Applying GIS and Markov chain in establishing the land use change map and forecasting land use changes in Thach That district, Hanoi city

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Ứng dụng GIS và chuỗi Markov trong thành lập bản đồ biến động đất đai và dự báo biến động sử dụng đất huyện Thạch Thất, thành phố Hà Nội

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ABSTRACT

The study applied GIS and Markov chains to assess land use changes in the period 2015-2020 and forecast land use change trends in Thach That district, Hanoi city until 2030. Using two maps of the land use status quo map in 2015 and 2020 of Thach That district and 2 period land statistics, the research result has established a land use change map in Thach That district for the period 2015 - 2020 for 16 types of land with a land change rate of 9.63% of the total natural area. During this period, the land types that tend to increase are Perennial crop land; Special-use Forest land; Aquaculture land; Other agricultural land; Residential land; Special-use land; Land for religious establishments; Land for beliefs establishments and Specialized water surfaces with an increased rate of 0.05-2.28%. In contrast, land types with a decreasing trend are Annual crop land; Production Forest land; Protective Forest land; Cemetery land, cemetery, funeral home, crematorium; Land of rivers, streams, canals and streams; Other non-agricultural land, and Unused land which decreased at a rate of 0.02-2.34%. It is forecast that by 2030, agricultural land will have 10,271.28 hectares (accounting for 54.90%), non-agricultural land will have 8,432.22 hectares (accounting for 45.07%), unused land will have 4.76 hectares (accounting for 0.03%). Performing a T-Test (Paired two sample for Means) between the area from the forecast and the planned area until 2030 shows that ρ = 0.979 > 0.05. Thus, it proves that the results of forecasting land use changes to 2030 using the Markov chain compared to the land use planning plan of Thach That district do not have too big a difference. The results of assessing land use changes and making forecasts of land change trends in the Thach That district contribute to helping policymakers have an objective view of land-use planning and economic development sustainably.

Từ khóa:
Biến động sử dụng đất, chuỗi Markov, GIS, quy hoạch sử dụng đất, Thạch Thất.

TÓM TẮT

Nghiên cứu đã ứng dụng GIS và chuỗi Markov để đánh giá biến động sử dụng đất giai đoạn 2015-2020 và dự báo xu hướng biến động sử dụng đất trên địa bàn huyện Thạch Thất, thành phố Hà Nội đến năm 2030. Kết quả nghiên cứu đã thành lập bản đồ biến động sử dụng đất tại huyện Thạch Thất giai đoạn 2015 – 2020 cho 16 loại đất với tỷ lệ biến động đất đai là 9,63% tổng diện tích tự nhiên. Trong giai đoạn này, các loại đất có xu hướng biến động tăng là đất trồng cây lâu năm; đất rừng đặc dụng; đất nuôi trồng thủy sản; đất nông nghiệp khác; đất ở; đất chuyên dùng; đất cơ sở tôn giáo; đất cơ sở tín ngưỡng, đất có mặt nước chuyên dùng với tốc độ tăng từ 0,05-2,28%. Bên cạnh đó, các loại đất có xu hướng giảm là đất trông cây hàng năm; đất rừng sản xuất; đất rừng phòng hộ; đất nghĩa trang, nghĩa địa nhà tang lễ, nhà hỏa táng; đất sông, ngòi, kênh rạch; đất phi nông nghiệp khác và đất chưa sử dụng với tốc độ giảm từ 0,02-2,34%. Dự báo đến năm 2030, đất nông nghiệp có 10.271,28 ha (chiếm 54,90%), đất phi nông nghiệp có 8.432,22 ha (chiếm 45,07%), đất

chưa sử dụng có 4,76 ha (chiếm 0,03%). Thực hiện kiểm định T-Test giữa diện tích sử dụng đất từ dự báo và diện tích quy hoạch đến năm 2030 cho thấy ρ = 0,979 > 0,05. Như vậy, chứng tỏ kết quả dự báo biến động sử dụng đất đến năm 2030 bằng chuỗi Markov so với quy hoạch sử dụng đất huyện Thạch Thất không có sự khác biệt lớn. Kết quả đánh giá biến động sử dụng đất và đưa ra dự báo xu hướng biến động đất của huyện Thạch Thất góp phần giúp chính quyền địa phương có cái nhìn khách quan trong việc quy hoạch sử dụng đất, phát triển kinh tế bền vững.

1. INTRODUCTION

Land is constantly fluctuating in size, distribution, and type of use. Land use change is a complex process subject to internal and external influences, including natural geographical and socio-economic factors [1-3]. Therefore, if you want to manage land effectively and in detail, monitoring and evaluating land use changes is necessary. Land change assessment provides a comprehensive and general view of the land use situation in the area, evaluates production potential [4] and is a basis for planning, land use plan for the locality [2, 5].

Currently, the combination of remote sensing and GIS in assessing change has also been initially implemented, bringing many results. A typical example is the study of Le Thi Thu Ha (2016) on "Research on land use changes in relationship with some demographic factors in Giao Thuy district, Nam Dinh province". The author created a map of the current land use status with satellite images using eCognition Development and GIS software, assessed land use changes in the periods 1989 - 1999, 1999 - 2009, 2009 - 2013 and applied the Markov chain to predict land use changes, the results of the model have been verified and are completely accurate [6]. Research to evaluate space-time changes in land cover/use as well as their causes and impacts on changes in Phu Tan district, Ca Mau province over 30 years from 1989 to 2018 [7]. The authors used Landsat images that were collected and classified using an expert method. After accuracy assessment and post-classification processing, the maps were set to detect actual/land use change over three decades. The results of this study will contribute to the design of economic, social and environmental policies to ensure sustainable development at the district level. The project "Application of remote sensing and GIS to evaluate and predict urban land changes in Hiep Binh Phuoc ward, Thu Duc district" used remote sensing and GIS technology to analyze urban land changes in Hiep Binh ward. Phuoc District Thu Duc, Ho Chi Minh City and use Markov chains to forecast the speed of urban land development until 2026. Research results show that urban land in the area needs to be planning-oriented because it will affect both the urban development planning of Thu Duc district and Ho Chi Minh City. In addition, the study also found that the Hiep Binh Phuoc area has a relatively weak foundation and a significant risk of riverbank erosion that can endanger people's lives [8]. However, most of the changing areas are not in accordance with the general planning of the City. Ho Chi Minh shows that the use of Markov chains in predicting urban land development speed does not achieve the highest accuracy. The forecast results are only correct if there is no change in legal policy on urban land in the forecast year. Phan Hoang Vu and others (2017) applied geographic information systems (GIS) and algorithms to evaluate land use changes and forecast land demand for socio-economic development in the Ca Mau city, Ca Mau province [9]. Another study used GIS and Markov chains to predict land use change trends in Phu Tho province [10]. Nguyen Huu Cuong et al., 2022 integrated Markov chain and logistic regression to predict changes in land use purposes in Lam Ha district, Lam Dong province [11]. Author Phan Trong The et al. (2023) evaluated and predicted land use

changes in Nhon Trach district, Dong Nai provinces based on applying GIS and Markov chains in the period 2010-2020 and forecasting change trends in land-use change in the period between 2025 and 2030 [2]. In addition, there are many research projects using GIS and Markov chains that have achieved many expected results.

Thach That is a suburban district located northwest of Hanoi city with 23 communes with a total natural area of 18,752.51 hectares [12]. These communes have hilly terrain, low mountains, beautiful scenery, and abundant land fund, which is great potential for developing ecological urban areas and tourist areas. The district's economy is on the rise, the urbanization rate is happening quite quickly, Hoa Lac high-tech park, National University have been in operation, the urban areas formed will create new major changes and have significant impacts on the environment. Therefore, the district has rapid fluctuations and diversity in land use.

2. RESEARCH METHODS

2.1. Land use change analysis

Collect maps of the land use status quo map in 2015 and 2020 of Thach That district with *.dgn format, combined with land statistical data from the 2 periods [13, 14]. In addition, the study collects data on natural conditions, socio-economic conditions, and land use.

Standardize input data and build a database and assess changes according to land type groups specified in Circular 27/2018/TT-BTNMT, dated 14/12/2018 of the Ministry of Natural Resources and Environment regulating land statistics, inventory and land use status quo mapping [15]. Classify the current land use status into 16 land types as shown in table 1. Convert data to *.shp format and use QGIS software to build the attribute database and complete spatial data. The results are two layers of current land use status in 2015 and 2020. Using the Intersection tool in QGIS software, overlay two current status layers to create a map of land use changes in Thach That district. Use attribute data of change maps to conduct change analysis land use changes.

2.2. Land use prediction modeling

Based on the land use change matrix of the previous period, the fluctuation coefficient is determined to forecast the land use area in the next period. In this study, we use the results of land use changes in the period 2015-2020 to forecast land use changes in 2025 and 2030. To effectively do this, Markov chain was used. Markov chain is a useful technique for prediction of future land use change when dynamics landscapes changes are difficult to project. The Markov process predicts future state of a system based on the preceding state by developing a transition probability matrix of land use change starting from time one to time two. It shows the nature of changes as well as form the basis of future development forecasting [16]. Markov method of predicting future state of a landscape requires the state transition of a system to another. This transition of one state to another state is described by the transition probability expressed below as:

$$P = Pij = \begin{vmatrix} P_{11} & P_{12} & \dots. & P_{1n} \\ P_{21} & P_{22} & \dots. & P_{2n} \\ P_{31} & P_{32} & \dots. & P_{3n} \\ P_{41} & P_{42} & \dots. & P_{4n} \end{vmatrix} \quad (1)$$

Where:

P means probability from one state to another state (in this case state i to j) [17] Eq. (1) must meet the following two conditions:

$$\sum_{j=1}^{n} P_{ij} = 1 \text{ and } 0 \le P_{ij} \le 1$$

Obtaining a primary matrix and transition probability matrix (P_{ij}) is a major step in Markov model. Hence, the Markov forecast model is expressed as stated in Eq. (2).

$$P_n = P_{(n-1)}\ P_{ij} = P_{(0)}\ P_{ij}^{n} \quad (2)$$

where,

P_n represent the state probability while;

$P_{(0)}$ represents primary matrix.

3. RESULTS AND DISCUSTION

3.1. Current status of land use in Thach That district

Thach That district has a total area in 2020 of 18,752.51 hectares. The district's land use structure in 2020 shows that agricultural land occupies the main area with 10,533.08

hectares and non-agricultural land is 8,199.20 hectares, accounting for 56.17% and 43.72%, respectively. In Agricultural land, annual cropland occupies the majority (6,042.47 hectares). In the Non-agricultural land group, Special-use land accounts for the majority (5,621.10 hectares). Unused land is only 20.23 hectares, accounting for 0.11%.

Table 1. Current land use in Thach That district in the period 2015-2020

No.	Land types		Code	Area in 2015 (ha)	Area in 2020 (ha)
1	Agricultural land	Annual crop land	CHN	6,446.99	6,042.47
		Perennial crop land	CLN	1,154.73	1,531.49
		Production Forest land	RSX	1,762.30	1,635.92
		Protective Forest land	RPH	10.59	0.00
		Special-use Forest land	RDD	822.19	854.04
		Aquaculture land	NTS	331.95	358.72
		Other agricultural land	NKH	146.95	110.44
2	Non-agricultural land	Residential land	OTC	1,893.11	1,951.56
		Special-use land	CDG	5,384.51	5,621.10
		Land for religious establishments	TON	14.49	22.88
		Land for beliefs establishments	TIN	9.89	16.75
		Cemetery land, cemetery, funeral home, crematorium	NTD	143.33	126.06
		Land of rivers, streams, canals and streams	SON	365.22	184.54
		Specialized water surfaces	MNC	183.48	274.70
		Other non-agricultural land	PNK	6.47	1.61
3	Unused land		CSD	67.98	67.98
	Total			**18,744.18**	**18,752.51**

Source: Department of Natural Resources and Environment of Thach That district [13, 14]

Due to changes in administrative boundaries and cadastral measurements for more accurate areas, the total land area of Thach That district in 2020 (18,752.51ha) increased by 8.33ha compared to 2015 (18,744.18ha).

3.2. Assessing land use changes in the period 2015-2020

3.2.1. Create a land use change map

The collected data includes two maps of the current land use in Thach That district in 2015 and 2020 with digital files in *.dgn format. Evaluate changes according to 16 types of land in Table 1. Once the soil groups have been merged, convert the format from *.dgn to *.shp. After that, two maps of the current land use were corrected with geometric errors.

The maps of current land use in 2015 and 2020 have differences not only in the way of determining land types but also in boundaries and a need to correct geometric errors, gaps appearing between regions, and overlapping layers. Therefore, before overlaying maps, it is necessary to standardize the current maps.

3.2.2. Evaluating and establishing land-use change map

In the period from 2015 to 2020, Thach That district has a history of land use changes showed in table 2. The land area results from the current map and inventory data have differences due to the standardization of input data and map database construction. The data between the current status map and statistical data have no major differences with R=0.99. The results based on the T-Test (Paired two sample for Means) between the area according to statistics and the area according to the current map in 2015 was $\rho_{2015} = 0{,}871$>0,05, and in 2020 was $\rho_{2020} = 0{,}838$>0,05 shows that the area of land types from the current map and the statistical area does not have a big

difference. Thus, the data on the area of land types in the current map is completely suitable for use in assessing land changes in the Thach That district.

Table 2. Land use changes in the period 2015-2020 in Thach That district

No.	Code	Area in 2015 (ha)	Area in 2020 (ha)	Increase or decrease area (ha)	Rate of Increase or decrease area per total land area in 2020 (%)
1	CHN	6,475.55	6,037.76	-437.79	-2.34
2	CLN	1,155.32	1,582.22	426.90	2.28
3	RSX	1,766.41	1,567.54	-198.87	-1.06
4	RPH	10.59	0.00	-10.59	-0.06
5	RDD	810.45	917.93	107.48	0.57
6	NTS	349.38	357.44	8.06	0.04
7	NKH	104.64	145.88	41.24	0.22
8	OTC	1,944.06	1,948.04	3.98	0.02
9	CDG	5,329.33	5,532.09	202.76	1.08
10	TON	11.00	21.02	10.02	0.05
11	TIN	141.28	121.39	-19.89	-0.11
12	NTD	9.16	16.24	7.08	0.04
13	SON	342.97	171.36	-171.61	-0.92
14	MNC	173.18	266.60	93.42	0.50
15	PNK	5.27	2.03	-3.24	-0.02
16	CSD	79.65	20.13	-59.52	-0.32

The total area of change in the period is 1,802.45 hectares representing 9.63%. In the period 2015-2020, Annual cropland has dramatically fluctuated with a decrease of 437.79 hectares, representing 2.34%. Perennial cropland and Specially used land have tended to increase by 426.90 hectares (representing 2.28%) and 202.76ha (representing 1.08%), respectively. Productive forest decreased by 198.87ha representing 1.06%. The remaining land groups fluctuated with rates ranging from 0.02-0.92%.

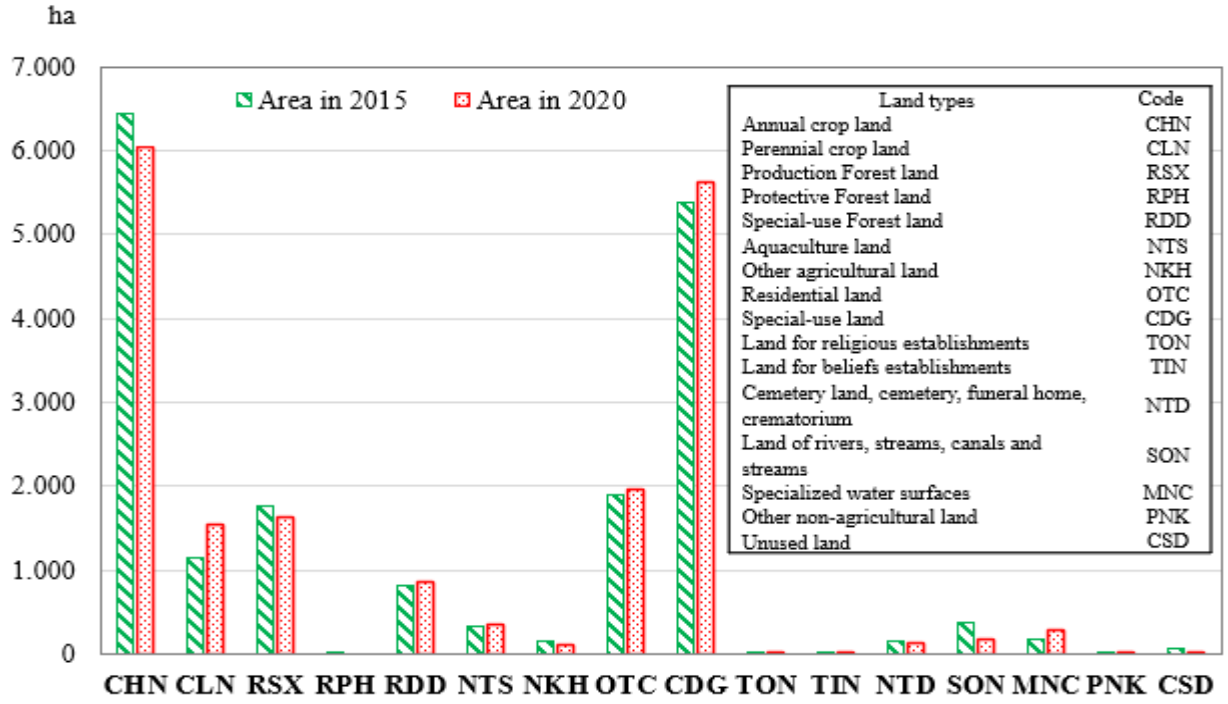

Figure 1. Area fluctuations according to land use type in Thach That district in the period 2015 – 2020

In the period 2015-2020, the changes in land types are not too large but show the trend of land changes following the trend of structural transformation of the economy, reducing the proportion of agriculture and increasing the proportion of industry, commerce, and services. In 2015, there was a milestone in economic change when the agricultural economy gradually decreased, and the non-agricultural economy increased.

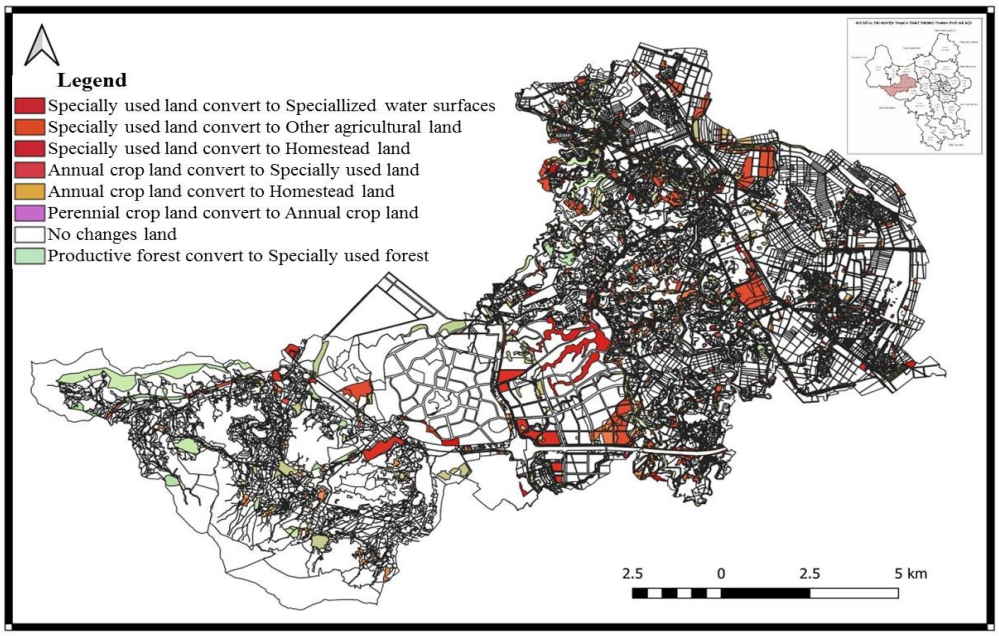

Figure 2. Map of land use changes in Thach That distric

3.3. Forecast of land use area in 2025 and 2030

The matrix of changes in the current land use status was built based on the current land use between 2015 and 2020 (Table 3). Using the matrix of current land use status in 2020 multiplied by the matrix of the fluctuation coefficient in the period 2015 - 2020, to obtain the result of forecasting land use changes until 2025, using the MMULT function in Excel software. Do the same with the current land use status in 2025 to get the results of forecasting land use changes in 2030. The results of forecasting land use types in 2025 and 2030 based on the Markov chain show that in 2025, the total area of agricultural land is 10,368.47 hectares, non-agricultural land is 8,334.23 hectares, unused land is 5,56 hectares. In 2030, the total area of agricultural land is 10,271.28 hectares, non-agricultural land is 8,432.22 hectares, and unused land is 4.76 hectares.

Compared to 2020, the land area forecast for 2025 and 2030 has significantly changed. There was a growth in the quantity of Perennial cropland, specially used forest, Aquaculture land, Other agricultural land, Residential land, and specially used land. On the other hand, Annual cropland, Productive Forest, Cemetery land, cemetery, funeral home, crematorium, other non-agricultural land, and unused land tended to reduce (Table 4). Specifically, from 2020 to 2025, agricultural land will be 10,368.47 hectares (accounting for 55.42%), a decrease of 117.22 hectares, non-agricultural land will be 8,334.23 hectares (accounting for 44.55%), an increase of 120 hectares, and unused land will be 5.56 hectares (accounting for 0.03%), down 2.78 hectares. By 2030, the area of agricultural land will continue to drop gradually, 10,271.28 hectares (accounting for 54.90%), and unused land will be 4.76 hectares. Thus, comparing 2020, agricultural and unused land will decrease by about 3.58 hectares, and 214.41 hectares, respectively. Non-agricultural land increased with an area of 8,432.22 hectares (accounting for 45.07%) and an increase of 217.99 hectares compared to 2020.

Table 3. Matrix of the probability of change in land use types determined from overlaying the map of current land use in the period 2015 - 2020

Code	CDG	CHN	CLN	CSD	MNC	NKH	NTD	NTS	OTC	PNK	RDD	RPH	RSX	SON	TIN	TON
CDG	0.875	0.082	0.007	0.000	0.018	0.002	0.001	0.004	0.005	-	0.000	-	0.003	0.001	0.001	0.001
CHN	0.065	0.785	0.066	0.000	0.002	0.013	0.006	0.022	0.034	-	-	-	0.000	0.005	0.000	0.000
CLN	0.042	0.024	0.849	0.000	0.003	-	0.001	0.002	0.069	0.000	-	-	0.010	0.000	0.000	0.000
CSD	0.112	0.448	0.037	0.149	0.002	0.003	0.005	0.071	0.092	-	-	-	0.020	0.055	0.001	0.005
MNC	0.061	0.206	0.017	0.001	0.510	0.014	0.003	0.124	0.060	-	-	-	0.002	0.003	0.001	0.000
NKH	0.052	0.190	0.252	-	0.000	0.346	0.000	0.151	-	-	-	-	-	0.006	0.000	0.002
NTD	0.085	0.339	0.029	-	0.002	0.004	0.494	0.006	0.031	-	-	-	0.000	0.003	0.001	0.005
NTS	0.138	0.126	0.058	0.000	0.102	0.024	0.007	0.294	0.195	0.000	-	-	0.017	0.034	0.002	0.001
OTC	0.098	0.066	0.026	0.000	0.004	0.001	0.001	0.017	0.780	-	-	-	-	0.003	0.003	0.003
PNK	0.537	-	0.017	-	-	-	-	-	0.017	0.429	-	-	-	-	-	-
RDD	-	-	-	-	-	-	-	-	-	-	0.988	-	0.012	-	-	-
RPH	0.001	0.000	0.003	-	-	-	-	-	-	-	-	-	0.996	-	-	-
RSX	0.040	0.016	0.012	-	0.001	-	0.001	0.001	0.007	-	0.066	-	0.853	0.000	0.000	0.002
SON	0.139	0.430	0.015	0.017	0.046	0.008	0.001	0.021	0.000	-	-	-	0.006	0.314	0.000	0.002
TIN	0.221	0.211	0.002	-	-	-	-	0.079	0.075	-	-	-	-	-	0.413	-
TON	0.051	0.324	0.150	-	-	-	-	0.009	0.086	-	-	-	-	-	0.017	0.364

The forecast results with the land use planning plan until 2030 of Thach That district are shown in Table 5. Compare the forecast results with the land use planning plan until 2030 of Thach That through T-test: Paired Two Sample for Means. Performing a T-Test between the area from the forecast and the planned area until 2030 shows that $\rho = 0.979 > 0.05$. Thus, it proves that the results of forecasting land use changes to 2030 using the Markov chain compared to the land use planning plan of Thach That district do not have too big a difference. Therefore, applying Markov chains to forecast results is quite reliable.

Table 4. Results of forecasting land area change in 2025 and 2030

(Unit: ha)

	Land types	Code	2020	2025	2030
Agricultural land	Annual crop land	CHN	5,643.70	5,330.71	5,090.81
	Perennial crop land	CLN	1,923.14	2,187.64	2,390.32
	Production Forest land	RSX	1,391.38	1,245.39	1,124.41
	Protective Forest land	RPH	0.00	0.00	0.00
	Special-use Forest land	RDD	1,010.98	1,091.27	1,160.95
	Aquaculture land	NTS	361.84	360.51	356.28
	Other agricultural land	NKH	154.65	152.94	148.52
Non-agricultural land	Residential land	OTC	1,967.36	1,994.16	2,022.62
	Special-use land	CDG	5,668.89	5,765.81	5,835.69
	Land for religious establishments	TON	23.74	24.27	24.17
	Land for beliefs establishments	TIN	19.52	21.11	21.95
	Cemetery land, cemetery, funeral home, crematorium	NTD	109.34	101.48	96.06
	Land of rivers, streams, canals and streams	SON	112.97	92.54	84.59
	Specialized water surfaces	MNC	310.77	333.55	345.91
	Other non-agricultural land	PNK	1.62	1.29	1.23
Unused land		CSD	20,13	8.34	5.56

Therefore, by 2030 Thach That district will continue to have a shift in land use structure between agricultural land, and non-agricultural land. In particular, the group of agricultural production land still plays a leading role (>50%) although agricultural land has tended to decrease. Non-agricultural land gradually increases with the view of giving priority to industrial development, crop restructuring, striving to modernize agriculture, and growing competitiveness under the market mechanism and following the urbanization process.

Table 5. Forecast results and land use planning options for Thach That district until 2030

No.	Land types	Forecast results		Land use planning options		Percentage difference between forecast and planning
		Area (ha)	Rate (%)	Area (ha)	Rate (%)	
1	Annual crop land	5,090.81	27.21	4,557.66	24.30	11.70
2	Perennial crop land	2,390.32	12.78	1,531.75	8.17	56.05
3	Production Forest land	1,124.41	6.01	1,218.51	6.50	-7.72
4	Protective Forest land	0.00	0.00	0.00	0.00	0.00
5	Special-use Forest land	1,160.95	6.21	854.04	4.55	35.94
6	Aquaculture land	356.28	1.90	440.83	2.35	-19.18
7	Other agricultural land	148.52	0.79	107.41	0.57	38.27
8	Residential land	2,022.62	10.81	2,258.06	12.04	-10.43
9	Special-use land	5,835.69	31.19	6,969.79	37.17	-16.27
10	Land for religious establishments	24.17	0.13	22.95	0.12	5.30
11	Land for beliefs establishments	21.95	0.12	17.09	0.09	28.45
12	Cemetery land, cemetery, funeral home, crematorium	96.06	0.51	302.30	1.61	-68.22
13	Land of rivers, streams, canals and streams	84.59	0.45	181.84	0.97	-53.48
14	Specialized water surfaces	345.91	1.85	269.90	1.44	28.16
15	Other non-agricultural land	1.23	0.01	1.60	0.01	-23.00
16	Unused land	4.76	0.03	18.78	0.10	-74.63
	Total	**18,708.26**	**100.00**	**18,752.51**	**100.00**	**-0.24**

4. CONCLUSION

In the period 2015-2020, land use changes in Thach That district have increased and decreased differently in different types of land. Specifically, agricultural land and unused land decreased, and non-agricultural land increased. Of these, the most obvious change is the sharp increase in land area for Perennial cropland (CLN) of 426.90 hectares and Specially used land (CDG) of 202.76 hectares. In comparison, there is also a dramatic decrease in the Annual cropland (CHN) area of 437.79 hectares and Productive forest (RSX) of 198.87 hectares.

According to the results of land use forecasts for 2025 and 2030, agricultural land and unused land tend to decrease, and non-agricultural land tends to increase clearly. In 2030, agricultural land and unused land will decrease by 214.41 hectares and 3.58 hectares compared to 2020, respectively. Non-agricultural land will increase by 217.99 hectares. The forecast area by 2025 and 2030 is relatively consistent with the land use change trend of previous periods. The accuracy of the model in predicting land use changes and land use planning in 2030 was performed a T-Test with $\rho=0.979>0.05$. Therefore, applying Markov chains to forecast results is quite reliable.

The research results contribute to helping policymakers have an objective view of land use arrangement and planning, and have a basis for exploiting land resources for effective and safe socio-economic development, and protect the ecological environment. Land is

limited, and land use demand for socio-economic sectors is increasing, mainly for agricultural land. Therefore, it is necessary to choose a reasonable land use structure, limit unreasonable land use, limit conversion of land for wet rice cultivation, and invest in exploiting unused land, and land with low economic efficiency.

REFERENCES

[1]. Shi Qing Wang, XQ Zheng & XB Zang (2012). Accuracy assessments of land use change simulation based on Markov-cellular automata model. Procedia Environmental Sciences. 13: 1238-1245.

[2]. Trong The Phan, Thi Huyen Mai & Ba Long Nguyen (2023). Assessing and forecasting land use changes based on applying gis and markov chain in Nhon Trach district, Dong Nai province. Journal of Forestry Science and Technology. 12(2): 146 – 155
DOI: https://doi.org/10.55250/jo.vnuf.2023.2.146-155

[3]. David J Campbell, David P Lusch, Thomas A Smucker & Edna E Wangui (2005). Multiple methods in the study of driving forces of land use and land cover change: a case study of SE Kajiado District, Kenya. Human Ecology. 33: 763-794.

[4]. Trong Phuong Tran & Thanh Son Ngo (2021). Assessment of land use changes in Loc Ha district, Ha Tinh province by GIS technology. Vietnam Journal of Agriculture and Rural development. 422: 145-151.

[5]. Muhammad Qasim, Klaus Hubacek, Mette Termansen & Ahmad Khan (2011). Spatial and temporal dynamics of land use pattern in District Swat, Hindu Kush Himalayan region of Pakistan. Applied Geography. 31(2): 820-828.

[6]. Thi Thu Ha Tran (2016). Predicting land use change affected by population growth by integrating logistic regression, Markov chain and cellular automata models. Hanoi University of Mining and Geology.

[7]. Hanh Hong Tran, Anh Van Tran & Nghi Thanh Le (2020). Study on land use changes, causes and impacts by remote sensing, GIS and Delphi methods in the coastal area of Ca Mau province in 30 years. Journal of Mining and Earth Sciences. 61(4): 36-45.

[8]. Minh Tuan Vu & Van Trung Le (2011). Applying remote sensing and GIS to evaluate changes and forecast urban land in Hiep Binh Phuoc ward, Thu Duc district. Proceedings of the 2011 national GIS conference.

[9]. Hoang Vu Phan, Cam Tu Tran, Thanh Vu Pham & Quang Minh Vo (2017). Applying geographic information system and Markov chains for assessing the fluctuation and forecast of land use demand. Can Tho Univ. J. Sci. 119-124.
DOI: 10.22144/ctu.jsi.2017.016.

[10]. Van Khanh Dao & Trong Truong Son Nguyen (2019). Research and forecast land use changes in Phu Tho province through application of Markov chain CA and GIS. Vietnam Science and Technology (VISTECH). 151-158.

[11]. Huu Cuong Nguyen, Van Cuong Nguyen & Thanh Hang Nguyen (2022). Integration of Markov chain and logistic regression for prediction of changing land use purpose in Lam Ha district, Lam Dong province. CTU Journal of Science-CTUJoS. 58(2A): 32-42.
DOI: 10.22144/ctu.jvn.2022.034.

[12]. People's Committee of Thach That district (2020). Explanatory report on land statistics in 2019.

[13]. People's Committee of Thach That district (2016). Land statistical report of Thach That district, Hanoi city in 2015.

[14]. People's Committee of Thach That district (2021). Land statistical report of Thach That district, Hanoi City in 2020.

[15]. Ministry of Natural Resources and Environment (2018). Circular 27/2018/TT-BTNMT, Regulations on statistics, land inventory and land-use status quo mapping.

[16]. Miles G Logsdon, Earl J Bell & Frank V Westerlund (1996). Probability mapping of land use change: A GIS interface for visualizing transition probabilities. Computers, Environment and Urban Systems. 20(6): 389-398.

[17]. LI Jianping, Zhang Bai & Gao Feng (2005). RS-and-GIS-supported forecast of grassland degradation in southwest Songnen plain by Markov model. Geo-spatial Information Science. 8(2): 104-109.