SOCIO-ECONOMIC DRIVING FORCES OF LAND USE CHANGE IN HANOI URBAN FRINGE, CASE STUDY IN THANH TRI DISTRICT

Dinh Thi Bao Hoa, Nguyen Cao Huan

Vietnam National University, Hanoi (VNU)

Abstract

This paper analyses characteristics, major driving forces and alternative management measures of land use change in Hanoi urban fringe - Thanh Tri district, Vietnam. This study used remote sensing (RS) maps and socio-economic data. Based on RS-derived maps, three change matrices were constructed for detecting land use change between 1994-1999, 1999-2001 and 2001-2003 through post-classification comparisons method. The outcomes shown that paddy field, crop land and water surface were decreasing in different rate during three periods mentioned above. In contrast, the following land uses increasing greatly are construction land, rural settlements and urban settlements. In conclusion, after ten years, paddy field was cut off 20 percent, crop land was rose 8 percent, and water surface was lost 6 percent. Beside, construction land, rural settlements and urban settlements were increased 9 percent, 7 percent and 1 percent respectively.

Socio-economic data were used to analyze major driving forces affecting to land use change at Hanoi urban fringe. The result indicated that industrialization, urbanization, population growth and land use planning are four major forces. Finally, we suggested some possible management measures to monitor land use change and push the socio-economic development of the study area.

Keywords: land use change, urban fringe, fragmentation, driving forces.

1. Introduction

In Vietnam, the shift from a centrally planned economy to a market oriented one in 1986 by Economic Renovation has prompted the rapid expansion in the city suburb. The phenomenon of mixed land use at suburb At the heart of growth in urban fringe is land development. One of serious implication of land development due to rapid expansion of urban area is the conversion of agricultural land to urban one (UN, 1995). In summary, the conversion of cultivated land to non-agricultural land has been considered a major feature of land use change at urban fringe.

The fragmentation of cultivation land can be also observed due to construction on land of urban fringe. In addition, the adoption of market principles have results in the internal restructuring of agricultural land use from traditional paddy production to more diversified agricultural activities such as fruit, vegetable and especially aquaculture. The accelerated population increases have greatly affected land use change through increase of built up area, fragmentation of land use as well as decrease cultivated land. Infrastructure development (e.g. road network, electricity) has further enhanced the land use change process in the area. With economic growth, massive farm land loss for the benefit of market farming and non-agricultural development may occur without appropriate planning and management land resources that leads serious problem to environment.

It is very important to study the driving forces of land use change to understand the change process. The result will be very useful to support decision making in use of land at urban fringe.

Remote sensing (RS), geographic information system (GIS) and cartographic modeling have been widely applied and recognized as powerful tools in researching the patio-temporal dynamic of land use and land cover [1]. RS can provide valuable multi-temporal data for monitoring that is necessary in urban fringe due to land use change without plan accelerating. This causes serious problem in the urban fringe as environmental degradation and poverty. GIS techniques make possible the analysis mapping and modeling of this pattern. One can develop spatial explicit time series of land use change based on RS.

Recently, issues related to land use change are interested in wide variety of researchers ranging from those who favor modeling spatial and temporal pattern of land conversion based on RS techniques to those who try to understand causes and consequences of land use change based on statistics analysis. Although, industrialization, urbanization and population growth have been considered the most common forces contributing to land use change on global scale.

An approach of change detection enables us to discover the structural variation among different land use pattern. In addition, statistical analysis such as correlation analysis, multivariate analysis, principle component analysis, cellular automat, urban fraction, landscape metric are used to diagnosis land use change based on time series socio-economic data [4,6,7,15]. These time series analysis of land use change and the identification the driving forces responsible for these change are significant not only for sustainable development of land resources, its environment but also for forcasting land use in the future [8].

2. Materials and method

2.1. Study area

Our study area is a suburb located in the south of Hanoi city. It ranges from 20°52'33" N to 20°59'01" N and from 105°47'27" E to 105°56'11" E. The area is of 9.828 ha. Average elevation is around 4-5m. High level of topography can be ranged into three categories: the first below 3.5m, the second from 3.5 to 6m, the last above 6m. The environmental issue here is water pollution that come from industry production, domestic or agricultural production. Moreover, the wasted water sometime is kept in the soil longer than normal due to concaved topography that made soil polluted. This topography is also unique due to the dyke that divides study area into two parts, one inside the dyke, and another outside the dyke, along Hong River. The main road in Thanh Tri is national road number 1. Beside, there are many small road along the river, canals that connect between communes and villages in Thanh Tri. Thanh Tri's population has been increasing by an annual rate of 3 percent since 1990s. Total population is about 11 thousands persons. Population density was up to 2.3 thousands persons/km^2. This value was double compared to the highest population density in Thai Binh province. Of the total population, haft was engaged in farming.

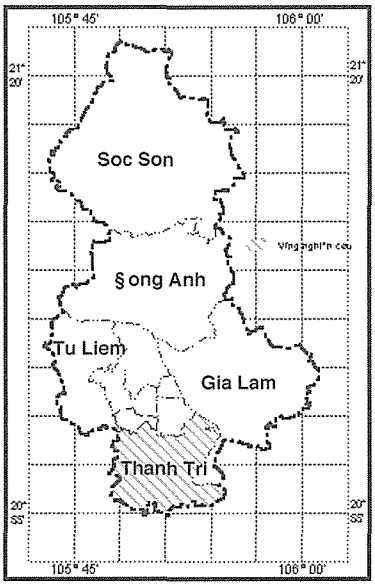

Figure 1. Location of study area

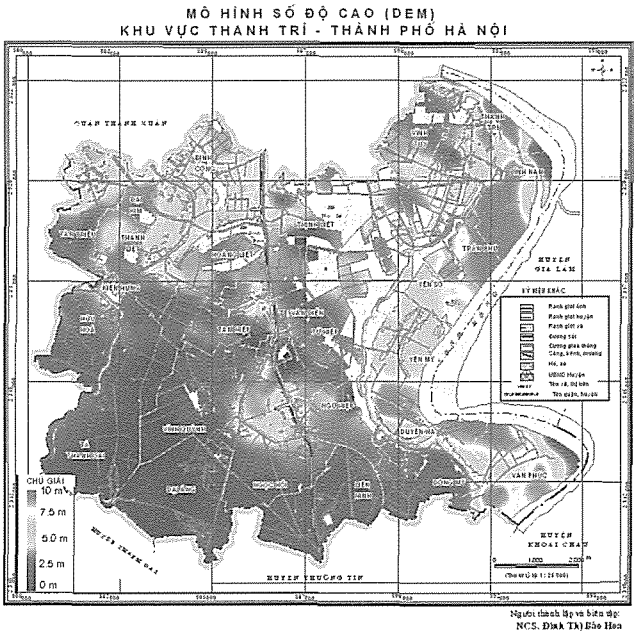

Fig. 2. Thanh Tri's topography

Administration system in Thanh Tri has shown that there are 25 communes in which, 8 communes locate outside the dyke. The non-agricultural population has been increasing very slowly at annual rate of 3 percent for five years. Beside, ratio between labor forces in agriculture and agricultural population has been increasing. Evidently, the area of cultivated land per a labor is also decreased.

2.2. Data sources and processing

The analysis of land use change in Hanoi urban fringe is based on four maps at a 1:25.000 scale. These maps were extracted from SPOT images which were acquired on 22/10/1994 and 26/9/1999 and ASTER which are acquired on 16/11/2001 and 13/01/2003. Figure 3 shown flowchart of satellite image processing.

Satellite image was classified into 7 classes consisting of paddy field, water surface, rural settlement, urban settlement, construction land and transportation, crop and vegetable land, Hong river. The process of classification was done by using PCI software. Post-classification was implemented by using ENVI software based on its decision tree function to correct misclassification pixel. After geometrical image correction and georeferencing, the accuracy was acceptable because the root mean square error was smaller than one pixel. To take right sample for further image processing, ground truth data was collected during field survey. Pair image classifications were used to construct change matrix in raster format. By using vector transfer function, vector format of those classification image were created for analyze the characteristic of land use in each date. Figure 4 illustrated four classification images dated 1994, 1999, 2001 and 2003 of SPOT and ASTER images respectively. Fig. 5 illustrated three land use change according to three periods (1994-1999, 1999-2001 and 2001-2003).

In order to analysis driving forces to land use change, socio-economic data were collected from authority (table 1). Those socio-economic data include time series data on population, agriculture (crop yield, agricultural land), aquaculture (fish product), industry, economic structure, commercial in whole district between 1985 to 2003. Annual consensus were normally not complete so that some difficulties occurred when comparing between them. However, these data were used to analyze potential driving forces resulting of land use change.

2.3. Methods

Based on four classification images dated 1994, 1999, 2001 and 2003, each pair of raster image were used to construct change matrix. Then for each land use class i in a change matrix A, the change between two date was calculated according to the following equation:

$$CHi=(pi.-p.i)/p.ix100$$

In which:

CHi change of land use in row i relative to the previous compared year.

pi.: row total for class i

p.i: column total for class i

Land use conversion between two date were considered. The land in each class lost is assigned to "conversion loss to", by contrast, the land gained is assigned to "conversion gain from" in relation to the total "loss" or "gain" according to the equation below:

In which:

Ploss (i)j is the percentage taken by class j in the total "conversion loss" of class row i,

Pgain (i)j is the percentage taken by class j in the total "conversion gain" of class row i,

Pi,j and pj,i is the individual entry in the a change matrix A.

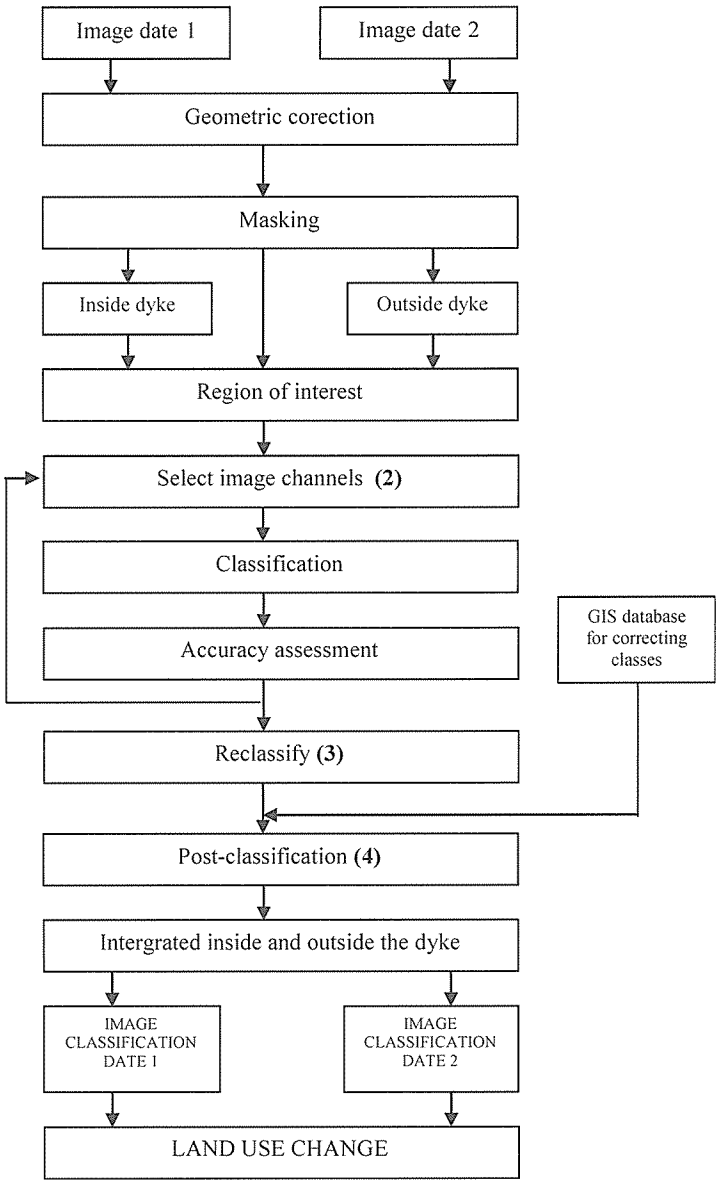

Fig. 3. Flowchart of satellite image processing

Landscape ecology deals with the pattern of ecosystems in space through its structure, function and change characteristics. It would be better to use the number of index for qualifying the landscape pattern. Most of indices highly redundant and depend among themselves, since only a few primary measurements can be made from patches (such as patch type, area, edge, entropy, etc.), and all metrics are derived from these primary measures. Some will be selected to study on land use change. In urban study, to assess spatial pattern such as fragmentation or change, the index could be used as patch count, average patch or combination parameter in one formula such as MSI, SCI, SDI, Entropy, etc.

$$E(A) = E(\omega_1, \omega_2, \omega_3 ... \omega_n) = -\sum_{i=1}^{n} \log_2 \omega_i \times \omega_i$$

in which: ω_i is area of landscape i^{th}

3. Result

3.1. Characteristics of land use change in Hanoi urban fringe

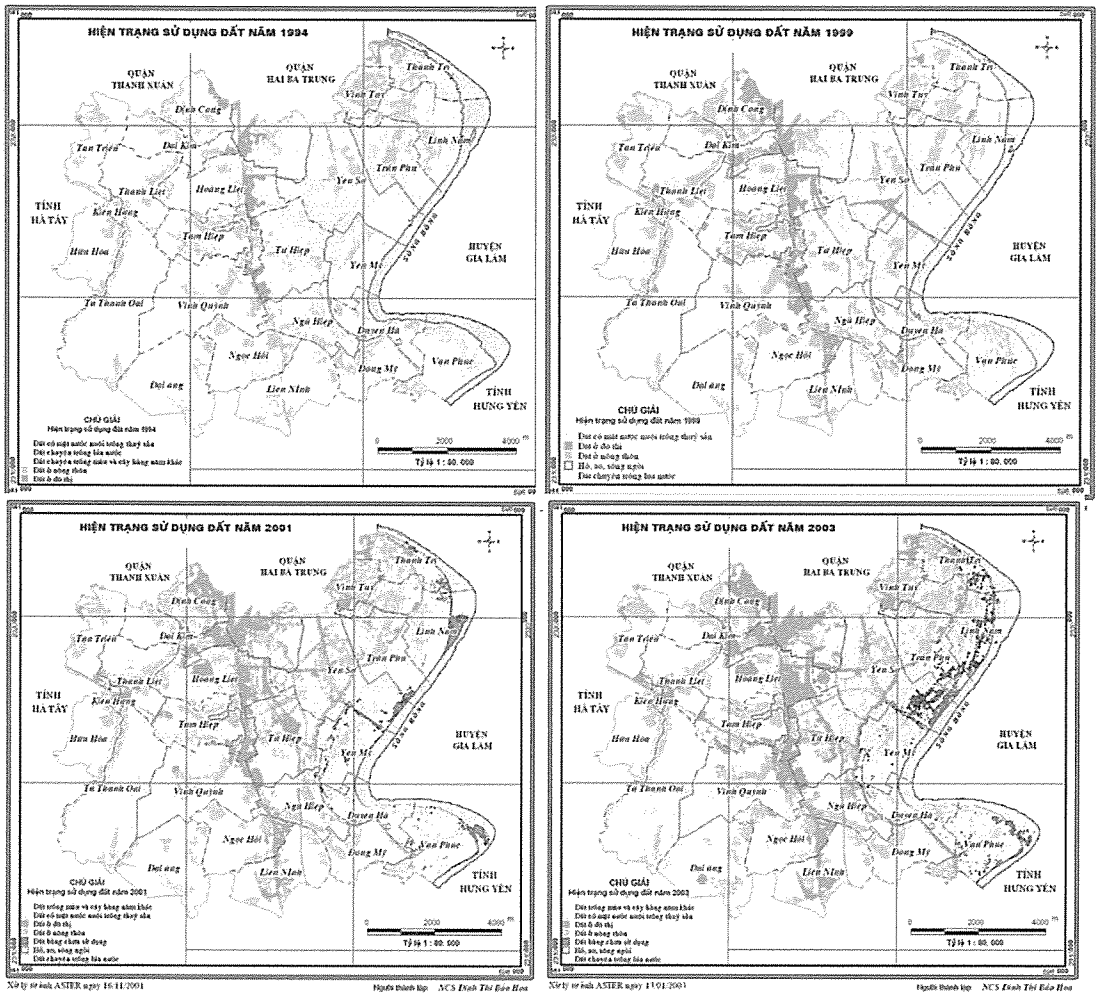

Fig. 4. Landuse maps of Thanh Tri District in 1994, 1999, 2001 and 2003

After ten years (from 1994 to 2003), in Thanh Tri district, paddy field was cut off 20 percent, crop land was rose 8 percent, and water surface was lost 6 percent. Beside, construction land, rural settlements and urban settlements were increased 9 percent, 7 percent and 1 percent respectively.

Area of paddy field was downscaling from 53.36 percent to 41.87 percent. One was converted to crop and vegetable land, another to land for special use or settlement. Average of reduction rate during two periods is 76.07 ha/year and 270.89 ha/year (between 1994-1999 and 1999-2001 respectively), about four fold decreased. Area of paddy field was kept stable during 2001-2003.

Crop and vegetable land increased at rate 59.79 ha/year during 1994-1999. Moved to 1999-2001, this value was two fold (about 126 ha/year). After 2001, the opposite trend occurred. Crop and vegetable land decreased at rate 115.16 ha/year.

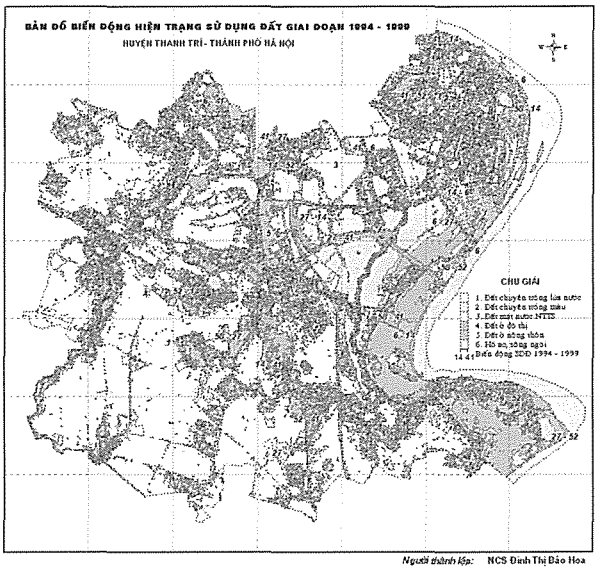

Fig. 5. Land use change between 1994-1999

Table 1. Land use change matrix in Thanh Tri district during 1994-1999

1994 \ 1999	1	2	3	4	5	6	7	**Total 1994**	%
1	**4091,08**	925,52	0	186,68	61,20	14,96	21,20	5300,64	53,36
2	0	**808,24**	0	0	256,80	0	0	1065,04	10,72
3	68,4	76,72	**1460,64**	82,08	19,32	0	0,32	1707,48	17,19
4	0	0	0	**277,84**	0	0	0	277,84	2,80
5	0	0	0	0	**1019,64**	0	0	1019,64	10,26
6	0	0	0,24	2,20	0	**22,48**	1,96	26,88	0,27
7	0	16,44	0	0	0	0	**519,84**	536,28	5,40
								9933,80	100,00
Total 1999	4159,48	1826,92	1460,88	548,80	1356,96	37,44	543,32		
ha	4159,48	1826,92	1460,88	548,80	1356,96	37,44	543,32	**9933,80**	
%	41,87	18,39	14,71	5,52	13,66	0,38	5,47	100,00	

From 1994 to 2003, land use for construction purpose sharply increased about 9 percent from 2.8 percent to 11.59 percent while land use for agriculture is deeply decreased from 53.36 to 34.42 percent. The positive trend in urban settlement almost had been given at high rate from annual rate of 0.7ha between 1994-1999 shifted to 2.1ha between 1999-2001 and lastly jumped up to 27.3ha between 2001-2003. Likewise, rural settlement was shifting from 4.2ha per year to 21.1ha and standing at 92 ha during that three periods.

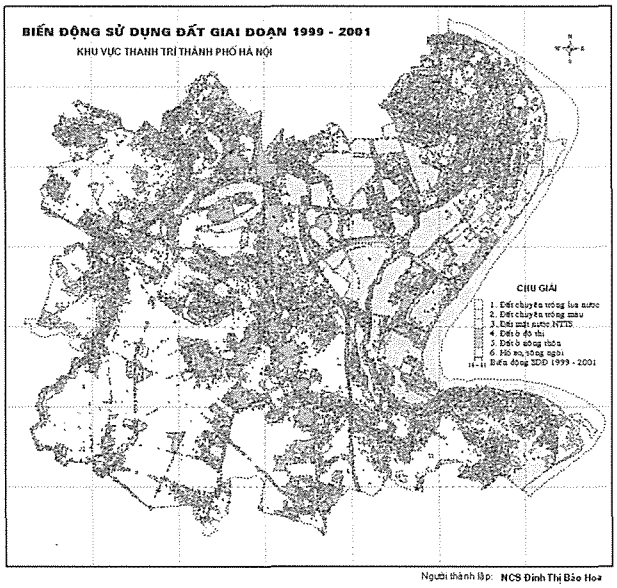

Fig. 6. Land use change between 1999-2001

Table 2. Land use change matrix in Thanh Tri district during 1999 - 2001

2001 / 1999	1	2	3	4	5	6	7	**Total 1999**	%
1	**3320,52**	393,76	157,48	217,4	42,8	1,08	0,16	4133,2	41,61
2	0	**1760,8**	0	70,04	0	0	0	1830,84	18,43
3	0	41,44	**1313,36**	63,6	18,64	10,04	0,24	1447,32	14,57
4	0	0	0	**581,4**	0	1,68	0	583,08	5,87
5	0	0	0	0	**1356,96**	0	0	1356,96	13,66
6	0	4,76	0	0	1,6	**31,08**	0	37,44	0,38
7	0	8,32	0	0	0,28	0	**536,28**	544,88	5,49
								9933,72	100,00
Total 2001	3320,52	2209,08	1470,84	932,44	1420,28	43,88	536,68		
ha	3320,52	2209,08	1470,84	932,44	1420,28	43,88	536,68	**9933,72**	
%	33,43	22,24	14,81	9,39	14,30	0,44	5,40	100,00	

Consequently, increase of population forces the demand of housing construction directly in one way. In the other way, it would create high pressure to land use indirectly. More population, higher land invasion according to power rule.

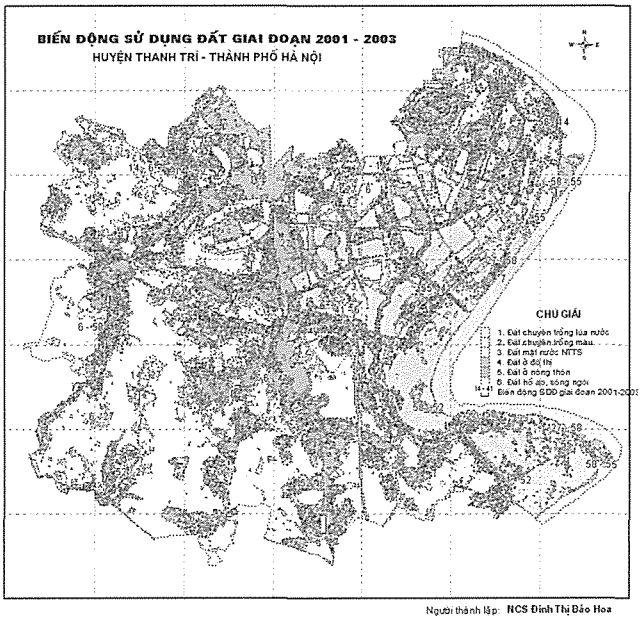

Fig. 7. Land use change between 2001-2003

Table 3. Land use change matrix in Thanh Tri district during 2001-2003

2001 \ 2003	1	2	3	4	5	6	7	**Total 2001**	%
1	**3182,32**	0	0	23,84	28,44	85,68	0,08	3320,36	33,42
2	74,4	**1760,65**	0	122,4	247,4	0	8,6	2213,45	22,28
3	152,96	105,88	**1148,68**	66,56	0	0	0	1474,08	14,84
4	0	0	0	**938,76**	0,12	0,52	0	939,4	9,46
5	0	0	0	0	**1412,68**	0	0,08	1412,76	14,22
6	0	1,44	2,76	0	0,12	**33,08**	0	37,4	0,38
7	0	0	0,08	0	0	0	**536,28**	536,36	5,40
								9933,81	100,00
Total **2003**	3409,68	1867,97	1151,52	1151,56	1688,76	119,28	545,04		
ha	3409,68	1867,97	1151,52	1151,56	1688,76	119,28	545,04	**9933,81**	
%	34,32	18,80	11,59	11,59	17,00	1,20	5,49	100,00	

3.2. Major driving forces of land use change in Hanoi urban fringe

Industrialization

The major land use change is caused by increasing demand for non-agricultural land because of urban and manufacture development. Before renovation, some factories in Hanoi located in edge of the city. Due to urban expansion, those factories in edge of the city now turned out to be in the center, very closed to resident so that impact human health and environment. The Hanoi master plan

was set up to 2020 following the idea as moving the manufactories from city center away from the city in the urban fringe. Agricultural land in Ngọc Hoi and Lien Ninh communes was collected for that purpose. Industry not only alters the economic development in the area where it located but also change in land use pattern. Land for construction and transportation reflected relative of industrialization and land use change.

Urbanization

Urbanization contributed to the loss of agricultural land in Vietnam and is generally seen as one of the most important factor of land use change. The direct result of urbanization was reduction of agricultural land by increasing urban settlements.

Population growth and economic development

With a great intention of globalization and integration, Vietnam entered a period of transition since the Economic Renovation started in 1986. The change to a multi-sector economy is reflected in there structuring of economic sectors.

The GDP grew at a yearly rate of 12.52% from 1991 to 1995 and a rate of 10.18 percent from 1996 to 2000. Hanoi has increased its GDP by 11.2 fold from 1985 to the year 2000. The speed of growth of Hanoi average GDP from 1996 to 2000 was 3-4 percent higher than any where else nation wide and average GDP per capita increased by 2.1 fold too. Hanoi's economic growth is quite high, and development can be seen in all sectors and industries. Hanoi's economy has fundamentally shifted to a market economy while socialist-oriented relations in production are highly respected, built up and strengthened. The economic structure has taken important steps toward industrialization and modernization.

Table 4. Annual production value and average economic growth rate managed by district authority during period 1991-2000 (in billion VND based on the value in 1994)

Index	Annual production value (Billion VND)			Annual average economic growth rate (%)		
	1991	1995	2000	1991-2000	1991-1995	1996-2000
Production value in total	139,155	236,685	388,652	12,08	14,20	10,42
In which						
Construction and industry	24,474	62,479	128,846	20,28	26,42	15,57
Agriculture	102,480	143,250	204,839	7,95	8,65	7,40
Services	11,805	30,956	54,967	18,63	21,27	12,17

Source: Authority census by the year 2000 and 2001

Recent year, people immigration to Thanh Tri district is quite high (higher than mort ability index). This situation rise up the demand for settlement as shown in average of settlement land per person. Having higher population density is Dinh Cong, Hoang Liet communes that locate next to city centre. In some communes far from city center, population density is lower such as Dai Ang, Huu Hoa.

Aquacultural production increase every year through yield in this field. This number increased 10.000 million VND after 10 years from starting point in 1994. By contrast, plant production decreased 20.000 million VND and breeding production increased 10.000 million VND. Summary, economic structure had been changed in Thanh Tri following the trend as more service, more breeding and more aquaculture (table 5).

Table 5. Production value in agricultural field (in billion VND based on the value in 1994)

Year	Agriculture	Aquaculture	Planting	Breeding	Agricultural labor force (person)	Agricultural population (person)	Ratio between agricultural labor force and agricultural population
1995	149.247	27.115	104.935	44.312			
1996	147.153	29.616	105.830	41.323			
1997	109.537	28.029	76.285	33.252			
1998	118.369	26.559	82.190	36.179	48.888	125.719	38.88%
2000	147.710	29.014	93.393	51.317	63.841	131.296	48.62%
2001	142.636	36.471	85.138	57.498	52.861	96.092	55.01%
2002	150.585	37.357	91.885	58.700			
2003	147.480	38.980	89.552	57.928			

Source: Authority census by the year 2000 and 2001

Land use master plan

Land use master plan in Thanh Tri had set up in 2001 until the year 2010. After the year of 2001, land use issue in Thanh Tri has been monitoring.

After more than a decade of renovation, Hanoi city has been changed so much in multi-dimensions. However, it may be observed that the master plan regulating the development of Hanoi has proven to be of limited value in its present formulation. The master plan has not met its ambition to strongly control city development, as a result, housing units boomed in new urbanized areas without the formal process of urban planning as seen in the case of Phu Thuong, Tay Ho district - northwestern of Hanoi. This mean that there is still a big gap between urban planning and reality. Detailed plans, basement of development control, are available only for new urban development and not available in most of urban fringe area.

In Thanh Tri, degree of land use change to non-agriculture is regulated according to master plan as had seen at Ngoc Hoi, Lien Ninh (for industry area) or Dinh Cong, Hoang Liet (for new urban development). This means that land use planning in Thanh Tri had been implemented rather than land use planning in Tay Ho (case Phu Thuong).

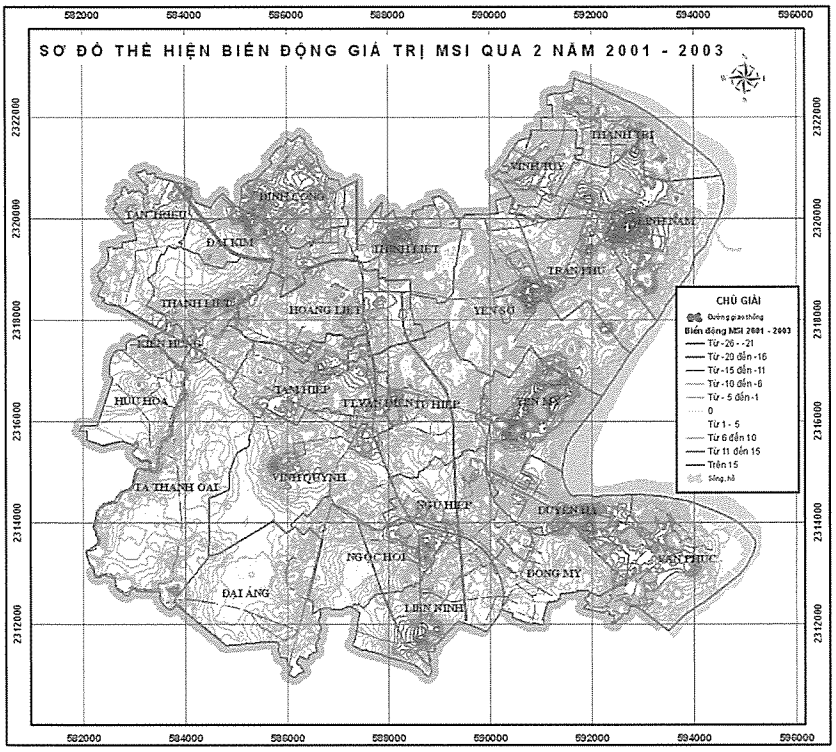

Fig. 8. Change in MSI value between 2001-2003

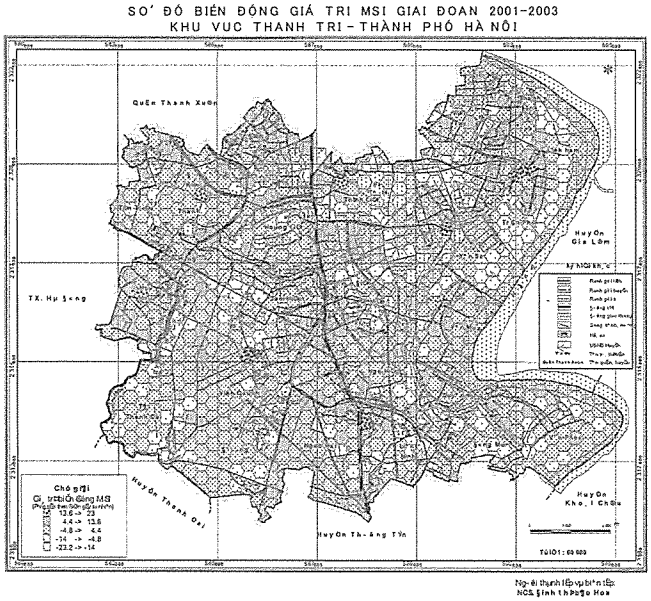

Fig. 9. MSI modeling of land use change pattern between 2001- 2003

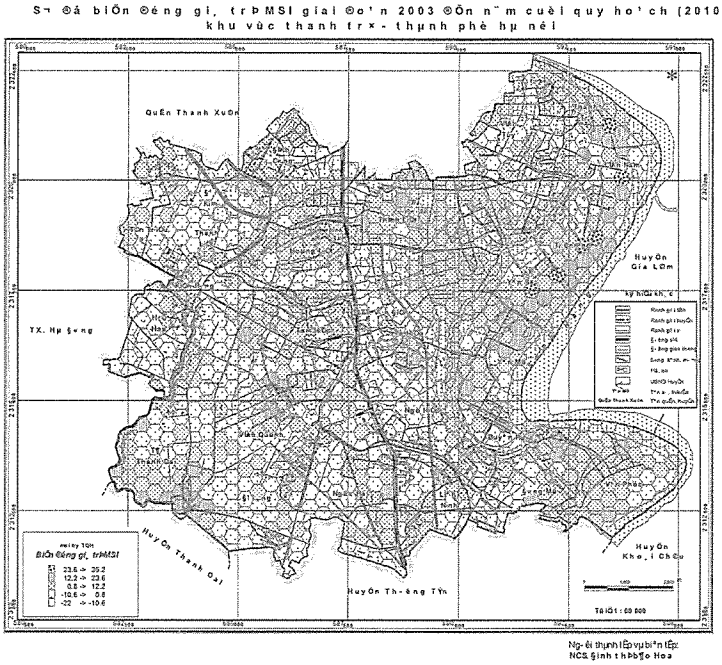

Fig. 10. MSI modeling of land use change pattern between 2003- 2010

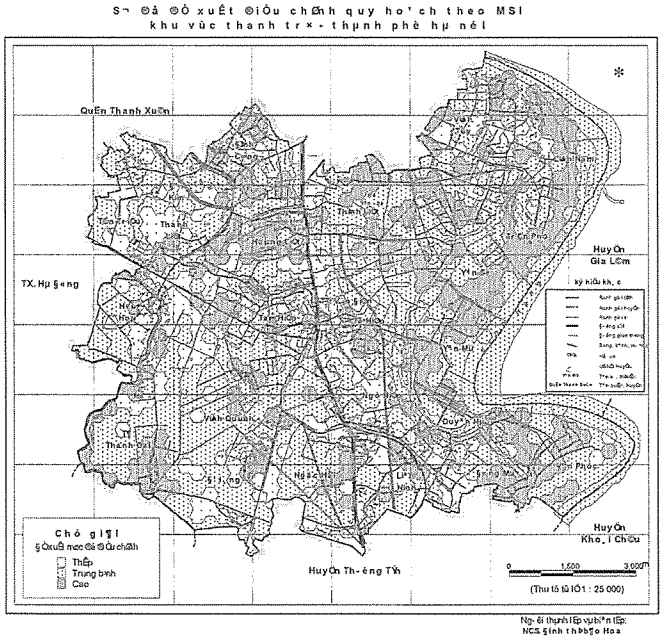

Fig. 11. Suggestion alternative degree of land use following land use master plan

4. Discussion

Economists identify three underlying forces that interact with land values to create spatial urban expansion or sprawl [8]. First, population growth results in the outward expansion of urban areas. Second, rising incomes allow residents to purchase greater living space. These residents locate where housing options are less expensive, such as in suburban and ex-urban areas generally located at the periphery of metropolitan areas. Third, decreasing commuting costs produced by investments in transportation infrastructure also fuels outward expansion of development.

With a high demand for low density, single-family housing developments, residents seek to locate where housing options are inexpensive, such as in the suburbs along the urban fringe. The rising affluence of many people really drives the development of the fringe, because as income increases, the choices of what to spend money on expands as well.

In addition to socio-economic factors, decreases in commuting costs due to infrastructure investment are another underlying force in the sprawling expansion of cities. Improvements in transportation infrastructure as one of the primary reasons for a city expanding outwards. New road construction will provide more access to the fringe. Infrastructure drives the growth of cities by providing the essential framework for development. Once new development takes place, residents then demand improvements in infrastructure that further ignites development along the urban fringe. Widespread access provided by improvements in transportation infrastructure allows developers to utilize cheap land located outside the city center for manufactories and housing or open space..

Infrastructure investments had mixed effects on growth at the urban fringe. Roadway investments appeared to have impact on growth in suburban counties, while demand on agricultural product as market oriented occasionally led to greater growth at the urban fringe that created new change in use of the land for other purpose that meet human's requirement in the city.

5. Conclusion

- There main features of land use change in Thanh Tri have been found out as follows: firstly, invasion of construction and transportation land and settlement by paddy field is serious issue in Thanh Tri; secondly, conversion land use among agricultural land (from paddy field or other type of use - aquaculture land); and the last, increasing of settlement area is at high rate.
- Beside, fragmentation of land in use as shown through entropy and number of patch suggested that in some where, fragmentation is high at the boundary where the topography change dramatically.
- Socio-economic driving forces in Thanh Tri strongest is master plan, stronger is population immigration, economic development and industrialization.
- In order to come up master plan, somewhere outside the dyke, alternative degree is highest. Other area inside the dyke is given the medium or less degree of alternation.

References

1. Đinh Thị Bảo Hoa (2007), *Nghiên cứu sử dụng hợp lý đất vùng ven đô - huyện Thanh Trì, Hà Nội với sự hỗ trợ của công nghệ viễn thám và hệ thông tin địa lý, Luận án Tiến sĩ Địa lý, Đại học Quốc gia Hà Nội,* 150 trang.
2. Uỷ ban Nhân dân huyện Thanh Trì (2001), Quy hoạch tổng thể phát triển kinh tế - xã hội huyện Thanh Trì giai đoạn 2001-2010, Hà Nội 2001.
3. Uỷ ban Nhân dân huyện Thanh Trì (2002), Báo cáo tổng hợp Quy hoạch Kế hoạch sử dụng đất đai huyện Thanh Trì – Thành phố Hà Nội thời kỳ 2001-2010.
4. Claudia Maria de Almeida, Michael Batty, Antonio Miguel Vieira Monteiro, Gilberto Camara, Britaldo Silveira Soares-Filho, Gustavo Coutinho Cerqueira, Cessio Lopes Pennachin (2003), *Stochastic cellular automata modeling of urban land use dynamic: empirical development and estimation,* Computers, Environment and urban systems 27 (2003) 481-509, http://www.elsevier.com/locate/compenurbsys
5. Pham Van Cu, Rajesh Bahadur Thapa and Frederic Borne (2005), *Multicriteria GIS analysis for peri-urban agriculture: a case study of Hanoi Province, Vietnam,* CD-ROM Proceedings, The 26th Asian Conference on Remote Sensing, 7-11/2005, Melia Hotel, Hanoi, Vietnam.
6. Fung P., and Ellsworths L. (1987), *Application of principal component analysis to change detection,* Journal of photogrametry engineering and remote sensing 53, pp. 1649-1659.
7. Graham A. J., Danson F. M., Giraudoux P., Craig P. S. (2004) *Ecological epidemiology: landscape metrics and human alveolar echinocossis,* Acta Tropica 91 (2004) pp. 267-278. http://www.elsevier.com/locate/ actatropica
8. Hualou Long et. Al. (2006), *Socio-economic driving forces of land use change in Kunshan, the Yangtze river delta economic area of China,* Journal of environmental management Vol. 83 (2007), pp. 351-364
9. John O. Browder, James R. Bohnland, and Joseph L. Scarpaci (1995), *Patterns of development on the Metropolitan Fringe, Urban Fringe Expansion in Bangkok, Jakarta, and Santiago,* APA Journal, Summer 1995 pp. 310-325.
10. Jos I. Barredo, Marjo Kasanko, Niall MeCormick, Carlo Lavalle (2005), *Modelling dynamic spatial processes: simulation of urban future scenario through cellular automata,* Lanscape and urban planning 64: 145 – 180, http://www.elsevier.com/locate/landurbplan
11. Kawamura M., Jayamamana S., and Tsujiko Y. (2003*), Comparision of urbanization and Environmental condition in Asian Cities using satellite remote sensing data,* http://www.gisdevelopment.net/aars/1997/ps1/ps2008.html
12. Martin Herold, Helen Couclelis, Keith C. Clarke (2004), *The role of spatial metrics in the analysis and modeling of urban land use change,* Computers, Environment and urban systems, http://www.elsevier.com/locate/compenurbsys
13. Michael Leaf (2002), *A Tale of two villages, globalization and peri-urban change in China and Vietnam,* http://www.elsevier.com/locate/cities
14. Quarmby, N. A., Cushnie, J. L. (1989), *Monitoring urban land cover changes at the urban fringe from SPOT HRV imagery in south-east England,* International Journal of Remote Sensing, Vol.10, p.951-963
15. White R. et. al. (1993), *Cellular automata and fractal urban form: a cellular modeling approach to the evolution of urban land-use pattern,* Journal of environment and planning A, Vol. 25, pp. 1175-1199