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Nguyen Duc Thanh

**LAND ASSESSMENT STUDY IN NINH BINH AND HA
NAM PROVINCES TO SERVE THE LAND RESOURCE
REASONABLE USE AND ENVIRONMENTAL
PROTECTION**

**SUMMARY OF DISSERTATION THESIS ON
EARTH SCIENCES**

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Supervisors:

1. Supervisor 1: Assoc. Prof. Ph.D. Luu The Anh
2. Supervisor 2: Prof. Ph.D. Nguyen Manh Khai

Referee 1:

Referee 2:

Referee 3:

The dissertation is examined by Examination Board of Graduate University of Science and Technology, Vietnam Academy of Science and Technology at on 2024

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INTRODUCTION

1. The urgency of the dissertation

Reasonable and economical land use has become a strategy to maintain, promote, and restore soil health. Sustainable agricultural production requires improving ecological balance and soil nutrition, adjusting farming systems through reasonable land management, and following natural laws.

From 2010 to 2020, the average growth rate of Ninh Binh and Ha Nam reached more than 13 %/year, and agricultural production contributed an average of 9.87 %/year, followed by a change in land use structure. During this period, the area of agricultural land in the entire region decreased from 67,71% of the natural land area to 45,9%; the unused land area remained at 4,5% of the natural land area, which has shown that the land's potential has been exploited to the limit. As of December 2020, the area of degraded land in Ninh Binh is 46,778 hectares; Ha Nam is 45,474 hectares. The leading causes of land degradation are land exploitation and use, which are not based on land characteristics, which have reduced soil fertility, and the alternating appearance of limiting factors. Along with that, the intense competition between land used for agricultural and non-agricultural purposes is becoming increasingly complex, giving rise to environmental conflicts and causing degradation and waste of soil resources. The need to convert land used for agricultural purposes to non-agricultural land is becoming increasingly stronger and more complex, causing environmental conflicts such as degradation and waste of soil resources.

For the above reasons, a study of soil quality based on a comprehensive review, balancing land use purposes, improving and maintaining soil health, and protecting resources for the future is urgently needed for Ninh Binh and Ha Nam provinces. Therefore, this dissertation, titled " Land Assessment Study in Ninh Binh and Ha Nam Provinces to Serve the Land Reasonable Use and Environmental Protection," was implemented and completed.

2. Objectives of the dissertation

- Evaluate and identify factors that change the soil quality in Ninh Binh and Ha Nam provinces.
- Assess soil quality and agricultural land potential of Ninh Binh and Ha Nam provinces.
- Propose solutions to rationally protect and use land resources to develop sustainable agriculture in the Ninh Binh and Ha Nam provinces.

3. Main study contents of the dissertation

- To study the theoretical basis for assessing changes and spatial orientation for rational use of land resources.
- To assess agricultural land use changes in 2010 - 2020 in Ninh Binh and Ha Nam provinces and determine the causes.
- To assess agricultural soil potential and identify the main impacts that change soil quality in the Ninh Binh and Ha Nam provinces.
- To propose orientations and solutions for land use in Ninh Binh and Ha Nam provinces to 2050 based on analyzing the multi-criteria (MCE) system.

4. Study subjects and scope of the dissertation

- Study Subject: Agricultural production land of Ninh Binh and Ha Nam provinces
- Scientific scope: Agricultural production land serves the land resources' reasonable use.

Spatial scope: The study area is limited to the geographical coordinates from 19^o56'34" to 20^o55'33" North latitude and 105^o48'10" to 106^o11'11" East.

5. Defense argument of the dissertation

Argument 1: Agricultural land resources in Ninh Binh and Ha Nam provinces have been exploited to the limit, misusing land and leading to a decline in the quality of land resources.

Argument 2: Orientation for agricultural land use based on a combination of soil properties and factors that directly impact soil quality contributes to the reasonable use of agricultural land resources

in limited land area conditions.

6. List of new scientific contributions of the dissertation

- The change in soil quality and agricultural land potential in Ninh Binh and Ha Nam provinces has been clarified.

- Proposed directions and solutions for sustainable land use based on analyzing the multi-criteria (MCE) system for Ninh Binh and Ha Nam provinces to manage and use land reasonably in conditions of limited land area.

7. Scientific and practical significance of the dissertation

Scientific significance: The dissertation results provide the scientific basis for the rational, economical, and effective use of agricultural land to develop sustainable agricultural production.

- *Scientific significance:* The dissertation has studied in detail and combined sources of documents and data to evaluate the quality of soil types for the main crops in Ninh Binh and Ha Nam provinces as a scientific basis to supplement the land use scale of each crop towards the development of sustainable agricultural production. Gradually overcome limiting factors in the soil to protect the environment of arable land at risk of degradation in intensive farming.

- *Practical significance:* The dissertation results provide the basis for Ninh Binh and Ha Nam provinces to refer to the layout of crop production areas and develop agricultural land use plans. Refer to plan a program for using suitable fertilizers for each crop's main crops.

8. Documentation base of the dissertation

- *Reference and collected data:* Academic documents, published works, topics, projects, maps related to the study area, and dissertation content.

- *Actual survey documents and analysis data:* Actual survey documents and analysis data from projects that PhD students have directly participated in for many years in Ninh Binh, Ha Nam, and the Red River Delta region.

CHAPTER 1. OVERVIEW, THEORETICAL BASIS IN STUDY AND LAND ASSESSMENT

1.1. Overview

1.1.1. Land assessment serves reasonable land resource use and management.

Studying changes in soil properties is systematically concerned, based on spatial variations in soil health in different LUTs. Accordingly, land assessment evaluates changes in soil properties with changes in land use and provides a scientific basis for rational land exploitation and use.

FAO has developed and unified soil assessment principles and standards globally to serve as a basis for appropriate applications to evaluate and classify soil depending on specific conditions in countries and regions. Using separate parameters and small numbers of indicators to assess soil potential will not accurately reflect soil potential.

Establishing a common index framework to measure the relationship between agricultural ecosystems and the environment comprehensively is impossible. Based on the specific requirements and conditions of each region and territory, select criteria and levels of land assessment. FAO's assessment method considers the ability to protect, maintain, and improve soil productivity to create a new, stable, and reasonable productivity towards building sustainable agriculture.

1.1.2. Soil assessment according to FAO in the world and in Vietnam

1.1.2.1. Soil assessment in the world

A case study in Hubei province (China) established a comprehensive assessment framework for factors related to soil characteristics. It supplemented 12 socio-economic indicators to

assess land and form comprehensive land protection and use strategies. In 2014, land investigation and assessment were carried out at the district level in 34 provinces; In 2015, land surveys and inspections were carried out nationwide. The European Union (EU) uses the results of land assessment as a strategy to build and adjust policies to protect land. Indicators for soil quality are divided into physical, chemical, and biological soil properties. In the United States, five sets of criteria are used to assess soil in the short term, and three sets of indicators are used in long-term land assessment.

Evaluation methods based on the principles of land assessment proposed by FAO aim to optimally use soil resources and develop detailed land use plans to balance desires and limits of resources.

1.1.2.2. Soil assessment in Vietnam

Since the early 1990s, land evaluation and classification have been mandatory regulations in production organization and territorial planning. At the national level, the Institute of Agricultural Planning and Design has carried out land assessments nationwide based on five principles and four steps (10 TCN 343-98) as a basis for building an agricultural development planning map for the whole country during the period 1996 -2000, orientation 2010. At the regional level, Cao Liem (1992), Nguyen Cong Pho (1995), and Dao The Tuan (1995)... have implemented land assessment in the Red River Delta based on the decentralization of 4 indicators. General Department of Land Management - Ministry of Natural Resources and Environment (2012 - 2014 and 2017 - 2019), project DĐLCN.48/16 (2017 - 2019).

In Ninh Binh and Ha Nam, studies on land resources have begun to be conducted with interest since the 60s of the last century. The first document on land on a province-wide scale is the Soil Map

of Ninh Binh and Ha Nam provinces at a scale of 1/50,000, published in 1967. Institute of Agrochemical Soils (2000 and 2020); Institute of Agricultural Planning and Design (2016); Vu Van Thanh and others (2020)... conducted an assessment of soil quality, land potential, classification of agricultural soil, and assessment of soil degradation and pollution as a scientific basis to develop a plan for sustainable use of land resources.

In general, studies on land assessment in Ninh Binh and Ha Nam use the same set of indicators according to the instructions in Circular 60/2015/TT-BTNMT and TCVN 8409-2012. Therefore, it only reflects some of the study area's socio-economic factors and landscape characteristics, which are the leading causes of changes in agricultural soil quality.

1.2. Theoretical basis for reasonable land management and use and agricultural production practices in Vietnam.

1.2.1. Theoretical basis for reasonable land management and use

Soil is the origin/beginning of all life (Soul of Infinite Life). According to V. Nosik (2006), rational use of land resources is the scientific, comprehensive, and most suitable land use for the intended purpose. Rational use of land resources is also followed by mandatory compliance with agricultural scientific and technical systems, ensuring the maintenance and improvement of soil fertility while complying with the rules of behavior with natural resources and improving the environment for future generations.

The strategy of rational use of land resources towards sustainable goals comes from the desire to nurture land "land husbandry" and protect land while restoring and improving soil health. Reasonable land use is using land for the proper purpose within the allowable limits of resources, maintaining and protecting soil health,

and harmonizing socio-economic goals and environmental efficiency. Soil management and farming practices greatly influence soil health (Suman et al., 2006). Therefore, soil health needs to be maintained, protected, or restored through the implementation of appropriate land use and management measures and adherence to core principles of preserving, protecting, and improving soil health, including (i) Crop rotation and intercropping; (ii) Minimum tillage; (iii) Maximum land cover; (iv) Crop diversification and agricultural biodiversity.

Thus, reasonable land management and use protect, maintain, and improve soil health by arranging land use structures according to each ecological region's landscape characteristics and management goals, maintaining a positive balance system over time.

1.2.2. Agricultural production practices in Vietnam

From 1960 - 1980, agricultural production depended on exploiting the productivity of the land, and inorganic fertilizers were used insignificantly. During 1980 - 1986, the land allocation process was intentional, with fairness given priority (Southern provinces did not consider this factor). This process has led to the fragmentation of land structure, and policies on land management practices in agricultural production are not respected. From 1990 to 2000, the farmland area expanded mainly due to the conversion of forest land into agricultural land. Environmental pollution, land resource degradation due to intensive farming, and overuse of inorganic fertilizers in agricultural production are starting to become "problems" for Vietnam. This period marked the beginning of the transition from expanding production to improving quality and efficiency.

From 2001 to 2010, the agricultural production system was maximized to concretize the agricultural strategy as the main driving force for socio-economic development. During this period, increased productivity contributed over 80% of the output; the remaining 20%

was due to increased area. Farmers must give up 74,000 hectares of agricultural land each year for industrial, urban, and infrastructure development (Ministry of Agriculture and Rural Development, 2010). From 2010 to the present, it has been recognized that inappropriate farming systems and land use planning are leading causes of environmental pollution and land resource degradation. Strategies related to land use during this period have further emphasized the rationality of land use and management and the sustainable land use practices applied to minimize land resource degradation in the context of climate change.

1.3. Research approach and methods

1.3.1. Research Approach

Systematic and integrated approach: Land resources are recognized as a complete natural synthesis in the organic relationship between arising factors and farming level, institutions, and policies. Consider the Agricultural ecosystem in a systematic, integrated relationship with landscape ecological characteristics and human factors.

Historical-perspective approach: Soil health is closely related to land exploitation and use history. Soil is a complete natural entity, constantly changing (ecological succession). Applying the historical-perspective approach method can analyze, evaluate, and clarify developments in land resources in the past and present and predict future development trends.

Ecosystem approach: The ecosystem approach is a strategy for integrated management of land and water resources and other natural resources to protect and use them reasonably and equitably. The approach requires that human decisions in exploiting and using land resources be appropriate and harmonious with culture and the environment, especially in maintaining and protecting soil health.

Sustainable development approach: In Ninh Binh and Ha Nam, ecosystems show signs of degradation and inadequacies in natural resource management and land resource use. Therefore, the

sustainable development approach is one of the main approaches used in this Ph.D. thesis.

1.3.2. Methodology

The methods used in the thesis include inheriting and synthesizing documents, investigation, field survey, soil analysis, economic efficiency assessment, multi-criteria evaluation (MCE), mapping-remote sensing, and determining fertilizer amount.

The study process includes steps: Step 1: Planning and building a scientific basis and methodology; Step 2: Assessing land resources; and Step 3: Proposing orientations and solutions for reasonable use of agricultural land.

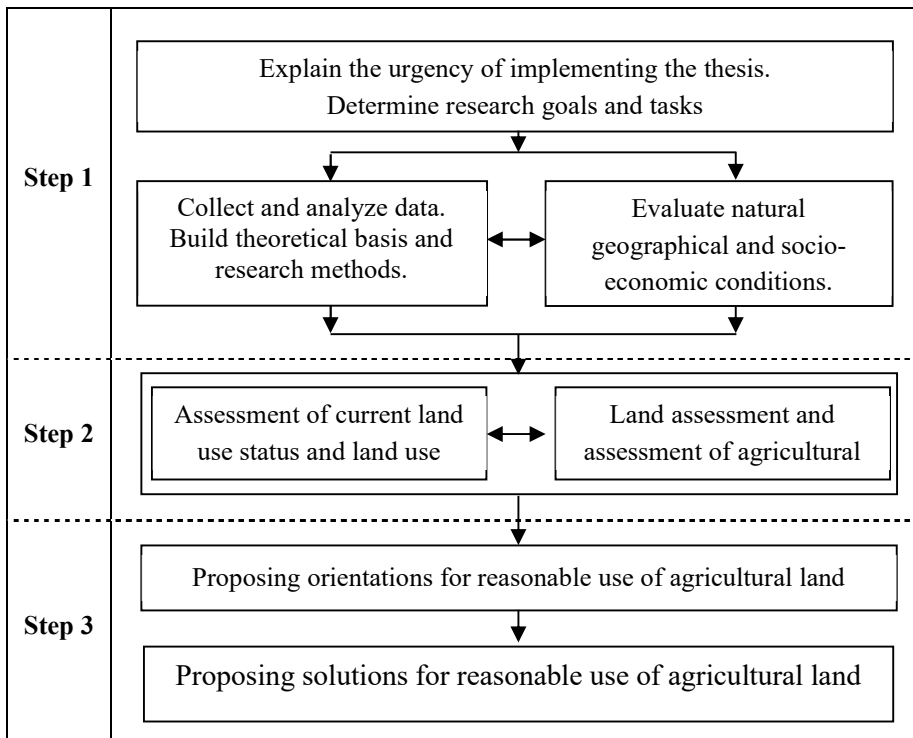


Figure 1.1. Study process

CHAPTER 2. CHANGES IN AGRICULTURAL LAND USE AND LAND RESOURCES IN NINH BINH AND HA NAM PROVINCE

2.1. Factors affecting the changes in agricultural land

2.1.1. *Natural elements*

Geographic location: The research territory is the southern gateway of the Northern coastal region, connecting with the Northwest and North Central regions. Located in the critical economic area of the Red River Delta, influencing and being influenced by the Capital region, the development triangle of Hanoi - Hai Phong - Quang Ninh, the development quadrilateral of Hanoi - Hai Phong - Quang Ninh - Thanh Hoa and is a growth pole of the Thai Binh - Nam Dinh - Ninh Binh maritime economic corridor.

Geology: In the research territory, the oldest sediments are Paleoproterozoic, exposed in a narrow area at An Lao Mountain (Ha Nam), Ho Hill, and Co Hill (Ninh Binh). Paleozoic sediments do not appear; Mesozoic sediments are west of the study area, and the remaining are Cenozoic sediments, including Quaternary accumulations of the Thai Binh and Hung Yen formations. Surface sediments in the study area mainly include sediment types such as sand, sand silt, muddy sand, silt, and clay interwoven, formed by materials transported by the Red River and Day River, only a tiny part from neighboring areas.

Terrain - Geomorphology: Inheriting the geological structure and clearly showing the imprints of sea transgressions forming bare bedrock mountains, limestone weathering product accumulation valleys, surfaces humus accumulation limestone mountains... Most of the study area shows the morphology of the Holocene transgressions and regressions in coastal marine environments or sediment-deficient bays. Natural development history with riverbank sedimentation and human impact forming dikes and roads, creating local depressions

forming low-lying areas in the field. It can be divided Ninh Binh - Ha Nam into 02 terrain types as follows: (I) The Red River and Day River Delta includes 03 sub-regions: highland delta sub-region, lowland delta sub-region, and coastal plain sub-region; (II) Western mountainous region. The mountainous areas in the west of the study area have low altitudes. They are not the dominant factor in the entire region's climate but can only form a sub-climate region that is relatively different from the plains.

Climate: The study territory is a tropical monsoon climate with cold winters. Due to the impact of atmospheric circulation, anomalies in climate and weather, such as cold and wet rain, are considered a variation of the tropical climate, forming an interleaved cold, wet winter. Based on the spatial differentiation of temperature and precipitation, divide the research territory into 02 sub-regions, specifically: (i) Sub-region 1: Average annual temperature $\geq 23^{\circ}$; Rainfall $\leq 1,800\text{mm}$ (85 - 90% of the study territory). (ii) Sub-region 2: Average annual temperature $< 23^{\circ}$; Rainfall $> 1,800\text{mm}$ (10 - 15% of the study territory).

Hydrology—oceanography: The average river density of Ha Nam is 0.25 km/km^2 and Ninh Binh is 0.5 km/km^2 . Surface runoff from the Red River, Day River, and Nhue River annually brings about 14,050 billion m^3 of water into the territory.

The Red River and Day River are the leading irrigation axes of the study territory. Water and alluvial materials of the Red River are supplied through irrigation drains running through the Ha Nam and Nam Dinh Rivers (Dao River). Alluvial materials from the Red River are also provided during flood years through the Day River. Ninh Binh has a coastline of over 15 km long, mainly diurnal regime; the Kim Son mudflat is being accreted at the fastest rate in Vietnam due to the addition of a large amount of material from the Ba Lat estuary to the Day and Can estuary.

Vegetation: The primary vegetation in the area is a type of closed evergreen tropical humid forest that grows entirely on limestone, so it is identified as a particular soil subtype on limestone. Mangrove forests are only distributed in narrow strips in the coastal area of Ninh Binh (from the Lach Can estuary to the Day River estuary). The artificial ecosystem imbued with the humanity of the Northern Delta wet rice civilization includes mainly rice growing areas (one crop or two crops) distributed primarily in dikes and land for growing vegetables or trees. The short-term industrial tree is mainly distributed outside the dyke.

2.1.2. Socio-economic factors

Labor: As of December 2020, the labor force working in agriculture is around 48,9% of the total working-age population. Qualified agricultural workers are only 0,65% of the total rural workers. Agricultural workers are still the majority, but the low rate of skilled farm workers will hinder the process of economic structural transformation and the application of science and technology to agricultural production.

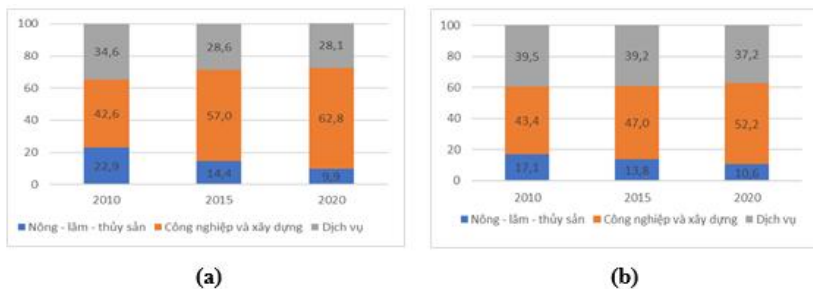


Figure 2.1. Structure of production value in Ha Nam (a) and Ninh Binh (b) in the period 2010 - 2020

Economy: During 2010 - 2020, the study area had an average growth rate of 9.6%/year. The proportion of the agricultural sector decreases by an average of 3 - 5 %/year. The average annual growth rate of production value of the agriculture, forestry, and fisheries

sectors is maintained at 10 - 15 %/year. Within the agricultural industry, the proportion of the entire region's crop sector accounted for 80,8% (in 2010) and decreased to 52,7% (in 2020). The trend of restructuring within the agricultural industry is shifting based on promoting land's potential, advantages, and strengths to increase product value.

Urbanization: The ratio of urban land area increase to population growth in Ha Nam is 1,24 times, and Ninh Binh is only 1,09 times, equal to 50% of the average level of the Red River Delta. Thus, Ha Nam and Ninh Binh are two provinces in the Red River Delta. The development speed needs to catch up with the pace of urbanization, leading to urban ruralization and waste of agricultural land.

2.2. Characteristics of land resources

In the research territory, 22 soil types belong to 09 soil groups. The alluvial soil group is the largest area, 147.254,14 hectares (65,48% of the natural area); The yellow-red soil group is an area of 26.876,42 (11,95% of the natural area); The saline soil group is 4.295,42 hectares (1,91% of the natural area); the alum soil group is 107,46 hectares (0,05% of the natural area); the marshy soil and peat soil group is an area of 653,81 hectares (0,29% of the natural area), black soil group is an area of 1.829,36 hectares (0,81% of the natural area), gray and infertile soil group is an area of 2.372,28 hectares (1,05% of the natural area); valley soil group is an area of 139,11 hectares (0,06% of the natural area); the group of eroded and rocky soil is an area of 672,91 hectares (0,3% of natural area).

Feralit is a typical process for low mountainous areas in the study area, forming yellow-red soils. Intense weathering of metamorphic rocks on limestone bedrock has formed a soil layer up to 2 - 3m thick (Ba Sao, Dong Giao). The feral process makes the soil acidic, with low alkalinity saturation, rich in mobile iron and

aluminum. The feral process at a mild level will form red-yellow variegated spots or soft red-yellow conglomerates (plinthic characteristic). The impact of the low rainy season, along with low groundwater levels, has promoted the formation of iron and manganese conglomerates in the western mountains of the study area, revealing a solid laterite layer in the Kim Bang area (Ha Nam), Nho Quan (Ninh Binh).

In the delta of the study area, the alluvial deposition process depends mainly on the operating regime of the Red River system formed in the late Holocene system (Q_1^{5-3}). In the center of the study area, local depressions formed during transgressions and regressions under conditions of sediment deficiency exist. This process takes place over a long period, along with human activities that have changed the original soil properties and differentiated the surface morphology.

Vertical leaching is dominant in the research area and is distributed according to non-geographical rules. This process results in the arable layer (topsoil) becoming poor in structure and nutrients and accumulating ions that cause acidic reactions: H^+ , Al^{3+} , and Fe^{3+} . The Gley process commonly occurs on alluvial, valley, and boggy soils. Due to anaerobic decomposition, soil often loses structure, is compact, and contains many elements that are toxic to plants.

The saltwater overflow process in the study area no longer occurs; it is only salinized due to the influence of the underground water level. Many areas of medium and low salinity land in Ninh Binh have reduced salinity through reclamation and use, so they have been classified as alluvial land.

2.3. Status and changes in land use

Status in land use: As of December 31, 2019, the two provinces of Ha Nam and Ninh Binh have exploited and put into use for different purposes 216.551,9 hectares (96,3% of the entire region's natural area); Unused land is about 8.302,5 hectares (3,7% of the

whole region's natural area). Of which, unused flat land is only 4.142,5 hectares, unused hilly land is 1.235,7 hectares (0,55% of natural area), and rocky mountains without forests are 2.942.3 hectares (1,31 %).

Changes in land use: During 2010 - 2020, rice land decreased by 2,13% from 36,66% in 2010 to 34,53% in 2019, Of which Ninh Binh decreased by 0,78%, and Ha Nam decreased by 4,29%. Land for other annual crops increased by 0,15%, of which Ninh Binh decreased by 0,49% while Ha Nam increased by 1,19%. Land for perennial crops increased by 0,45%, Ninh Binh increased by 1,04% while Ha Nam decreased by 0,50%). Aquaculture land increased by 0,4% (Ninh Binh increased by 0,77% while Ha Nam decreased by 0,22%); Other agricultural land increased by 0,63% (Ninh Binh increased by 0,1% and Ha Nam increased by 1,5%). Production forest land increased by 0,51% (Ninh Binh increased by 1,17% while Ha Nam decreased by 0,55%); Protective and special-use forest land decreased by 1,03% and 0,09%.

2.4. Quality and potential of agricultural land

2.4.1. Surface soil fertility

Use the fuzzy set method (Fuzzy Analytic Hierarchy Process - FAHP) in Arc to interpolate 08 layers of information about agrochemical indicators (pH_{KCL} , OC%, N%, total P_2O_5 , total K_2O , digestible P_2O_5 , easily digestible K_2O , CEC) based on the hierarchy of each indicator. The result is a combination of 180 map units containing eight agrochemical characteristics.

Highly fertile land is an area of 78,127.51 hectares, accounting for 59,14% of urban area and 34,74% of natural area (Ha Nam is 42.506,20 hectares, equivalent to 84,32% of urban area; Ninh Binh is 35.621,31 hectares, equivalent to 62,51% of metropolitan area). Land with average fertility is an area of 49.642,06 hectares, equivalent to 37,58% of the urban area and 22,08% of the natural area (Ha Nam is 7.667,77 hectares, and Ninh Binh has 41.974,29 hectares).

Land with low fertility is an area of 4,330.03 hectares, accounting for 3,28% of the urban area and 1,95% of the natural area (Ha Nam is 233,79 hectares while Ninh Binh is 4.096,24 hectares).

Table 2.1. Statistics of surface soil fertility area according to hierarchy

N	Province	Classification of surface soil fertility			Investigated area	Non investigated area
		Low	Average	High		
1	Ha Nam	233,79	7.667,77	42.506,20	50.407,76	35.785,65
2	Ninh Binh	4.096,24	41.974,29	35.621,31	81.691,84	56.987,17
	Total	4.330,03	49.642,06	78.127,51	132.099,60	92.772,82
	Rate (%)	3,28	37,58	59,14	100,0	

2.4.2. Soil quality

Based on the ecological requirements of 4 crop groups, essential soil factors (soil type, topsoil fertility, gley depth), relative terrain, and cultivation were selected to create a map of soil quality in the study area. The results show that Ninh Binh and Ha Nam have 122 soil quality units with different characteristics.

High-quality soil is 58.489,31 hectares, equivalent to 44,28% of the urban area and 26,01% of the natural area (Ha Nam is 35.938,27 hectares, equivalent to 41,69% of the natural area; Ninh Binh is 22.551,05 hectares, equivalent to 16,26% of the natural area). Average land quality is 62.388,12 hectares, equivalent to 47,23% of the urban area and 27,24% of the natural area (Ha Nam is 11.089,08 hectares, equivalent to 12,87% of the natural area; Ninh Binh is 51.299,04 hectares, equivalent to 36,99% of the natural area). Low-quality land is only 11.222,16 hectares, equivalent to 8,5% of the urban area and 4,99% of the natural area (Ha Nam is 3.380,42 hectares, equivalent to 3,92% of the natural area; Ninh Binh is 7.841,74 hectares, equivalent

to 5,65% of the natural area)

Table 2.2. Results of soil quality assessment

N	Province	Classification of soil quality			Investigated area	Non investigated area
		Low	Average	High		
1	Ha Nam	35.938,27	11.089,08	3.380,42	50.407,77	35785,65
2	Ninh Binh	22.551,05	51.299,04	7.841,74	81.691,83	56987,17
	Total	58.489,31	62.388,12	11.222,16	132.099,60	92.772,82

2.5. Potential of agricultural production soil

Soil with high potential is an area of 31.331,8 hectares (27,55% of the investigated area). Soil with average potential is an area of 78.889,7 hectares (69,36% of the investigated area). Land with low potential is a total area of 3.512,7 hectares (3,09% of the investigated area).

Table 2.3. Soil potential level

N	Level division	Total		Ninh Binh	Ha Nam
		Area (ha)	Rate (%)		
1	High potential	31.331,8	27,55	22.206,0	9,125,8
2	Average potential	78.889,7	69,36	45.924,9	32.964,8
3	Low potential	3.512,7	3,09	1.987,1	1.534,6
	Investigated area	113.734,2	100,00	70.109,0	43.625,2
	Non investigated area	111.138,2		68.570,0	42.568,2
	Natural area	224.872,2		138.679,0	86.193,4

The area of agricultural land (including unused land) in Ninh Binh - Ha Nam is 113.734,2 hectares (Ninh Binh is 70.109,0 hectares; Ha Nam is 43.625,2 hectares). Rice land is 77.648,9 hectares (68,27% of the investigated area); Annual cropland is 17.042,4 hectares (14,98% of the investigated area); Land for perennial crops and fruit trees is 19.042,9 hectares (16,74% of the investigated area).

CHAPTER 3. PROPOSAL SOLUTIONS FOR REASONABLE LAND USE

3.1. Development Orientation

Ly Nhan, Binh Luc, Gia Vien, Yen Khanh, and Kim Son districts are essential for concentrated, commercial agricultural development.

- Duy Tien town, Thanh Liem, Nho Quan, and Yen Mo districts develop peri-urban agriculture combined with preserving and processing agricultural products.

The Kim Bang, Hoa Lu, and Tam Diep districts develop agriculture combined with tourism and services; ecological agriculture serves tourism.

Phu Ly City and Ninh Binh City are developing agriculture in the direction of urban agriculture, which means the scale is small but mainly typical models applying science and technology.

3.2. Orientation for rational use of land

3.2.1. Factors affecting sustainability in land use

The economic factor (profit) has the most significant impact ($WKT = 0,68$), directly influencing the decision to maintain or change the land use types of people in Ninh Binh and Ha Nam. Social factors are the second most influential ($WXH = 0,19$), and environmental factors have the lowest level of impact ($WMT = 0,12$).

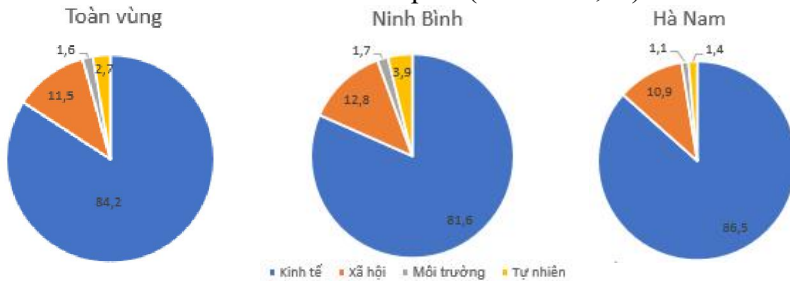


Figure 3.1. The influence of each factor affecting the sustainability of agricultural land use in Ninh Binh and Ha Nam

3.2.2. Land use orientation until 2050

Based on the results of soil quality assessment, soil suitability assessment, and soil classification, and at the same time refer to government agriculture development planning for agriculture, forestry, and irrigation in Ninh Binh, Ha Nam, and the Red River Delta region to 2050, agricultural land use orientation to 2050 is proposed with 101,580.3 hectares, equivalent to 42,75% of the natural area. Ninh Binh and Ha Nam's agricultural land structure is 42,12% of the natural area (down 1,83% compared to 2020) and 43,76% (down 3,39% compared to 2020).

Agricultural production land: The area of agricultural production land to 2050 is 96.127,30 hectares (42,75% of the natural area), down 5.453 hectares compared to 2020 (Ha Nam decreased by 2.921 hectares and Ninh Binh decreased by 2.532 hectares). In which:

- *Rice land:* Proposed to stabilize 66.979 hectares of rice land (Ha Nam is 27.545 hectares and Ninh Binh is 39.434 hectares), equivalent to 29,79% of natural area, down 10.669,9 hectares compared to 2020.

- *Land for other annual crops:* The proposed land area to 2050 for other annual crops is 14,918 hectares (Ninh Binh is 8,356 hectares; Ha Nam is 6,562 hectares), equivalent to 6,63% of natural area, an increase of 4.045,8 hectares compared to 2020 (Ha Nam increased to 1,791.8 hectares and Ninh Binh increased by 2,254 hectares).

Land for perennial crops: The proposed land area for perennial crops to 2050 is 14.230 hectares (Ha Nam is 3.611 hectares, and Ninh Binh is 10.619 hectares), equivalent to 6,33% of natural area, an increase of 1.170,8 hectares compared to 2020 (Ha Nam increased to 227,8 hectares, and Ninh Binh increased to 943 hectares).

Aquaculture land: The proposed aquaculture land area to 2050 is 12.869 hectares (Ha Nam is 5.309 hectares and Ninh Binh is 7.560 hectares), equivalent to 5.72% of the natural area, increasing to

1.459,4 hectares (Ha Nam increased by 659,4 hectares and Ninh Binh by 764 hectares).

Other agricultural land: The proposed other agricultural land area to 2050 is 3.199,7 hectares (Ha Nam is 1.905 hectares and Ninh Binh is 1.294,7 hectares), equivalent to 1,42% of the natural area, increasing to 1.172 hectares (Ha Nam increased to 213,3 hectares and Ninh Binh increased to 958,7 hectares).

- *Non-agricultural land:* The proposed non-agricultural land area for 2050 is 73.521 hectares (Ha Nam is 34.393 hectares and Ninh Binh is 39.128 hectares), which increased to 5.333,1 hectares compared to 2020 (Ha Nam increased to 2.176,1 hectares and Ninh Binh increased to 3.157 hectares)

- *Unused land:* Proposed to put 2.707 hectares of unused land (Ha Nam 176 hectares and Ninh Binh 2.531 hectares) into exploitation and construction for different purposes.

Table 3.2. Proposal for land use conversion in Ninh Binh and Ha Nam provinces until 2050

LUTs	Curent status (ha)	Land use change										Decrease (ha)	Changes (ha)	Propose (ha)
		LUA	CHN	CLN	RSX	RPH	RDD	NTS	NKH	PNK	CSD			
LUA	77.648,9	66.979,0	4.039,0					1.348,0	964,0	4.319,3		10.669,9	-10.669,9	66.979,0
CHN	10.872,2		10.799,0						20,0	53,2		73,2	4.046,8	14.918,0
CLN	13.059,2			12.915					103,0	41,2		144,2	1.170,8	14.230,0
RSX	4.748,0			814	3.921				13,0			827,0	-821,0	3.921,0
RPH	12.184,4					12.184,4						0,0	1.023,0	13.207,4
RDD	16.414,0						16.414,0					0,0	0,0	16.414,0
NTS	11.409,6							11.298,0	87,0	24,6		111,2	1.459,4	12.869,0
NKH	2.027,70								2.012,7	15,0		15,0	1.171,0	3.199,7
PNK	68.187,9									68.187,9		0	5.333,1	73.521,0
CSD	8.320,5		80,0	501		1.023,0		223,0		880,0	5.613,5	2.714,0	-2.707,0	5.613,5
Cộng tăng (ha)		0,0	4.119,0	1.315,0	0,0	1.023,0	0,0	1.571,0	1.187,0	5.333,4	0			

Note: LUT: Rice land; CHN: Annual cropland; CLN: Perennial cropland; RSX: Production Forest; RPH: Protection forest; RDD: Special-use forest; NTS: Aquaculture land; NKH: Other agricultural land; PNK: Non-agricultural land; CSD: Unused land.

3.3. Solutions to protect and reasonable land use

3.3.1. Group of management solutions

Policy solutions: Use land resources economically and effectively and encourage the development of circular agriculture. Planning areas become concentrated, high-quality, large-scale commodity production areas. Planning is harmonious between rural and urban areas.

Production support solutions: Support structural transformation within the agricultural sector. Promote and support converting ineffective rice-growing land areas to ecological agrarian development.

3.3.2. Group of technical solutions

Solutions to improve and maintain soil health: Increase organic and microorganic fertilizers and reduce the single fertilizer used for specific crops.

Use agricultural waste on-site to create organic fertilizer.

Fertilize as recommended based on plant nutritional needs and soil fertility.

Other farming solutions: Apply minimum soil preparation methods, cover the soil, and intercrop short-term crops when the primary crops still need to close their canopy.

3.3.3. Group of other solutions

Encourage and ensure legality for agricultural land users.

Encourage investment, joint ventures, and linkages between the "four houses" with preferential capital, consumption, and product protection policies.

Developing community brands and applying scientific and technical advances to organic agricultural production. Train and improve the qualifications of agricultural production human resources and promote and apply post-harvest technology to guarantee the value of products.

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusion

1. As of December 2020, the area of land resources taken into exploitation and use is 216.551,9 hectares, equivalent to 96,3% of the natural area; Agricultural land is 148.364 hectares, equivalent to 65,98%. In 2010 - 2020, agricultural land decreased by 1,16% (land for rice cultivation decreased by 2,13%; land for annual crops increased by 0,15%; land for perennial crops increased by 0,45%).

2. Land resources in Ninh Binh and Ha Nam are diverse; there are 22 types of soil belonging to 9 soil groups. The alluvial soil groups (147.254,14 hectares) and the red-yellow (26.876,42 hectares) are the largest area soil groups. Highly fertile land is 78.127,51 hectares (34,74% of the natural area); land with average fertility is 49.642,06 hectares (22,08% of the natural area); and land with low fertility is 4.330,03 hectares (1,95% of the natural area).

3. The results have identified 122 land quality units with different characteristics. High-quality land with 58.489,31 hectares (26,01% of the natural area); Average land quality with 62.388,12 hectares (27,24% of the natural area); low-quality land with only 11.222,16 hectares (4,99% of the natural area). Land with high potential is 31.331,8 hectares (13,93% of natural area); land with average potential with an area of 78.889,7 hectares (35,08% of natural area); Land with low potential with an area of 3.512,7 hectares (1,56% of natural area) (Ha Nam is 1.534,6 hectares and Ninh Binh is 1.987,1 hectares).

4. Based on the land assessment results, development orientations, and strategies of the region and each locality, propose reasonable land use and management solutions to effectively exploit land potential and improve, maintain, and protect healthy soil.

2. Recommendations

1. Detailed research on the theory and methods of selecting indicators/criteria for land evaluation for different agricultural ecological zones.

2. Continue the research direction of the dissertation, considering land assessment as a tool to serve production organization and territorial planning.

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