

APPLICATION OF GIS AND REMOTE SENSING TO EVALUATE THE URBAN LANDUSE CHANGES DURING 1975 - 2014 IN HUONG THUY COUNTY TOWN, THUA THIEN HUE PROVINCE, VIETNAM

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ABSTRACT

Huong Thuy Town has higher development steps in urbanization aspects in comparison to other districts in Thua Thien Hue Province, however, there is no research about urbanization process in Huong Thuy after 1975, especially there is no research about application of multitemporal satellite images to address the changes in land using and planning across many periods of time. This research focuses on using multitemporal satellite images to identify the tendency in land using to have rational foundation for making land planning in the future. This research relies on the approach of multiple scales, including scale of spectrums, scale of time, and scale of GIS data to improve the classification results of urban objects toward higher details and more accurate. The urbanization process in Huong Thuy Town has led to sharply increase the area of impervious surfaces in a higher rate, in the meanwhile, the area of natural forest and other agrarian land has the curtailed tendency. The result reconfirms that using multitemporal satellite images in doing research about urbanization process can give good outcomes in which it helps visualizing the changing tendency in land using and supporting decision maker in making land planning destined to sustainable development. Besides, this research also shows that there is a demand for doing urbanization research in many adjacent towns or districts in order to create rational protection solutions in the facets of ecology and environment for the mother urban cities nearby.

1. INTRODUCTION

Huong Thuy County Town has high speed of urbanization and it is the directly important sub-urban area of Hue city, Thua Thien Hue Province. Over years, the speed of economic development in Huong Thuy Town continuously maintains in high rate, including service sectors has grown dramatically and now rising to become the spearhead economic sector, economic structure transfers in the right direction, from agriculture-industry-service into industry-service-agriculture, the proportion of non-agriculture sectors is ascending and descending on agriculture sector, the service sectors gradually play the key role in Huong Thuy's economics. The speed of urbanization is particularly high in Phu Bai Town and other communes along the National Highway and outskirts of Hue city. The structure of technical infrastructure and society has been concurrently invested, stimulating the urbanization process in Huong Thuy County Town.

Huong Thuy County Town underwent many stages of development that leading to

many considerable changes during the urbanization process. From 1975 to 1981, Huong Thuy's border lines include communes: Thuy Bang, Thuy Xuan, Thuy Truong, Thuy Phuoc, Thuy An, Thuy Van, Thuy Duong, Thuy Thanh, Thuy Phuong, Thuy Chau, Thuy Luong, Thuy Phu, Thuy Tan, Thuy Bieu. Until 1989, Huong Thuy was adjusted to belong to Huong Phu District, in which there were some communes, including Thuy An, Thuy Phuoc, Thuy Bang, Thuy Xuan, Thuy Bieu, merging to Hue city. Then in 1990, Huong Thuy was separated from Huong Phu District, officially took the name of Huong Thuy, and became an independent administrative unit with Phu Bai Town and 11 communes, including Thuy Luong, Thuy Chau, Thuy Phuong, Thuy Duong, Thuy Bang, Thuy Phu, Thuy Tan, Thuy Thanh, Thuy Van, Duong Hoa, Phu Son. In 2010, Huong Thuy District was approved to become Huong Thuy Country Town with all the previous communes. From 2010 to 2014, there is no change in Huong Thuy Country Town's borders.

Therefore, we conducted this research with the selected years, including 1975, 1990, 2005, 2014 that coincided with some milestone years in adjusting the administrative boundaries of Huong Thuy County Town. This helps us in making maps and giving evaluations about the changes of land using in Huong Thuy County Town since 1975 up to date. To avoid many expensive lessons about urbanization that other cities underwent, this research has the meaning in giving the evidence of the urbanization tendency and proposing good recommendations for land planning in the next period of development in Huong Thuy County Town.

2. MATERIALS AND METHODS

2.1. Data source

Remote Sensing sources were used in this research includes multi-temporal satellite images, LandsatMSS, TM and OLI that has been taken in the dry seasons with high quality in the years of 1975, 1990, 2005 and 2014. These images were freely supplied and used by the United States Geological Survey (USGS).

Table 1. Satellite images in this research

Type	Name	Date	Resolution
MSS L1T	LM21340491975073GDS03	14/3/1975	60
TM 5	LT51250491990048BKT00	17/2/1990	30
TM	LT51250492005124BKT00	4/5/2005	30
Landsat OLI	LC81250492014117LGN00	7/4/2014	30

Besides, this research used some background data to support the building maps process and verify the results of classification. The sources of GIS: (1) Digital map of topography in the scale of 1 : 50.000 with UTM coordinates; (2) Map of land using status in Huong Thuy District in 2005, in the scale of 1 : 50.000; and (3) Information from the fieldtrip in May 2014.

2.2. Methods

2.2.1. Pre-processing images

Radiation adjustment: In this research, we conduct many steps to adjust radiation, including: (1) converting DN value to the value of radiation on satellite, (2) converting radiation value to reflection value on the satellite and (3) converting to surface reflection on the surface. The function of radiation adjustment is in the following sentences:

* For Landsat MSS and TM:

$$L_{\lambda} = \frac{LMAX_{\lambda} - LMIN_{\lambda}}{QCALMAX} \times QCAL + LMIN_{\lambda}$$

$LMIN_{\lambda}$: Value of spectrum variation at $QCAL = 0$

$LMAX_{\lambda}$: Value of spectrum radiation at $QCAL = QCALMAX$

* For Landsat 8 OLI:

$$L_{\lambda} = M_L Q_{cal} + A_L$$

L_{λ} : Value of spectrum radiation of λ channel ($W/m^2 \times srad \times \mu m$)

M_L, A_L : Number value of each pixel (DN)

Geometric correction: We used satellite images with two different levels of space resolution: 30 m and 60 m. In this research, 30 m resolution will be chosen for the optimal re-dividing samples to guarantee the space quality and radiation of satellite images used for the following processing. Many image channels will be re-divided into samples with a certain size, later they will be corrected by selected control points on the topography map in the scale of 1:50.000 with the RMSE error less than 0.5 pixel. The remaining satellite images will be corrected in accordance with the first satellite image to warrant that the error of correction among satellite images is smallest and there will be the re-divided samples in accordance with the 30 m resolution chosen. The error of correction less than 1 pixel will be accepted in the case of multi-source data.

2.2.2. Classification

The Maximum Likelihood Classification is used in this research. Simultaneously, urban environment is very complicated due to the rough and mixture of surfaces, materials making the urban character have the physical property very close to natural objects, such as, the physical properties of impervious surfaces is very similar to the physical properties of bare ground, or on satellite images with average resolution, spectrum of urban areas with highly vegetation density is very similar to some wetland areas. Therefore, the problem of separating spectrum reflection of some impervious surfaces of urban area out from bare soil and wetland needs to be considered. They are related to establish good training samples.

2.2.3. Combination and extraction information

The results of classification and division of values will be extracted and written in two types: impervious surface and other land (non-impervious surface). The Maximum Likelihood Classification gives good results in which impervious surface separated out of water and wetland areas but there is a little mistaken with bare soil, whereas the result classification from dividing values of NDVI map with $NDVI < 0$ shows that impervious surface isolated from bare soil but mixed in wetland and wet soil. AND logical operations will be conducted to eliminate these mistake pixels and isolated the final type of impervious surfaces. In the processing, GIS materials about administrative boundaries, hydraulic system and transport lines will be converted into the system of image processing to check and making statistical analyses simultaneously in order to eliminate mistake pixels according to

experts. Maps of land using status will be overlaid on the results of satellite images processing as the reference materials to compare and evaluate the degree of accuracy.

2.2.4. Evaluation the degree of accuracy

In this research, we use the combine methodology of visual investigation on satellite images and statistical data from many maps of land using status. Particularly the results in the year 2014 were referenced in more details thanks to the information from the fieldtrip in May 2014. We took at random from combined color images many points that distribute across the research area with 100 GPS points in each year following three lines: one vertical line and one horizon line. Each GPS point was taken photo, coordinates, topography details, vegetation, land use types, etc., to have the basic for evaluating the degree of accuracy.

Optical data is often affected by many atmospheric conditions, lighting, visual angle and humidity that makes it is very difficult to directly compare the values of reflection. Therefore, the action of independent classification each satellite image will help analyser in actively controlling many mistakes of identifying objects and can help to adjust immediately after the classification for that image. In this research, we apply the methodology of analyzing the changes after the classification along with combine the supportive GIS materials and fieldtrip to improve the degree of accuracy. Maps of urban space distribution in the years of 1975, 1990, 2005 and 2014 will be overlaid to evaluate the changes of urban land in Huong Thuy County Town.

3. RESULTS AND DISCUSSIONS

3.1. Processing the impervious surface information from satellite images in Huong Thuy County Town

3.1.1. Land using status in the years of 1975, 1990, 2005 and 2014

Huong Thuy in 1975 had the shape and area far different from now. At this time, there was huge area of impervious surfaces, including transport line (Phu Bai airport), residential area, and cemetery area. The impervious surface concentrated in center area of Huong Thuy district where the main road went through, occupied a large area with 2,940.93 ha, equivalent to the ratio of 15.32%. The appearance of large impervious area at this time was mainly due to the large area of spontaneous cemetery near the mountain in Thuy Phuong and Thuy Chau communes. As a result, the high concentration of impervious area cannot give the evidence that there was the rapid development of urban areas in Huong Thuy in 1975 because these areas were not represent for the degree of development of constructing land, transport land, residential land and industry areas. We can conclude that Huong Thuy economics in 1975 was underdeveloped and relied mainly on agriculture.

In 1990, Huong Thuy district had the total area were 45,606.42 ha, in which the water area occupied the area of 560.16 ha, equal to 1.56%; the area of bare soil occupied 2,21%, mainly concentrated in Thuy Phu, Thuy Tan, Thuy Luong, Thuy Chau, Phu Bai; the area of impervious surface occupied the ratio of 5,05% in the north of study area; the area of other agricultural land occupied the ratio of 14,95%; the area of rice planting occupied the ratio of 9,25%; the area for forest planting was 10,791.00 ha, equivalent to the ratio of 23,65% in Phu Son, Thuy Bang and the area of natural forest was 20,070.90 ha (43,33%) in Duong Hoa commune. The interpret process gave the results with high quality, especially rice land, water

surface, natural forest and artificial forest. There is one exception for bare soil which has the value of light reflection similar to impervious surface, leading to the mistakes in interpreting. These mistakes were corrected and supplemented in order to supply the right information for building maps.

In 2005, Huong Thuy had 29,344.14 ha area of forest, occupied 64.34% the natural land, in which, natural forest was 16,652.25 ha equal to the ratio of 56.75% forest area. The water area beside the area of natural rivers and streams, other remaining water area was used for aquaculture, including shrimp and fish hatching. At this time, bare soil was mainly arid land, cemetery land and the forest land after harvesting. The agricultural land was used for rice planting, short crops and herb crops. Due to the topography of terrain and the development of economics, forest land distributed mainly in the Duong Hoa. The area of impervious surface (mainly specific land and residential land) occupied small area because of the separation of topography and the distribution of terrain from the East to the West. As a result, residential area and industry area concentrated near the transport line, factories and planning land and re-settle areas.

In 2014, the area of forest-agriculture land occupied the larger portion with the ratio of 91.49%, including rice land, artificial forest, natural forest and other agricultural land. The area of natural forest occupied the most area with 21,123.72 ha equal to 46.32% of the natural area of Huong Thuy. Natural forest distributed in Phu Son, Thuy Bang, Thuy Phuong, Thuy Chau, Thuy Phu and Duong Hoa. The area of natural forest in Huong Thuy County Town continuously decreases since there was project of building Ta Trach reservoir in Duong Hoa commune, until 2014 the area of natural forest is only 10,441.8 ha, occupies 22.89% of natural area, mainly distributes in the south of Duong Hoa commune.

Another type of land using in Huong Thuy County Town that contributes a lot for local economics is agricultural land, occupies over 22.00% the area of natural land, including rice land with the area of 4,875.75 ha equal to 10.69% and other agricultural land with the area of 5,282.73 ha equivalent to 11.58%. Among of them, rice land distributes mainly in the north of Huong Thuy County Town, encompassing Thuy Thanh, Thuy Van and Thuy Chau. The area of non-agricultural land evenly distributes along two sides of National Highway, dispersing in Thuy Bang and Phu Son.

And the area of impervious surfaces in Huong Thuy County Town is 2,263.86 ha equal to 4.96%. The impervious surface concentrates in central area, including 5 wards along National Highway and near Ta Trach reservoir. We can recognize that in 2014, the area of impervious surface area still concentrates in the convenience area for living and doing economics, they are areas near the markets, schools and transport lines. The further land is used for forest planting and making agriculture.

Table 2. The situation of land using in study area in 1975, 1990, 2005, 2014

No.	Type of land using	1975		1990		2005		2014	
		Area	Ratio (%)	Area (ha)	Ratio (%)	Area (ha)	Ratio (%)	Area	Ratio (%)
1	Impervious surface	2,940.93	15.32	2,302.11	5.05	1,390.77	3.05	2,263.86	4.96
2	Bare soil	45.72	0.24	853.47	2.21	244.71	0.54	274.23	0.60
3	Water area	911.52	4.75	560.16	1.56	969.57	2.13	1,345.05	2.95
4	Rice land	6,103.62	31.80	4,209.48	9.25	3,599.10	7.89	4,875.75	10.69
5	Other agricultural land	3,513.06	18.30	6,819.3	14.95	10,058.13	22.05	5,282.73	11.58
6	Artificial forest	5,596.29	29.16	10,791.00	23.65	12,691.89	27.83	21,123.72	46.32
7	Natural forest	83.34	0.43	20,070.90	43.33	16,652.25	36.51	10,441.08	22.89
	Total	19,194.48	100.00	45,606.42	100.00	45,606.42	100.00	45,606.42	100.00

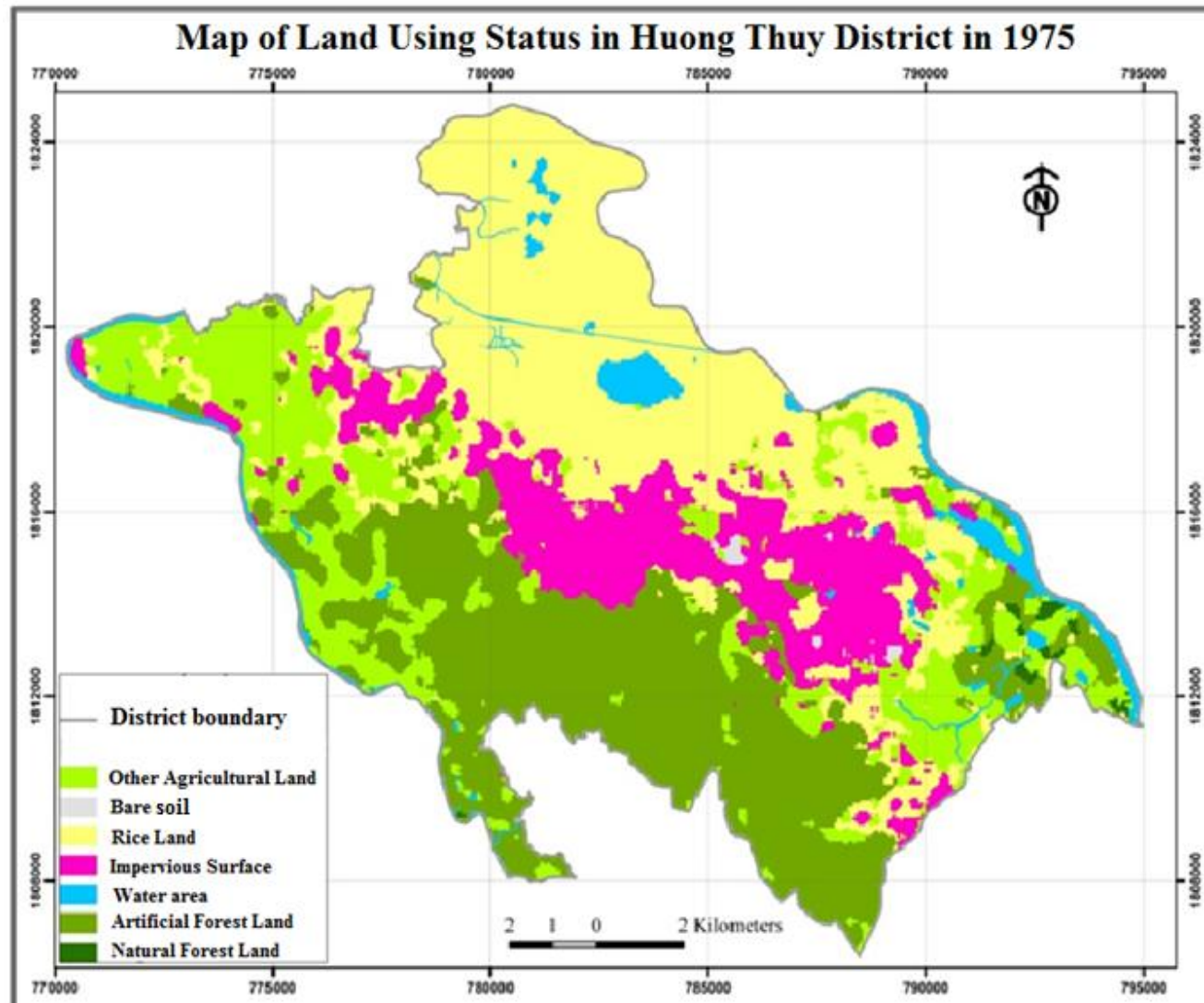


Figure 1. Map of land using status in Huong Thuy District in 1975

Map of Land Using Status in Huong Thuy District in 1990

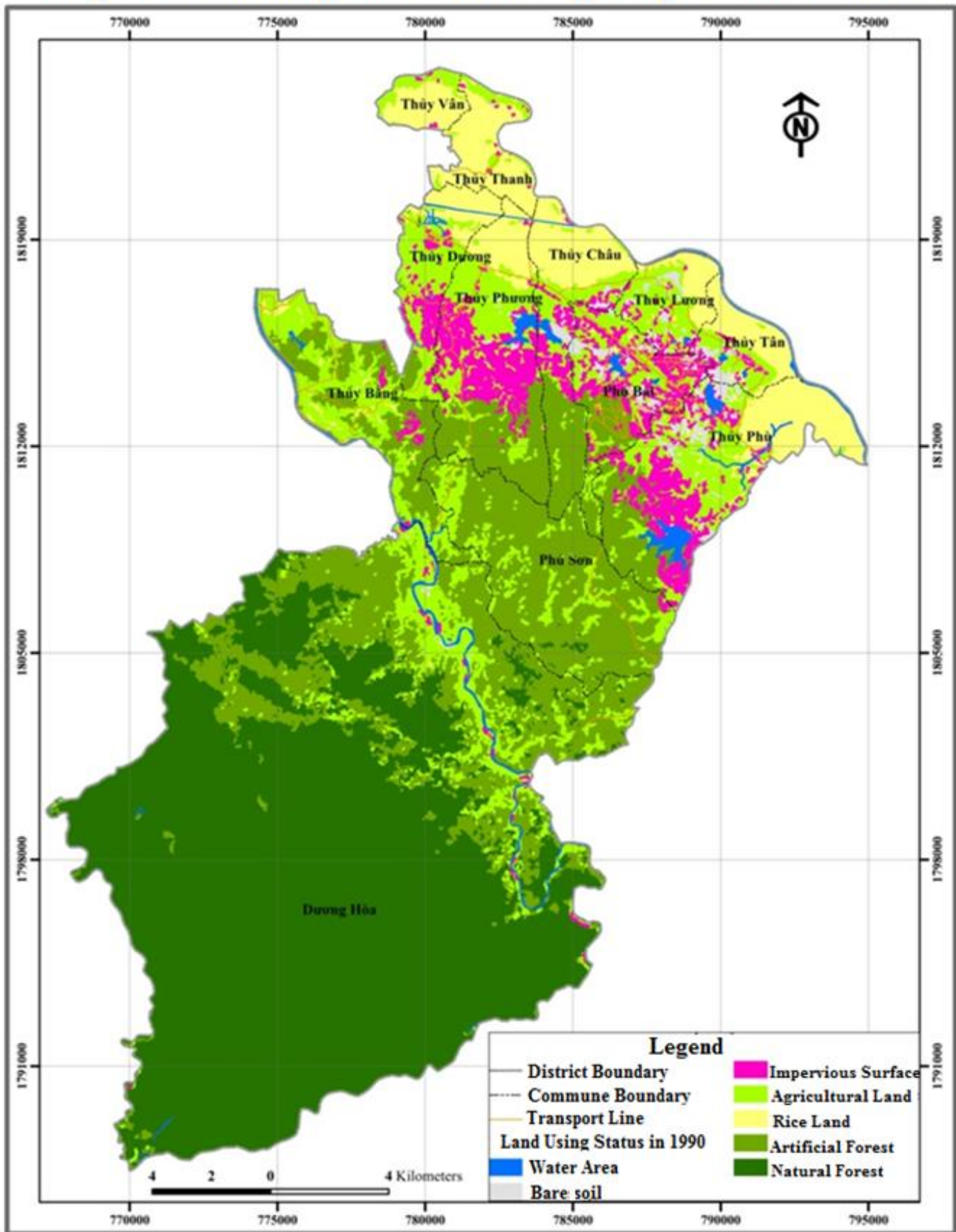


Figure 2. Map of Land Using Status in Huong Thuy District in 1990

Map of Land Using Status in Huong Thuy District in 2005

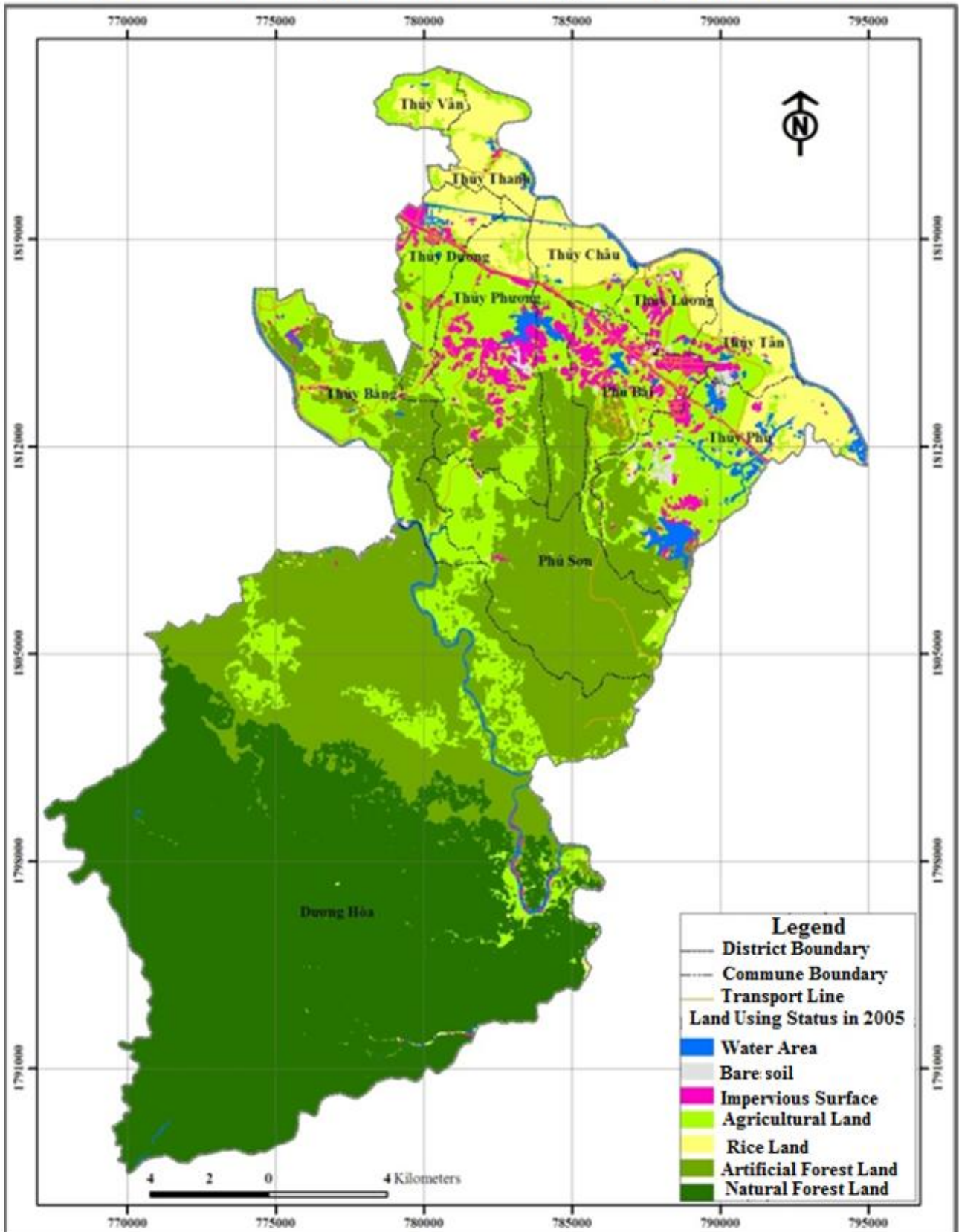


Figure 3. Map of Land Using Status in Huong Thuy District in 2005

Map of Land Using Status in Huong Thuy District in 2014

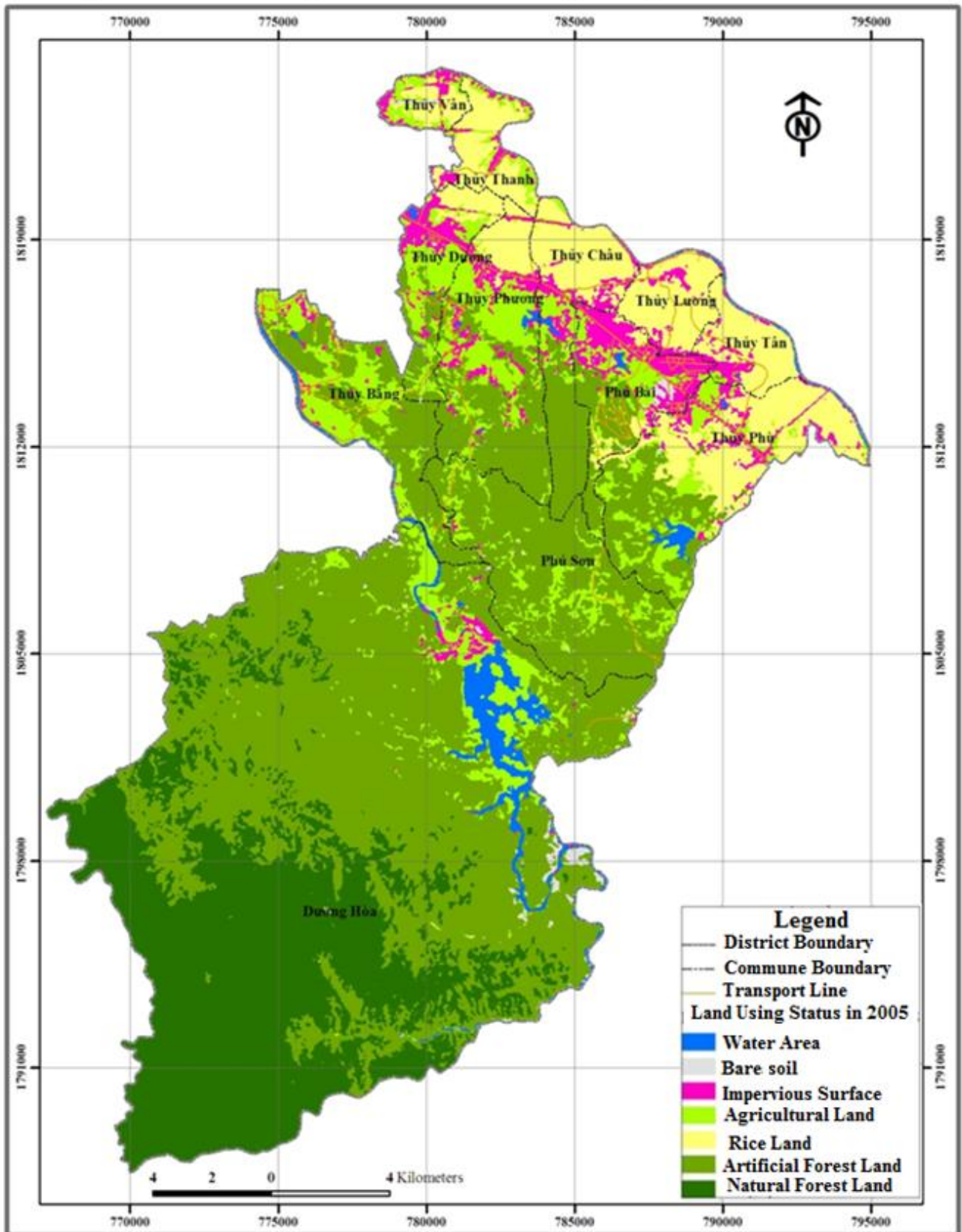


Figure 4. Map of Land Using Status in Huong Thuy County Town in 2014

3.1.2. Evaluation the degree of accuracy of image classification

To evaluate the degree of accuracy of image analyzation, we used maps of land using status in Huong Thuy District in 1975, 2005 and 2014. However, in 1990, we cannot evaluate the degree of accuracy of image classification because we do not have the map of land using in Huong Thuy District in 1990.

The degree of accuracy of map in 1975 was evaluated by relying on air photos at the same time with the original photos from Geo-Eye and Planet Action Foundations. These air photos only concentrated on the north of Huong Thuy District, therefore, we can evaluate some types of land using that clearly showed on the photos, such as, impervious surface, baresoils, rice land, and other agricultural land. Some other types of land using that did not show in the air photos would not consider in evaluating the degree of accuracy in 1975, for example, water area, natural forest land and artificial forest land. The map of land using status in 2005 in the scale of 1 : 50.000 on available is the foundation to evaluate the degree of accuracy the result of image processing at the same time. In 2014, research team conducted the fieldtrip in May 2014. We collected 100 GPS points dispersing across the study area in different setting conditions.

Table 3. The degree of accuracy in the years of 1975, 2005 and 2014

Unit: %

No.	Type of land using	1975	2005	2014
1	Impervious surface	91.18	82.35	57.14
2	Bare soil	70.00	61.54	91.30
3	Water area	-	77.78	94.12
4	Rice land	84.21	71.43	70.00
5	Other agricultural land	58.82	56.25	100.00
6	Artificial forest land	-	94.44	50.00
7	Natural forest land	-	88.89	56.52
Total ratio of accuracy		75.70	76.41	78.30
Kappa Index		67.17	71.75	74.20

The total ratio of accuracy and Kappa index of maps of land using status in 2014 is highest with 78.30% and 74.20% respectively. In the year of 1975 has the lowest degree of accuracy with the total ratio of accuracy and Kappa index respectively 75.70% and 67.17% because the Landsat MSS satellite image at this time had the lowest quality and resolution in comparison with Landsat images recently. Moreover, we did not have enough data to do the evaluation of the whole study area that affected the degree of accuracy of total accuracy. However, the degree of accuracy of impervious surface and rice land in 1975 was highest in comparison with other years with respectively 91.18% and 84.21%. It is possible that there was high concentration of residential areas, transport lines and industry areas and other impervious surfaces, in the meanwhile, these types of land using are dispersed along with the large coverage of Landsat could affect the degree of accuracy of interpretation.

3.2. Evaluation the urban process of Huong Thuy County Town during 1975 – 2014

Huong Thuy was first launched in 1835 with the name of Loi Bong, from that time, this area has been changed internal and external boundaries to adapt to the demand of increasing population and administrative management, such as in the years of 1945, 1956, 1981. However, we selected the years of after 1975 because this period will play the key role in the following development stage of this area. Since 1975, Huong Thuy had the total area of 19,194.48 ha, however, in 1990, its total area was 45,606.42 ha. These changes lead to entire changes about the land using in all aspects since that time.

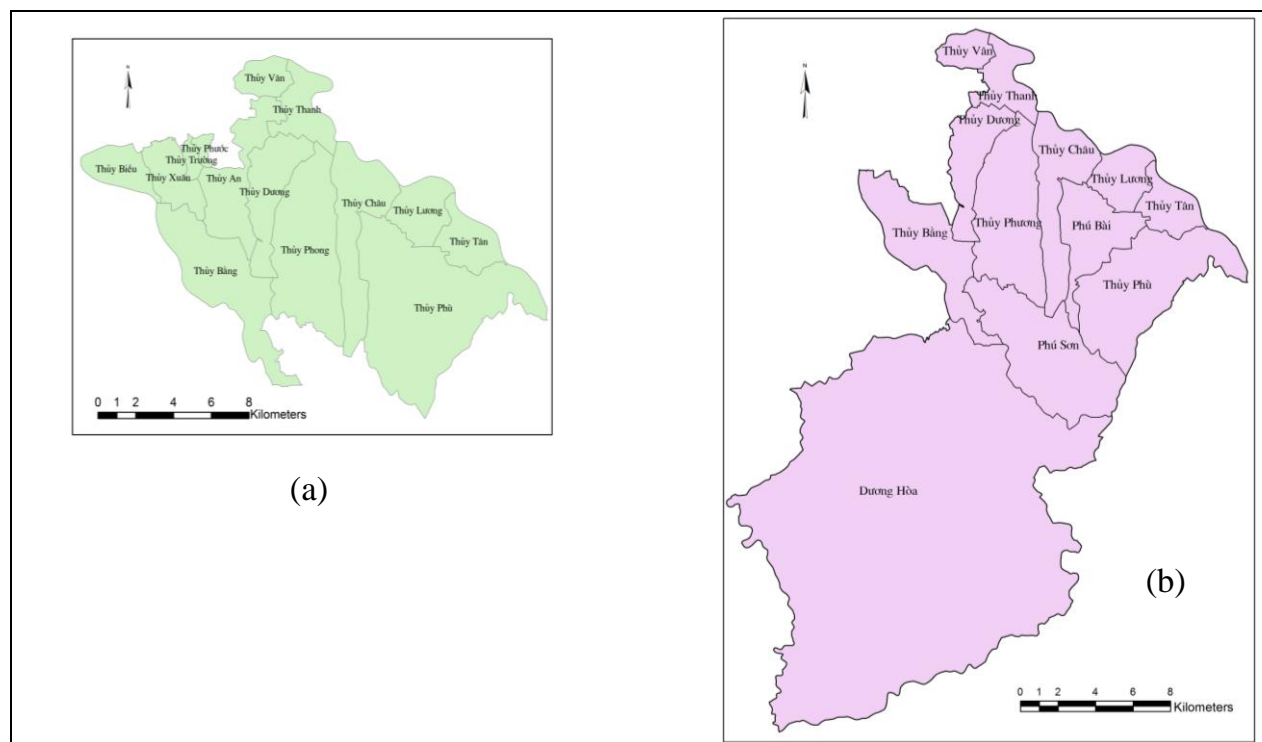


Figure 5. Administrative boundary of Huong Thuy District in 1975 (a) and after 1990 (b)

Table 4. Summary of land using changes in Huong Thuy District during 1975 – 2014

Land using	1975	1990	2005	2014
Impervious surface	2,940.93	2,302.11	1,390.77	2,263.86
Bare soil	45.72	853.47	244.71	274.23
Water area	911.52	560.16	969.57	1,345.05
Rice land	6,103.62	4,209.48	3,599.10	4,875.75
Other agricultural land	3,513.06	6,819.3	10,058.13	5,282.73
Artificial forest land	5,596.29	10,791.00	12,691.89	21,123.72
Natural forest land	83.34	20,070.90	16,652.25	10,441.08
Total area	19,194.48	45,606.42	45,606.42	45,606.42

3.2.1. The period of 1975 – 1990

Table 5. Land usingchanges in Huong Thuy District during 1975 – 1990

Land using	1975	1990	Biến động
Impervious surface	2,940.93	2,302.11	-638.82
Bare soil	45.72	853.47	807.75
Water area	911.52	560.16	-351.36
Rice land	6,103.62	4,209.48	-1,894.14
Other agricultural land	3,513.06	6,819.3	3,297.24
Artificial forest land	5,596.29	10,791.00	5,194.71
Natural forest land	83.34	20,070.90	19,987.56
Total area	19,194.48	45,606.42	26,411.85

The data showed that there was an increasing tendency of natural forest, from 83.34 ha in 1975 up to 20,070.90 ha in 1990. Along with this tendency, the area of artificial forest land also double increased during constant 15 years and became one of two popular types of land using in 1990. Because of this reduction of area in the north-west of Huong Thuy where there was the concentration of urban area and cultivation land, therefore, the area of impervious surface and rice land decreased respectively 638.82 ha and 1894.14 ha.

3.2.2. The period of 1990 – 2005

The shift of land using during 1990 – 2005 showed in table 6 and figure 6. The data in table 6 addressed that there was about 25.37% reduction of natural forest land area and 80.07% reduction of artificial forest land to convert these areas into agricultural area. As a result, during this period the area of other agricultural land sharply increases, about 3,238.83 ha. On the contrary, there was only a small change of water area and . However, there was the sharply dropped in the area of impervious surface and rice land, respectively 911.34 ha and 610.38 ha during the period of 1990 – 2005 due to the policy of moving cemetery land.

Table 6. The matrix of changing land using in Huong Thuy District during the period of 1990 – 2005

Type of land	Impervious surface	Bare soil	Water area	Rice Land	Other agricultural land	Artificial forest land	Natural forest land	Year 1990
Impervious surface	539,19	80,91	65,52	54,81	1.285,56	270,18	5,94	2.302,11
Bare soil	166,14	70,20	39,96	16,02	507,24	53,91	0,00	853,47
Water area	17,64	1,17	468,18	3,69	45,81	18,45	5,22	560,16
Rice Land	91,53	4,41	161,55	3.195,36	741,42	15,21	0,00	4.209,48
Other agricultural land	473,76	66,51	122,58	229,59	4.306,59	1.582,56	37,71	6.819,30
Artificial forest land	84,69	20,79	50,94	52,02	2.205,54	8.036,64	340,38	10.791,00
Natural forest land	17,82	0,72	60,84	47,61	965,97	2.714,94	16.263,00	20.070,90
Year 2005	1.390,77	244,71	969,57	3.599,10	10.058,13	12.691,89	16.652,25	45.606,42

Changing of Land Using in Huong Thuy District in the period of 1990 - 2005

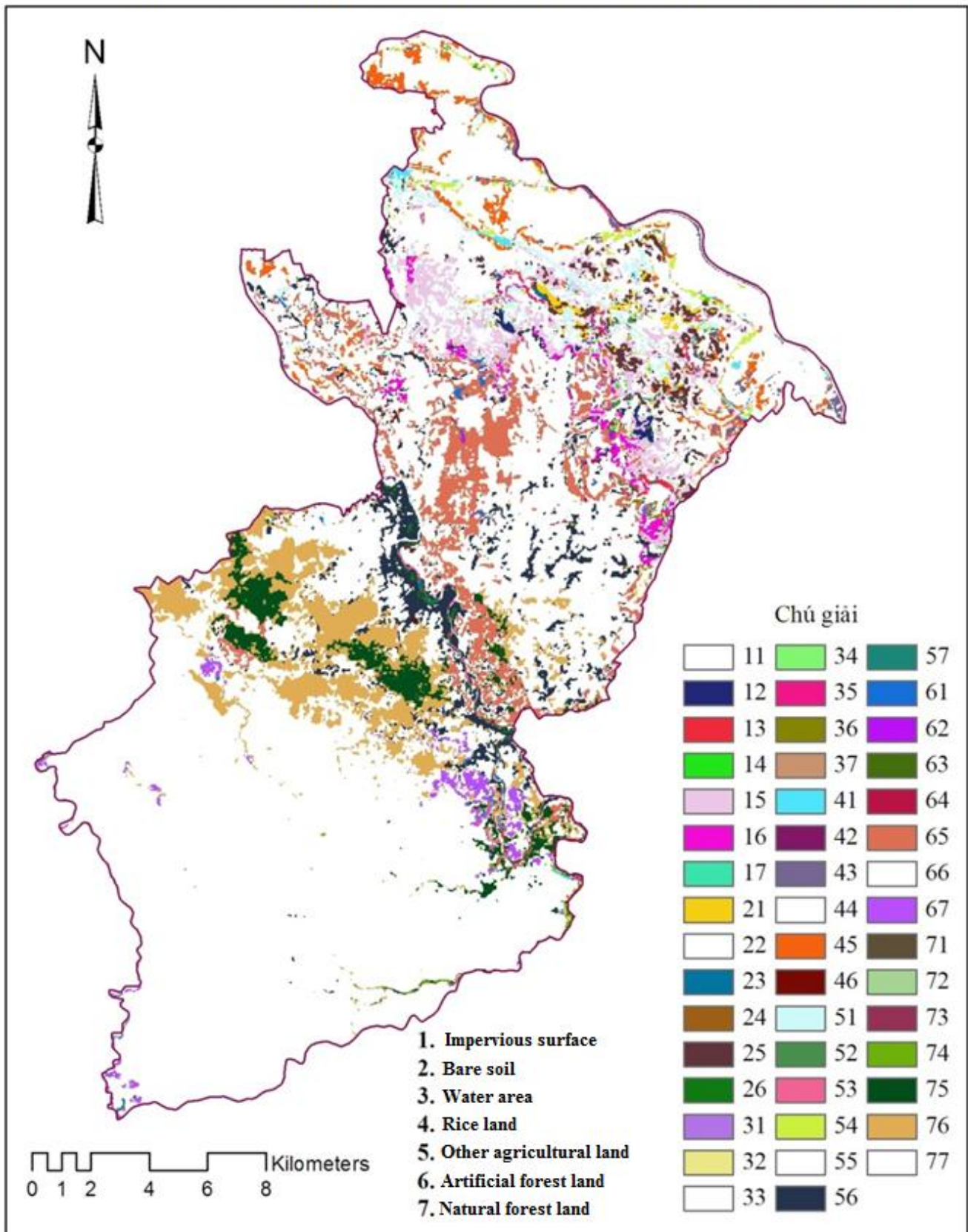


Figure 6. Changing of land using in Huong Thuy District in the period of 1990 – 2005

3.2.3. The period of 2005 – 2014

During continuous 15 years, there was evenly decreasing in the area of natural forest, from 16,652.25 ha in 2005 low to only 10,441.10 ha in 2014. However, along with artificial forest land, they are still the most popular type of land in 2014. Because there is the lost of a large area of natural forest land due to the conversion, about 6,455.89 ha, along with the shift of 3562.02 ha area from other agricultural land, the total area of artificial forest land sharply increases. In this period, the area of rice land in 2005 was less 1.5 times than this type of land in 2014. There was about 23.29% and 70.43% area of rice land converted into artificial forest land and other agricultural land. In the meanwhile, there is an increasing about 1.5 times of impervious surface and water area. The sharply increase area of impervious surface in this period because of the conversion 12.44% area of rice land and 69.58% area of other agricultural land. However, the expansion of urban land, including residential land, cemetery and industry area, dispersing distributed along with agricultural land and forest land, therefore, it is needed to make a suitable planning about urban space in this Huong Thuy County Town.

Table 7. The matrix of changing land using in Huong Thuy District in the period of 2005 – 2014

Type of land	Impervious surface	Bare soil	Water area	Rice land	Other agricultural land	Artificial forest land	Natural forest land	Year 2005
Impervious surface	631,08	19,35	34,29	108,09	303,48	292,32	2,16	1.390,77
Bare soil	81,45	3,33	0,90	62,46	43,92	52,65	0,00	244,71
Water area	112,68	1,71	616,77	104,13	96,12	36,45	1,71	969,57
Rice land	203,13	23,49	14,04	2.956,50	299,61	99,09	3,24	3.599,10
Other agricultural land	1.136,07	133,29	284,85	1.625,31	3.231,00	3.562,02	85,59	10.058,13
Artificial forest land	98,37	64,44	360,54	19,26	1.288,53	10.625,31	235,44	12.691,89
Natural forest land	1,10	28,55	33,68	0,00	20,08	6.455,89	10.112,95	16.652,25
Year 2014	2.263,86	274,23	1.345,05	4.875,75	5.282,73	21.123,70	10.441,1	45.606,42

Changing of Land Using in Huong Thuy District in the period of 2005 - 2014

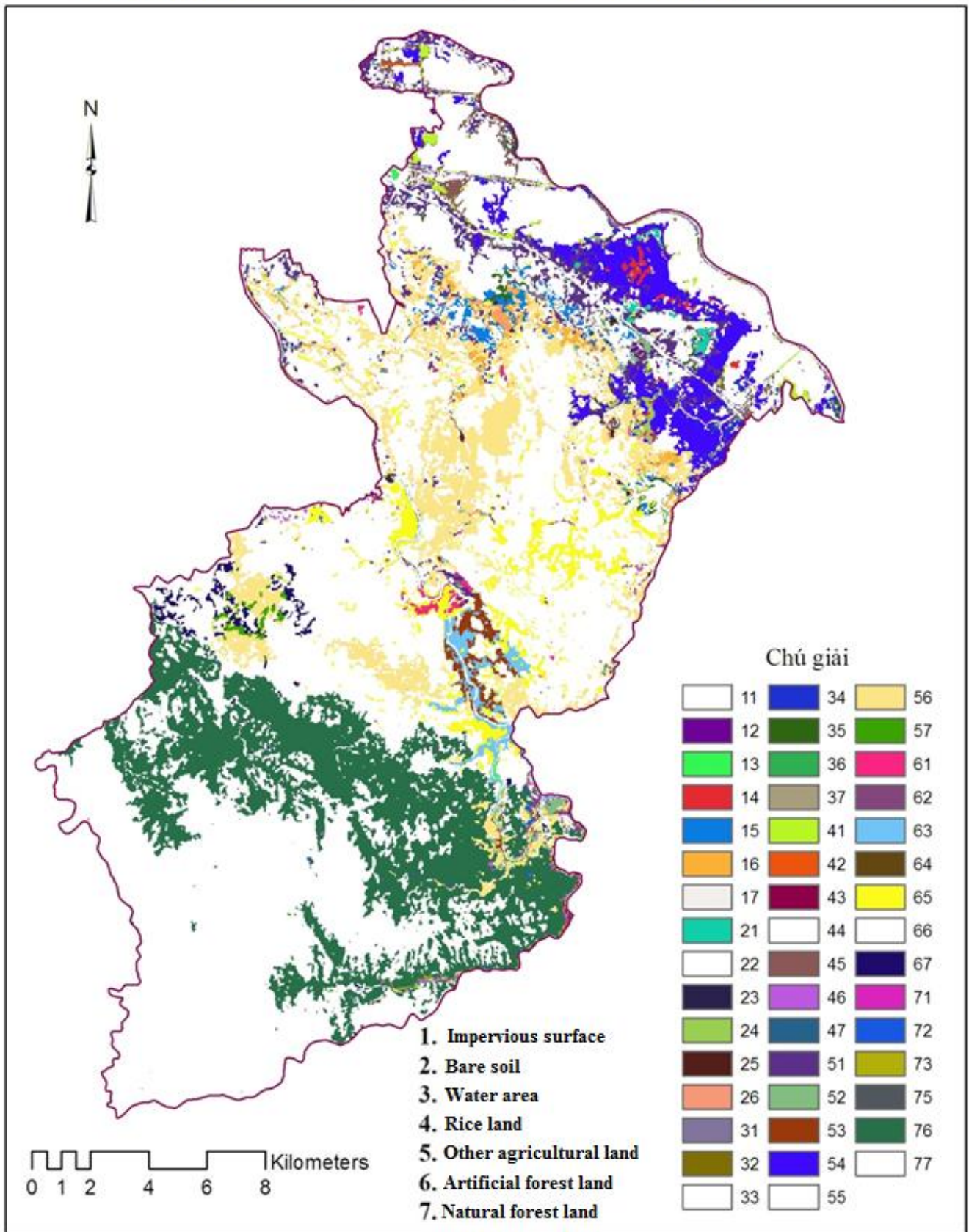


Figure 7. Changing of land using in Huong Thuy District in the period of 2005 – 2014

5. CONCLUSIONS

1. Huong Thuy County Town has high speed of urbanization, clearly showed in many maps of land using status and land changing over the years of 1975, 1990, 2005 and 2014. The urbanization process in Huong Thuy County Town has the tendency of decreasing the area of natural forest land, increasing the area of impervious surface but gradually reduce the area of other agricultural land.

2. Huong Thuy County Town needs to adjust development activities in area, focusing on increasing the area of other agricultural land to maintain food security. Beside, it is needed to make plan for land using to avoid the situation of the industry area next to the residential area or agricultural land. HuongThuy County Town also needs to increase the quality of forest to gain the balance in development toward sustainable development.

3. GIS and Remote Sensing diversifies many data and researches about urbanization in Huong Thuy County Town to have better foundations for further research and planning about land using in the future. This research showed that the demand to do research about urbanization should be expanded to smaller district or town to identify many problems rising along with the urbanization to design the optimal solutions to protect the main city in the large scale.

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