suitability (S3)		Not Suitable (N)	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
A-I	7.285	1,98	25.486	6,93	44.399	12,07	104.711	28,46	186.057	50,57
A-II			12024	3,27	74553	20,26	114811	31,20	166550	45,27
A-III			31120	8,46	68663	18,66	145191	39,46	122964	33,42
A-IV	275	0,07	21.321	5,79	66.014	17,94	116.081	31,55	164.247	44,64

3.5. Solutions for Land Use in Growing Medicinal Plants in Lao Cai Province

3.5.1. Orientation for Agricultural Land Use in Growing Medicinal Plants

The results of the summarized medicinal plant development planning needs for Lao Cai Province are shown in the following table:

Table 3.46: Current and Planned Area for Medicinal Plants in Lao Cai Province

Unit: ha

TT	Medicinal Plant	2022	2030

I	**Annual Medicinal Plants**	**573**	**1.600**
1	**A-I**	98	200
2	A-II	7	140
3	A-III	51	260
4	A-IV	96	300
5	Other Medicinal Plants	321	700
II	**Perennial Medicinal Plants**	**2.977**	**3.400**
	Total	**3.550**	**5.000**

(Source: Author's compilation from Provincial Party Committee, People's Committee of Lao Cai Province)

3.5.2. Proposed Agricultural Land Use for Medicinal Plant Development in Lao Cai Province

Based on the development policies and orientations for medicinal plants in Lao Cai Province, scientific foundations, and the results of evaluating the suitability of agricultural land for several potential medicinal plants, the thesis proposes several measures for utilizing agricultural land to develop the four medicinal plants studied in the following years:

First, agricultural land for growing medicinal plants should only be developed in land units with a multi-criteria suitability index of 7.0 or higher (Si > 7.0), meaning those in the S1(0) and S1(1) suitability levels. This will ensure economic efficiency since the investment costs are not too high and are aligned with the current income levels of the people.

Second, for each medicinal plant with suitable land area at different levels, compare the development planning needs for medicinal plants in the province with the results of multi-criteria land suitability evaluation for each plant:

For Platycodon Grandiflorus, focus on exploiting agricultural land with high suitability level S1(0) in Bac Ha, Bat Xat (such as Nam Mon, Ta Chai, Coc Ly, etc.) and some communes of SaPa town (such as Sa Pa, Trung Chai).

For Angelica Sinensis, focus on exploiting agricultural land with suitability level S1(1) with an area of 12,024 ha.

For Cynara Scolymus, focus on exploiting agricultural land with suitability level S1(1) with an area of 31,120 ha.

For Ligusticum Wallichii, focus on exploiting agricultural land

with high suitability level S1(0) with an area of 275 ha in SaPa, or expand to consider other areas with suitability level S1(1) with an area of 21,321 ha in Bat Xat and Bac Ha districts.

The proposed prioritization is to first exploit areas with suitability level S1(0), then move to S1(1), as shown in the table below::

Table 3.47: Planned and Suitable Land Area for Medicinal Plants in Lao Cai Province

Unit: ha

No	Medicinal Plant	2022	2030	Highly Suitable S1(0)	Suitable S1(1)
I	Annual Medicinal Plants	**573**	**1.600**	**7.575**	**98.627**
1	**A-I**	98	200	7.285	25.486
2	A-II	7	140	-	12.024
3	A-III	51	260	-	31.120
4	A-IV	96	300	275	21.321
6	Other Medicinal Plants	321	700		

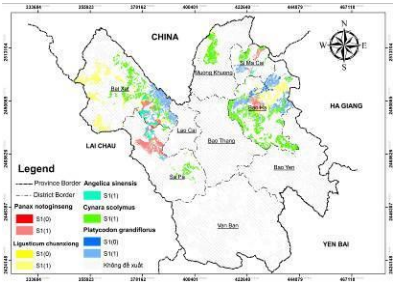

Figure 3.13: Diagram of proposed agricultural land planning area for the development of four potential medicinal plants in Lao Cai province.

The diagram Figure 3.13 illustrates the area for agricultural land planning for the development of four potential medicinal plants: Platycodon Grandiflorus, Angelica Sinensis, Cynara Scolymus, Ligusticum Wallichii in Lao Cai province.:

3.5.3. Solutions to improve the effectiveness of agricultural land use for medicinal plant cultivation in Lao Cai province

Based on the research on criteria for land suitability assessment and the study of relevant legal documents related to the development of medicinal plants in Lao Cai, the thesis proposes several groups of solutions to enhance the effectiveness of agricultural land use for medicinal plant development as follows:

3.5.3.1. Solutions related to land

3.5.3.2. Solutions related to capital and credit

3.5.3.3. Organizational solutions, production linkage, and product consumption promotion

3.5.3.4. Scientific and technological solutions, market development

3.5.3.5. Information dissemination, training, and human resource development

3.5.3.6. Orientation for suitable production areas and quality management of raw material regions.

CONCLUSION - RECOMMENDATION

1. Conclusion

Lao Cai, a mountainous border province located between the Northeastern and Northwestern regions, has a total natural area of 636,425 ha, with agricultural land covering 551,690 ha, accounting for 86.69% of the province's total area.

Current status of medicinal plant cultivation land: As of the end of 2022, Lao Cai had 3,550 ha of land used for medicinal plants, accounting for 2.67% of the total agricultural land area. The assessment results on the economic, social, and environmental effectiveness, along with the analysis of the advantages and challenges of each medicinal plant, aligned with the selection criteria/requirements of the thesis, identified four potential medicinal plants for suitability evaluation of agricultural land: Platycodon grandiflorus (Cát cánh), Angelica sinensis (Đương quy), Cynara scolymus (Artichoke), and Ligusticum wallichii (Xuyên khung).

Land quality assessment: The land quality was evaluated by land type, identifying 5 groups of land corresponding to 15 different land types. Additionally, 8 thematic maps were developed, including maps of land types, soil thickness, soil texture, soil pH, altitude, slope, total organic carbon, and rainfall. This allowed for the construction of a land unit map consisting of 8,032 land parcels, corresponding to 735 land units based on natural conditions.

Agricultural land potential evaluation for medicinal plants: The study determined the weights (Wi) of the 8 criteria affecting each medicinal plant and calculated the point values (Xi) to represent the suitability level for each criterion classification. The land suitability index (Si) was computed and integrated with GIS to determine the

suitability level of the 735 land units for the four potential medicinal plants. Specifically:

+Platycodon grandiflorus (Cát cánh): Very suitable land (S1(0)) covers 7,285 ha (1.98% of the total area), and suitable land (S1(1)) covers 25,486 ha (6.93%).

+Angelica sinensis (Đương quy): Suitable land (S1(1)) covers 12,024 ha (3.27%), and moderately suitable land (S2) covers 74,553 ha (20.26%).

+Cynara scolymus (Artichoke): Suitable land (S1(1)) covers 31,120 ha (8.46%), and moderately suitable land (S2) covers 68,663 ha (18.66%).

+ Ligusticum wallichii (Xuyên khung): Highly suitable land (S1(0)) covers 275 ha (0.07%).

+ Land suitability map: A land suitability map was created, specifying the area and priority locations for developing the four medicinal plants studied. In addition, the thesis proposes a set of solutions for improving the effectiveness of medicinal plant cultivation in Lao Cai.

2. Recommendations

Using the results of agricultural land suitability classification for medicinal plants as a basis for developing planning and development plans for medicinal plants in Lao Cai province in the coming years.