



ASSESSMENT OF FOREST AREA CHANGE TRENDS IN HA TINH PROVINCE USING NON-PARAMETRIC ESTIMATION METHODS

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Abstract

This article applies non-parametric estimation methods to assess forest area change trends in Ha Tinh province from 2017 to 2023. The study focuses on analyzing changes in various forest categories, including protective forests, special-use forests, and production forests, across districts within the province. Results indicate an increase in protective and production forest areas in regions such as Ky Anh and Cam Xuyen districts, while other areas like Duc Tho district and Hong Linh town show a trend of decline or stability. Overall, these changes align with the province's forestry development policies and strategies. This research aims to provide a scientific basis for developing forest management policies. Additionally, it offers statistical analyses to support climate change response efforts, advancing toward sustainable development goals.

Keywords: Non-parametric estimation; Trend analysis; Forest area; Special-use forests; Protection forests; Production forests; Mann-Kendall; Climate change.

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1. Introduction

The Vietnamese government considers forests an important ecological resource with valuable contributions to socio-economic development and improving the quality of life for communities across the country [1, 2]. Currently, about 25 million Vietnamese

people derive 20 to 40 % of their annual income from forests [3]. In addition, forests play an extremely important role in climate change adaptation through environmental functions such as erosion control and maintaining air circulation. According to data from the Global Forest Watch platform (WRI, 2002),

in 2023, Vietnam lost 94.2 hectares of natural forest, equivalent to releasing 118 million tons of CO₂ emissions into the atmosphere. The North Central region, including Ha Tinh province, also has a rich forest system with many rare tree species, which plays a significant role in protecting river basins and related ecosystems. According to the Ha Tinh Department of Agriculture and Rural Development, by 2023, the province will have nearly 360,000 hectares of forest and forestry land, accounting for over 60 % of its natural area [4]. Comparing the total forest and forestry land area in 2022 with 2015, the province experienced a reduction of 1,185 hectares.

Resolution No. 01-NQ/DH dated October 16, 2020, of the 19th Ha Tinh Provincial Party Congress, term 2020 - 2025, details the development of forestry. Specifically, the resolution emphasizes harnessing the potential and advantages of forest resources and forestry land. The measures outlined include managing, protecting, and developing special-use forests, upstream protective forests, coastal forests, and natural forests to enhance resilience to climate change. The resolution also encourages the development of concentrated medicinal and raw material forest plantations, intensively cultivated in partnership with processing factories to support the growth of other economic sectors [2]. In addition, the Vietnam Forestry Development Strategy for the period 2021 - 2030, with a vision toward 2050, has been approved to build the forestry sector into a modern, efficient, and highly competitive economic-technical sector. This strategy

includes development orientations such as natural forest restoration, agroforestry development, non-timber forest products, and improving the productivity and quality of planted forests [5].

The departments, sectors, localities, forest owners, and relevant units in Ha Tinh Province have focused resources on forest management and protection efforts [6], however, several challenges remain due to various causes. First, natural factors: Ha Tinh frequently experiences storms, floods, and droughts, with harsh climate conditions, barren soil, and complex, fragmented terrain. Next, infrastructure-related causes: Forestry infrastructure is inadequate, including the system of patrol roads for protection, forest fire prevention and control, and the transportation of materials for forest planting, as well as for harvesting and selling forest products [6]. Finally, but no less important, the system of legal documents, mechanisms, and policies related to forestry frequently changes. Regulatory authorities have yet to provide timely, specific, and consistent implementation guidelines [7, 8]. These issues have created difficulties and challenges in the management and protection of forest resources at the local level.

The non-parametric Mann-Kendall method is widely used to assess trends in time series data. This method does not require data to follow a specific distribution, making it suitable for analyzing environmental and climatic conditions. Additionally, in forestry research, this method has proven effective in evaluating changes in forest area and deforestation. Specifically, the study by

Santos et al., (2020) applied this method to analyze changes in forest cover in the semi-arid region of Brazil, helping to identify the areas most severely affected by deforestation [9]. Another study by Zhu et al., (2021) also applied this method to analyze mangrove forest dynamics in the Qinglangang Reserve, China, enabling the tracking of decline and recovery trends within the forest ecosystem [10].

From these issues, in this article, we will present some evaluation results on forest change trends, based on the Mann-Kendall [11] and Sen [12]. Non-parametric trend calculation and testing methods. These results not only provide a scientific basis for forest management and protection policies but also help forecast and effectively respond to changes caused by climate change.

2. Research methods and data

2.1. Research methodology

The application of probability and statistical theory in social life analysis is widely popular and considered an effective approach for forecasting changes. Traditional methods such as graph theory and linear regression have certain advantages but face difficulties in analyzing forest trends, especially when dealing with diverse spatial, temporal, and environmental factors. To address these challenges, this study employs the non-parametric Mann-Kendall test and Sen's slope estimator to analyze the changing trends of different forest types.

2.1.1. Mann-Kendall Non-Parametric Test method

The Mann-Kendall test is a widely used non-parametric method for detecting

trends in forest changes over time. This test aims to identify trends in a time series (a sample set) that has been arranged sequentially [11]. The method compares the relative magnitudes of the elements in the series rather than their actual values. This helps to avoid artificial trends caused by a few local extreme values, which can occur when using traditional linear trend calculations through the least squares method. Another advantage of this method is that it does not require the sample set to follow any particular distribution [13].

The calculation formulas for this method, as applied in the study, are briefly described below. Suppose there is a time series (x_1, x_2, \dots, x_n) where x_i represents the forest area statistics at time i . The Mann-Kendall statistic (S) is defined as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sign}(x_j - x_k) \quad (1)$$

Since the time series of forest area statistics is short, this study uses an approach suited for small samples. The value of S is determined based on the following Mann-Kendall (Z) value:

$$\text{If } S > 0 \quad Z = \frac{S-1}{\sqrt{V(S)}} \quad (2)$$

$$\text{If } S < 0 \quad Z = \frac{S+1}{\sqrt{V(S)}} \quad (3)$$

$$\text{If } S = 0, \quad \tau = 0 \quad (4)$$

Z is tested under the following conditions to examine the null hypothesis of no monotonic trend. The corresponding confidence levels for each hypothesis are specified below:

$$|\tau| > \left\{ \tau \left(\frac{1-0.99}{2} \right) \right\} = 2.576 \quad (5)$$

with the confidence level 99.5

$$|\tau| > \left\{ \tau \left(\frac{1-0.95}{2} \right) = 1.96 \right\} \quad (6)$$

with the confidence level 97.5

$$|\tau| > \left\{ \tau \left(\frac{1-0.9}{2} \right) = 1.645 \right\} \quad (7)$$

with the confidence level 95

$$\frac{n(n-1)}{2} \text{ elements } \{x_j - x_{k_j} - k; \text{ với } k = 1, 2; \dots; n-1; j > k\}$$

With this definition, Q has the same sign as τ . In the figures in this study, Q will be displayed at each station point for each factor. Trends with a statistical significance level above 95% will also be indicated.

2.2. Research data

Table 1. Summary of research data by district and forest type

No.	Location	Data	Time period	Source
1	Cam Xuyen district	TDD, TPH, TSX	2017 -2023	Chi cuc Kiem Lam Ha Tinh
2	Can Loc district	TPH, TSX	2017 -2023	
3	Duc Tho district	TPH, TSX	2017 -2023	
4	Huong Khe district	TDD, TPH, TSX	2017 -2023	
5	Huong Son district	TDD, TPH, TSX	2017 -2023	
6	Ky Anh district	TDD, TPH, TSX	2017 -2023	
7	Loc Ha district	TPH, TSX	2017 -2023	
8	Nghi Xuan district	TPH, TSX	2017 -2023	
9	Thach Ha district	TPH, TSX	2017 -2023	
10	Vu Quang district	TDD, TPH, TSX	2017 -2023	
11	Ha Tinh city	TPH, TSX	2017 -2023	
12	Hong Linh town	TPH, TSX	2017 -2023	
13	Ky Anh town	TPH, TSX	2017 -2023	

Note: TDD is the total area of special-use forest,

TPH is the total area of protection forest, and TSX is the total area of production forest.

Ha Tinh province currently classifies its forest data into three main categories: special-use forests, protection forests, and production forests. Each type of forest plays a crucial role in environmental protection and economic development. Special-use forests are strictly protected to preserve ecological values, natural landscapes, and cultural heritage. These forests not only serve conservation purposes but are also used for scientific research and the development of ecotourism. Protection forests play a key role in safeguarding

soil and water resources, mitigating the impacts of natural disasters such as floods and landslides, and responding to climate change. Lastly, production forests are utilized for supplying raw materials for the wood processing industry and other forest products, making a significant contribution to the province's forestry economy. Data on the areas of these three forest types have been collected and compiled from official sources, such as Ha Tinh's forest status report by the Forest Protection Department, the Department

of Agriculture and Rural Development, and published research studies.

3. Results and discussion

3.1. Evaluation results of the trend in protection forest area changes

According to Resolution No. 34/NQ-HDND dated December 15, 2016, the protection and development of protective forests is identified as a strategic task. Decision No. 607/QD-UBND dated March 3, 2017, by the Provincial People's

Committee, detailed the measures and action plans, aiming to manage and protect an area of 101,345 hectares of protective forests annually until 2020, with an additional target of planting 2,425 hectares per year. As a result of these protective forest policies, the province has achieved significant accomplishments. From 2017 to 2023, the area increased to 108,047 hectares, thereby exceeding the management target, with an average forest area increase of 558.9 hectares per year (Figure 1).

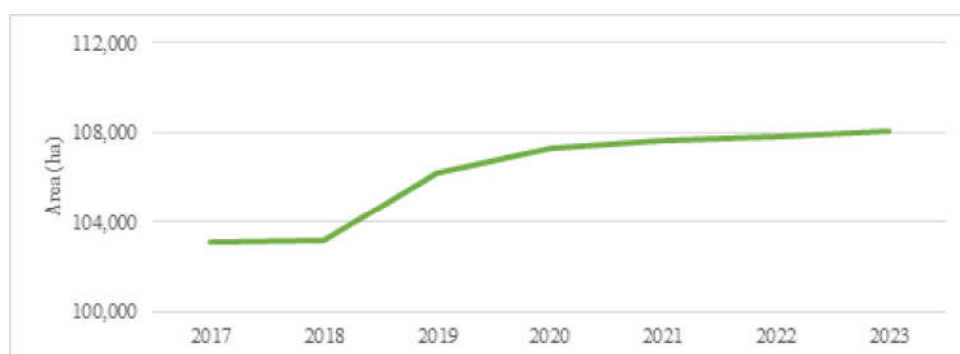


Figure 1: Trends in protection forest changes in Ha Tinh province from 2017 to 2023

Building on these efforts, Plan No. 71/KH-UBND dated March 13, 2018, issued by the Ha Tinh Provincial People's Committee, was implemented to fulfill Resolution No. 04-NQ/TU dated December 7, 2017, by the Provincial Party Committee on strengthening the management, protection, development, and effective exploitation of forest and forestry land resources until 2025 and beyond. The plan emphasizes that the Department of Agriculture and Rural Development is responsible for protecting

and developing over 94,000 hectares of upstream protective forests in major river areas, such as Huong Son (Ngan Pho), Vu Quang and Duc Tho (Ngan Sau), Vu Quang (Ngan Trui), and Cam Xuyen and Thach Ha (Ke Go). This plan not only aims to protect the existing area of protective forests but also promotes the expansion of protective forests in key areas. Statistical analysis results (Table 2) show the impact of the province's sound management policies on the stable development of protective forest resources.

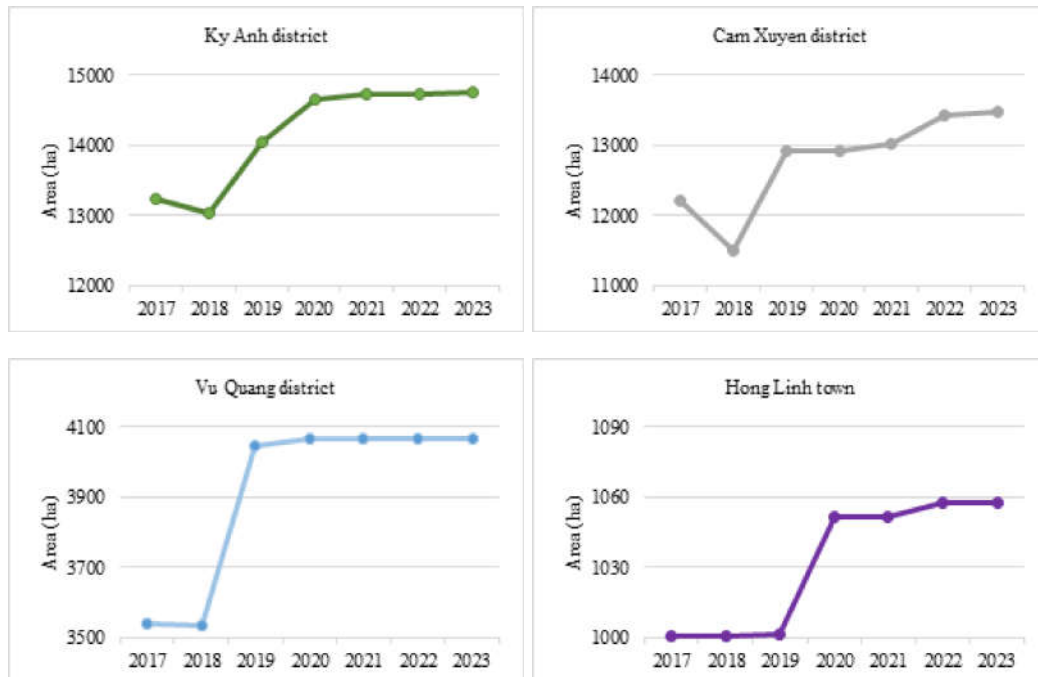
Table 2. Results of the protection forest trend analysis in Ha Tinh using the Mann-Kendall and Sen's slope methods

No.	Location	Mann-Kendall τ	p-value	Sen's slope
1	Cam Xuyen district	1.00	0.00	231.60
2	Can Loc district	0.20	0.72	21.63
3	Duc Tho district	-0.77	0.04	0.00
4	Huong Khe district	-0.28	0.44	-1.85

No.	Location	Mann-Kendall τ	p-value	Sen's slope
5	Huong Son district	0.73	0.06	183.98
6	Ky Anh district	0.87	0.02	223.44
7	Loc Ha district	-0.07	1.00	-0.03
8	Nghi Xuan district	0.28	0.44	0.00
9	Thach Ha district	0.73	0.06	53.08
10	Vu Quang district	0.93	0.01	7.34
11	Ha Tinh city	0.58	0.14	0.00
12	Hong Linh town	0.87	0.02	11.38
13	Ky Anh town	0.20	0.72	18.60

Specifically, the assessment results show that several districts in Ha Tinh province experienced a significant increase in protective forest area from 2017 to 2023, at a 95 % statistical significance level. Cam Xuyen and Ky Anh districts showed a notable average annual increase of 231.60 hectares and 223.44 hectares, respectively, indicating statistically significant growth with a p-value < 0.05. Similarly, Vu Quang district and Hong Linh town recorded average annual increases of 7.34 hectares and 11.38 hectares, respectively. In contrast, Duc Tho district was the only district that showed stable protective forest areas

without statistically significant changes. This indicates that the protective forest development and protection measures have been effective in most districts, except Duc Tho. By 2023, protective forest areas had changed variably across regions. The group of regions with strong growth included Huong Son, with an increase of 1,830.70 hectares, and Cam Xuyen, with an increase of 664.67 hectares. The group with slight growth included Vu Quang, with an increase of 30.04 hectares, and Hong Linh, with an increase of 50.98 hectares. Duc Tho showed no change, maintaining its protective forest area (Figure 2).



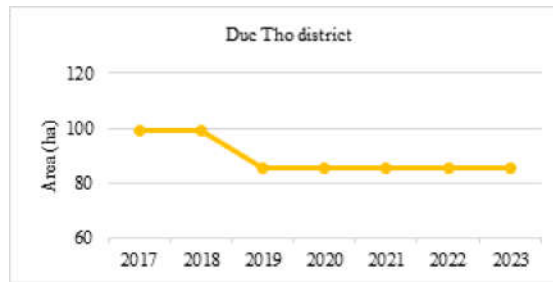


Figure 2: Trends in Protection Forest Changes (ha) in Selected Districts of Ha Tinh Province from 2017 to 2023

In addition to managing and protecting existing forests, the plan emphasizes collaboration and support for domestic and international research and development projects. The goal of these projects is to protect and improve forest quality by applying advanced techniques, technology, and new management methods. Additionally, the plan aims to leverage the ecosystem and forest landscape potential, linking it with historical sites, tourism, and implementing forest environmental service payment policies. Finally, it seeks to develop models of linkage, collaboration, and forest landscape leasing to maintain and enhance the value of protective forests.

3.2. Evaluation results of the trend in special-use forest area changes

The Mann-Kendall method was applied to analyze the trend in special-use forest areas from 2017 to 2023, but it did not show statistical significance (Table 3). The results indicate no statistically clear trend in the increase or decrease of forest area. It is noteworthy that Resolution 04/NQ-TU of the Ha Tinh Provincial Party Committee emphasizes the protection and sustainable development of existing special-use forests. The resolution specifically focuses on the strict management and protection of designated special-use forest areas to prevent disruption to the natural ecosystem structure and avert unforeseen environmental consequences.

Table 3. Analysis results of special-use forest trends in Ha Tinh using the Mann-Kendall and Sen's slope methods

No.	Location	Mann-Kendall τ	p-value	Sen's slope
1	Cam Xuyen district	-0.15	0.69	0.00
2	Huong Khe district	0.41	0.25	7.67
3	Huong Son district	-0.08	0.84	0.00
4	Ky Anh district	0.14	0.70	7.66
5	Vu Quang district	-0.08	0.84	0.00

To provide an overview and detailed insight into the current state of special-use forests, analytical charts are used to compare forest areas from 2017 to

2023, highlighting stability or minor fluctuations. This approach helps assess the effectiveness of forest protection policies.

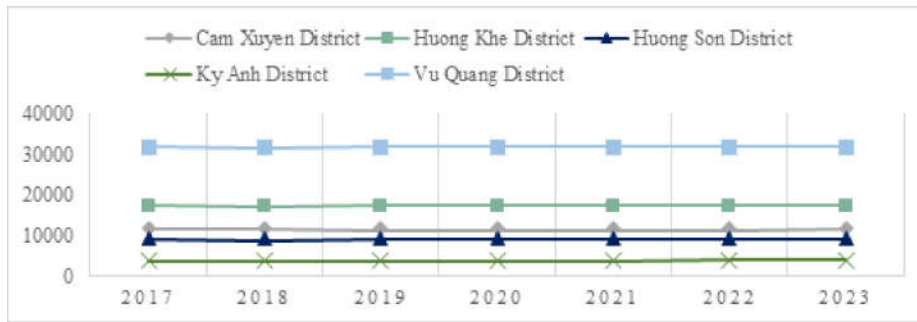


Figure 3: Trends in special-use forest changes (ha) in Ha Tinh province from 2017 to 2023

From 2017 to 2023, the total forest area in the province increased by 82.13 hectares, marking a positive step in forest resource management and protection. This growth was primarily contributed by the increase in forest area in Ky Anh district, with an increase of 38.36 hectares, and Cam Xuyen District, with an increase of 13.82 hectares. Other districts, such as Vu Quang and Huong Khe, maintained stability, which helped sustain the province’s forest area. Overall, this increase reflects the efforts of these districts in protecting and sustainably developing special-use forests across the province.

3.3. Evaluation results of the trend in production forest area changes

Decision No. 886/QĐ-TTg dated June 16, 2017, by the Prime Minister, and Resolution No. 04-NQ/TU dated December 7, 2017, by Ha Tinh province laid a strong foundation for the development of production forests in Ha Tinh during the 2017 - 2023 period. These policies not only continued the objectives of forest protection and development but also expanded financial, technical, and seedling support. Specifically, from 2017 to 2023, the production forest area in the province increased by nearly 20,000 hectares (Figure 4), with Huong Khe, Ky Anh, and Vu Quang districts showing the highest growth.

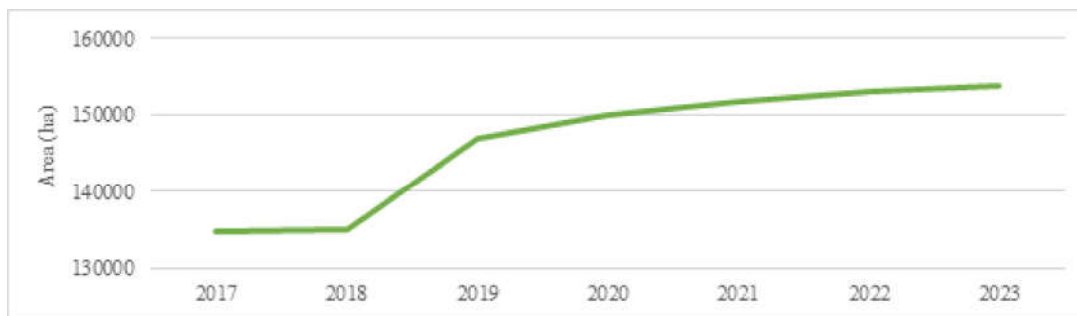


Figure 4: Trends in production forest changes (ha) in Ha Tinh province from 2017 to 2023

To maximize the sustainable economic potential of forest resources, Resolution No. 04-NQ/TU set a target to convert 6,300 hectares of forests and forestry land to develop key agricultural and forestry products, optimizing the

production of forest areas. Ha Tinh province aims to increase the total value of goods and services from forestry land from VND 3,000 billion in 2016 to over VND 7,700 billion by 2025 and achieve an annual wood export value

exceeding USD 90 million, promoting the development of the forestry processing industry. To achieve these objectives, Action Plan No. 71 from the Department of Agriculture and Rural Development reaffirms its commitment to developing timber resources and key agricultural products. The province also emphasizes controlling agricultural production on forestry land, ensuring compliance with

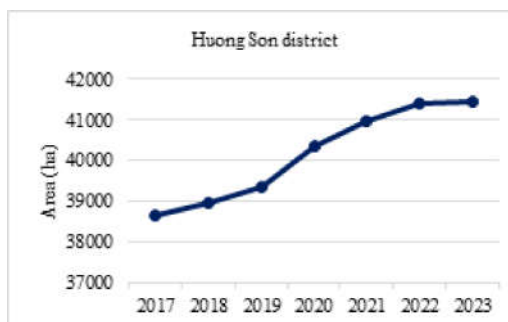
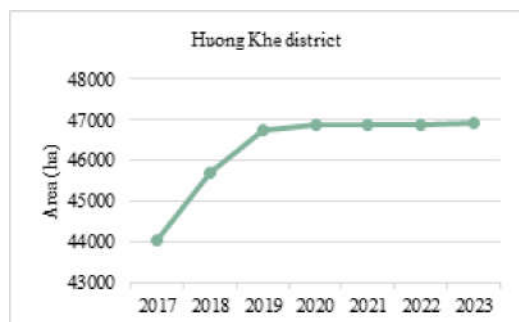
planning and environmental protection. This facilitates residents and organizations to participate in afforestation, thereby not only expanding the production of forest areas but also contributing positively to sustainable economic development and forest resource protection in Ha Tinh. Statistical analysis results (Table 4) show uneven growth in production forest area across districts.

Table 4. Analysis results of production forest trends in Ha Tinh using the Mann-Kendall and Sen's slope methods

No.	Location	Mann-Kendall τ	p-value	Sen's slope
1	Cam Xuyen district	0.60	0.14	265.00
2	Can Loc district	-0.73	0.06	-20.37
3	Duc Tho district	0.87	0.02	21.98
4	Huong Khe district	1.00	0.00	41.88
5	Huong Son district	1.00	0.00	532.62
6	Ky Anh district	0.87	0.02	637.71
7	Loc Ha district	0.73	0.06	12.13
8	Nghi Xuan district	-1.00	0.00	-9.92
9	Thach Ha district	0.87	0.02	63.76
10	Vu Quang district	1.00	0.00	352.72
11	Ha Tinh city	-	-	-
12	Hong Linh town	-0.97	0.01	-5.34
13	Ky Anh town	0.73	0.06	146.32

Specifically, districts such as Duc Tho, Huong Khe, Huong Son, Ky Anh, Thach Ha, and Vu Quang all demonstrate a clear upward growth trend over time. Among them, Ky Anh district shows the highest increase, with an average annual

growth of 637.71 hectares, corresponding to an average annual increase of 2.93 %. Similarly, Huong Son and Thach Ha districts also exhibit stable growth, with annual increases of 1.38 % and 2.12 %, respectively (Figure 5).



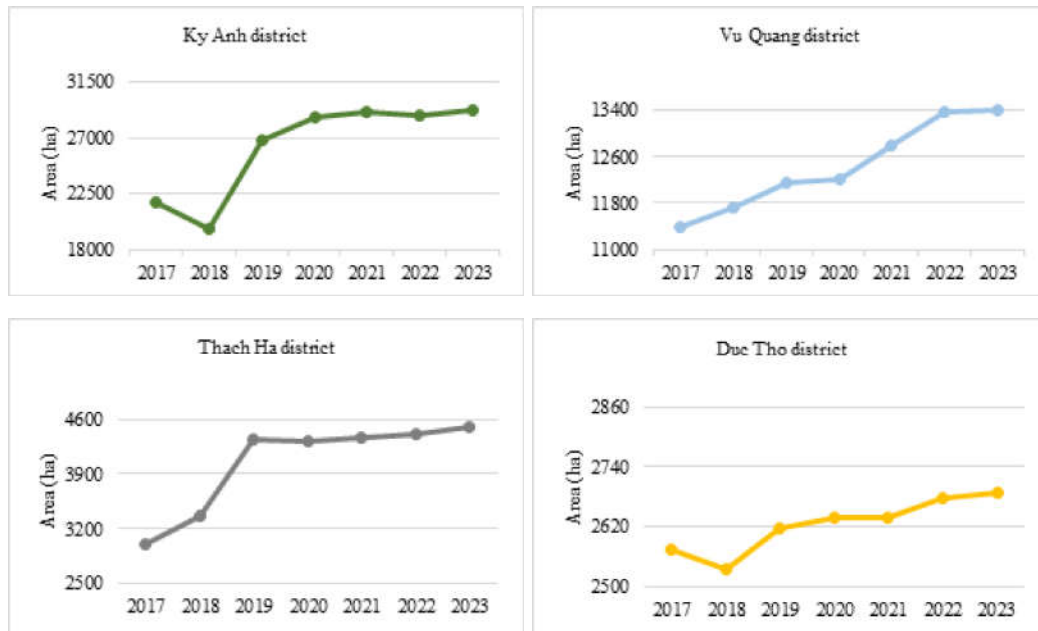


Figure 5: Trends in the increase of production forests (ha) in selected districts of Ha Tinh province from 2017 to 2023

Although the overall trend is growth, some districts still show a downward trend according to non-linear method results. The production forest area in both locations declined relatively from 2017

to 2023, with Nghi Xuan decreasing by an average of 9.92 hectares per year and Hong Linh decreasing by 5.34 hectares per year, as indicated by the non-linear method results (Figure 6).

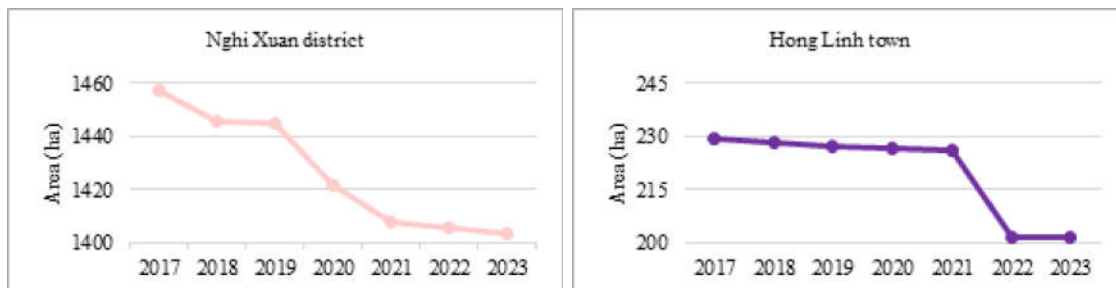


Figure 6: Trends in the decrease of production forests in Nghi Xuan district and Hong Linh town (2017 - 2023)

Specifically, the Nghi Xuan district, located in Northern Ha Tinh and bordering Nghe An, has a long coastline favorable for marine economy and tourism. Hong Linh town, centrally located in Ha Tinh, is near National Highway 1A and the North-South railway, providing advantages for industry and services. The forest cover rate in Nghi Xuan is 21.14 %, and in Hong Linh, it is 24.35 %, primarily

consisting of protective forests. In Nghi Xuan, production forests occupy a small portion and do not play a significant role in the district's economic structure, with the agriculture-forestry-fishery sector accounting for only 18.56 %. In contrast, industry construction accounts for 47.67 %, and trade services make up 33.77 %, indicating a strong shift toward other economic sectors. In response, the district

People's Committee set a target to achieve the new rural development standards for Nghi Xuan by 2020 and aims to develop it as a northern economic-cultural center of Ha Tinh by 2025. Additionally, according to Resolution No. 01-NQ/TXHL dated September 24, 2016, Hong Linh town has oriented its development strongly toward industry, handicrafts, trade, and services, aiming to achieve Class III urban status before 2020. The emphasis on industrial and trade-service development, along with investment incentives for industrial clusters, clearly reflects Hong Linh's economic orientation. In this development structure, agriculture, particularly forestry, is neither emphasized nor plays a significant role. The shift in economic structure toward urbanization has significantly reduced the proportion of agriculture-forestry, which now accounts for less than 2 % of the total economic structure.

4. Conclusion

Based on the research results on the trends in forest area changes in Ha Tinh Province from 2017 to 2023, several important conclusions can be drawn. First, districts such as Ky Anh, Cam Xuyen, and Huong Khe have shown significant increases in the areas of protection and production of forests, reflecting the effectiveness of forest protection and development policies in these areas. Second, the area of special-use forests did not exhibit significant changes during the study period, aligning with strict protection policies aimed at maintaining the stability and sustainability of special-use forest ecosystems. On the other hand,

districts like Nghi Xuan and Hong Linh Town, due to a strong shift in economic structure towards industrial and service sectors, have experienced a decline in production forest areas. This represents a challenge that needs to be carefully considered in the economic development planning process for these localities.

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