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ASSESSMENT OF LAND USE CHANGES IN HUNG YEN PROVINCE FROM 2010 TO 2020, FORECAST TO 2030 AND PROPOSED SOLUTIONS FOR SUSTAINABLE LAND USE OF THE PROVINCE

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ABSTRACT

Hung Yen is a province in the Red River Delta, located in the center of the Northern Delta and the Northern Economic Zone (Hanoi - Hung Yen - Hai Duong - Hai Phong - Quang Ninh). Due to that favorable geographical location, in recent years, infrastructure and industrial parks in the province have developed strongly. The results of the assessment of land use changes in the period 2010-2020 in Hung Yen province show that the period 2015-2020 had more significant changes than the period 2010-2015. For industrial land, the period 2015-2020 saw an increase of 137.70%, while the period 2010-2015 saw an increase of 84.25%. Residential land, office buildings, transportation, and other non-agricultural land increased by 8.3% in the period 2015-2020, while it increased by 6.81% in the period 2010-2015. On the other hand, the agricultural land fund also saw a faster decline in the period 2015-2020 than in the period 2010-2015. For example, the area of land for perennial crops decreased by 18.71% in the period 2015-2020, while it decreased by 7.75% in the period 2010-2015. The results of the forecast of land use status to 2030 show that the area of non-agricultural land has surpassed that of agricultural land. In particular, the area of land for annual crops has decreased significantly, with a decrease of 8.88%, much higher than the 4.60% in the period 2010-2020. This type of land was used for growing rice and other vegetables to ensure food security for the province and the country. In addition, due to the shrinking agricultural land area, it is necessary to switch the crop structure to be suitable for climatic conditions as well as for each type of soil and terrain conditions. In addition, it is necessary to apply scientific and technical methods to agriculture to increase productivity and achieve high economic efficiency.

Keywords: land use change, sustainable land use, hung yen.

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1. INTRODUCTION

Hung Yen is a province in the Red River Delta, located in the center of the Northern Delta and the Northern Economic Zone (Hanoi - Hung Yen - Hai Duong - Hai Phong - Quang Ninh). Hung Yen province has 923.45 km^2 of natural area and 1.156 million people, with an average population density of 1,252 people/km^2. The province has a system of important highways, including National Highway 5A, 39A, 38, 38B, Hanoi - Hai Phong expressway; Provincial routes 200, 207, 208, 199 ... and the Hanoi - Hai Duong - Hai Phong railway, connecting Hung Yen with the northern provinces, especially with Hanoi, Hai Phong and Quang Ninh; There is a system of the Red River and Luoc River, forming a relatively convenient transportation network for goods exchange and travel [2].

With that favorable geographical condition, Hung Yen province is currently very developed in terms of infrastructure and typical industrial parks such as Pho Noi A Industrial Park, Pho Noi B Industrial Park, Minh Duc Industrial Park, Thang Long 2 Industrial Park,...Some urban areas such as ECOPARK, SUDICO, Villa Park Pho Noi,... [2]. The rapid development of industrial parks and urban areas will affect the province's agricultural land and tree land as well as raise environmental problems.

The application of remote sensing to study the relationship between land use changes and factors promoting socio-economic development such as the development of transport infrastructure, and hydrology,... has been developed as an Application to evaluate usage fluctuations for many different regions. Recently, research on integrating Logistic regression models, and Markov chains with Cellular Automata on GIS allows forecasting of land use changes in space and time with high reliability [6], [9], [10].

Therefore, to provide more scientific basis for managing and orienting land use in a more reasonable, effective and sustainable way of land resources in Hung Yen province, this study was carried out with the following objectives: (i) Assess developments in the current state of land use, land environment and the effectiveness of implementing land use planning in Hung Yen province in the period 2010 - 2020; (ii) Applying Logistic regression models, Markov chains with Cellular Automata on GIS to forecast land use changes, land environment and propose planning directions for sustainable use of land resources in the province in the period 2020 - 2030.

2. DATA AND METHODS

2.1 Data

The data used in this study included Landsat 5 data from 2000, 2010 Landsat 8 data from 2015, 2020 [8] in the Hung Yen province area with image information presented in Table-1.

Data on natural conditions, socio-economic conditions, planning, land use plans, and local land use policies for the period 2000-2020.

Table-1. Landsat satellite images used in research [8].

No	Year	Image ID	Resolution (m)	Cloud coverage (%)	Image types
1	2010	LT05_L1TP_126046_20101203_20200823_02_T1 LT05_L1TP_127045_20101108_20200823_02_T1	30 30	2.0 1.0	Landsat 5
2	2015	LC08_L2SP_127046_20150122_20200910_02_T1 LC08_L2SP_126046_20150225_20200910_02_T1	30 30	4.9 6.07	Landsat 8
3	2020	LC08_L1TP_126046_20200621_20200823_02_T1 LC08_L1TP_127046_20200628_20200824_02_T1	30 30	5.7 6.37	Landsat 8

2.2 Methods

2.2.1 Remote sensing image interpretation method

To create land use maps for each year, the study used supervised remote sensing image interpretation [4]. The process of conducting remote sensing image interpretation is carried out in the following steps: (1) Geometric correction (The images are unified to the UTM WGS84 ZONE 48 coordinate system). (2) Image enhancement (Maximum Likelihood method). (3) Image cropping according to the research area boundaries. (4) Image interpretation key establishment. (5) Remote sensing image classification using the supervised method. (6) Evaluation of classification results. The accuracy of the interpretation is evaluated based on the Kappa coefficient (K).

Based on the basic color combination principle of remote sensing images, the interpretation of Landsat 5 and Landsat 8 images, the research objects are classified and monitored according to the following color combinations in Table-2.

Table-2. Color combination type, and application [7].

Image types and spectral band	Color combination	Characteristic/Application
Landsat 8 (band 4,3,2) Landsat 5 (band 3,2,1)	Natural color	Distinguish between vegetation and bare land, very little other information about vegetation.
Landsat 8 (band 5,4,3) Landsat 5 (band 4,3,2)	Near-infrared	Roads, water, distinguish between deciduous forests and fruit trees, easy to identify agricultural and non-agricultural land.

The following five land cover types were selected for interpretation in satellite images (Table-3). The interpretation process combined with field surveys of five selected land cover types, with the number of survey points ranging from 7 to 12 ground control points for each group of objects for the objects in the 2020 satellite image (Table-3). For the years 2010 and 2015, data on the current land use of the province were used to recover the actual use corresponding to each year [1].

Table-3. Land cover types and ground control points used in image interpretation.

No	Land cover type	Number of field survey samples (ground control points)
1	Annual cropland	12
2	Perennial cropland	9
3	Residential, commercial, transportation, and other non-agricultural land	10
4	Industrial areas	8
5	Water bodies, rivers, canals	7

The interpretation area is carried out based on the position on the satellite image and the field survey object, and historical land use data at the points. The evaluation of the correlation of training samples is extremely important, because they show the possibility of overlap, causing

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errors in the object classification stage. Sample difference assessment is the calculation of the correlation of spectral values between pairs of selected training samples for a given input file. Sample difference assessment values have a range of values from 0 to 2, indicating the separation between pairs of training samples in statistical terms. If the value is greater than 1.9, it indicates that the training pair has a good separation. For training pairs with lower values, training samples should be improved or modified [4].

After interpreting and building a land use map, the area will be calculated and the land use change will be evaluated for the periods 2010–2015; 2015–2020, and 2010–2020.

2.2.2 Land use change prediction method

To conduct land-use change prediction in the future, the study uses an integrated Markov chain and logistic regression model. In the case of simulating land use change, the basic assumption of the Markov chain model is to consider land use change as a random process that occurs in a sequence of steps through a set of states [5]. This process gives a value at time t, Xt, and only depends on its value at a time (t-1), Xt-1, but not on the chain of values Xt-2, Xt-3, ..., X0 that the process has gone through to arrive at Xt-1. It can be expressed as follows: $N(t+1) = N(t) \times P$. In which: Nt+1 and Nt are respectively the vectors containing the areas of each land type at a time (t+1) and time t; P is a square matrix, with the value of cell Pij is the probability of transition from horizontal i to j in time t and (t+1).

The Markov chain model is integrated with the logistic regression model to determine the spatial distribution of land types. As a statistical model, the logistic regression model estimates the probability of the occurrence of change events in the form of a binary dependent variable. Corresponding to a value of 1 representing the presence of land use change and a value of 0 representing the absence of land use change. Thus, at each pixel, the logistic model determines the probability of occurrence of each type of land being considered. In other words, the product of the logistic model is a spatial probability map of transition from one land use type to another under the influence of driving factors (transport network, hydrological system, in Figure-1) with data built by ArcGIS software 10.2 in the form of Euclidean distance maps (Euclidean Distance maps) (Figure-1). The analyses are based on the LCM Model (Land Change Modeler) integrated into the TerrSet IDRISI 18 software to predict.

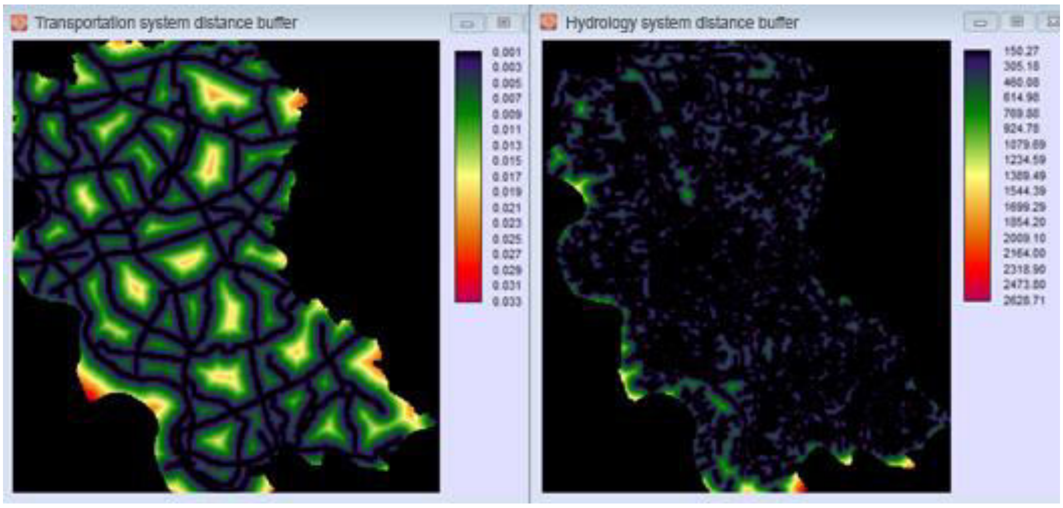

Figure-1. Distance buffer to the transportation system (left) and hydrology system (right) are used as driving factors in the prediction model.

2.2.3 Land use prediction method

The essence of the Markov chain analysis method is to build the relationship between 2 land use maps at 2 assessment periods to provide a scientific basis for the modeling process in the next steps. The reason the forecast time is 2030 is based on the calculation of the Markov transition matrix to determine the time step for the evaluation process. The forecast time of 2030 is determined by calculating the time interval between 2010 and 2020, specifically according to the following formula:

$$TDB = TCT + (TCT - TCD) \quad (1)$$

In which:

TDB: Forecast time
TCT: Upper time limit of the evaluation process
TCD: Lower time limit of the evaluation process

Applying the formula above, we will determine the forecast time for land cover change in Hung Yen province as follows:

TDB = 2020 + (2020 – 2010) = 2030

The steps for evaluating land use change and forecasting are shown in the diagram in the following research steps in diagram Figure-2.

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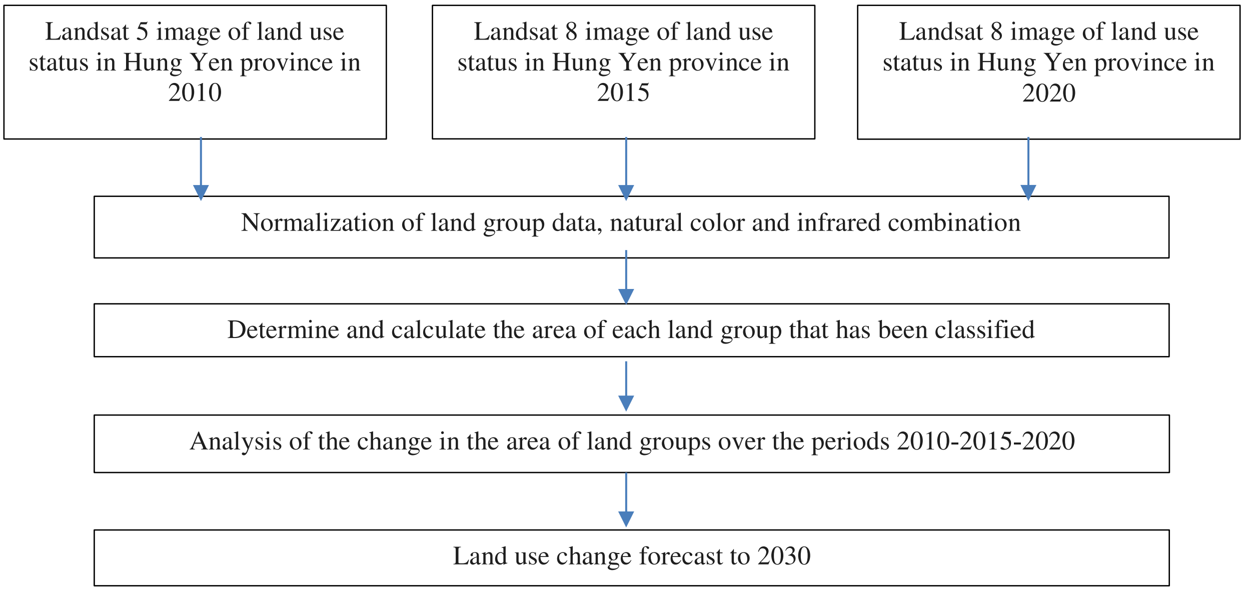

Figure-2. Land use change and forecast evaluation process in Hung Yen province.

3. RESULTS AND DISCUSSIONS

3.1 Building Land Use Maps for 2010, 2015, and 2020

The results of image interpretation for building land use maps for the years 2010, 2015, and 2020 are shown in Figure-3. The results of image interpretation were evaluated using the Kappa coefficient, with a value of 0.79 for the map for 2010, 0.86 for the map for 2015, and 0.82 for the map for 2020. These coefficients are considered to be good or better, and the image interpretation results meet the accuracy requirements.

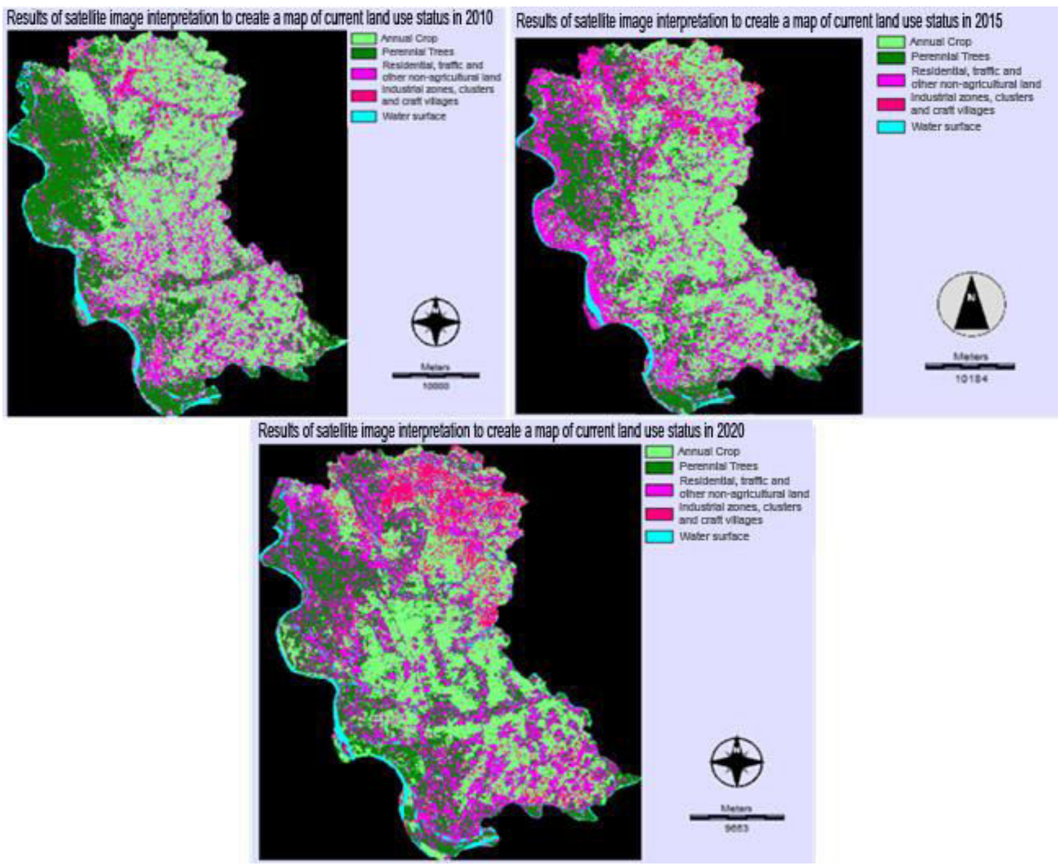

Figure-3. Image map of the results of land use classification for the years 2010, 2015, and 2020.

From the interpreted map, the area of 5 land types is calculated for the years 2010, 2015, and 2020. The results of the area calculation are shown in Table-4. These results are used to assess land use change for the periods.

Table-4. Current land use area by land cover type, year.

Land use types	Year (ha)		
	2010	**2015**	**2020**
Annual cropland	32,857.47	32,275.50	31,346.70
Perennial cropland	24,589.08	22,683.18	18,439.86
Residential, administrative, transportation, and other non-agricultural land	25,363.08	27,090.88	29,339.83
Industrial zones and clusters	1,309.14	2,412.14	5,733.71
Ponds, rivers, canals and ditches	8,794.08	8,451.15	8,052.75
Total	92,912.85	92,912.85	92,912.85

3.2 Assessment of Land Use Changes from 2010 to 2020 and Forecast for 2030

Results of the comprehensive analysis of land use changes for the periods 2010 - 2015, 2015 - 2020, and 2010-2020 are shown in Table-5. In general, during the period 2010-2020, the province saw a significant increase in the land area of industrial zones and clusters, with an increase of 337.98%, corresponding to 4,424.57 ha. The land area of agriculture decreased the most, with the land area of perennial crops (mainly fruit trees) decreasing by 25.01%, corresponding to 6,149.22 ha. The land area of residential, administrative, transportation, and other non-agricultural land also increased by 15.68%, corresponding to an area of 3,976.75 ha.

During the period 2010-2020, the period 2015-2020 saw more significant changes than the period 2010-2015. For industrial zones and clusters, the land area increased by 137.70% in the period 2015-2020, while it increased by 84.25% in the period 2010-2015. The land area of residential, administrative, transportation, and other non-agricultural land increased by 8.3% in the period 2015-2020, while it increased by 6.81% in the period 2010-2015. On the other hand, the land area of agriculture also saw a greater decrease in the period 2015-2020 than in the period 2010-2015, for example, the land area of perennial crops decreased by 18.71% in the period 2015-2020, while it decreased by 7.75% in the period 2010-2015.

In general, during the period 2010-2020, the land area of the province saw a significant change in the land area of industrial zones and clusters, which is due to the policy of industrial development as well as the province's favorable geographical location in the center of the Red River Delta and the Northern Economic Zone.

Table-5. Land use area changes by land cover type by period.

Land use type	Land use change by period (ha) Increase (+)/Decrease (-)					
	2010 - 2015		**2015 - 2020**		**2010-2020**	
	ha	**%**	**Ha**	**%**	**ha**	**%**
Annual cropland	-581.97	-1.77	-92.80	-2.88	-1,510.77	-4.60
Perennial cropland	-1,905.90	-7.75	-4,243.32	-18.71	-6,149.22	-25.01
Residential, administrative, transportation, and other non-agricultural land	1,727.80	6.81	2,248.95	8.30	3,976.75	15.68
Industrial zones and clusters	1,103.00	84.25	3,321.57	137.70	4,424.57	337.98
Ponds, rivers, canals, and ditches	-342.93	-3.90	-398.40	-4.71	-741.33	-8.43

3.3 Land Use Change Forecast for 2030

The land use simulation map for 2020 was created by an integrated Markov chain model based on the land use maps for 2010 and 2015. The results of the evaluation showed that the Kappa coefficients (Kstandard; Kno; Klocation; KlocationStrata) were all greater than 0.8, which is considered to be good [3]. This indicates that the model is accepted for forecasting future land use changes.

Using the data from 2010 and 2020, along with the driving forces of the transportation and water infrastructure systems (Figure-1), to input data for the LCM model with the support of the Markov-CA model integrated into the IDRISI-Terrset software, the results of building the land use forecast map for 2030 in Hung Yen province are shown in Figure-4.

From the results of building the forecast map, the area of land by type is calculated as shown in Table-6. The forecast results show that by 2030, the area of non-agricultural land (including residential, administrative, transportation, and other non-agricultural land and industrial zones and clusters) will have an area of 45,215.50 ha, which is already superior to agricultural land with an area of 40,119.10 ha. Land use changes from 2020 to 2030 are mainly focused on converting agricultural land to industrial zones and clusters, which still account for the largest proportion with an increase of 81.28%, and converting to residential, administrative, transportation, and other non-agricultural land with an increase of 18.68%. In particular, this period has a significant decrease in annual cropland with a decrease of 8.88%, much higher than 4.60% in the 2010-2020 period. This type of land is used to grow rice and other vegetables to ensure food security for the province and the country. Therefore, in the process of development planning, it is necessary to ensure the agricultural land fund to ensure the food security goal.

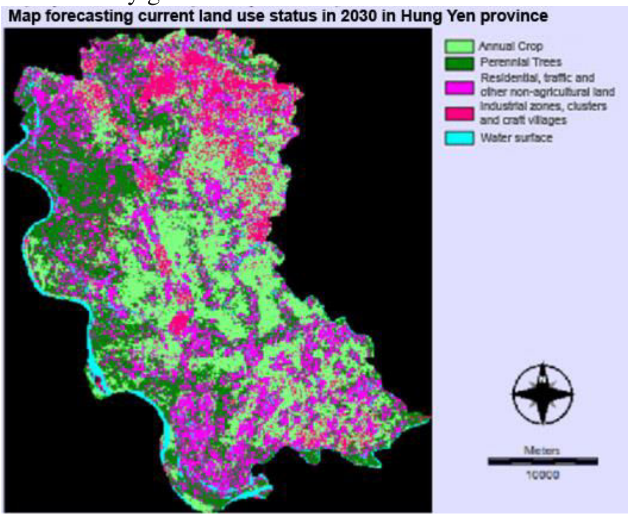

Figure-4. Map forecasting current land use status in 2030 in Hung Yen province

Table-6. Forecasted land use changes by group by 2030.

Land use types	Area forecast for 2030		Area in 2020		Change 2020-2030 Increase (+)/Decrease (-)	
	ha	%	(ha)	%	ha	%
Annual cropland	28,564.24	30.74	31,346.70	33.74	-2,782.46	-8.88
Perennial cropland	11,554.86	12.44	18,43.86	19.85	-6,885.00	-37.34
Residential, administrative, transportation, and other non-agricultural land	34,821.26	37.48	29,339.83	31.58	5,481.43	18.68
Industrial zones and clusters	10,394.24	11.19	5,733.71	6.17	4,660.53	81.28
Ponds, rivers, canals, and ditches	7,578.25	8.16	8,052.75	8.67	-474.50	-5.89
Total	92,912.85	100.00	92,912.85	100.00	-	-

Currently, the Vietnam government has set a goal of ensuring domestic food supply by 2030 by maintaining 3.5 million hectares of rice-growing land and 1.2-1.3 million hectares of cropland, equivalent to about 15% of the total land area of the country. However, Hung Yen province is located in the Red River Delta, one of the eight major agricultural ecosystems in the country, with a current agricultural land rate of 51.2% of the region. Therefore, to ensure food security and economic efficiency for the province and the country, it is necessary to have solutions to protect and maintain this land fund.

Because agricultural land funds are increasingly being reduced due to conversion to non-agricultural purposes. Therefore, it is necessary to change the crop structure to suit the climatic conditions and each soil type to increase efficiency. In addition, it is necessary to apply scientific and technical measures to agriculture to increase productivity and achieve high economic efficiency.

Based on the characteristics of the province's terrain, for the land outside the dike that is not irrigated in the dry season, the rainy season is often flooded by 3-4 meters. The soil in this area is characterized by annual sedimentation, so it is quite fertile. For this area, only 2 crops of vegetables can be planted in the winter and winter-spring seasons mulberry, and ornamental trees that can be moved to avoid flooding such as oranges, grapefruits, bonsai trees, etc. The alluvial soil in the dike, distributed in the medium and high terrain, is arranged for many types of dry land crops such as vegetables, flowers, and ornamental plants and fruit trees such as lychee, mandarin oranges, lemons, grapefruits, etc. On this land, if the irrigation conditions are favorable, it can be arranged to produce 2 crops of rice and 1 crop of vegetables. The alluvial land distributed in the low and low-lying terrain is suitable for 2 crops of rice.

4. CONCLUSIONS

The results of the evaluation of land use changes in the period 2010-2020 in Hung Yen province show that, in the period 2010-2020, the province's land fund has seen a significant change in industrial zones and clusters, due to the industrial development policy as well as its favorable geographical location in the center of the Red River Delta and the Northern Economic Zone. The 2015-2020 period saw a more significant change than the 2010-2020 period. On the other hand, agricultural land also decreased sharply in the 2010-2020 period, with a decrease of 29.61%.

The results of the forecast of land use status by 2030 show that the area of non-agricultural land (including residential land, office land, transportation, and other non-agricultural land and industrial zones and clusters) has an area of 45,215.50 ha, which has already exceeded the area of agricultural land with an area of 40,119.10 ha. Land use changes from 2020 to 2030 will focus on converting agricultural land to industrial zones and clusters. In particular, this period saw a significant decrease in annual cropland, with a decrease of 8.88%, much higher than the 4.60% in the 2010-2020 period. This type of land is used to grow rice and other vegetables to ensure food security for the province and the country. Therefore, to ensure food security and economic efficiency for the province and the country, it is necessary to maintain the province's agricultural land fund. In addition, due to the shrinking agricultural land fund, it is necessary to change the crop structure to be suitable for climatic conditions, soil, and terrain conditions. In addition, it is necessary to apply scientific and technical methods to agriculture to increase productivity and achieve high economic efficiency.

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