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STUDY ON LANDSCAPE ECOLOGY FOR SUSTAINABLE AGRICULTURE AND FORESTRY DEVELOPMENT IN VAN YEN DISTRICT, YEN BAI PROVINCE BASED ON APPROACH OF QUANTITATIVE GEOGRAPHY

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1. The reason for choosing the topic

Landscape ecology studies natural, socio-economic factors and the interaction between them, so using and accessing research methods and quantitative models plays an important role. Within any territory, there are always forms of factor movement, criteria reflecting natural processes and socio-economic activities of different and asynchronous nature. For comprehensive research, it is necessary to use mathematical tools to synchronize data sources into a unified reference system. With the development of computer science, problems of analysis and general assessment using quantitative models and methods in geographical research, referred to as quantitative geography, are conducted with the feasibility.

Van Yen is a northern mountainous district of Yen Bai with favorable natural conditions for developing agricultural and forestry crops. However, the terrain is fragmented, transportation is difficult, the natural land area is large but the arab land area is small, while the population is scattered, including many ethnic minorities. The low level of education and the ability to absorb scientific advances... are the internal weaknesses of the territory. In addition, the territory faces challenges such as: agricultural land tends to be degraded, negative impacts due to climate change, spontaneous expansion of production land areas not according to planning, conflicts between industrial Conservation and expansion of production areas, increasing mechanical migration to the area and the market economy erode local knowledge. This not only creates many challenges in using resources effectively but also affects the goal of developing sustainable agriculture and forestry.

To solve this problem from a scientific perspective, the application of quantitative geographical models in studying landscape ecology in mountainous territories in Van Yen district was chosen. Stemming from the above practical reasons, the thesis topic "***Study on landscape ecology for sustainable agriculture and forestry development in Van Yen district, Yen Bai province based on approach of quantitative geography*** " was chosen for research and complete it.

2. Research purpose and tasks of the topic

Establishing a scientific basis for landscape ecology and quantitative geography in analyzing the rules of differentiation of landscape ecology conditions, evaluating and forecasting landscape changes, analyzing landscape management and use activities to serve spatial orientation and recommendations of strategies and solutions to prioritize sustainable agriculture and forestry development in Van Yen district, Yen Bai province.

CHAPTER 1. THEORETICAL BASIS AND RESEARCH METHODS OF LANDSCAPE ECOLOGY FOR SUSTAINABLE AGRICULTURE AND FORESTRY DEVELOPMENT IN VAN YEN DISTRICT

1.1. Overview of research issues related to the topic

1.1.1. Overview of landscape ecology research projects

Since the 1980s, landscape ecology became an independent scientific discipline, with its own research objects, methodology and research methods. In terms of landscape research serving environmental protection, while the United States has strongly developed the direction of modeling metamorphic population dynamics and ecosystem processes in fragmented landscapes to solve environmental consequences of logging (Forman and Godron, 1986; McGarigal, 2002). Western and Eastern European countries only limit the analysis of population dynamics in relation to landscape fragmentation due to agricultural land use change to solve environmental problems (Naveh, Zonneveld, 1995).

1.1.2. The situation of quantitative approaches in geographical research

The appearance of electronic computers since the mid-20th century has opened up the trend of "mathematicizing geography", especially in Western countries and North America, pioneering geographers in building geographical directions. Quantitative theorist Brian J.L.Berry, William Bunge and Richard Morill in the 1960s founded the Chicago school of theoretical geography. By the 1980s, four schools of quantitative geography had formed in the US: Chicago, Washington, Wisconsin and Iowa (Holt-Jensen, 1988). The younger generation of European geographers also pioneered the quantitative direction. Peter Haggett with his work "Geography: a modern synthesis" (1972,1975, 1983). David Harvey's famous book "Scientific explanation in geography" addresses the difficult issue of the philosophical and methodological basis of scientific explanation in geography, from which we can understand More thoroughly understand the relationship between quantitative and qualitative in geographical research.

Currently, the quantitative approach - specifically the mathematical approach - is widely and effectively used in different scientific disciplines, not only in the natural sciences but also in the social sciences. The application of mathematical models to geographical research is developed in many

countries around the world with two main schools: the Western European - North American school (Cole & King, Steinhard U.,...) and the Western European - North American school (Cole & King, Steinhard U.,...) and Soviet Union (former) - Eastern Europe (Botrarov, Serbenniuk, Tikunov...).

In Vietnam, mathematics has been applied in many research fields of Earth Sciences at different levels, especially strongly developed in meteorology, climate, hydrology and oceanography; while research on geomorphology, geobotany, soil, landscape... is still at a very modest level. Socio-economic geographers have quantitative perspectives and approaches in socio-economic geography research including: (i) selecting indicators, (ii) correlation analysis, (iii) regression, (iv) classification. Natural geographers develop the direction of ecological research from pure description to compositional analysis, from qualitative analysis to quantitative analysis, from structurally oriented studies to functionally oriented studies, from morphology-oriented research to system-oriented research. With the support of remote sensing and GIS technology, scientists can expand the spatial and temporal scale of research.

1.1.3. Overview of research projects related to the topic

There are not many general geographical research projects in Yen Bai province in general and Van Yen district in particular. Only the work of author Nguyen Anh Hoang (2010, 2015) was carried out in Van Yen district. Within the framework of the master's thesis and doctoral thesis, the author initially conducted research on theoretical and methodological issues of general natural geography for analyzing and evaluating the landscape of Van Yen district, Yen province. Bai. Analyze the characteristics of the factors that make up the territorial landscape, build a landscape classification system, landscape maps, and territorial landscape assessment maps. Research serves the purpose of rational use of natural resources and sustainable development. Analyze the assessment results and propose recommendations, orienting the development of agriculture and forestry sectors towards reasonable use of natural resources and sustainable development. However, the project has not solved the problem of managing landscape agricultural products at district level and specifically in each typical study area associated with specific ethnic groups in the locality, the problem of sustainable development of some important commodity crops. local mainstay.

1.2. Theoretical basis

1.2.1. Ecological approach in landscape ecology research for sustainable development of agriculture and forestry in mountainous areas

Landscape ecology research must reflect the specificity of vegetation types on the basis of arising ecological. With the thesis of emergent ecology, Vietnam's tropical monsoon landscape diversity model must demonstrate the ecological genesis between formation factors and landscape diversity characteristics. The applied problems of ecology are the foundation for developing applied landscape ecology research in natural landscape ecology research.

Reasonable use of resources and environmental protection in sustainable agriculture and forestry development according to the landscape ecology approach means: (i) Relying on landscape to comprehensively study the territory, which means considering specifically comprehensive and comprehensive characteristics of natural conditions and human impacts, including human factors along with human activities. (ii) Through the study of the territorial landscape, it leads to a fairly complete understanding of the structure, functions, dynamics and rules of change and differentiation of the territorial natural geography and is also the basis for conducting an assessment of the territorial landscape. (iii) Landscape ecology research results are always associated with the landscape classification system and zoning.

In the spatial organization of rational use of resources and protection of the mountainous environment, there must always be an area of watershed protection forest, which can be located in landscapes with key locations to regulate flow, reduce water flow and harmful effects of natural disasters.

1.2.2. Quantitative approach in analyzing landscape structure and function for sustainable development of agriculture and forestry

Currently, the application of mathematics in geographical research is understood from many different perspectives, considering mathematics as a data processing tool, support method, and interdisciplinary science connecting geography and mathematics. Among the three viewpoints, the application of mathematics in geographical research is the supporting method supported by domestic scientists. Foreign authors tend to support the view that it is considered an interdisciplinary science that connects geography and

mathematics with common terms (Quantitative geography, Mathematical geography, Statiscal geography). This perspective of foreign geographers is approached in different directions: Mathematical models, geographical phenomena/processes; Research geography using mathematical methods.

1.3. Perspectives, methods and conceptual models

1.3.1. Research perspective

The main perspectives used in the thesis include system - synthesis, history - perspective, ecology, sustainable development.

1.3.2. Research Methods

a. Methods of landscape assessment: Organize/standardize documents, synthesize surveys, quickly assess rural areas, consult experts. Used during investigations and field surveys

b. Methods of map and geographic information system (GIS): Implemented during the process of establishing and editing component maps. Analyze and overlay component maps to create thematic maps. Analyze and overlay component maps and thematic maps to create a landscape map. Adaptive hierarchy of component LULC maps to create a landscape change prediction map. Analyze, interpolate, and overlay maps of natural resources assessment criteria to create a natural natural resources map. Overlay natural resource maps and landscape maps to create a spatial orientation map

c. Methods of quantitative geographical: Delphi survey of PSR factors, analytical hierarchy (AHP), SWOT analysis, Markov-CA, CBA analysis Implemented in structural analysis, functional assessment, forecasting changes, evaluate economic efficiency and propose solutions.

1.4. Process of implementation, research design and conceptual model

Two preliminary surveys were carried out in 2016. At the end of the preliminary survey, a map of the geographical zoning was sketched, allowing an overview of the research territory, which is the basis for designing landscape landscape transects in the detailed survey (2017-2018).

A detailed survey of natural ecological components in April 2017 verified the law of differentiation according to elevation. The survey of human ecology and land use components was carried out in 2018. In addition to collecting statistical data, using the rural rapid survey (RRA) method.

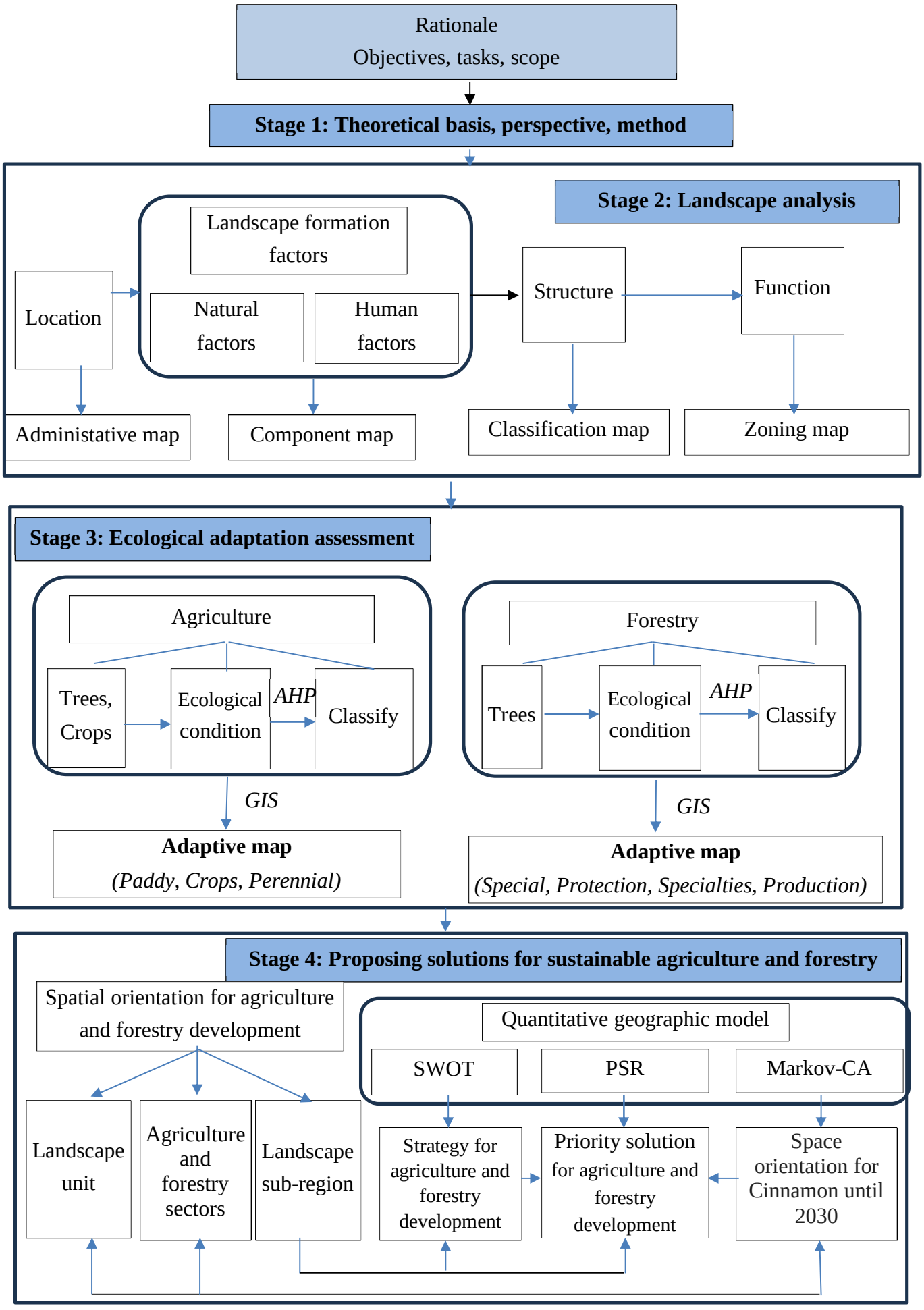
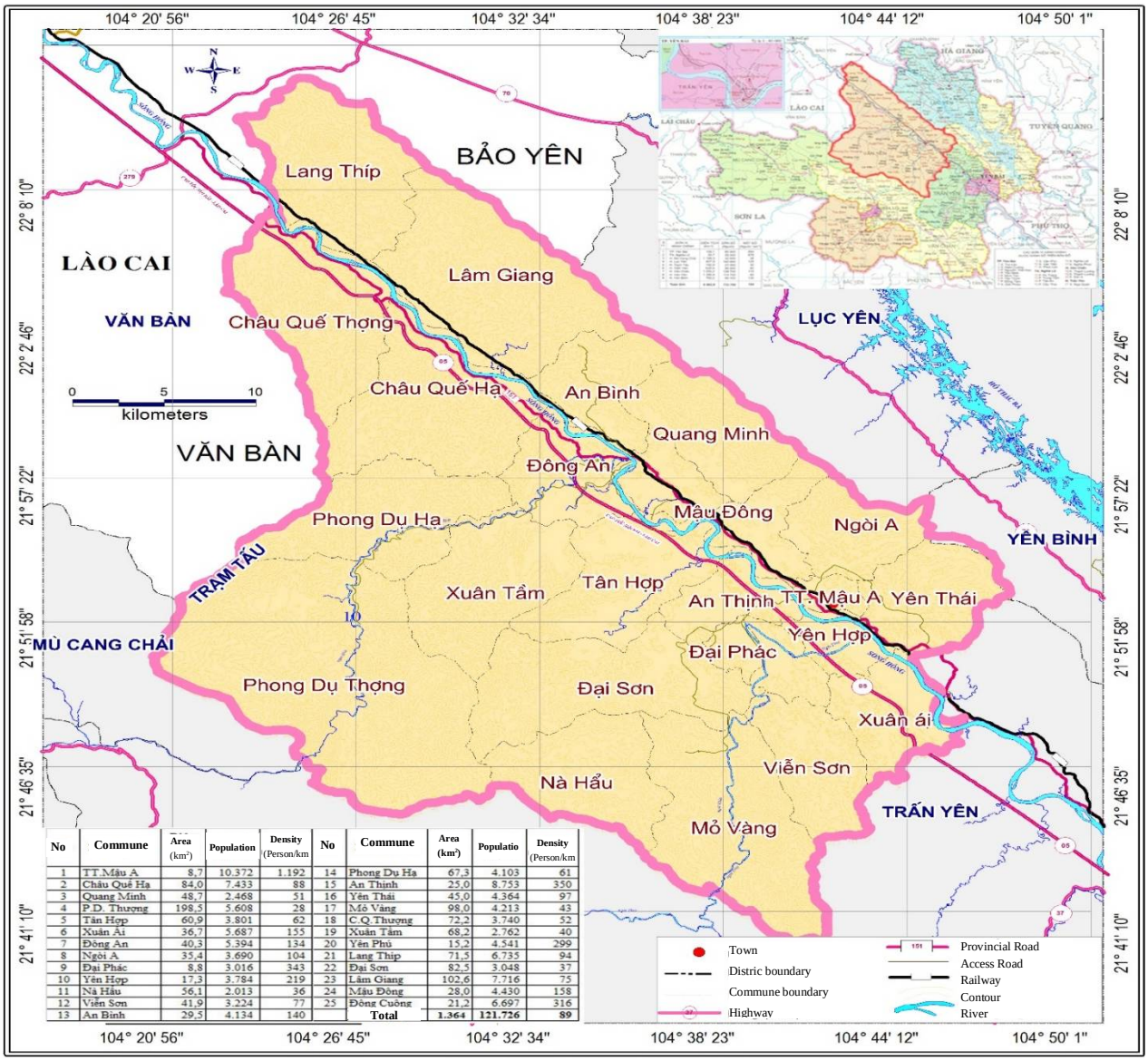


Figure 1.1. Conceptual model

CHAPTER 2. CHARACTERISTICS OF LANDSCAPE ECOLOGY OF VAN YEN DISTRICT

2.1. Geographical location

Van Yen district is a mountainous district located in the north of Yen Bai province, with coordinates 104º20' to 104º50' East longitude and from 21º50'30" to 22º12' North latitude. The East borders Luc Yen and Yen Binh districts, the West borders Mu Cang Chai district, the South borders Tran Yen and Van Chan districts, the North borders Van Ban and Bao Yen districts of the province. Lao Cai. Because it is located near the tropic of cancer, there is a large altitude difference that complicates the landscape of Van Yen district according to the elevation belt. Because it is located at the transition between the mountains and the midlands, it has convenient transportation.



No	Commune	Area (km²)	Population	Density (Person/km	No	Commune	Area (km²)	Populatio	Density (Person/km
1	TT.Mậu A	8,7	10.372	1.192	14	Phong Dụ Hạ	67,3	4.103	61
2	Châu Quế Hạ	84,0	7.433	88	15	An Thịnh	25,0	8.753	350
3	Quang Minh	48,7	2.468	51	16	Yên Thái	45,0	4.364	97
4	P.D. Thượng	198,5	5.608	28	17	Mỏ Vàng	98,0	4.213	43
5	Tân Hợp	60,9	3.801	62	18	C.Q.Thượng	72,2	3.740	52
6	Xuân Ái	36,7	5.687	155	19	Xuân Tầm	68,2	2.762	40
7	Đông An	40,3	5.394	134	20	Yên Phú	15,2	4.541	299
8	Ngòi A	35,4	3.690	104	21	Lang Thíp	71,5	6.735	94
9	Đại Phác	8,8	3.016	343	22	Đại Sơn	82,5	3.048	37
10	Yên Hợp	17,3	3.784	219	23	Lâm Giang	102,6	7.716	75
11	Nà Hẩu	56,1	2.013	36	24	Mậu Đông	28,0	4.430	158
12	Viễn Sơn	41,9	3.224	77	25	Đông Cuông	21,2	6.697	316
13	An Bình	29,5	4.134	140		Total	1.364	121.726	89

Figure 1.1. Administrative map of Van Yen district

2.2. Characteristic of factors forming the landscape of Van Yen district

2.2.1. Natural ecological factors

2.2.1.1. Solid foundation (substance – terrain)

a. Geology - tectonics: Geological - tectonic characteristics are important in the process of emergence and development of a territory's landscape, and are a foundational factor that greatly influences other factors such as topography, climate, soil, etc. nutrition, hydrology and biology in the process of forming the landscape of the territory..

b. Topography and geomorphology: Van Yen is a transition area from the Northwest high mountains to the midland hills. The mountain ranges all run in the Northwest - Southeast direction, with an average altitude of 500 m, the lowest is 20 m, the highest is 1,952 m.

2.2.1.2. Thermal and humid foundation (climate – hydrology)

c. Climate: Van Yen is a mountainous district located deep inland, stretching along both banks of the Red river and located on the transition area between the Northwest and Northeast, and is also the transition area between the Northwest and midland regions. Northern region. Van Yen has the characteristics of a tropical monsoon climate, influenced by mountainous terrain, so its nature changes. The average annual temperature is 22^{o}-23^{o} C, average rainfall is 1500-2000 mm/year, high humidity is 83 - 87%, lush green vegetation all year round.

d. Hydrology: The flows transport and deposite alluvium to form basins and river terrace surfaces in Van Yen and contribute to landscape differentiation. Abundant water resources play a role in the development of evergreen tropical forest landscape in Yen Bai during the low rainy season.

2.2.1.3. Nutritional foundation factor (soil)

Van Yen territory, with its specific location and natural conditions, has influenced the process of generation and formation of soil types (4 groups and 9 types). (i) The alluvial soil group includes 2 types: neutral, low-acid alluvium (Pbe), stream alluvium (Py) distributed mainly downstream of Thia and Hut streams, along the Red River. (ii) The yellow-red soil group occupies the largest area and is widely distributed, including 5 types (Red-yellow soil on acid igneous rocks (Fa), Yellow-red soil on clay and metamorphic rocks (Fs), Light yellow soil on sandstone (Fq), Yellow-brown soil on ancient

alluvium (Fp), Yellow-red soil changed by wet rice cultivation (Fl)). (iii) Yellow-red humus soil group on mountains (Hs), distributed at altitudes from 900 - 1,700m in the southwest communes and part of the western edge of Con Voi Mountain. (iv) The valley soil group is developed by sloping products in places with valley terrain between mountains.

2.2.1.4. Vegetation

Natural forest is a type of closed, mixed, broad-leaved evergreen humid forest, divided into types according to terrain elevation and species composition: (i) Closed evergreen, mixed species, cold humid forest type mountainous areas over 1,500m. (ii) Closed evergreen, mixed, cool moist forest in low and medium mountainous areas at altitudes from 700-1500m, including 4 subtypes (mixed evergreen closed forest, secondary forest, mixed wood/bamboo forest cork, grassland/shrub). (iii) Hot and humid evergreen broad-leaved closed forest type in lowland altitudes below 700m, including 3 subtypes (secondary forest, mixed wood/bamboo forest, grass/shrub/scattered trees). Artificial vegetation includes: planted forests, rice, crops, fruit trees, and trees planted in residential areas.

2.2.2. Human ecological factors

2.2.2.1. Livelihood characteristics of ethnic groups

The population in 2020 is 130,218, of which 91.12% in rural areas, unevenly distributed among regions. The method of sedentary farming and settlement still depends largely on natural. In the center of the region, Van Yen is a stopping point for streams of migrants. Currently, Van Yen is home to 11 ethnic groups (Kinh 52.86%, Tay 15.58%; Dao 25.4%; Mong 4.43%, others 1.73%). The Kinh, Tay, Muong, and Nung live in village communities in lowland areas. Traditional livelihoods are raising livestock, growing wet rice, crops, fruit trees, industrial crops and planting forests for timber. Dao resides in the mid-lying areas. The main livelihood is agricultural production (cultivating low terraced fields along the hillsides, growing Cinnamon). Mong and other ethnic minorities reside in the highlands. The main livelihood is cultivating wet rice on terraced fields, planting forests, raising livestock, short-term industrial crops and medicinal plants.

2.2.2.2. Land use activities

The crop structure is oriented towards reducing the area of annual crops and increasing the area of perennial crops in ineffective rice and forest

growing areas. The production forest area in the period 2010-2015 increased due to conversion from unused land (reclaimed and improved land to grow Cinnamon), however in the period 2015-2020 it was due to conversion of a part of forest land of timber trees in lowland areas for other purposes.

2.2.2.3. Economic development activities

Economic development activities, specifically agro-foestry economics, have an impact on the landscape of Van Yen district through orienting the development of crop structure in the context of industrialization. The increasing proportion of the forestry industry in the context of a general decrease in the proportion of agro-forestry can see the role of Cinnamon trees in the economic structure.

2.3. Landscape structure

2.3.1. Classification system of landscape

Table 3.1. Van Yen district landscape classification system

No	Level	Criterias	Result
1	Class	The form of great terrain arises	(1) Mountain, (2) Hill
2	Sub-class	Surveying terrain morphology, climate and plant.	(1) High mountain, (2) Medium mountain, (3) Low mountain, (4) High hill, (5) Low hill, (6) Hilly valley
3	Type	Bioclimatology	(1) Evergreen closed forest, mixed species, cold and damp; (2) Evergreen closed forest, mixed species, cool and humid; (3) Hot and humid closed evergreen broad-leaved forest; (4) Hot, dry closed evergreen broad-leaved forest
4	Sub-type	Extreme bioclimatic characteristics	(1) Cold, lots of rain, long cold season, short dry season; (2) Cool and humid, lots of rain, slightly long cold season, short dry season; (3) Cool, average rain, average cold season, short dry season; (4) Hot and humid, lots of rain, average cold season, short dry season; (5) Hot and humid, average rain, average cold season, average dry season; (6) Hot and dry, little rain, short cold season, long dry season
5	Kind	Relationship between plant and soil	- 25 kinds
6	Form	Terrain forms and soil variations	- 92 forms

2.3.2. Landscape structure characteristics

- Mountain landscape class: are terrain types with an altitude of over 600m, of erosive - tectonic origin, with steep slopes from 15^{o} - 30^{o}. Exogenous processes occur strongly, mainly landslides, landslides, flash floods, washouts, and erosion. Composed mainly of blocky hard rock, erosional trenches and tectonic depressions are quite common. The mountain landscape class includes 3 sub-classes as follows: (*i) High mountain*: at altitudes above 1700 m, coniferous plant species of the Himalaya-Van Quy system appear, interwoven with broad-leaved tree species, forming a closed evergreen mixed forest with coniferous broad-leaved trees. and the closed, dwarf forest type with broad-leaved trees on the mountain tops dominates. (*ii) Medium mountain*: Distributed at altitudes of 1000 - 1700 m, landscape type is wet rice terraced fields, natural forests, secondary. (*iii) Low mountain*: Distributed at altitudes of 600 - 1,000 m, natural forest habitat with average reserves and poorer than the upper sub-layer, most of which have been exploited, planted forests and bamboo forests account for a large area.

- Hill landscape class: are denuded surfaces with an altitude of less than 600m, a slope of less than 15^{o}, and terrain in the form of soft hills or hill ranges. Terrain types originating from flows include sunken trough bottoms, erosion-accumulation terraces distributed along river valleys, streams... including 3 sub-layers as follows: *(i) High hill*: Distributed at altitudes of 300-600m, poor natural habitat, mainly myrtle, mutu, and shrubs. TTV agents of planted forests (Cinnamon, Bodhi), annual crops (Corn, Cassava). *(ii) Low hill*: is the transition from the mountains to the midlands, with an altitude of 50-300m. In addition to planted forests (Cinnamon), the majority of the area is artificial vegetation types (rice, crops and fruit trees, citrus trees). Natural forest habitat has been thoroughly exploited, only appearing where bedrock exists. *(iii) Hilly valley*: with elevations from 20-50m, natural forest habitat has been exploited for a long time, now only artificial vegetation remains. Secondary forests are only found in the Thia valley, contributing to water regulation for hydropower.

Landscape diversity at type and subtype levels due to fragmentation of mountainous terrain. As a result, there are 4 landscape types characterized by average annual temperature and rainfall indicators differentiated at the sub-class level; The 6 landscape subtypes are differentiated within the type level

according to the criteria of dry season length and cold season length. 92 landscape forms formed by human activities and ecological succession, are identified as the basic units for evaluation for development purposes..

2.4. Landscape ecological zoning

2.4.1. Principles and methods of landscape ecology zoning

Methods used in zoning the landscape ecology of Van Yen district include: method of general analysis of landscape maps and component maps, dominant factor analysis method and field survey method..

2.4.2. Characteristics and functions of landscape ecology sub-regions

- *Low hills and Red River valley landscape ecology sub-region group:* Divided into 3 sub-regions (I.1, I.2, I.3), formed from the terraces and mudflats of the Red river, Thia, Hut,... relatively flat, with high altitudes. Absolute height under 200m. Besides the function of producing agricultural energy, this sub-regional group performs the function of a political and commercial center and is a driving force for economic development.
- *High hills, low mountains landscape ecology sub-region group:* Divided into 6 sub-regions (II.1, II.2, II.3, II.4, II.5, II.6), formed on the erosion - erosion slopes of the Thia and Hut stream valleys. The hill topography includes an upside-down bowl shape, round top, gentle slopes, absolute altitude below 300m, and hill ranges made up of different rocks. The sub-region has economic development functions including: developing planted forests, developing farm-scale agroforestry models.
- *Pu Luong medium mountains landscape ecology sub-region group:* Divided into 2 sub-regions (III.1, III.2), with altitude > 500 m, distributed at the outer edge of Pu Luong mountain range (Phong Du Ha, Phong Du Thuong, Na Hau, Dai Son, Mo Vang) borders Van Chan district, Mu Cang Chai district... performs protection and conservation functions (Na Hau nature reserve).
- *Con Voi medium mountains landscape ecology sub-region group:* Divided into 4 sub-regions (IV.1, IV.2, IV.3, IV.4), with an altitude of > 300 m, distributed at the outer edge of the Con Voi mountain range (Lang Thip, Lam Giang, Quang Minh, Ngoi A, Yen Thai) bordering Luc Yen district Consists of consecutive mountain ranges, moderately divided, with relatively large slopes, with different high and low terraces. Functions of forestry production, providing forest products, and raising livestock.

CHAPTER 3. LANDSCAPE ASSESSMENT FOR THE SPATIAL ORIENTATION OF THE SUSTAINABLE AGRICULTURE AND FORESTRY DEVELOPMENT IN VAN YEN DISTRICT

3.1. Assessing landscape ecological adaptation

3.1.1. Scientific basis of assessment

Criterias have differentiation, important role, number of indicators depends on specific crop, omit units and limiting factors

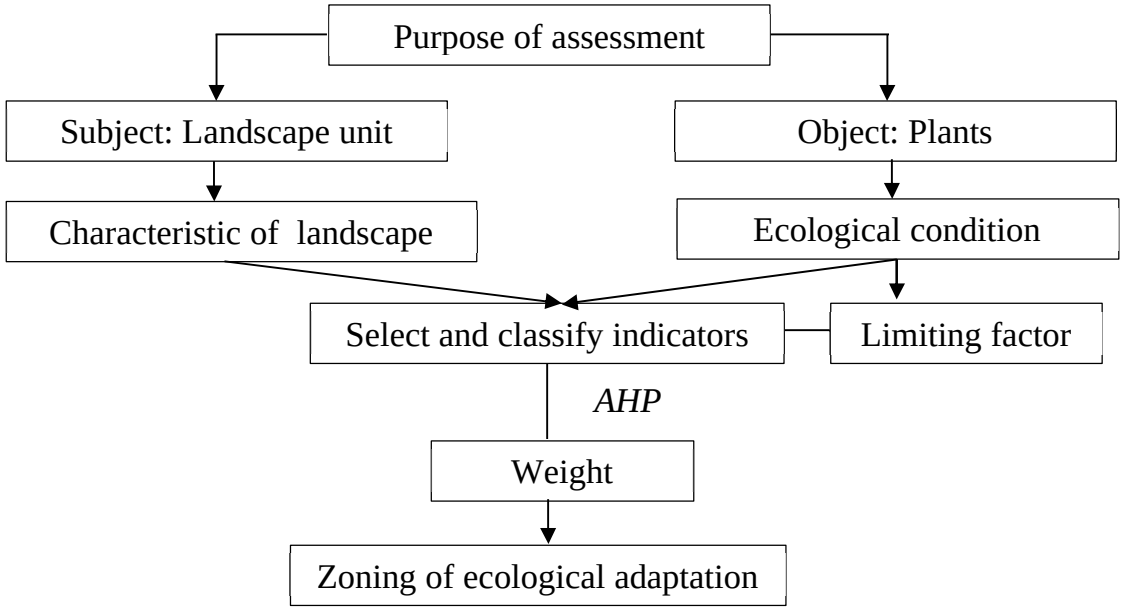


Figure 3.1. Chart of landscape ecological adaptation assessment process

3.1.2. Landscape assessment for agricultural development

Table 3.2. Indicator system for assessing ecological suitability of agricultural plants

No	Factor	Indicator	Weight	Suited level		
				Well suited	Suited	Less suited
1. Paddy	Climate	Rain fall (mm)	0,077	>1700	1500 - 1700	≤ 1500
		Dry months	0,029	≤ 2	3 - 4	≥ 5
	Soil	Type	0,160	Fp, Py	Fl, Pbe	Hs, Fa, Fs, Fq, D
		Slope (degree)	0,159	≤ 3º	3º -8º	8º -15º; >15º
		Depth (cm)	0,081	≥ 100	50 - 100	≤ 50
		Texture	0,051	Medium	Heavy	Light
	Irrigation	Irrigation	0,442	Active	Semi-active	Not irrigated
	Limiting factor			(1) Reserve forest, (2) Water body (3) resident land		
2. Annual crops	Climate	Rain fall (mm)	0,373	>1700	1500 - 1700	≤ 1500
		Dry months	0,176	≤ 2	3 - 4	≥ 5
	Soil	Type	0,245	Fp, Fl, Pbe, Py	Fs, Fq, D	Hs, Fa
		Depth (cm)	0,12	≥ 100	50 - 100	≤ 50
		Texture	0,048	Medium	Heavy	Light, mixed sand
	Topography	Slope (degree)	0,037	3º -8º	8º -15º	>15º
	Limiting factor			(1) Reserve forest, (2) Water body (3) resident land		
3. Perenial plants	Climate	Temperature (ºC)	0,197	>22	18-22	16-18
		Rain fall ((mm)	0,113	>2000	1500 - 2000	≤ 1500
		Dry months	0,03	3-4	<2	≥ 5

No	Factor	Indicator	Weight	Suited level		
				Well suited	Suited	Less suited
		Cool months	0,116	2-3	3-4	5-6
	Soil	Type	0,324	Fs, Fq, Fp, D	Fq, Fl, Hs, Fa	Pbe, Py
		Depth (cm)	0,145	≥ 100	50 - 100	≤ 50
	Topography	Slope (degree)	0,044	3º -8º	8º -15º	15º -25º
		Type	0,031	Valley, hill	High hill, medium mountain	High mountain
	Limiting factor: 1) Reserve forest, (2) Resident land, (3) Water body, (4) Temperature <16 ºC, (5) Cool months >6, (6) Slope >25 º					

Table 3.2. Results of landscape assessment for agricultural development

Type	Suited level	Landscape unit	Area (km^2)	Scale
Paddy	Well suited	50, 51, 54	23,04	1,66
	Suited	4, 6, 8, 37, 44, 46, 47, 49, 77, 79, 86, 87, 90, 91, 93, 94	212,55	15,29
	Less suited	10, 29, 35, 39, 55, 62, 68, 69, 74, 75, 78, 88, 89	57,91	4,17
Annual plants	Well suited	78, 79, 84, 89-91	52,56	3,78
	Suited	4, 6, 7, 29, 30, 31, 35, 36, 38, 47, 48, 49, 54, 55, 63, 67, 68, 69, 74, 76, 77, 80, 82, 87, 88	203,02	14,61
	Less suited	8, 10, 32, 33, 39, 40, 44, 45, 50-52, 58, 62, 66, 73, 75, 86	55,54	4,00
Perenial plants	Well suited	36, 47, 55, 61, 62, 67, 71, 78, 90	97,79	7,04
	Suited	30, 38, 39, 41, 51, 53, 54, 68-70, 75, 79, 80, 83, 84, 86, 88, 89, 91	276,19	19,87
	Less suited	5, 9, 10, 11, 12, 17, 22, 24, 26, 29, 32, 34, 35, 37, 40, 43, 44, 45, 46, 48, 63, 65, 66, 73, 81, 82	672,13	48,35

3.1.3. Landscape assessment for forestry development

Table 0.3. Indicator system for forestries of reserve, protection and production

No	Factor	Indicator	Weight	Suited level		
				Well suited	Thích nghi	Ít thích nghi
Reserve forest	Location	Location	0,27	Core zone	Buffer zone	Buffer zone
	Climate	Rain fall (mm)	0,041	>1700	<1700	<1700
		Temperature (°C)	0,032	<18	18-20	>20
	Topography	Type	0,16	High, medium mountains	Low mountain	Hill
		Slope (degree)	0,095	>35	25-35	<35
	Cover	Cover	0,40	Natural forest	Planted forests	Vegetation
	Limiting factor			(1) Outside Na Hau Nature Reserve		
Protection forest	Climate	Rain fall (mm)	0,152	>1700	1500-1700	<1500
	Topography	Type	0,501	High, medium mountain	Low mountain	High hill
		Slope (degree)	0,206	>35	25-35	15-25
	Soil	Type	0,043	Hs, Fa	Fs, Fq	Fl, Fp, D
		Depth (cm)	0,025	>100	70-100	<70
	Cover	Cover	0,072	Natural forest	Secondary forest	Planted forests
	Limiting factor: (1) Reserve forest, (2) Water body, (3) Agricultural land, (4) Non-agricultural land					
Production forest	Climate	Rain fall (mm)	0,21	>1700	1500-1700	<1500
	Topography	Type	0,083	Hill	Low mountain	Medium mountain
		Slope (degree)	0,108	8-15	15-20	20-25
	Soil	Type	0,049	Fs	Hs, Fa, Fq, Fl, D	Fp, Pbe, Py
		Depth (cm)	0,026	>100	70-100	<70
	Cover	Cover	0,526	Planted forests	shrubs, perennial	Annual plants
	Limiting factor: (1) Reserve forest, (2) Water body, (3) High mountain, (4) Rice, (5) Resident land					

Table 0.4. Indicator system for assessing ecological suitability of Cinnamon

Factor	Indicator	Weight	Sub-indicator	Weight	Suited level
Topographic	Elevation (ELV) *(Unit: Meters)*	0.161	200-500	0.659	S1
			<200, 500-1000	0.263	S2
			>1000	0.079	S3
	Slope (SLP) *(Unit: Degree)*	0.027	15-25	0.637	S1
			8-15	0.258	S2
			0-8; >25	0.105	S3
	Aspect (ASP)	0.020	Flat, South, West, Southwest	0.540	S1
			East, Northeast, Southeast	0.297	S2
			North, Northwest	0.163	S3
Climatic	Temperature (TEM) *(Unit: ^oC)*	0.079	20-22	0.600	S1
			>22	0.226	S2
			16-20	0.124	S3
			<16	0.051	N
	Rain (RAN) *(Unit: mm)*	0.105	>1700	0.661	S1
			1500-1700	0.272	S2
			<1500	0.067	S3
Pedologic	Soil (SOL) *(Unit: Meters)*	0.184	Fs, Fa	0.590	S1
			Fq, Hs, Fp, Fl	0.267	S2
			Py, Pb, Pbe	0.100	S3
			D	0.042	N
	Depth (DEP) *(Unit: cm)*	0.069	>100	0.707	S1
			50-100	0.223	S2
			<50	0.070	S3
	Texture (TEX)	0.057	Ligth clay	0.603	S1
			Medium clay	0.238	S2
			Loamy sand, Heavy clay	0.117	S3
			Sand	0.043	N
	Mixed rock (MXR) *(Unit: %)*	0.029	<15	0.598	S1
			15-35	0.243	S2
			35-55	0.105	S3
			>55	0.053	N
Fertilizer	(FER) *(Unit: mg/100g)*	0.087	High (>20)	0.644	S1
			Medium (10-20)	0.271	S2
			Low (<10)	0.085	S3
Land use and Land cover	LULC (LUC)	0.038	Open canopy	0.581	S1
			Plant tree, Closed canopy	0.260	S2
			Annual plant, Shrubs, Built	0.119	S3
			Bare soil, water body	0.039	N
Drainage	Drainage (DRA)	0.021	Good	0.699	S1
			Medium	0.237	S3
			Weak	0.064	N
Stream Density	Stream Density (SDI) *(Unit: km/km^2)*	0.036	High (35-112)	0.644	S1
			Medium (9-34)	0.271	S2
			Low (<9)	0.085	S3
Groundwater	Groundwater (GRW) *(Unit: Q.l/s)*	0.088	Rich (5-13)	0.696	S1
			Medium (3-5)	0.229	S2
			Poor (<3)	0.075	S3

Table 3.5. Results of landscape assessment for forestry development

Type	Suited level	Landscape unit	Area (km^2)	Scale (%)
Reserve forest	Well suited	1, 2, 3, 4, 6, 7, 10, 20, 22, 23, 25, 26, 29, 30, 31, 33, 60, 71, 72	128,6	9,3

Type	Suited level	Landscape unit	Area (km^2)	Scale (%)
	Suited	32, 37, 40, 44, 46, 48, 57, 83, 85, 86, 88	35,3	2,55
	Less suited	38, 47, 62	10,3	0,75
Protection forest	Well suited	1, 2, 3, 5, 6, 7, 10, 11, 14, 17, 24	103,6	7,45
	Suited	9, 12, 13, 15, 16, 29, 32, 34, 35, 37, 38, 58, 59, 61, 62, 64, 65, 66, 70, 71, 73, 74, 75, 77, 81, 83, 84, 88	306,1	22,02
	Less suited	26, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 52, 53, 55, 67, 69, 76, 78, 79, 82, 87, 91, 92	518,1	37,27
Protection forest	Well suited	5, 9, 12, 14, 17, 19, 22, 24, 26, 29, 32, 34, 35, 36, 37, 40, 42, 43, 44, 45, 47, 48, 49, 63, 65, 67, 69, 73, 74, 75, 77, 80, 81, 87	616,6	44,36
	Suited	38, 39, 41, 53, 52, 55, 68, 78, 89, 91, 92	118,42	8,52
	Less suited	4, 6, 8, 10, 30, 33, 51, 66, 76, 79, 83, 88, 90, 93, 94	210,31	15,13
Specialty forest (Cinnamon)	Well suited	21, 29, 34, 35, 37, 38, 40, 42, 43, 45, 47, 52, 60, 62, 67, 68, 69, 70, 74, 78, 80, 86, 87	362,84	26,10
	Suited	28, 31, 32, 41, 44, 49, 55, 58, 63, 64, 65, 66, 73, 75, 76, 81, 82, 88	424,58	30,55
	Less suited	5, 7, 9, 10, 12, 17, 18, 19, 20, 23, 25, 26, 51, 53, 79, 83, 84, 89, 90, 94	268,42	19,31

3.2. Forecasting landscape change

The forecast is made based on the multi-criteria evaluation model (MCE). The results of the model will create LULC change forecast maps until 2025 and 2030. The specific implementation steps are as follows:

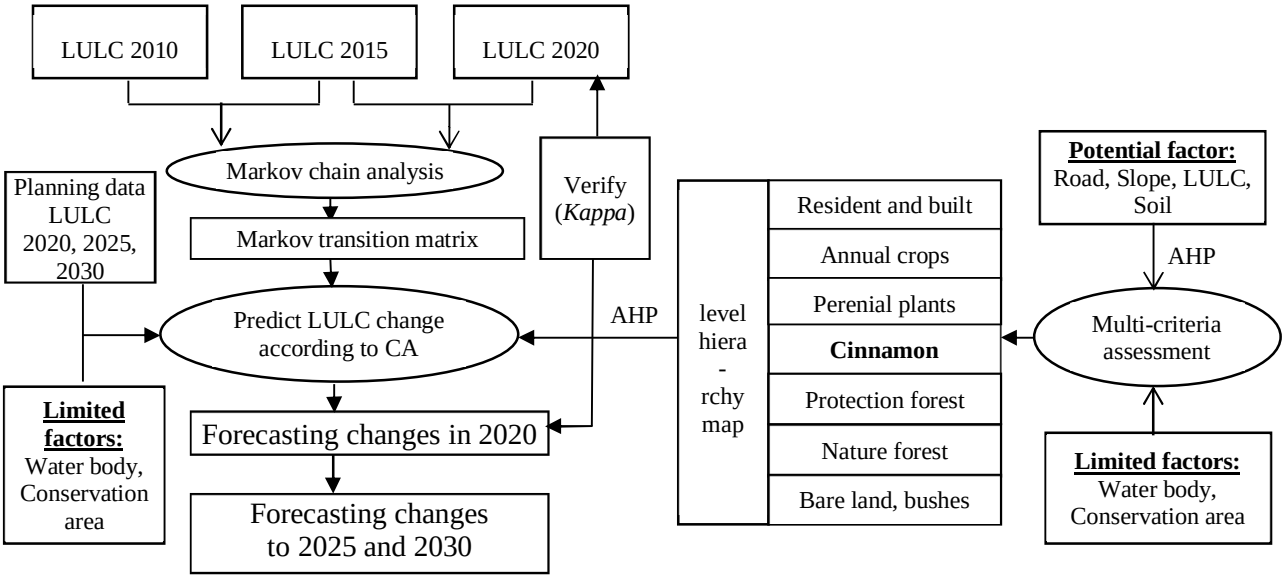


Figure 3.2. Chart of landscape change forecasting process

LULC change trend to 2025 and 2030: types of production forests, protective forests, water surfaces, bare land/shrubs tend to reduce conversion to other forms of land use such as Cinnamon, land construction and annual plants.

3.3. Spatial orientation for sustainable agro-forestry development

3.3.1. Priority space for agriculture and forestry development

Reserve forest: Na Hau nature reserve (1-7, 10, 19-22, 23, 25, 26-33, 37, 40, 44, 46-48, 57, 60, 71, 72, 83-86, 88), Protection forest (1-3, 7, 9-13, 15, 16, 19, 28, 29, 58, 59, 61-63, 65, 66, 70, 75), Specialty forest (Cinnamon) (28, 29, 31-35, 37, 38, 40, 42-49, 57, 59, 60, 64-71, 73-82, 88, 94), Protection forest (7, 37-39, 41, 47, 49, 57, 62, 66, 74, 78-81, 83-85). Perenial plants (29, 35-37, 39, 40, 48, 49, 55, 57, 62, 63, 67, 70, 74-80, 86, 88-90, 93, 94), Annual plants (38, 39, 48, 52-55, 57, 78, 79, 86, 87, 90, 92), Rice (47, 50, 51, 54, 56, 57, 91).

Table 0.6. Spatial orientation prioritizes development according to sub-regions

No	sub-regio-ns	Type of development (Km^2)							Priority space for development
		Forestry				Agriculture			
		RF	PF	SF	PDF	PP	AP	R	
I	**4. Low hills and Red river valley group**								
1	I.1			22,23	16,49		45,84	12,20	1- AP, 2- SF, 3- PDF, 4-R
2	I.2			31,62	1,82	11,70	44,96	10,82	1- AP, 2- SF, 3-R, 4-PDF
3	I.3			7,94	8,81	9,87	17,08	4,97	1-AP,2-PP,3-PDF,4- SF,5-R
II	**High hills, low mountains group**								
1	II.1		24,31	21,08	1,72				1- PF, 2- SF, 3-PDF
2	II.2			122,28	6,84	6,85	3,58		1- SF,2-PP, 3-PDF, 4-AP
3	II.3			101,95	11,39		1,89	0,30	1- SF, 2-PDF, 3-AP, 4-R
4	II.4			139,50	7,83	10,65	15,34		1- SF, 2-AP, 3-PP, 4-PDF
5	II.5			34,37					1- SF
6	II.6			72,27	8,21	1,21		0,66	1- SF, 2-PDF, 3-PP
III	**Pu Luong medium mountain group**								
1	III.1	173,7							RF
2	III.2		57,07		1,79				1- PF, 2-PDF
IV	**Con Voi medium mountain group**								
1	IV.1			70,46	4,75	7,89	2,28	1,44	1- SF, 2-PP, 3-AP, 4-L
2	IV.2		0,22	51,95	17,23	7,92	5	1,65	1- SF,2-PDF,3-PP,4-L,5-RPH
3	IV.3		2,45	31,33	3,11	7,49			1- SF, 2-PP, 3-PDF, 4-RPH
4	IV.4		79,32						1- RPH
Total		**160,1**	**178,78**	**565,07**	**90,0**	**35,95**	**96,71**	**33,38**	
Planning		**160,1**	**157,2**	**600**	**313,2**	**66**	**148**	**31,7**	

Note: RF-Reserve forest, RPH-Protection forest, Q- Specialty forest (Cinnamon), PDF-Production forest, PP-Perenial plants, AP-Annual plants, R-Rice.

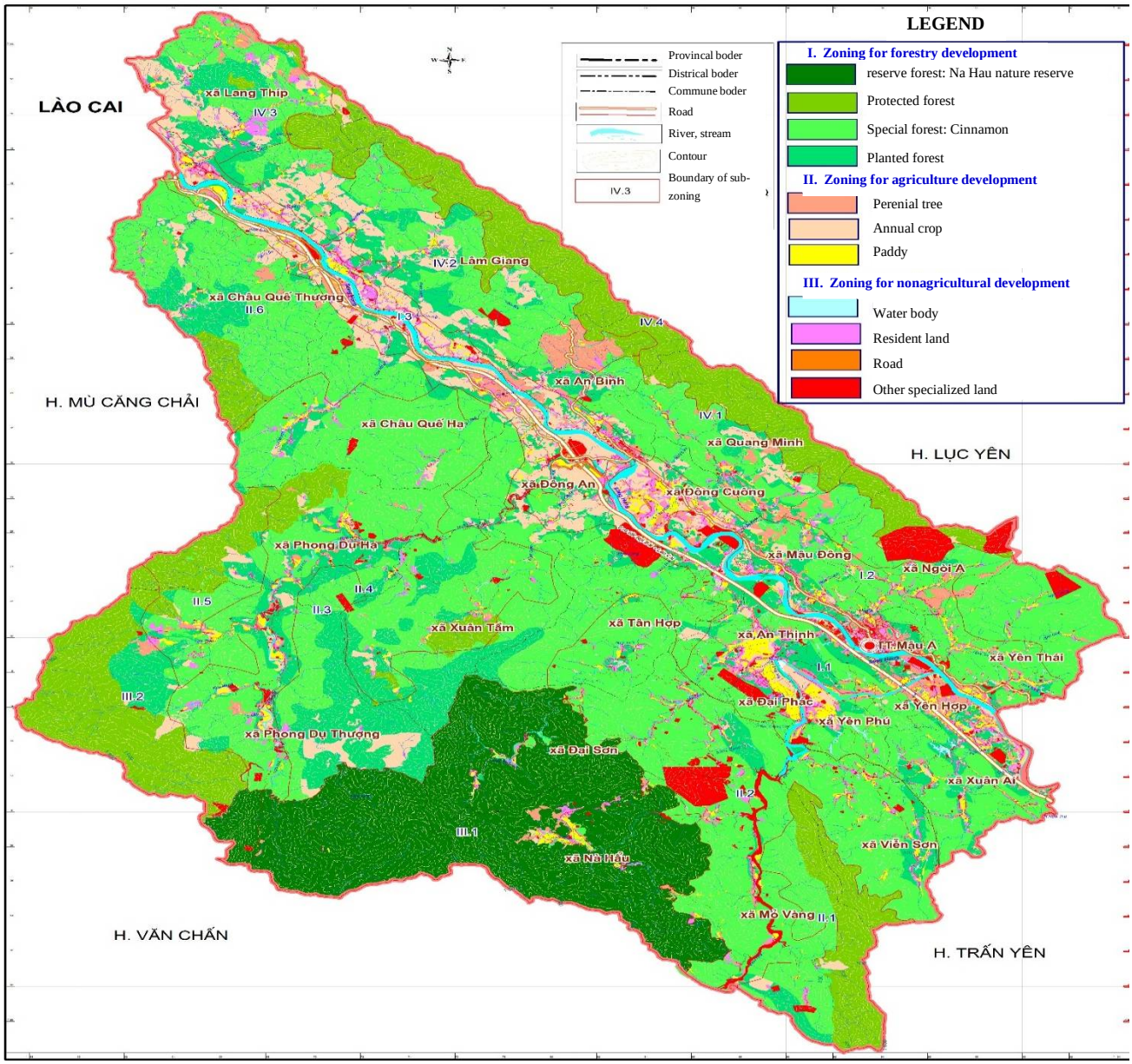


Figure 3.3. Map of spatial orientation for agriculture and forestry development

3.3.2. Proposed space for growing Cinnamon trees

From 2025 onwards, the area of Cinnamon land will expand nearly to the limit in the S1 region, expand rapidly in the S2 and S3 regions and begin to expand to land assessed as unsuitable. It is necessary to control the area in areas S1 and S2, limit expansion to areas S3 and not expand to area N.

Table 0.7. Statistics forecasting the expansion of Cinnamon growing areas

Year / Suited level	**Total area** *(km²)*	**Cinnamon growing areas** *(km²)*					
		2020		**2025**		**2030**	
		Diện tích	%	Diện tích	%	Diện tích	%
Well suited (S1)	**362,84**	289,55	*79,8*	310,99	*85,71*	339,47	*93,56*
Suited (S2)	**424,58**	85,13	*20,05*	178,92	*42,14*	259,97	*61,23*
Less suited (S3)	**268,42**	25,63	*9,55*	71,48	*26,63*	78,16	*29,12*
Not suited (N)	**334,16**			20,11	*6,02*	25,10	*7,51*
Total	**1.390**	**400,31**	***28,80***	**581,5**	***41,83***	**702,7**	***50,55***

In Van Yen, the three ethnic groups that own the most land for growing Cinnamon are Dao, Mong and Tay, corresponding to three characteristic groups of Cinnamon soil. Analysis of the B/C of growing Cinnamon shows that areas that are considered very suitable will bring the highest economic efficiency. On the contrary, areas with little adaptation will bring low economic efficiency due to longer recovery times.

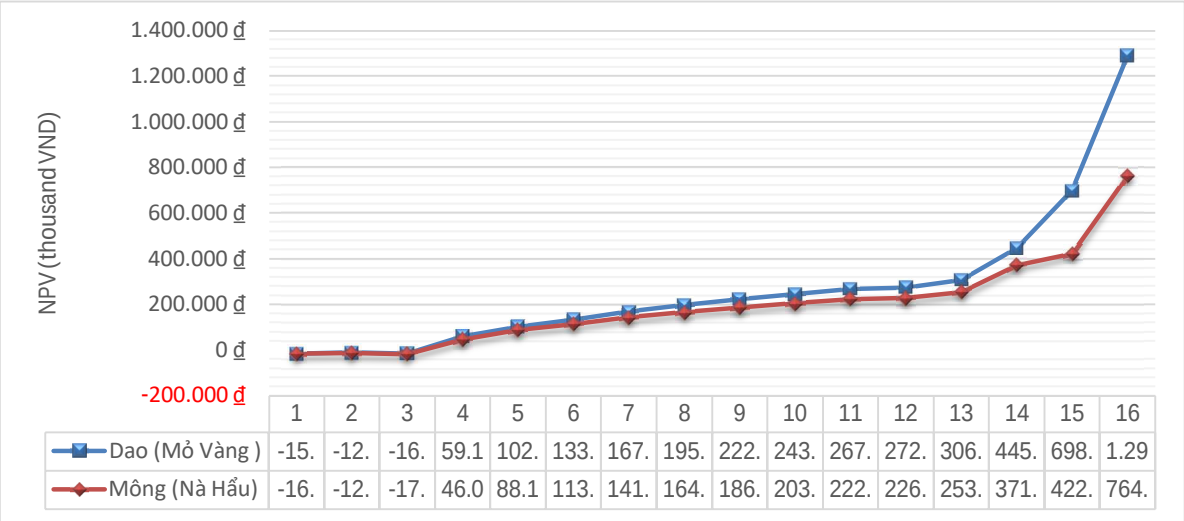


Figure 3.4. Net present value (NPV) of Cinnamon cultivation of ethnic groups

Propose space for cinnamon tree development until 2025 and 2030 on the basis of eliminating areas where the forecast results fall into less-adapted and unadapted areas. The deficit area after removal will be proposed to be developed into lands that are considered very suitable and suitable after deducting the planning for other types of forestry.

Table 0.9. Proposed space for developing Cinnamon trees until 2030

No	Communes /town	Total area	Status 2020	Total	Forecast 2025		Forecast 2030			Orienta-tion
					Keep	Remove	Total	Keep	Remove	
1	An Binh	36,2	3,8	13,9	9,5	4,4	18,0	12,2	5,8	16,7
2	An Thịnh	26,6	13,9	6,9	5,1	1,8	11,9	8,1	3,7	11,5
3	Chau Que Ha	86,7	46,5	39,6	38,0	1,6	51,6	47,5	4,0	62,7
4	C.Q.Thuong	75,6	2,6	36,6	28,7	8,0	43,4	34,1	9,3	47,8
5	Dai Phac	11,4	3,0	3,3	3,2	0,1	4,1	3,7	0,4	4,0
6	Dai Son	81,2	33,6	34,6	28,7	5,9	36,3	32,3	4,0	51,7
7	Dong An	40,3	10,7	7,5	7,0	0,5	11,6	9,5	2,1	13,8
8	Dong Cuong	21,2	2,1	1,7	1,5	0,2	4,1	3,0	1,1	4,6
9	Lam Giang	103,7	2,8	43,4	21,8	21,6	50,0	25,5	24,5	30,9
10	Lang Thip	75,8	11,2	25,9	14,7	11,3	35,1	16,5	18,6	24,6
11	Mau Dong	28,0	9,6	4,8	2,3	2,5	11,4	6,2	5,2	11,8
12	Mo Vang	99,6	46,7	56,8	43,1	13,6	55,2	46,1	9,1	68,9
13	Na Hau	56,4	5,6	0,3	0,2	0,1	0,1	0,0	0,0	12,4

No	Communes /town	Total area	Status 2020	Total	Forecast 2025		Forecast 2030			Orienta-tion
					Keep	Remove	Total	Keep	Remove	
14	Ngoi A	36,9	10,9	16,0	10,0	5,9	22,1	11,4	10,7	21,9
15	Phong.D.Ha	67,0	23,8	31,5	23,4	8,1	36,6	26,6	10,0	38,7
16	P.D. Thuong	195,2	21,3	54,3	28,4	25,8	61,8	34,4	27,4	54,4
17	Quang Minh	48,7	14,6	18,3	11,6	6,7	22,6	11,4	11,2	15,9
18	Tan Hop	62,9	26,2	43,8	40,5	3,4	50,2	44,3	5,9	47,1
19	TT Mau A	8,0	2,2	1,1	1,1	0,0	2,3	1,8	0,5	2,1
20	Vien Son	42,5	27,5	35,1	25,5	9,7	40,1	29,3	10,8	31,2
21	Xuan Ai	36,5	21,3	14,1	12,7	1,4	21,5	17,9	3,6	21,3
22	Xuan Tam	71,3	31,7	56,0	36,8	19,2	62,6	41,4	21,2	45,3
23	Yen Hop	17,9	3,6	4,2	4,0	0,2	6,4	5,2	1,2	8,0
24	Yen Phu	15,7	8,8	4,2	3,8	0,5	7,6	6,2	1,4	9,4
25	Yen Thai	45,0	16,2	27,3	27,3		35,8	34,8	1,0	40,5
	Total	**1.390,1**	**400,2**	**581,1**	**428,6**	**152,5**	**702,3**	**509,6**	**192,6**	**565,1**

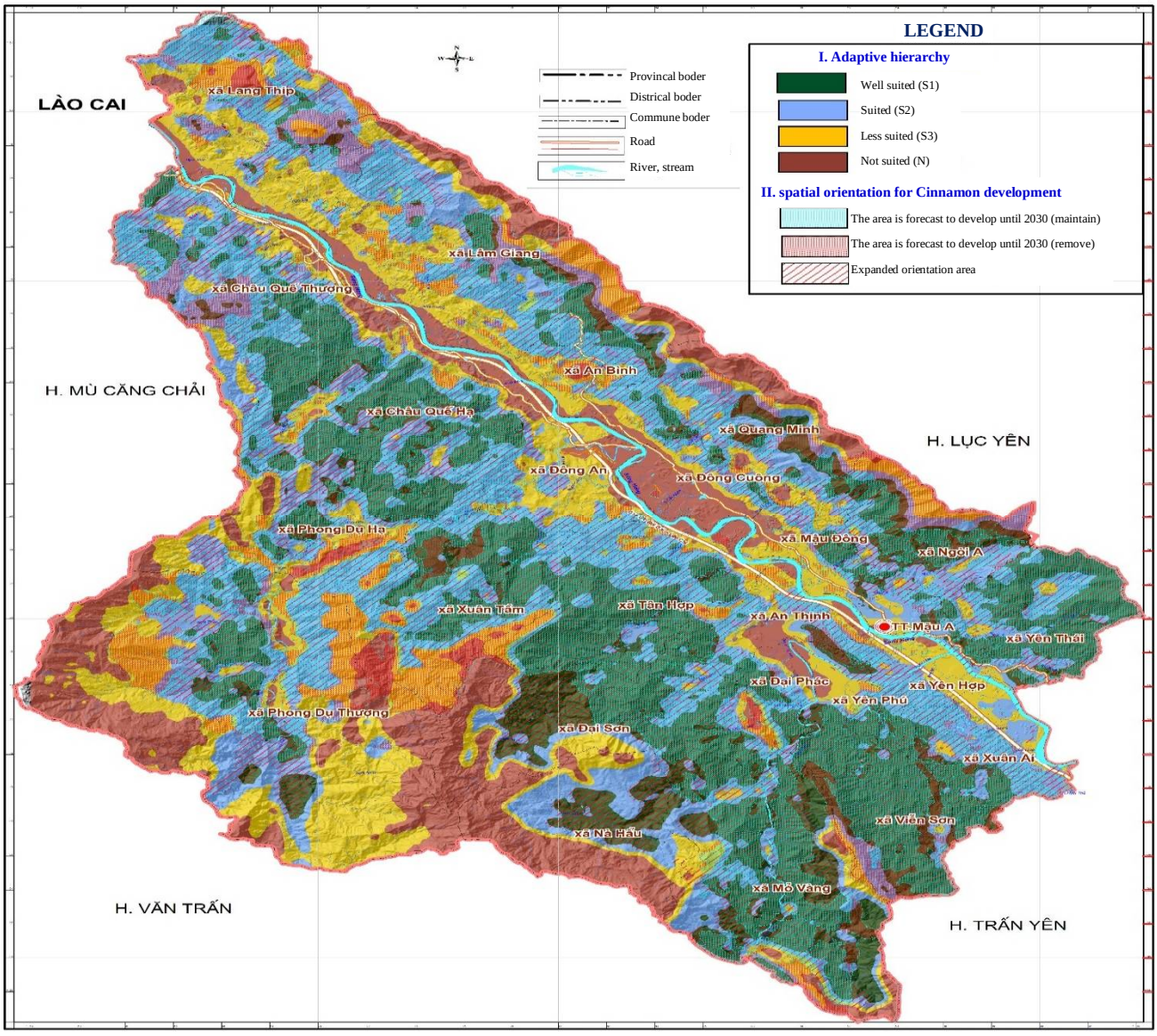


Figure 3.5. Map of spatial orientation for cinnamon development until 2030

3.4. Proposing solutions to sustainable agriculture and forestry development

3.4.1. SWOT analysis in landscape management to propose strategies for agriculture and forestry development

- Sub-region groups of low hills and Red river valley (S1)*:* The strengths and opportunities (S-O) factors group predominates. Specifically, the natural and socio-economic characteristics of the low-lying plain along the Red river provide strengths corresponding to favorable conditions for current agricultural productivity development. The sub-region's agriculture and forestry development strategy is to "***use strengths to exploit opportunities***" to serve sustainable agriculture and forestry development: (i) apply technical measures to convert and expand the area areas where strong agricultural crops are grown; (ii) Take advantage of resources and consumer market opportunities, propose to expand and build new facilities for primary processing and processing of agricultural products for consumption and export.

- Sub-region group of high hills, low mountains sub-region group (S2)*:* The strengths and challenges (S-T) factors group predominates. Specifically, the natural and socio-economic characteristics of the low mountainous area provide strengths corresponding to favorable conditions for current forestry development. Next, the challenges correspond to the difficult conditions faced when developing NLN in the future. The sub-region's human resources development strategy is "***using strengths to limit and prevent risks***". From there, limit risks and ensure stable and developed agricultural production activities: (i) Take advantage of the potential strength of land fund to expand Cinnamon growing area in appropriate areas. Proposing a strategy for auctioning land use rights for Cinnamon cultivation for a limited period in newly reclaimed areas. A portion of the auction proceeds will be used as a financial tool to serve the need for loans for Cinnamon planting of ethnic minorities who lack capital for production; (ii) Taking advantage of the Dao people's strengths in local knowledge to expand the area of organic cinnamon growing to reduce challenges related to soil environmental degradation, climate change and disease.

- Sub-region group of Pu Luong and Con Voi medium mountains (S3,4): Weaknesses and threats (W-T) factor group predominates. Specifically, natural and socio-economic characteristics have hidden weaknesses. Next, the challenge is related to low educational level, making it difficult to apply technology to production. The sub-region's forestry development strategy is to "***overcome weaknesses to limit risks***": (i)

Diversify livelihoods with agroforestry models; (ii) Universalization of education to improve the intellectual level of ethnic minorities; (iii) Upgrade infrastructure to reduce challenges in transporting agricultural products.

3.4.2. Analyze the factors of Pressure (P), Situation (S), Response (R) in agro-forestry production

3.4.2.1. Factors of Pressure

There are differences in Pressure factors (natural, socio-economic, policy) between the 3 ethnic communities in agro-forestry production: (i) for the Tay people, they are mainly affected by flash floods and extreme weather. epidemics, population growth, market prices and people using too much chemical fertilizer incorrectly; (ii) for the Dao people, the strongest impact is epidemics, prolonged drought, high poverty, and difficulty in transportation; (iii) for the Mong people, it is mainly due to the phenomenon of bad weather, severe cold, and because in higher areas, transportation is extremely difficult, the poverty situation has not improved much.

3.4.2.2. Factors of Situation

- Tay ethnic group: The land quality and environment of the Tay ethnic group is being degraded and lacks water in the dry season. The Tay ethnic people's sloping land farming systems have the potential to diversify cropping systems. However, the excessive expansion of cassava growing areas has reduced indigenous crop varieties, thereby making it difficult to convert crop varieties. The Tay people tend to apply modern science and technology in farming, contributing to the expectation of increasing income from agricultural production.

- Dao ethnic group: Dao ethnic group's cultivated land is degraded, lacks water in the dry season, and is washed away by erosion in the rainy season. There is potential to expand Cinnamon growing land, traditional farming practices apply and use indigenous knowledge in sloping land use.

- Mong people: In addition to the same problems as the Tay and Dao people, the Mong people's farmland is also fragmented, causing difficulties for production. The area inhabited by the Mong people has much potential to develop a combined forestry and agriculture system. It is necessary to increase the area of terraced fields to expand the area of cultivated land in sloping lands with difficulty in irrigation water sources, maintaining traditional farming methods.

3.4.2.3. Factors of Response

Ethnic / Solution	Tay	Dao	Hmong
Traditional	- Plant cover crops, rotate crops, overlap crops; - Use native varieties.	- Cultivation along contour lines; - Use native varieties	- Reclamation and construction of terraced fields; - Cultivation along contour lines
Land use	- Convert crop structure; - Reestablishing mountainous ecological agricultural systems in places with steep slopes.	- Reestablishing mountainous ecological agricultural systems; - Diversity of agricultural systems.	- Diverse highland ecological agricultural systems; - Develop combined agroforestry systems.
Policy	- People's participation in land use planning - Stabilize prices of agricultural output products	- People's participation in land use planning	- People's participation in land use planning
Technique	- Increase organic matter in the soil; - Crop rotation, intercropping	- Increase organic matter in the soil - Cover the soil	- Crop rotation and intercropping - Growing grass for livestock

CONCLUSIONS AND RECOMMENDATIONS

1. Conclution

1) Van Yen district's landscape is divided into 2 classes, 6 sub-classes, 4 types, 6 sub-types, 25 kinds and 92 forms. Based on the results of assessment, landscape change forecast, CBA analysis and planning reference, the thesis has provided directions for reasonable arrangement of agricultural energy production development space. Expansion of Cinnamon growing area into areas with little or no adaptation will inevitably occur, it is necessary to control a maximum of 565 km^2 (*40.6% of the natural area*).

2) SWOT analysis in landscape management has proposed agriculture and forestry development strategies for each sub-zonning. Delphi analysis of PSR factors has proposed priority solutions in using mountainous landscapes (*traditional, land use, policies, techniques*) suitable to the habitat of each landscape and customs of indigenous residents.

2. Recomendations

1) It is necessary to carry out comprehensive geographical assessment research to serve the development of sustainable agriculture and tourism. Detailed research down to a larger scale to move towards establishing a household-scale agroforestry system.

2) Choosing Cinnamon trees to research the value chain will increase sustainability. In addition, forecasting the expansion of cinnamon tree area needs to be conducted on a smaller scale to provide a scientific basis for managers in the process of making planning decisions.

NEW CONTRIBUTIONS OF THE THESIS

- **New point 1**: Integrating landscape landscape theory with quantitative geography model in structural analysis, function assessment, and landscape change forecast to serve spatial orientation to prioritize the development of agriculture and forestry in mountainous territories of Van Yen district, Yen Bai province.
- **New point 2:** Combining SWOT analysis and Delphi analysis of PSR factors in landscape management and use to propose strategies and priority solutions to sustainable agriculture and forestry development in Van Yen district, Yen Bai province

LIST OF THE PUBLICATIONS RELATED TO THE THESIS

1) **Ta Van Hanh**, Nguyen An Thinh (2016). *An application of SWOT-AHP to dertermine priorities of agro-forestry in Van Yen district, Yen Bai province*. Proceedings of the 9th National Geography Conference, Vol 1, p 1258-1264.
2) **Ta Van Hanh**, Nguyen An Thinh (2017). *Using Delphi technique to determine solutions for sloping land use in Van Yen district, Yen Bai province*. Human Geography Review, Vol 1, p 47-52
3) An Thinh Nguyen, Le Truc Nguyen, Hanh Hong Nguyen, **Hanh Van Ta**, Hong Van Nguyen, Tuan Anh Pham, Bich Thi Nguyen, Thao Thi Pham, Nhan Thi Thanh Tang & Luc Hens (2020). *Rural livelihood diversification of Dzao farmers in response to unpredictable risks associated with agriculture in Vietnamese Northern Mountains today*. Environment, Development and Sustainability, Vol 22, p 5387–5407.
4) Thinh An Nguyen, Bich Thi Nguyen, **Hanh Van Ta**, Nhung Thi Phuong Nguyen, Huong Thi Hoang, Quan Phung Nguyen & Luc Hens (2021). *Livelihood vulnerability to climate change in the mountains of Northern Vietnam: comparing the Môn*g *and the Dzao ethnic minority populations.* Environment, Development and Sustainability, Vol 23, p 13469–13489.
5) An Thinh Nguyen, **Van Hanh Ta**, Van Hong Nguyen, Anh Tuan Pham, Mélie Monnerat & Luc Hens (2022). *Shifting challenges for Cinnamomum cassia production in the mountains of Northern Vietnam: spatial analysis combined with semi-structured interviews*. Environment, Development and Sustainability, Vol 24, p 7213–7235.
6) **Ta Van Hanh**, Pham Quang Vinh (2023). *Integration of CA - Markov chain and AHP for predicting change of land use and land cover in Van Yen district, Yen Bai province*. Journal of Geodesy and Cartography, Vol 58-12, p 49-56
7) **Ta Van Hanh**, Nguyen An Thinh, Pham Quang Vinh (2023). *Assessment of landscape ecological adaptation for sustainable agricultural and forestry development in Van Yen district, Yen Bai province*. Human Geography Review, Vol 04, p 87-97.