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COMPREHENSIVE RESEARCH IN WET RICE LAND SUSTAINABLE DEVELOPMENT TO SERVE THE SOCIO-ECONOMIC DEVELOPMENT OF THE RED RIVER DELTA

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INTRODUCTION

1. Urgency

The Red River Delta (RRD) is the second largest rice granary in the country, providing rice to ensure food security for the North. Despite being greatly affected by land loss due to urbanization and industrialization, in 2020 the RRD still had more than 560,000 hectares of rice land with an annual rice cultivation area of 983,400 hectares (accounting for more than 72% of the agricultural land area of the whole region) (Ministry of Natural Resources and Environment, 2021; General Statistics Office of Vietnam 2021). In order to promote the socio-economic development of the RRD as a motivation for the socio-economic development of the whole country, improving the material, cultural and spiritual life of the people, on April 19th 2022, the Prime Minister issued Decision No. 492/QD-TTg approving the task of developing the RRD Regional Planning. The Government has assigned specific tasks to each Ministry in organizing the development of integrated planning components into the RRD Regional Planning for the period of 2021 - 2030, with a vision to 2050.

Land for agriculture, especially rice land, is very limited, climate change and over-cultivation are taking place very quickly, causing negative impacts on soil quality. The consequences of the abuse of chemical fertilizers and pesticides in specialized areas have caused serious changes in the soil and water environment. Many fertile alluvial rice cultivation areas of the Red River Delta have been and are degrading in different forms: acidification, gleyification, salinization, infertileness and eutrophication. The impact of land degradation will directly threaten rice production, causing difficulties in ensuring food security, thereby negatively affecting the socio-economic development of the whole region. Although there are many models of converting rice cultivation land to other uses that bring higher profits such as: aquaculture, rice-fish farming, rice-shrimp farming, vegetable and flower growing... but to ensure food security, it is still necessary to maintain a stable rice cultivation area. Therefore, it is necessary to conduct comprehensive studies on the characteristics, laws of formation, development, degradation, protection and reasonable use of rice cultivation land from a comprehensive geographical perspective for the whole Red River Delta.

2. Objectives

- Assess the current status of the law of formation and development of rice cultivation land and changes in the quality of rice cultivation land in the Red River Delta in the period of 2010 - 2020;

- Propose directions for management of land environment resources, protection, improvement, and reasonable use of rice cultivation land to adapt to climate change and ensure sustainable socio-economic development of the whole region.

3. Research contents

To achieve the above objectives, the thesis carries out the following contents:

- Give the overview of research works on rice cultivation land in the world and Vietnam;

- Establish the theoretical basis for research on rice cultivation land and the role of rice cultivation land in sustainable socio-economic development;

- Analyze the conditions of formation, classification and main characteristics of rice cultivation land in the Red River Delta;

- Evaluate the current status and changes in rice cultivation land use in the period of 2010 - 2020, the causes of changes and advantages and challenges in rice production;

- Evaluate the current fertility and current soil degradation of rice cultivation land, the impact of drought on the problem of soil fertility reduction causing soil degradation and desertification;

- Evaluate the suitability for rice and geographical zoning of rice cultivation land in the Red River Delta;

- Orientate the planning of rice cultivation land use until 2030 based on the perspective of adapting to climate change and sustainable socio-economic development.

4. Research scope and limitations

- ***Territorial scope:*** The research territory is limited to the geographical location and administrative boundaries of 10 provinces/cities in the Red River Delta (Vinh Phuc, Hanoi, Hung Yen, Hai Duong, Hai Phong, Thai Binh, Nam Dinh, Ha Nam, Ninh Binh, Bac Ninh).

- ***Scientific scope:*** The research focuses on the main issues:

+ Geography of the formation and degradation of wet rice land in the Red River Delta, assessment on the ecological suitability of wet rice crops in the Red River Delta, and soil geographical zoning.

+ Assessment on the quality and potential of land types according to the purpose of use (area, distribution) of the region as a basis for proposing solutions to protect, orient the exploitation and effective use of land resources.

- ***Research object:*** rice cultivation land in the Red River Delta.

5. Theoretical points for defence

- Theoretical point 1: Through a long-term exploitation process by humans from the beginning until now, combined with the unique characteristics of the Red River Delta with the strong impact of climate change, rice cultivation land has had many fluctuations in both area and quality. Through research in area fluctuations, current cultivation status and influencing factors to find out the causes, factors affecting the efficiency of rice cultivation land use, land quality and the trend of fluctuations in rice cultivation land area in the Red River Delta in the past ten years.

- Theoretical point 2: Through the assessment on current fertility and degradation of rice cultivation land, the impact of drought, soil geographical zoning and appropriate assessment, the thesis has proposed the orientation for using rice cultivation land in the Red River Delta until 2030.

6. Novelty of the thesis

- The thesis is a work that clarifies the theoretical basis of wet rice land, contributing to perfecting the methodology for comprehensive research in wet rice land from the perspective of geography and sustainable development (Research in the conditions of formation, development, change and transformation, degradation and characteristics of the main groups of rice land in the Red River Delta);

- Based on assessments on land degradation, classification of suitable land for rice cultivation, and orientations for socio-economic development and land use planning of the region until 2030, maps of land suitability assessment for rice, maps of soil geographical zoning for the Red River Delta at a scale of 1/250,000, and causes of rice land degradation have been developed as a basis for proposing orientations for management, improvement and use of wet rice land in the Red River Delta to be effective and sustainable in adapting to climate change and the industrialization and modernization process of the whole region.

7. Scientific and practical significance

- Scientific significance:

Contribute to building a scientific basis for sustainable use of rice cultivation land in the Red River Delta based on a comprehensive assessment of the geography of land origin, change, transformation, and degradation. Contribute to perfecting the research methodology and the process of investigating and comprehensively assessing rice cultivation land in the Red River Delta in the context of climate change in the period 2010 - 2020.

- Practical significance:

Provide a scientific and practical basis to assist scientists, managers and farmers in the management and exploitation of sustainable use of rice cultivation land to serve the socio-economic development of the Red River Delta.

8. Documentary basis of the thesis

The thesis is based on a rich volume of documents including published research works of scientists and documents collected and implemented by the author during the process of participating in research in topics at all levels. Topics chaired by the Institute of Geography, the author participated in and related to the thesis include: (1) Topic "Research and assessment on the impact of climate change on land resources in the Red River Delta and proposal of proactive response solutions". National independent topic, code: DTDLCN.48/16; (3) Topic "Research and assessment on the phenomenon of phosphorus fixation in alluvial soil in the Red River Delta and propose solutions to improve the effectiveness of phosphate fertilizers in agricultural cultivation - Case study of Thai Binh province" Topic code: VAST05.06/20-21; (4) Project “Research in ecological functional zoning as a basis for sustainable socio-economic development and proactive adaptation to climate change in Thai Binh province”, 2015 - 2016, Vietnam Academy of Science and Technology level; (5) Project “Consultancy and assessment on the current status of quality and solutions for sustainable use of agricultural land in Hanoi”.

The author has also consulted and inherited many valuable documents, including: other published research works, articles, and topics; Summary reports of

programs, projects, and topics are archived at the following Ministries: Ministry of Natural Resources and Environment, Ministry of Science and Technology, Ministry of Agriculture and Rural Development... Specialized research institutes such as: Institute of Geography, General Department of Land Management, National Institute of Agricultural Planning and Projection... At universities: University of Science, Vietnam National University of Agriculture, Kunming University of Science and Technology (China)... Updated documents from the websites of universities, research organizations in the world and in Vietnam, localities in the research area related to the research content; Documents and plans for socio-economic development of the Red River Delta region, of the Provincial People's Committee and related departments such as "Report of the current situation and solutions to protect and minimize land degradation" in 2019 of the Ministry of Natural Resources and Environment, "*Master plan for socio-economic development of the Red River Delta region to 2030"*...

9. Thesis structure

In addition to the introduction, conclusion, references and appendix, the thesis consists of 3 chapters:

Chapter 1: Theoretical basis and research methods of wet rice cultivation land in the Red River Delta

Chapter 2: Conditions for formation and changes in wet rice cultivation land area in the Red River Delta in the period of 2010 - 2020

Chapter 3: Comprehensive assessment and recommendations for sustainable use of wet rice cultivation land in the Red River Delta.

CHAPTER 1: THEORETICAL BASIS AND RESEARCH METHODS OF WET RICE CULTIVATION LAND IN THE RED RIVER DELTA

1.1. Overview of rice cultivation land in the world and Vietnam

1.1.1. Concept of rice cultivation land and some used concepts

The concept of rice cultivation land is presented in many different documents. The simplest way to understand this is the land that is specialized in growing or has rice (*Oryza sativa and Oryza glaberrima*) as the main crop in the rotational cultivation system. Rice is a water-loving plant that usually grows in shallow water (about 5-10cm in depth).

Because rice needs water to be inundated throughout its growth cycle, in the world as well as in Vietnam, rice cultivation land is a type of wetland (WW). The term "wetland" is understood in many different ways. According to Dugan (1990), there are about 50 definitions of wetlands, divided into 2 groups, the first group according to the broad definition, the second group according to the narrow definition, depending on the point of view, people can accept different definitions. Definitions of wetlands in the broad sense such as the definition of the Ramsa Convention, definitions according to the wetland survey programs of the US, Canada, New Zealand and Australia. In addition, the concepts of soil fertility and actual fertility; soil degradation and current degradation; land and land evaluation for sustainable socio-economic development; land use planning and spatial organization have also been mentioned and clarified.

1.1.2. Classification of wet rice land in the world

Wet rice land is the first object to be considered in land management. Ancient and modern history records that rice was widely grown and formed wet rice civilizations that appeared in Asia about 4,000 years ago and in Africa about 3,500 years ago. Countries which focus on protecting basic agricultural land such as United States, Canada, Japan, and Russia all propose protecting basic agricultural land in land management. In developed countries such as the United Kingdom, Germany, United States, Canada, etc., research in methods and theories about land was conducted quite early, but it was not until the years after 1950 that the first systematic classification was made in the United States (Mai Dinh Yen, 2002) and a fairly complete theoretical system was formed.

According to wetland classification of the Ramsar Convention (1971), the rice cultivation land in the Red River Delta is an artificial inland irrigated wetland. During the implementation of the Ramsar Convention, and its practical application in different regions and countries, this classification has changed: in 1994, wetlands were divided into 3 main groups, with a total of 35 types (Davis, 1994 - Ramsar Convention Bureau); Also according to the Ramsar Convention Bureau (1997), the types of wetlands were reviewed and divided into 40 different types; In recent years, the wetland classification system has been reviewed, revised and supplemented into 42 types, the rice cultivation delta region is designated as an inland wetland (L,13/42).

The wetland classification system of the International Union for Conservation of Nature (Dugan, 1999) represents the ecological perspective of formation, the rice fields of the Red River Delta are classified as "Irrigated land and irrigation channels, including rice fields, canals, and ditches", belonging to type 3 artificial wetlands, unit of level 4 (32/36). In the wetland classification system of the International Union for Conservation of Nature (IUCN) (1999), rice fields belong to the group of artificial agricultural wetlands.

1.1.3. Classification of wet rice land in Vietnam

In Vietnam, the research and classification of wetlands has always been interested by scientists since the early days of wet rice land, which has been classified according to production experience such as high-altitude land, low-altitude land... and implemented, many works recorded the dedicated contributions of leading scientists such as:

- Classification/Inventory of wetlands by Le Dien Duc (1989), wet rice land belongs to group 19: cultivated wetland, irrigated land, the author and his colleagues conducted surveys, inventories, and descriptions of typical wetlands in Vietnam based on the concept of wetlands of the Ramsar Convention;

- Some research and application works in the classification of wetlands in Vietnam by Phan Nguyen Hong et al. (1997), by Le Dien Duc (1998), by Nguyen Chu Hoi et al. (1999), by Nguyen Ngoc Anh et al. (1999), of the Ministry of Science and Technology (2001) and the works of Nguyen Chi Thanh and his colleagues in 1999 and 2002; Vu Trung Tang (2004); authors Hoang Van Thang and Le Dien Duc (2006), accordingly, rice cultivation land belongs to system B (artificial wetlands), sub-system "inland wetlands" (II, L, AII, 13), delta plains often have water. Land Law

2003 and 2013, wetlands include "wet rice cultivation land". Accordingly, in Article 3, Chapter 1 of Decree 35/2015/ND-CP, rice cultivation land is the land with suitable conditions for rice cultivation, including land specialized in rice cultivation and other rice cultivation land. Of which, land specialized for wet rice cultivation is the land that can grow two or more wet rice crops per year and other rice cultivation land includes remaining wet rice land and upland rice land, remaining wet rice land is that land that is only suitable for growing one wet rice crop per year (Government of the Socialist Republic of Vietnam, 2015). The above studies received many discussions, but also contributed to clarifying basic research in classification of wet rice cultivation land.

1.2. Research works in rice cultivation land in the world and Vietnam

1.2.1. Research works in rice cultivation land in the world

In the world, since the 1950s, researches in land assessment and classification in the world have been formed with many methods and 3 quite popular assessment systems including: 1/ Guidelines for irrigation land suitability classification in the United States; 2/ Researches in land assessment and classification have also been carried out since the 1960s according to the formation perspective of V.V. Docuchaev, by scoring the formation factors and soil properties based on the unified standard scale; 3/ Land assessment of the FAO, the research and development of different land assessment systems among countries makes the exchange of land assessment results in the world difficult. “Land Evaluation Framework” of the FAO was established in 1976 to unify land evaluation standards worldwide.

The FAO’s subsequent researches have provided detailed application guidelines for specific disciplines, including: Land assessment for rainfed agriculture (1983), land assessment for irrigated agriculture (1985); Reference values for ecological requirements of crops in tropical and subtropical regions (Sys Ir. C., et al., 1993), including ecological requirements for wet rice crops. Research in cultivation regimes, impacts on rice production and rice cultivation land use, in a research by Kalnay and Cal (2003) confirmed that urbanization and changes in land use have affected the surface temperature of the Earth.

Since the 1970s, the widespread use of remote sensing systems, information technology and mathematics, satellite data and maps in land research has improved the scientific nature, accuracy and efficiency of investigation and research. The results of physical suitability assessment or combined with economic suitability assessment based on the highest limit principle (FAO, 1976, 1985, 2007) have shown the suitability level of land units for the crops being assessed, the ranking principle at that level and the map representation (Oldeman L.R., et al., 1993), (Shendi M.M., et al., 2004), (Ahmed S., et al., 2013). Or use modeling tools in GIS to compare soil properties and ecological requirements of crops, and combine thematic information layers, overlays and analyses in GIS to build land unit maps and land suitability classification maps for crops (Mongkolsawat C., et al., 2002), (Orhan D., 2013), (Shalaby A., et al., 2017).

1.2.2. Research works in rice cultivation land in Vietnam and the Red River Delta

Wet rice cultivation was developed in the Neolithic period in the Hoa Binh - Bac Son culture, about 9 thousand years ago (Holocene period). Researches in land

assessment in Vietnam are closely linked to the development of agriculture. The concept and work of land assessment and classification have existed since the feudal period, land was assessed according to experience for management, taxation, trading, etc. In 1092, the Ly Dynasty conducted the first land survey and land tax collection. During the Le Dynasty and the 15th century, land was divided into " four ranks of fields" to serve the land management and tax policies. In 1802, the Nguyen Dynasty divided the land into "four ranks of fields" (for rice fields) and "six ranks of land" (for fields for cultivation of crops) as the basis for buying and selling and classifying land (Nguyen Van Than, 1995).

The assessment and classification of land is based on many different bases: Based on the mechanical composition of the land, it is divided into sandy soil, loam soil, clay soil, etc. Based on the color, there are: black soil, brown soil, yellow soil, red soil. Based on the nature of the land, it is divided into: acidic land, salty acidic land, infertile land, etc. Based on the terrain, there are hilly land, alluvial land, high land, fertile land, lowland land. Based on the cultivation regime, there is specialized rice land, specialized crop land, rice - crop land, etc. In the 19th century, based on production experience, our people assessed land in a simple way such as "good" land, "bad" land.

Since the 1960s, the land assessment in our country has been studied and implemented in detail by many scientific agencies. Some works lay the foundation for land assessment research in Vietnam such as:

- Researches using Russian and American methods: Some typical ressearch works are as follows: "Research in land assessment for specialized areas" (Bui Quang Toan, Vu Cao Thai, Nguyen Van Than, Dinh Van Tinh, ... 1970) based on the Russian land assessment method with the factors included in the assessment including: Soil type, soil layer thickness, compactness, porosity, rain, drought, waterlogging, salinity, acidity, ... divided into 4 appropriate levels; “Research in general national land assessment on a map scale of 1:500,000” (Ton That Chieu et al., 1986) applied the land capability classification method of the US Department of Agriculture, the used criteria were soil and terrain characteristics, the result was that the land wass divided into 7 groups according to different levels of limitation;

- Researches using FAO methods: Since the late 1980s, land assessment research based on FAO methods has been widely deployed in localities nationwide. Land assessment has become a mandatory regulation in land use planning. Some typical works in large ecological regions include: In the program "*Master plan of Mekong Delta and Red River Delta*" (National Institute of Agricultural Planning and Projection, 1991-1995), the suitability of land for common land uses in the region was assessed; "*Application of FAO's contents and methods of land assessment and cultivation system analysis to practical conditions in Vietnam" by Tran An Phong in 1995; Works in the 1996 Vietnam National Atlas on "Landscape Geochemistry Map"; "Land Geochemistry"; "Land Zoning" which reflects the characteristics of the research area of the Red River Delta and rice fields; “Saline land” (Ho Quang Duc, 2009); Research in determination of the limiting factors of rice cultivation land fertility in the Red River Delta and the Mekong River Delta and propose solutions to*

overcome them (Nguyen Van Bo, 2014); Research in assessment on the impact of drought on the socio-economic situation in the lower Red River and propose response solutions (Vu Thi Thu Lan, 2015); Documents and plans for socio-economic development of the Red River Delta, of the Provincial People's Committee and related departments such as "Report of the current situation and solutions to protect and minimize land degradation" in 2019 of the Ministry of Natural Resources and Environment, "*Master plan for socio-economic development of the Red River Delta to 2030"; Research and assessment on the impact of climate change on land resources in the Red River Delta and propose proactive response solutions* (Luu The Anh, 2019); *Summary report of the results of the first investigation and assessment of land quality and land potential in the Red River Delta* (Center for Land Investigation and Planning, 2019); Consultancy and assessment on the current status of quality and solutions for sustainable use of agricultural land in Hanoi (Contract No. 01/HN 2019 between the Soils and Fertilizers Institute and the Institute of Geography, Package No. 3, 2019); Development of a set of soil samples in the Northeast region and the Red River Delta (Nguyen Manh Ha, 2022);

1.3. Research perspectives

1.3.1. Perspective on reasonable use of land resources for rice cultivation in the Red River Delta in the context of climate change

Improve and restore land health, maintain and limit land quality degradation in the Red River Delta during rice production must be considered a particularly important task in the short and long term, contribute to sustainable management and effective use of land resources, increase people's income from rice production; contribute to hunger eradication, poverty reduction, and firmly solve the task of food security.

The reasonable use of land resources for rice cultivation in the Red River Delta must be implemented synchronously with many scientific solutions, on the basis of a unified system of policies and laws of the State, while mobilizing the attention and contribution of the whole society, especially the role of the people - owners and direct users of land.

Strengthen the staff and adopt modern technology, inherit appropriate traditional experiences, closely combine the goals of economic and social development and environmental protection with the reasonable allocation of land resources, exploit and effectively use the limited land resources for rice cultivation in the Red River Delta and the rice cultivation land is being narrowed due to conversion to non-agricultural purposes.

1.3.2. Perspective on systemic and synthetic approach

The systemic perspective determines the spatial structure, analyzes the functions of the components and the elements that make up the vertical and horizontal structure of natural aggregates in the process of exchanging matter and energy. Applying this perspective, studying the land in a system with structure and function with interactions, interconnected between factors of land formation, land degradation, and land transformation, considering land not only as a "mirror of the landscape" or "carrier of the ecosystem" but also as a land landscape. In addition to resource

potential, food security function, economic function... land units are also specifically considered from a systemic perspective when proposing the reasonable use of rice land resources in the Red River Delta.

Based on the comprehensive approach, research and assessment on land suitability according to a number of appropriate indicators and representative of natural components according to vertical structure as well as the relationship between them using appropriate methods. Through the selection and processing of indicators representing components such as geology (parent rock), terrain (assessment, slope), climate (bioclimatic types, climate extremity), hydrology (drainage capacity), soil cover properties (land type, thickness, mechanical composition, acidity, humus content, total nutrient content, easily digestible nutrient content), vegetation... this perspective is applied. However, this perspective does not necessarily require to study all components but can select factors that play a leading role, which have a decisive nature on the most basic properties of the whole.

The characteristics of a geographical and pedological area are composed of many factors, which act simultaneously and cannot replace each other. Therefore, when the zoning is conducted, it is necessary to consider the synthesis of the factors that make up that zoning unit. The systemic and synthetic approach requires calculating all the components that make up the overall geography without excluding any component. That is, it is necessary to find the close interrelationships, linking all those components and factors together, unifying them into a complete geographical and pedological area. Doing so will make the geographical zoning, regardless of which main factor it follows, not become a separate zoning for that factor. Analyze the synthesis of the impacts and mutual relationships between the factors affecting the land, thereby deciding the orientation for use of different land units.

1.3.3. Perspective on geographical approach for sustainable rice cultivation land use solutions

The zoning results aim to divide the soil cover into separate regions, not overlapping in space, with specific characteristics in terms of land conditions and usage methods. Soil geographic zoning is an important link in the research of sustainable land use exploitation and its application in each territory, to propose solutions and methods for reasonable development of territories. Therefore, in the field of soil, the works serving territorial planning need to end with a soil geographic zoning.

Therefore, integrating the results of current land degradation and land classification assessment with soil geographic zoning will more effectively demonstrate the results of the comprehensive assessment of land units in the close relationship among soil geographic zones. The purpose of this process is to provide spatial solutions and adaptive land use solutions as a scientific basis for planning and land use of the territory towards sustainable development.

1.4. Research methods

1.4.1. Methods of collecting, analyzing and processing documents

- *Methods of collecting and inheriting documents:* The thesis has inherited and collected data and documents that have been published by authors in the world and in the country and by competent agencies on issues related to the research contents

(natural conditions, socio-economic conditions, current land use status, survey results, land classification, maps on topography, climate, hydrology, soil, current land use status of the Red River Delta, documents on policies for socio-economic development to 2020, vision 2030 - 2050 of the Red River Delta...

- *Methods of analyzing and processing documents:* The thesis groups documents according to topics, contents, suitability... compared to the requirements of the topic. On that basis, it conducts editing and updating of physical and chemical characteristics of soil groups in some typical soil profiles to clarify soil characteristics for the Land Mapping Units (LMUs), degraded land areas at different levels; Use Excel software to synthesize data for statistics and determine the main characteristics of land units..

1.4.2. Geographic comparison method

This method is applied to analyze the natural potential of LMUs, determine the ecological needs of rice plants, compare and contrast the land utilization types (LUTs) with each LMU in the research area to assess the level of suitability. From there, divide the degradation levels and trends to have an orientation for reasonable use of rice cultivation land.

1.4.3. Mapping method and geographic information system

Use specialized software such as Mapinfo, ArcGIS to edit, digitize, and correct single-dimensional maps of the research territory including geological maps, topographic maps, climate, hydrological, soil, vegetation, current land use status... at a scale of 1/250,000. Then, integrate GIS maps, land suitability assessment maps, geographical zoning maps of rice cultivation land and proposed land use orientation maps in the Red River Delta.

1.4.4. Field survey methods

Detailed field surveys were conducted along routes and studies at key points, coordinates were determined by GPS, typical soil profiles representing the main types of land used for rice cultivation, characteristics of the rice cultivation models currently being applied, and LUTs with rice plants related to the thesis research.

1.5. Procedures for establishing a suitable map for wet rice

Procedures for establishing a land suitability assessment map for wet rice

Step 1: Determine the assessment objectives, collect data, select and determine the ecological requirements of the land use type for rice cultivation; Select and classify the indicators for assessment and development of land mapping units of the research area.

Step 2: Based on the classification results, develop a land suitability classification map for land utilization types, the land suitability level is divided into 4 levels: very suitable (S1), suitable (S2), less suitable (S3) and unsuitable (N).

1.6. Procedures for establishing a soil geographic zoning map

Inherit the results of the soil geographic zoning of Vietnam at a scale of 1/1,000,000 of the Soil Science Association, determine the system of divisions and indicators for the soil geographic zoning of rice cultivation land in the Red River Delta at a scale of 1/250,000. Use the dominant factor method, the method of analyzing component maps, and the expert method, determine the specialized rice cultivation areas and areas with little or no rice cultivation.

1.7. Research ideas and implementation procedures

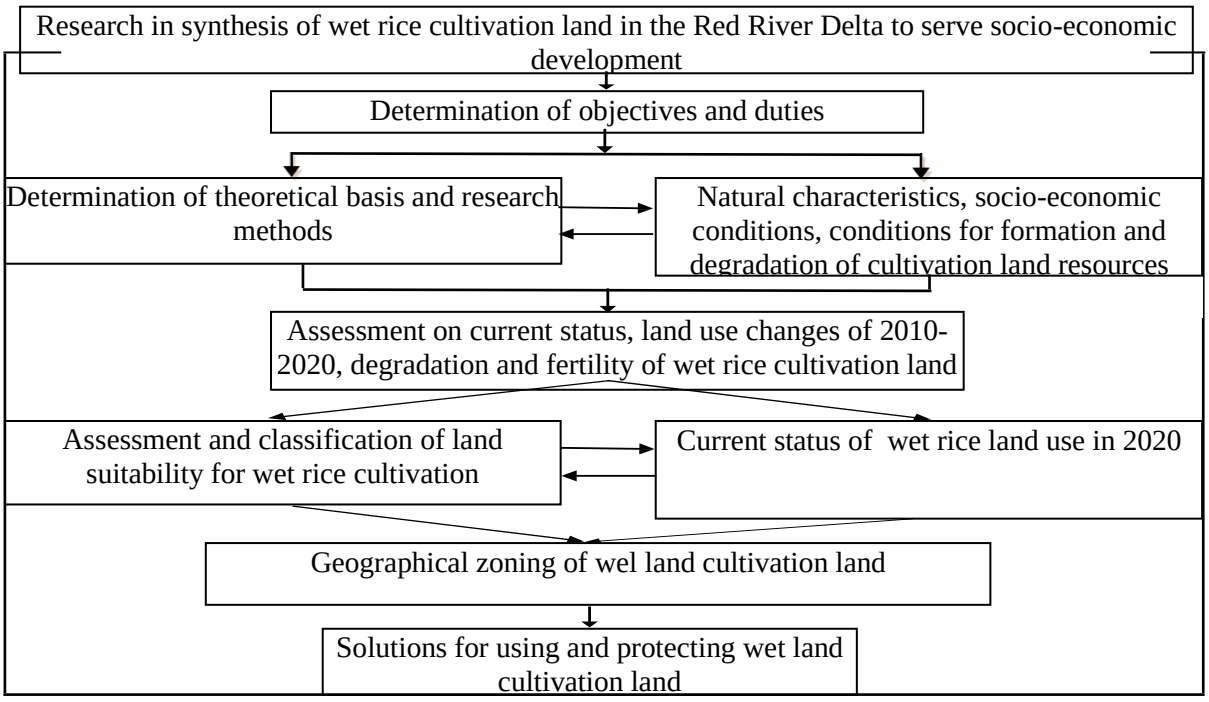

Figure 1.3. Research diagram

CHAPTER 2: CONDITIONS FOR FORMATION AND CHANGES IN WET RICE CULTIVATION LAND AREA IN THE RED RIVER DELTA IN THE PERIOD OF 2010 - 2020

2.1. Current conditions of land formation and degradation in the Red River Delta

2.1.1. Overview of geographical space

2.1.1.1. Location resources

The Red River Delta, also known as the "Northern Delta", is formed from alluvial sediments of the Red River and Thai Binh River systems with an area of nearly 1,507,067 hectares (accounting for 4.5% of the country's natural area). The geographical coordinates of the region range from $19^0$05' to $21^0$34' of North latitude and from $105^0$17' to $107^0$07' of East longitude. The Northern Delta triangle has its peak in Viet Tri and its bottom is the coastal estuary alluvial plain from Ninh Binh to Hai Phong. The wet rice cultivation land in the Red River Delta is concentrated within the administrative boundaries of 10 provinces and cities (Hanoi, Vinh Phuc, Bac Ninh, Hai Duong, Hai Phong, Hung Yen, Ha Nam, Thai Binh, Nam Dinh and Ninh Binh).

2.1.1.2. Geological features

The Holocene and Neogene alluvial sediments of the Red River Delta lie on ancient crystalline rocks, the typical bedrock of the Northeast region. 200 million years ago, at the end of the Paleozoic era, this rock layer collapsed, at that time, the marine transgression was in Viet Tri today, approaching the hills of Bac Ninh, Vinh Phuc, Nho Quan (Ninh Binh) provinces; the Red River mouth at that time was in Viet Tri. The marine transgression lasted over 170 million years. The Neogene sediments settled down, narrowing the bays. This sediment layer is up to 3,000 m thick in some places. The Holocene alluvial layer is on top, 80 - 100 m thick in the center of the Red River Delta, and the farther away from the center, the thinner this alluvial layer becomes.

In the Red River Delta there are many natural depressions, typically Ha Nam Ninh depression, Hai Hung depression, and Nho Quan depression. In addition, there are many swamps. Sediments and alluvium transported by rivers out of the riverbed each flood season have not filled these depressions and swamps because they are too far from the river or are blocked by artificial dikes. The change of course of rivers also creates swamps and lakes.

2.1.1.3. Topographic and geomorphological resources

The process of geological tectonic, marine transgression, regression, deposition, and erosion of alluvial sediments has created a typical diverse mosaic of the Red River Delta terrain: From the top of the Viet Tri triangle, the Northeast and Southwest equatorial terrace hills stretch out, with ancient alluvium mixed with limestone; The next is the flat central plain (Hanoi, Hai Duong, Hung Yen ...), new and old alluvium; The remaining depression strip along the edge is mixed with limestone; Towards the sea is a mixed alluvial plain of rivers and seas; Man-made terrain is the dikes, irrigation works, urbanization, etc.

The current terrain and geomorphology of the Red River Delta are the result of a long and complex development history related to the region's neotectonic activities: uplift and subsidence, accumulation and erosion, leveling and erosion. The terrain gradually decreases from the Northwest to the Southeast, with an average height of 0.4 m to 12 m above sea level. The entire region can be divided into 4 main types of terrain: 1/ Hilly terrain; 2/ Midland terrain; 3/ Coastal plain terrain divided into many plots with many low, sunken, waterlogged areas; 4/ Typical coastal terrain area, with low and flat land, affected by the process of salinization and acidification.

2.1.1.4. Climate resources

The characteristic climate of the Red River Delta is tropical and subtropical monsoon climate. Summer is hot, humid, and rainy from May to September (accounting for about 86% of the total average annual rainfall), the weather is hot with showers and storms; Winter from November to January of the following year, the temperature drops, the dryness greatly affects production and people's lives. The remaining months of the year generally have high humidity from 80-92%, with a small difference of only 12%. The climate of the North is suitable for 2 crops of hot-climate plants and 1 crop of cold-climate plants.

2.1.1.5. Water resources and hydrological regime

The Red River Delta has two natural river systems, the Red River system and the Thai Binh River system. This is the most irrigated region in the country and also the highly irrigated region in the world. The common characteristics of the rivers in the Red River Delta are small slopes, averaging 0.02 - 0.05 m/km and many winding curves. Along the major rivers, there are nearly 1,600 km of flood-prevention dykes built, this dyke system has made the river systems have different hydrological regimes. Hydrological and oceanographic regimes are one of the factors contributing to the salinization and drought of the region. The uneven flow distribution rate, mainly concentrated in the rainy season, is one of the causes of flooding in the rainy season and drought in some areas of the region in the dry season.

2.1.1.6. Vegetation resources

The Red River Delta is a land that has been exploited for a long time and mainly produces food, of which rice accounts for over 90% of the cultivated area. The remaining area is crops, short-term industrial crops, etc. Besides the anthropogenic vegetation, there is also natural vegetation, such as mangrove forests (Ninh Binh, Nam Dinh). The anthropogenic vegetation includes rice, crops, fruit trees, planted forests and natural forests, of which rice accounts for a large proportion of the area and strongly affects the land environment.

2.1.2. Overview of socio-economics

In the period of 2010 - 2020, the Red River Delta has developed its socio-economics quite comprehensively, maintaining a GDP level higher than the national average, making an important contribution to socio-economic development, promoting industrialization and modernization of the country. The impact of the Covid-19 pandemic disrupted the supply chain of raw materials, so the GDP growth rate in 2019 and 2020 had the lowest growth rate in the period of 2010-2021. Specifically, the GDP of the Red River Delta region in 2010 was 24.7% and the GDP growth rate in 2011-2021 was: 6.41%; 5.50%; 5.55%; 6.42%; 6.99%; 6.69%; 6.94%; 7.47%; 7.36%; 2.87%; 2.56%, respectively. The economic growth rate of the region in 2023 reached 6.28%, 1.24 times higher than the national average (5.05%).

However, in the period of 2010-2020, the crop structure changed in the direction of increasing the proportion of crops with high productivity and economic value, associated with changing some areas of rice and crops with low-output and low-economic value into short-term and long-term industrial crops and fruit trees. The orientation of the structural changes in the Red River Delta is to reduce the proportion of food crops, increase the proportion of food crops; the orientation of the economic structure change is to reduce the proportion of region I and rapidly increase the proportion of region II and III.

2.1.3. Assessment on land degradation in the Red River Delta

The main degradation processes affecting land resources in the region are erosion in mountainous areas and nutrient depletion in the delta. From the current status of the causes of land degradation, it can be seen that the decline in fertility is the biggest cause of land degradation in the Red River Delta.

2.1.4. Assessment on the impact of drought on the problem of land fertility decline causing wet rice land degradation

The impact of drought on land resources in the lower Red River Delta, drought, and water shortage are indirect causes of physical land degradation, reducing the productivity of wet rice land.

2.2. Current status and fluctuations in land use for rice cultivation in the Red River Delta in the period of 2010 - 2020

2.2.1. Current status of rice production in the world

According to statistics from the Food and Agriculture Organization of the United Nations (FAO), rice occupies an important position in the world, especially in Asia. In 2021, the world's rice cultivation area reached 165.25 million hectares and achieved a output of 787.29 million tons (FAOSTAT, 2022).

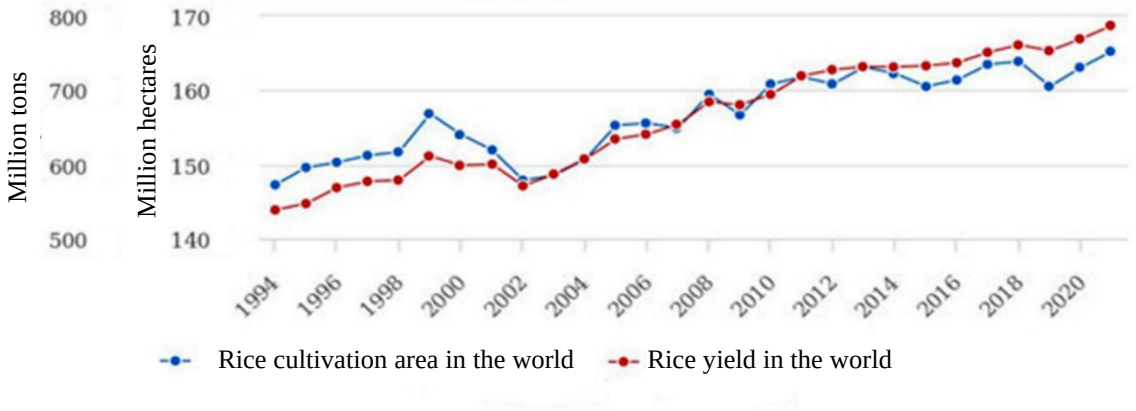

Figure 2.2. World rice cultivation area and output from 1994 to 2021

Soure: FAOSTAT 2022

From 2010 to 2021, the world rice cultivation area increased by 3.55 million hectares and the output increased by 86.19 million tons.

Table 2.4. World rice cultivation area and continents from 2010 to 2021

Year	Rice cultivation area (million hectares)					
	World	**Africa**	**America**	**Asia**	**Europe**	**Oceania**
2010	161,70	10,69	7,23	143,04	0,71	0,02
2014	164,30	13,07	6,59	143,91	0,64	0,08
2018	167,10	14,24	6,13	146,07	0,63	0,07
2021	165,25	15,83	5,70	143,06	0,61	0,05

Source: FAOSTAT 2022

Of which, Asia is the center of rice production in the world. From 2010 to 2021, the Asian region has a rice cultivation area accounting for over 80% of the world's rice cultivation area (Table 2.4)

According to Statista statistics, in 2021, three countries exporting the most rice in the world are India (21.5 million tons), Thailand (8.2 million tons) and Vietnam (6.8 million tons). The rice export output of India and Thailand accounts for more than 50% of the total rice export volume of the world.

2.2.2. Current status of rice production in Vietnam and the Red River Delta

In Vietnam, rice is the main food crop with the top priority, with a cultivation area and output exceeding other food crops. In rice production, Vietnam also excels in the Southeast Asian region thanks to its well-invested irrigation system and the ability to quickly apply new technical advances in seeds, fertilizers and plant protection. The year 1989 marked an important event when Vietnam ended the period of rice shortage for the first time. Today, Vietnam not only meets the domestic needs for rice but also becomes the third country in the world in rice export. The overseas journey of Vietnamese rice has quickly had a profound impact on the lives of farmers, causing them to actively expand production and increasing the supply of rice to the market.

With fundamental political and economic reforms, the applied market mechanism has promoted the rapid increase in production area, productivity and food output. During the period of 1986-2021, Vietnam's rice area and output continuously

increased, from 5.7 million hectares and 16.0 million tons in 1986 to 7.24 million hectares and 43.85 million tons in 2021 (General Statistics Office of Vietnam, 2022). In 2021, the country's rice production area increased by more than 1.27 times, rice productivity increased by more than 2.0 times and rice output increased by 2.7 times compared to 1986. After more than 30 years, rice output increased by nearly 28 million tons, an average increase of nearly 0.9 million tons/year. It can be seen that although Vietnam's rice cultivation area has fluctuated, it is not large (Figure 2.4). In 20 years, the cultivation area fluctuated between 7.2 and 7.8 million hectares/year. Since 2015, the cultivated area has tended to decrease due to a part of the rice land being converted to non-agricultural land and some crops with higher economic efficiency, especially fruit trees. The rice cultivation movement has also decreased because people have realized that intensive farming has caused negative impacts, reducing production efficiency: increasing pests and diseases, reducing alluvial deposition, increasing fertilizer costs...

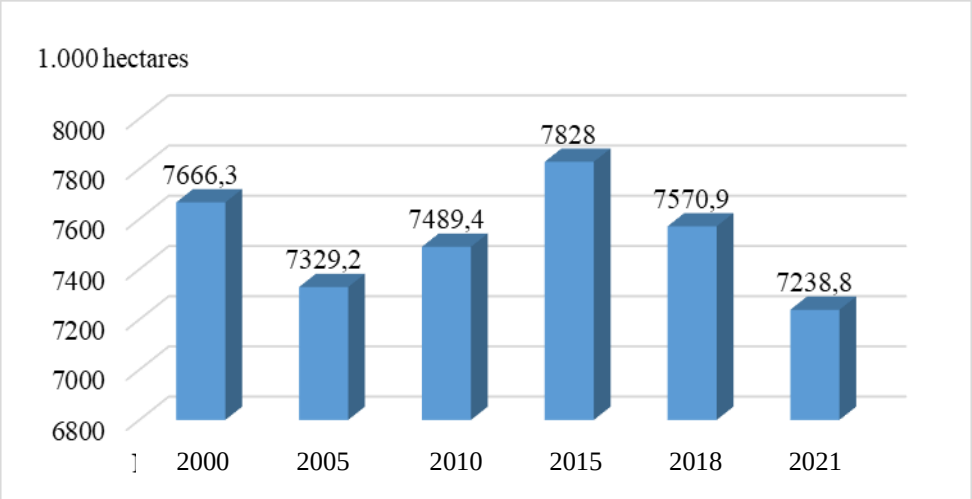

Figure 2.4. Rice cultivation area of Vietnam in the period of 2000 - 2021

Among the 7 ecological regions of Vietnam (Figure 2.5), the Mekong Delta has the largest rice cultivation area, accounting for nearly 54% of the country's rice cultivation area. The second place is the North Central and Central Coastal Region with nearly 1.2 million hectares. The Red River Delta is the largest rice granary in the North and the third place in the ecological regions of Vietnam in terms of rice cultivation area. In 2021, the rice cultivation area of the Red River Delta was 970,300 hectares. The provinces in the Red River Delta all have long-standing experience in rice cultivation and have natural conditions suitable for rice cultivation. However, the Red River Delta is also strongly affected by urbanization, leading to increasingly narrowing rice cultivation area. It is calculated that within 20 years, the rice cultivation area of the Red River Delta has decreased by 14,555 hectares each year.

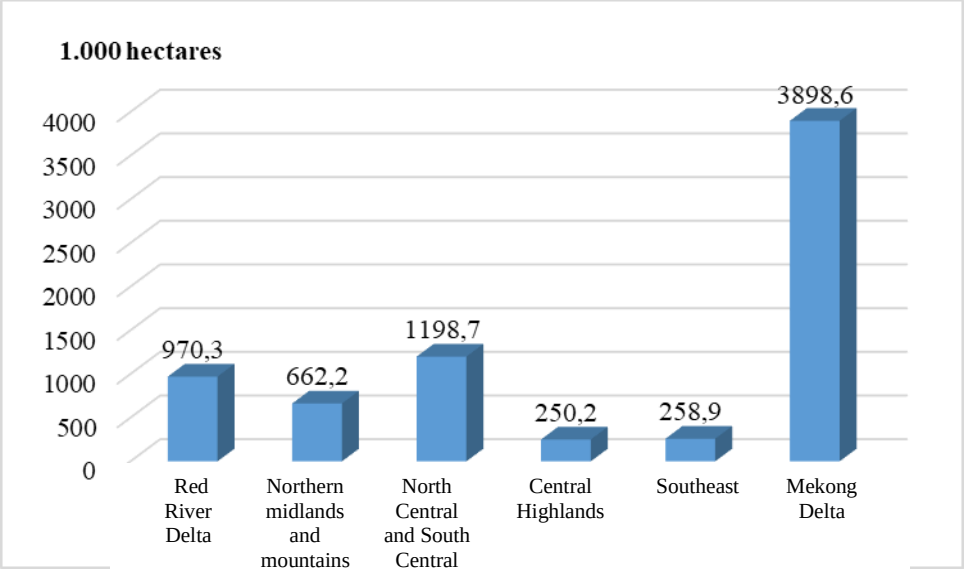

Figure 2.5. Vietnam's rice cultivation area in ecological regions in 2021 [74]

2.2.3. Current status of rice land use in 2010, 2020 and changes in rice land area in the Red River Delta in the period of 2010 – 2020

According to statistics up to 2020, 10 provinces in the Red River Delta have a natural area of 1,507,067 hectares, 98.88% of which has been put into use. Agricultural land accounts for 63.09% of the total natural area of the whole region. In the period of 2010-2020, the agricultural land decreased by 38,477 hectares mainly due to conversion to non-agricultural purposes (Table 2.6)

Table 2.6. Changes in land use in the Red River Delta in the period of 2010 - 2020

No.	Types of land	Current status in 2010		Current status in 2020		Fluctuations in the period of 2010 - 2020 (ha)
		Area, ha	Rate, %	Area, ha	Rate, %	
(1)	(2)	(3)	(5)	(6)	(7)	(8)=(6)-(3)
I	Agricultural land	912.360	61,43	950.837	63,09	38.477
II	Non-agricultural land	515.960	34,74	539.419	35,79	23.459
III	Unused land	56.827	3,83	16.812	1,12	-40.016
	Total natural area	**1.485.147**	100	**1.507.067**	100	**21.920**

Source: General Department of Land Administration, 2022

The published annual data of the Ministry of Natural Resources and Environment shows that the annual average rice land area in the Red River Delta has continuously decreased since 2010 due to the changes in land use purposes to non-agricultural land. The fluctuation in rice land use in the period of 2010 - 2020 of the entire Red River Delta has decreased strongly, with an average decrease of 3,488.6 ha/year. All 10/10 provinces and cities in the region have decreased rice land area, the largest decrease in rice land area is Hanoi with an average decrease of 1,405 ha/year. Hung Yen is the province with the second largest decrease in rice land area in the region with a total decrease of up to 10,403 ha, an average decrease of about 1,040 ha/year. Hai Duong, Thai Binh and Nam Dinh have rice land decreased in the period of 2010-2020 from 5,000-7,000 ha and mainly changed to build industrial parks and urban areas. The remaining provinces such as Hai Phong, Ha Nam, Bac Ninh, Vinh Phuc and Ninh Binh also decrease from 187-493 ha/year each year.

2.2.4. Rice land use situation in the Red River Delta region in the period of 2010-2020

In the period of 2010-2020, our country continues to promote industrialization and modernization, therefore, land use in the Red River Delta has fluctuated, agricultural land continues to decrease, mainly changing rice land to residential land, construction land and industrial land. Therefore, it can be seen that along with the decrease in rice land area, the annual rice cultivation area in the Red River Delta also decreases accordingly. Currently, the Red River Delta is cultivating rice in two main crops: spring crop (planted from January to February and harvested in May to June) and summer-autumn crop (planted from late June to early July and harvested in October).

Table 2.8. Annual rice area in the Red River Delta in the period 2010-2020

Unit: 1000 ha

Annual rice cultivation area	2010	2012	2014	2016	2018	2020	Comparison of 2020/2010
The whole region	1.105,4	1.095,1	1.079,6	1.052,1	999,7	944,9	-160,5
Hanoi	204,7	205,4	202,8	197,1	179,5	165,6	-39,1
Vinh Phuc	59,3	59,4	58,6	58,4	56,6	53,9	-5,40
Bac Ninh	74,3	72,6	72,7	70,8	66,4	64,1	-10,2
Hai Duong	127,5	126,4	125	120,3	116,4	112,5	-15,0
Hai Phong	80,9	79,2	77,1	74	69,4	58,6	-22,3
Hung Yen	81,9	81,8	78,9	74,1	66,4	58,7	-23,2
Thai Binh	166,4	162,8	161,8	160,1	157,1	153,7	-12,7
Ha Nam	70,3	69	67,4	65,6	63,2	60,5	-9,8
Nam Dinh	159	157,3	154,9	153	149,1	145,4	-13,6
Ninh Binh	81,1	81,2	80,4	78,7	75,6	71,9	-9,20

Source: General Statistics Office of Vietnam, 2021

In the 10 years from 2010-2020, the annual rice cultivation area of the Red River Delta decreased by 160,500 ha with an average rate of 14,590 ha/year. Hanoi City has the largest rice area decrease rate with an average rate of 3,554 ha/year.

2.2.5. Economic efficiency of rice land use types in the Red River Delta

Table 2.9. Economic efficiency of rice land use types in the Red River Delta

No.	Land use types	Production value	Intermediational Cost	Consolidated Income	Manpower	Working day value	Efficiency, (time)
		Million dong/ ha/year					
1	2 rice crops	87,81	31,32	56,49	430	131	1,80
2	Spring rice, Summer rice + corn/potato	125,15	42,18	82,97	521	159	1,97
3	Spring rice, Summer rice + winter vegetables	231,00	87,50	143,50	750	191	1,64
4	1 rice - 2 vegetable crops	168,06	40,98	127,08	694	183	3,10
5	Spring rice - fish	292,95	88,79	204,16	400	510	2,30

Source: Farmer household survey results

It can be clearly seen that among the land use types for rice cultivation, the land use type 5 (spring rice - fish) still brings the highest economic efficiency. Although land use types 1 and 2 do not bring high economic efficiency, the advantage is low cost, simple techniques, requiring very little manpower, so it is preferred by people in the suburbs and areas with strong industrialization.

2.2.6. Causes of fluctuations in rice area in the Red River Delta

There are 2 main groups of causes of fluctuations in rice area in the Red River Delta, including: Impact of natural factors (alluvial deposition, climate effects, drought, salinization, acidification, concretion, tides, geology, topography, etc.); Impact of human factors (infrastructure construction, land improvement, construction of irrigation works, customs, land use policies, etc.), of which human impact plays a main role in causing sland degradation, pollution and fluctuations in rice land area.

2.3. Classification of rice land in the Red River Delta and characteristics of rice cultivation land groups

The results of the synthesis of the land classification map of the entire Red River Delta have 16 main land groups, of which 4 main rice cultivation land groups account for the majority of the area, including alluvial land group, saline land group, acid sulfate land group, and infertile land group. The alluvial land group occupies the largest area (39.55% of the natural area), is fertile and suitable for rice cultivation; the saline land group occupies 6.19% of the natural area, and the acid sulfate land group occupies 5.17% of the natural area of the 10 provinces in the Red River Delta, but attention should be paid to its reasonable use and improvement; the infertile land group occupies 2.10% of the natural area of the 10 provinces in the Red River Delta, and has the advantage of being distributed in flat terrain. This is an extremely valuable resource that nature has favored the Red River Delta, formed from the deposits of the Red River and Thai Binh River systems, distributed widely in the provinces to develop the Red River Delta to be worthy of its position as the second largest specialized rice cultivation area in the country.

2.4. Assessment on the current fertility of rice cultivation land in the Red River Delta

The current fertility of land in the Red River Delta is assessed through two basic physical properties of land (mechanical composition, unit weight) and eight chemical properties (land acidity, total organic matter content, total nitrogen, total phosphorus, total potassium, absorption capacity, total soluble salts, total sulfur). The results of unit weight analysis show that during the cultivation process, the unreasonable use of machinery and chemical fertilizers is one of the causes of land compaction and land hardening, however, this rate is not much (only 11.11%). Applying a lot of chemical fertilizers that plants cannot use or use very little, leads to a lot of residue in the land, making the land acidic, rice cultivation land has acidity at acidic and slightly acidic levels with 405,070 ha, (accounting for 67.63% of the surveyed land area). The total organic matter content is rich in most of the area, in general, the land in the Red River Delta is quite fertile adn favorable for intensive cultivation to increase rice productivity.

2.5. Advantages and challenges in use of rice cultivation land in the Red River Delta in the period of 2020 - 2030

2.5.1. Advantages

i/ The Red River Delta is the most dynamic economic region in the country. In addition, it is also the cradle of wet rice cultivation, farmers have high rice cultivation skills, and are able to receive scientific advances in rice cultivation;

ii/ The infrastructure serving rice production is complete and has been invested appropriately (irrigation system, intra-field traffic system, agricultural material supply system, production management system, ...);

iii/ Market: Rice cultivation is not very effective but has a stable consumption market, creating peace of mind for producers;

iv/The land consolidation policy in building new rural areas has created the premise for the process of land accumulation, increasing mechanization in production towards developing high-quality rice cultivation areas.

2.5.2. Challenges

i/The Red River Delta is always the region with the largest population scale and the highest population density in the country. Along with the increase in population, the needs for residential land and agricultural land increase. The population pressure causes the area of rice cultivation land to be limited and increasingly narrowed due to conversion to other non-agricultural purposes. With a low average land area per person, people cannot ensure their lives with income from agriculture, leading to the phenomenon of abandoned fields in many localities.

ii/ The process of promoting industrialization and modernization of the region continues to require the conversion of agricultural land, mainly rice cultivation land, to develop infrastructure, causing a conflict between assurance of food security and socio-economic development

iii/Land use management is not strict, leading to unreasonable, ineffective and unplanned land use.

iv/ The Red River Delta is an area with a very high rate of urbanization and industrialization, so the risk of land pollution due to the impact of industrial waste and domestic waste is very high. Climate change and rising sea levels increase the risk of saltwater intrusion in estuaries.

CHAPTER 3: COMPREHENSIVE ASSESSMENT AND RECOMMENDATIONS FOR SUSTAINABLE USE OF WET RICE CULTIVATION LAND IN THE RED RIVER DELTA

3.1. Assessment on ecological suitability of wet rice in the Red River Delta

3.1.1. Ecological suitability criteria of wet rice

- *Selection and classification of criteria:* Based on previous survey results, it is found that most of the land area in the Red River Delta has a soil layer thickness of 50 cm or more, accounting for 95% of the surveyed area, the area with a layer thickness of less than 50 cm accounts for only about 4%, so most of the land area in the Red River Delta has a soil layer thickness suitable for wet rice cultivation. The ecological requirements of the selected type of land use for rice cultivation are assessed and the actual characteristics and quality of land (soil, terrain, climate, hydrology, irrigation) of the Red River Delta, the thesis selected 7 criteria to build a

map of current land units at a scale of 1:250,000, including: Type of land, mechanical composition, relative terrain, slope, irrigation regime, average annual temperature, drainage regime.

- *Determination of the ecological requirements of the type of land use for rice cultivation:* To classify the suitability of land units for the selected land use type for rice cultivation, it is necessary to determine the requirements for the characteristics and properties of the land use type. Based on the natural conditions in the Red River Delta and referring to the values of ecological requirements of rice in tropical and subtropical regions according to the documents of Sys I.C. (1993), and at the same time inheriting the results of related research, determined the ecological requirements of specialized rice land use types according to 4 levels of suitability: S1 is very suitable, S2 is suitable, S3 is little suitable and N is unsuitable.

Table 3.2. Hierarchy of ecological requirements of specialized rice cultivation land use types

Indicators	**Suitable/limited level**			
	Very suitable (S1)	**Suitable (S2)**	**Little suitable (S3)**	**Unsuitable (N)**
1. Type of land (G)	P, Ph,Pc, Pe, Pf, Phf, P/c, Py, D	M, Mi, Sj2, Sj2M, Sp2, Sp2M, Sp, Pg, Phg, Pj, Phj, J, Fl	Sp1, Sp1M, Pb, Phb, Pbe, Pbc, X, Xg, B,Bg	C, Cb, Cc, Cg, Mm, Mn, Sp1Mm, Sp1Mn, T, Rdv, Fy, Fk, Fn, Fe, Fp, Fa, Fs, Fq, Hs, Ha, Hk, Hq, E
2. Mechanical composition of topsoil	Loam and heavy loam	Light loam	Sandy soil	Sand
3. Land terrain	Middle	Low	Highly middle	High
4. Slope	0 - 3	3 - 8	-	> 8
5. Annual average temperature	≥ 20	18 - 20	< 18	-
6. Irrigation regime	Active irrigation	Active irrigation	Difficult irrigation	No irrigation
7. Drainage regime	Quick drainage	Quick drainage	Difficult drainage	Slow drainage

- *Land unit map:* The land unit map of the Red River Delta was developed by overlaying thematic maps of 7 selected indicators. Each land mapping unit (LMU) contains all the land properties shown in thematic maps and is distinguished from other units by the difference of at least one indicator. The results have been synthesized and determined that the Red River Delta has 339 LMUs.

3.1.2. Development of a suitable land map for rice cultivation at a scale of 1/250,000

- *Results of assessment and classification of rice cultivation land:* Assessment and classification of land aims to determine the suitability of land units for the type of land use being assessed.

Table 3.3. Assessment and classification of wet rice cultivation land of the Red River Delta

Classification	Land map unit	Area, ha	Rate, %
Very suitable (S1)	137;138; 139; 147	117.048,03	12,31
Suitable (S2)	42 - 46; 48 - 50; 52 - 54, 58; 59; 61-65; 67-71; 125- 128; 134 - 136; 166 - 172; 178 - 185; 187; 196 - 201;	510.694,55	53,71
Little suitable (S3)	41; 57; 60, 78; 79; 87 - 90; 92; 94 -103; 118-122; 124, 129 -132; 140- 144; 148; 161; 163; 164; 173 - 175; 186; 188 - 192; 209 - 213; 217 - 223; 226;	143.861,64	15,13
Unsuitable (N)	1 - 40; 47; 51; 55 - 56; 66; 68; 72 -77; 80 - 86; 91; 93; 104 -117; 123; 133; 145 - 146; 149 - 160; 162; 165; 176 - 177; 179; 193 - 195; 202 -208; 214 - 216; 224 - 225; 227 - 339.	179.232,77	18,85
Total	**Investigation area**	**950.837**	**100**

Source: My thesis assessment results

The assessment and classification are carried out by comparing and contrasting the properties of land units with the ecological requirements of the selected land use type (rice cultivation), according to the principle of limiting conditions (classification according to the highest level of limitation of the property factors of the land unit) and 4 levels of land suitability (S1, S2, S3, N) of FAO (1976, 2007), on the basis of the geographic information system (GIS).

Table 3.4. Assessment and classification according to present wet rice cultivation land area in 2020

Loại sử dụng đất	Area / Rate	Suitable level				2020 Present Area
		Very suitable (S1)	**Suitable** (S2)	**Little suitable** (S3)	**Unsuitable** (N)	
Wet rice cultivation	**Area (ha)**	62.720,82	280.156,70	130.005,17	83.646,31	556.529
	Rate (%)	11,27	50,34	23,36	15,03	*100,00*

Source: My thesis assessment results

Thereby, determining the limiting factors and contributing to the orientation of sustainable land use for agricultural development of wet rice cultivation in the Red River Delta.

3.2. Soil geographic zoning of the Red River Delta, orientation for sustainable development of wet rice cultivation

Inheriting the zoning system and zoning method of the Soil Science Association in soil geographic zoning, from which analyzing the specificity, in the differentiation of soil cover in the Red River Delta, the zoning system used for the zoning map and soil geographic sub-regions for the Red River Delta at a scale of 1:250,000 has been determined. Using the principles (relative homogeneity, shared territory, synthesis, dominant factors) and zoning methods (method of analyzing component maps, dominant factors and expert methods) to determine the regions and sub-regions of the

soil geographic sub-regions. The results divided the soil cover of the research territory into 16 soil geographic sub-regions, including 7 regions specializing in wet rice cultivation and 10 regions with little or no wet rice cultivation.

3.3. Solutions for using wet rice land in the Red River Delta region until 2030

- Basis and principles of orientation: From the results of land classification assessment combined with the synthesis and analysis of those results with the current status of wet rice land use, and at the same time referring to the planning and development plans for rice in the agricultural and irrigation sectors of the provinces and cities in the Red River Delta region until 2020 and orientation to 2030, to propose orientations for using land units based on the following principles:

+ Rice cultivation land: Only arrange rice cultivation land on suitable areas of S1 and S2.

According to the national land use planning target until 2030 recently approved by the National Assembly (2021), until 2030, nearly 350,000 hectares of rice cultivation land will be reduced compared to 2020, of which about 174,000 hectares of land is specialized in rice cultivation, this area will be converted to other annual crops and other types of uses.

CONCLUSIONS AND RECOMMENDATIONS

1. Wet rice cultivation land is an important production area of many countries in the world. In 2021, Vietnam became the third largest rice exporter in the world and achieved a high growth rate in the food production sector. The Red River Delta is a key rice production area in the North, ranking third among Vietnam's ecological regions in terms of rice cultivation area (in 2021, there were 970,300 hectares of rice cultivation). The Red River Delta has diverse and rich land resources. The main land groups exploited for wet rice cultivation are alluvial land, saline land, acid sulfate land and fertile land.

2. The provinces in the Red River Delta all have a long history of rice cultivation and have natural conditions suitable for rice cultivation. However, the Red River Delta is also strongly affected by urbanization, leading to increasingly narrowing rice cultivation areas. From 2010-2020, the rice area of 10 provinces in the Red River Delta decreased by 160,500 hectares, from 1,105,400 hectares in 2010 to 944,900 hectares in 2020 (an average decrease of about 14,590 hectares/year). Hanoi city has the fastest rate of rice land reduction of 3,554 hectares/year, followed by the following provinces: Hung Yen, Hai Duong, Thai Binh, Nam Dinh, Hai Phong, Ha Nam, Bac Ninh, Vinh Phuc. The province with the least change in rice cultivation is Ninh Binh province.

3. The thesis has assessed the impact of natural and human factors on land resources and pointed out some shortcomings in rice land use in the Red River Delta. The study has also drawn 4 advantages (geographical location - suitable natural conditions, abundant human resources and long-standing farming experience, good infrastructure and consumer markets, consumption is stable, there are policies to support rice production, consumption and processing) in addition to the challenges (pressure from a large population; Cultivated area shrinks, the risk of soil pollution increases due to the impact of urbanization and industrialization; ineffective land use

management; risk of land degradation, land loss due to climate change, sea level rise...) from the current status and fluctuations in rice land use in the Red River Delta.

4. The results of the assessment and classification of land suitability for wet rice cultivation (2 rice crops) in the Red River Delta in 2020 have determined the area and distribution of suitable levels of wet rice land use, of which the statistical results of the area of suitable levels, very suitable level (S1) is 51,478.93 hectares, suitable level (S2) is 351,281.10 ha, little suitable (S3) is 143,861.64 ha and unsuitable (N) is 179,232.77 hectares.

5. Using the principles (relative homogeneity, common territory, synthesis, dominant factors) and zoning methods (method of analyzing component maps, dominant factors and expert methods) to determine the soil geographic sub-regions. The results have built a map of geographical and pedological zoning of wet rice growing land in the Red River Delta, scale 1: 250,000, have divided the soil cover of the research territory into 16 soil geographic sub-regions, including 9 sub-regions specialized in wet rice cultivation (A) and 7 sub-regions with little or no wet rice cultivation (B).

6. The research also proposed solutions on the map proposing the use of land for wet rice cultivation in the Red River Delta in 2030, at a scale of 1: 250,000, according to the function of the land use unit and the soil geographical zoning with 3 focuses: economic exploitation for investment in high-tech rice cultivation; development of specialty rice cultivation; economic exploitation to ensure food security, stabilize quality and protect the natural ecological environment.

NEW CONTRIBUTIONS OF THE THESIS

Analyzing the specificity, in the differentiation of soil cover in the Red River Delta, the classification system used for the soil geographical map of the Red River Delta's rice cultivation land with the scale of 1:250.000 has been determined, resulting in 9/16 areas specializing in rice growing. At the same time, the results of the assessment of rice cultivation land suitability showed that the current rice gcultivation status in 2020 only accounts for 64,14% of the area assessed as suitable for rice cultivation (S1, S2), so the thesis recommends upgrading the regular irrigation system and adding more suitable rice cultivation areas in the region to ensure food security and sustainable socio-economic development in the new period.

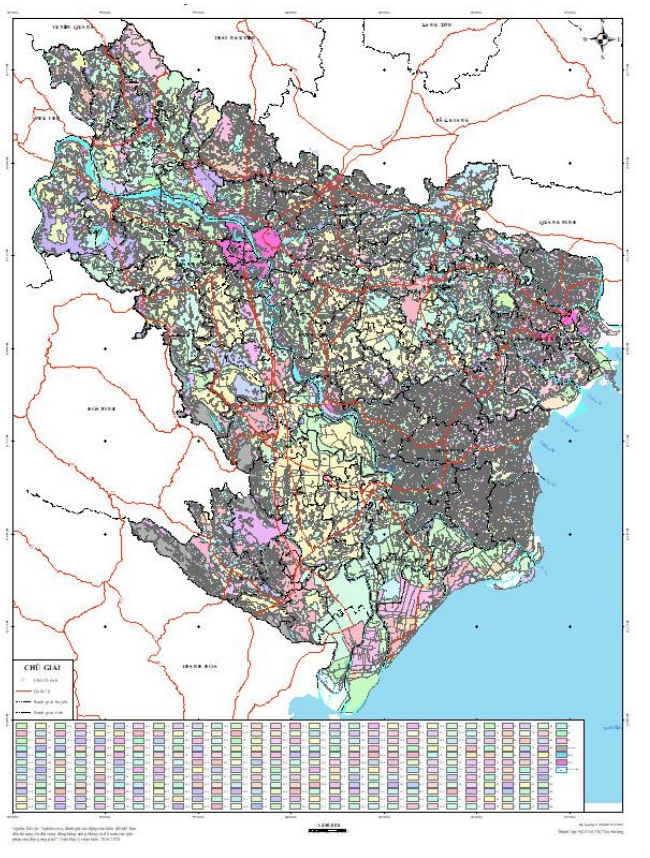

Figure 3.1. A land unit map for wet rice cultivation in the Red river Delta

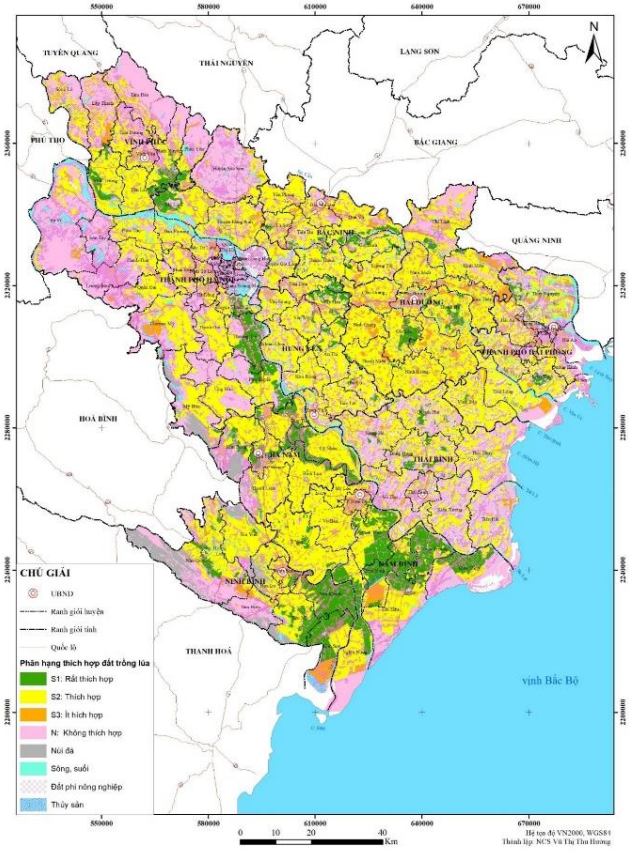

Figure 3.2. A map for suitability assessment for wet rice cultivation in the Red river Delta

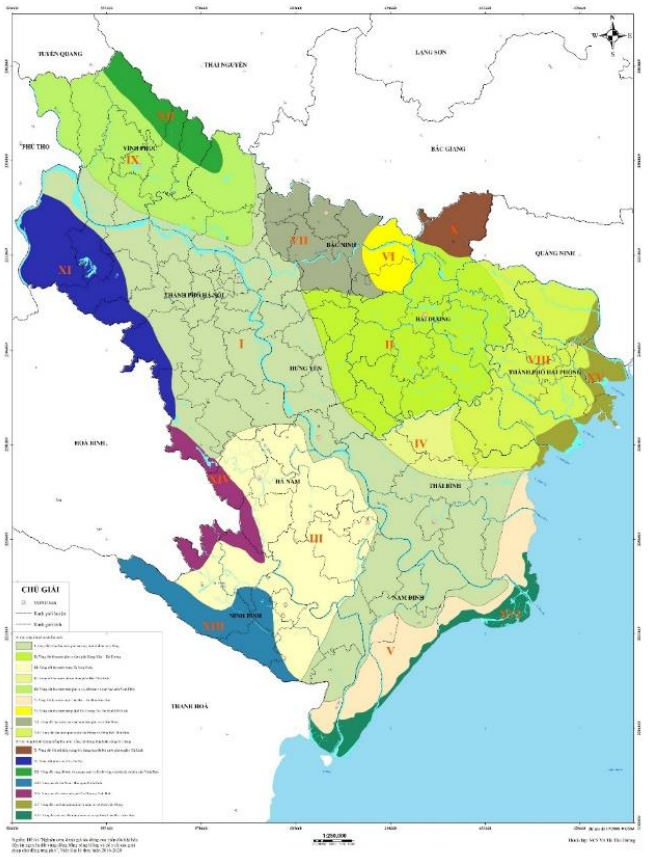

Figure 3.3. A soil geographical zoning map in the Red river Delta

Figure 3.4. A map for proposal of wet rice cultivation land use until 2030 in the Red river Delta

LIST OF THE PUBLICATIONS RELATED TO THE DISSERTATION

1. Vu Thi Thu Huong, Nguyen Manh Ha, Hoang Thi Huyen Ngoc, Nguyen Van Dung, Nguyen Thi Thuy (2019) *Study on land use change in Quang Binh province for the periord 2005 – 2015*, Journal of Soil Science, Vietnam Journal of Soil Science Association, No. 55, pp.155-161.
2. Vu Thi Thu Huong, Cao Viet Ha, Ngo Van Gioi (2021), *Assessment of current situation and variation of wet rice land cultivation area in the Red River Delta region*, TNU Journal Science and Technology; ISSN/eISSN:1859-2171/2615-9562; No. 226 (14), pp. 146-152, http://jst.tnu.edu.vn/jst/ft/view/92;
3. Hoang Thi Huyen Ngoc, Nguyen Manh Ha, Nguyen Van Dung, Vu Thi Thu Huong (2017) *The current situation and the possibility of saline intrusion in Tien Hai district, Thai Binh province*, Journal of Soil Science, Vietnam Journal of Soil Science Association, No. 52, pp. 34-40.
4. HaNguyen,TuanNguyen,NgocHoang,DungBui,HuongVu, Tap Van (2020) *The application of LSE software: A new approach for land suitability evaluation in agriculture*, Computers and Electronics in Agriculture, Elsevier, No. 173, 105440, pp. 1-16. https://doi.org/10.1016/j.compag.2020.105440;