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Spatio-temporal dynamics and evolution of landscape pattern in coastal areas of central region, Vietnam

M. Kappas[1,*], Nguyen Hoang Khanh Linh[1,2]

[1]*Dept. of Cartography, GIS & Remote Sensing, Georg-August-University Goettingen, Goldschmidtstr 5, 37077 Goettingen, Germany*

[2]*Faculty of Land Resources & Agricultural Environment, Hue University of Agriculture & Forestry, 102 Phung Hung, Hue City, Vietnam*

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Abstract. Studying temporal changes of land use and land cover from satellite images has been conducted in Vietnam several years. However, few studies have been done to consider seriously the changes and landscape fragmentation, especially in coastal region, one of the ecologically vulnerable regions due to the intensive human activities and urbanization processes. Hence, analyzing the changes of landscape pattern helps revealing the interactions between anthropogenic factors and the environment, through which planning actions could be effectively supported. The present study aimed to examine these changes in the surroundings of Da Nang City, Vietnam from 1979 to 2009 based multi-temporal imagery viz. LANDSAT MSS, TM, ETM+, and ASTER satellite images. The IR-MAD (iteratively re-weighted Multivariate Alteration Detection) transformation approach was employed for processing. Land cover change maps with six classes including agricultural land, urban, barren land, forest, shrub and water body were created by the supervised classification method based on maximum likelihood algorithm. Post-classification comparison was chosen as change detection method for four periods as 1979-1996, 1996-2003, 2003-2009, and 1979-2009. From which key landscape indices were applied by using FRAGSTATS software. The results showed that during the whole study period, there was a notable decrease of forest, shrub, agricultural land and barren land while urban areas expanded dramatically. Further spatial analysis by using landscape metrics underlined the evidence of changes in landscape characteristics with an increase in values of number of patches and patch density while the value of mean patch size decreased during the span of 30 years which indicated landscapes of Da Nang city have been becoming more fragmented and more heterogeneous.

Keywords: landscape pattern, change detection, coastal region, Vietnam.

1. Introduction

As stated in Competitive Cities in the Global Economy [1] and State of the World's Cities 2008/2009: Harmonious Cities [2], urbanization is a global phenomenon and is expected to continue for the next decades. According to the United Nations, roughly half of the world's population lives in urban areas, and in 2030 it will be reached at 60%. Developing countries are believed where the urbanization growth strongly happens up to

* Corresponding author:
E-mail: mkappas@uni-goettingen.de

2030 [3]. Urban areas concentrate not only people but also economic density and productivity [4]. This is often the reasons of changing in lifestyles, high consumption of energy, transportation, infrastructure, and production of waste, etc. [5-12]. Urbanization is believed one of the most prevalent anthropogenic causes of the losing arable land, devastating habitats, and the decline in natural vegetation cover [13]. As a consequence, rural areas have been converted into urban areas with an unprecedented rate and making a noted effect on the natural functioning of ecosystems [14]. Consequently, a profound understanding of land use change is very important to have a proper land use planning and sustainable development policies [15].

According to Myint and Wang [16], such a sustainable urban development must be summarized from numerous decisions, which extracted based on huge data sources, viz. physical, biological and social parameters of urban areas in the continued spectrum of spatial and temporal domains. Therefore, to understand urban land-use and land cover change (LULC) and to predict the change of LULC in future, it is important to have an effective spatial dynamic tool. Nowadays, remote sensing technologies have proven its capacity in providing accurate and timely information on the geographic distribution of land use, especially for region areas [17]. With the support of Geographical Information Systems (GIS), satellite images can be used effectively for estimating and analyzing changes and LULC trends [18].

Due to the fact that the rapid LULC change of one certain area is considered as the driving force of environmental and/or ecological changes, which is continuously transforming landscape pattern, thereby a need for comprehensive assessing and analyzing the change in landscape at broad scales is required. Importantly, understanding the changes in spatial contribution of landscape pattern helps revealing the critical implication of complex relationship between anthropogenic factors and environment [19]. To describe fragmentation and spatial distribution, a range of landscape metrics was calculated for each land use/cover class from satellite classification results by FRAGSTATS [20].

The Earth's coastal zone is known as home of diverse ecosystems, such as estuaries, sea-grass, coral reefs, lagoons, bays, tidal flats, etc.... It plays a crucial part for socio-economic development and national security. This zone is quite sensitive and vulnerable because of human development activities, especially, the tropical coast. As consequences, these activities causes loses of living environment of sea species, degradation of drinking water, changes of hydrological cycles, depletion of coastal resources and many other impacts to the global climate change. Therefore, the management of marine and coastal zone has particularly received great attention from managers as well as scientists all around the world. The urgent demands should be set as top national strategic missions and should be carried out with scientific fundamentals.

After the adoption of the Doimoi (Renovation) policy in economy of the national assembly since 1986, Da Nang city has developed in many aspects. In addition, it was separated from Quang Nam Province in 1997 and has officially become an administration unit that directly belongs to the government. Since then, Da Nang city has asserted as the important position at nation level and the crucial factor of the key area economy of Central region. This has caused the incessant land use/cover change in Da Nang for over past 20 years. Through exploring the land use map extracted from satellite data of different periods, the aims of the present study were to detect, quantify and characterize the changes of land use/cover and landscape fragmentation in Da Nang city.

2. Study area

Da Nang city is located in Central region of Viet Nam, between the 15°55'19" to 16°13'20"N and 107°49'11" to 108°20'20"E (Figure 1). It is a long-stretching narrow region and well known as a dynamic city of the Key Economic Zone in central Viet Nam. The area consists of hills and mountains in the northwest and the Eastern Sea in the east. The altitude varies from 400 meters to 1,524 meters above sea level; next to is the upland with low mountains and the delta takes ¼ areas in the southeast; it covers an area of 1,283.42 square kilometers, including Hoang Sa archipelago district of 305 square kilometers.

Da Nang city has typical tropical monsoon climate. The average annual temperature is about 26°C, average rainfall is about 2,505 mm per year and average humidity is 83.4%. There are two main seasons annually: the wet (August-December) and the dry (January-July). In 2009, the total population is about 887,070 and the population density is 906.7 persons per square kilometers. Da Nang city is known as one of the most densely populated and urbanized area in Vietnam. With the economy development and population increasing, the local LULC in Da Nang city has changed seriously.

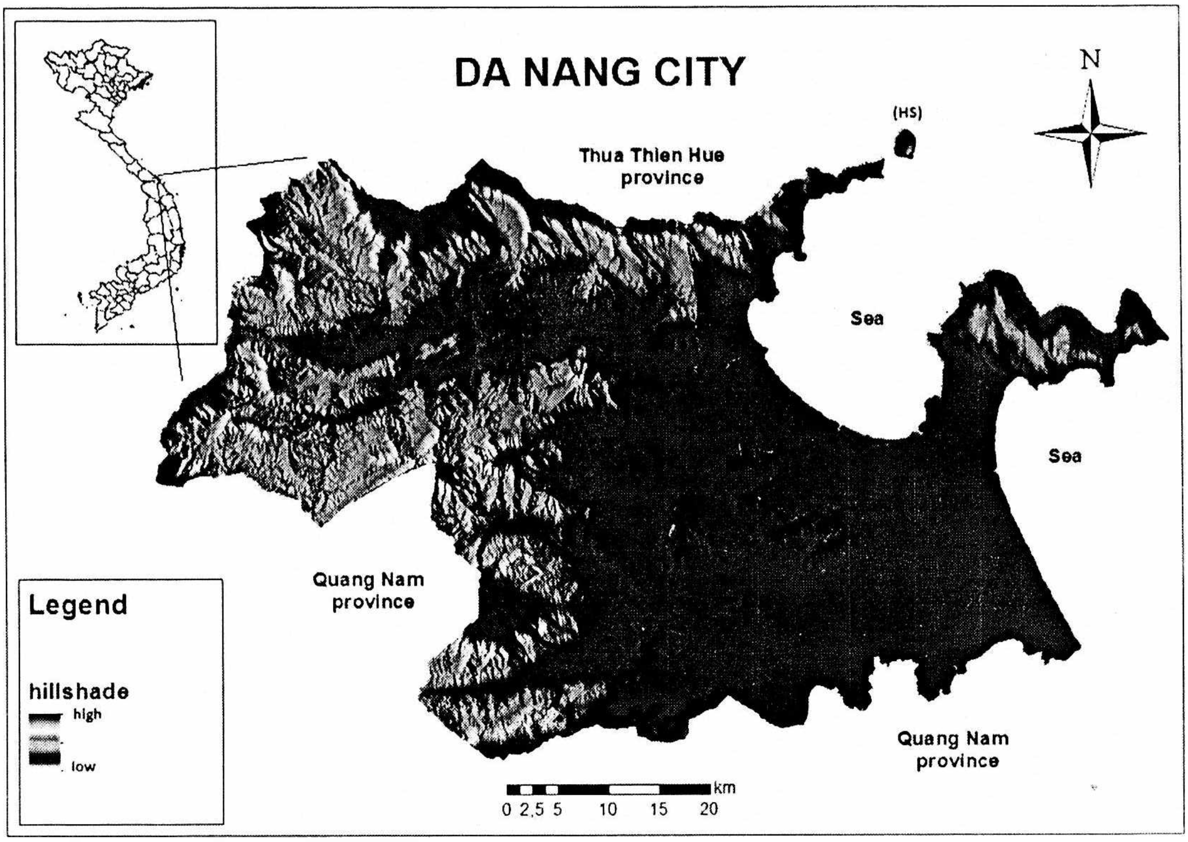

Figure 1. Location of Da Nang city in Vietnam.

3. Data and methods

3.1. Data sources and Image preprocessing

LANDSAT and ASTER satelliteimages were chosen for this study. The following criteria were considered for choosing proper data: (1) the images should be long time enough for detecting the land use change; (2) study area should not have cloud cover. Unfortunately, the study area is located near coastal. Due to the influence of climate, there are not many data satisfied both conditions. The images always have some thick cloud cover or haze. In addition, the study area is not entirely contained within one scene of LANDSAT either ASTER. Therefore, having acquisition images near anniversary dates for changing detection as Jensen mentioned [21] was unavailable. In this study, three periods of satellite images were selected to classify study area: LANDSAT-3 MSS July 24, 1979; LANDSAT-7 ETM+ March 04 and April 14, 2003 (download free at http://earthexplorer. usgs.gov/ and http://glovis.usgs.gov/); and ASTER April 02, 2009. The details of data were described in Table 1. For this study, the reference data were also used, included: (1) topographic map at scale of 1/50.000 conducted in 2001; and (2) land use maps at scale of 1/25.000 conducted in 1997, 2003 and 2010.

Because LANDSAT and ASTER imagery were collected at level 1T and 1B respectively, geometric correction do not require. However, images were acquired at different spatial resolution and projections. Therefore, all images were first rectified to Universal Transverse Mercator (UTM) coordinate system, Datum WGS 84, Zone 48 North for matching the geographic projection of the reference data. Images were also co-registered together within 25 well distributed GCPs (ground control points) and polynomial 1sd by means of OrthoEngine provided by PCI Geomatica 10.3 software. RMS < 0.5 was received. In addition, Nearest Neighbour resampling was set for not changing heavily the radiometric characteristic of image.

In this study, the iteratively re-weighted multivariate alteration detection (IR-MAD) transformation was used for automatic radiometric normalization for all images by means of ENVI 4.7 software; see [22-24]. ASTER 02/04/2009 was chosen as reference image. However, this image does not cover all the region of study area, therefore a subset of 1800 x 1100 pixels with 30m spatial resolution including 968.17 square kilometers was created for all images for further studying. This territory was chosen to ensure the specific study area was in the analysis image. Besides the requirement of the same dimension, images must have the same spectral resolution. Hence, the composite of standard false colours was used for this study: LANDSAT MSS (754); LANDSAT TM/ETM+ (432); ASTER (321).

Table 1. Characteristics of satellite data used in study area

Type of sensor	Spatial resolution (m)	Band	Date	Path	Row	Average cloud coverage (%)
LANDSAT-3 MSS	68	4-8	July 24, 1979	134	49	20
LANDSAT-7 ETM+	30	1-5, 7	March 04, 2003	125	49	34.65 *
	30	1-5,7	April 14, 2003	124	49	0.34
ASTER	15	1-3	April 02, 2009	-	-	4

* Although the average cloud coverage of LANDSAT-7 ETM+ is very high, there is almost no cloud in study area at that time.

3.2. LULC classification and Change detection

Six land use/cover classes were defined for image classification based on the modified Anderson land use/cover scheme level I [25], included: (1) water, (2) forest, (3) shrub, (4) agriculture, (5) barren and (6) urban land. Anderson classification scheme was chosen because of the major land use/cover classes using images with differences in spatial resolution, which are LANDSAT MSS, LANDSAT TM, LANDSAT ETM+ and ASTER. Supervised classification using maximum likelihood approach in ENVI 4.7 was individually applied for each image of study area to classify land use/cover. Maximum likelihood algorithm was preferred because this rule is considered to have accurate results because it has more accurate results than other algorithms [26-28].

Because of various image acquisition dates, training areas for the images of the years 1979, 1996, 2003 and 2009 were different during the classification. In addition, the training areas were verified by references data. As the next step, post-classification comparison change detection algorithm was selected to detect changes in LULC from 1979 to 2009 in study area in order to minimize the problem in radiometric calibration of imagery of two different dates. For comparison of the classification results of two dates, a change detection matrix was created based on pixel-by-pixel [21]. Thereby, each type of from-to LULC change is identified.

3.3. Landscape fragmentation

For quantifying landscape pattern and landscape fragmentation, FRAGSTATS was applied because this spatial statistic program offers a comprehensive choice of landscape metrics. This program was created by decision maker, forest manager and ecologists therefore it is appropriate for analyzing landscape fragmentation or describing characteristics of landscape, components of those landscapes [29]. However, landscape patterns were complicated; hence, to clarify the relationship of spatial pattern and process it cannot use single metric alone [19, 30].

Based on the scale of study area (i.e. the district level) and its characteristic as well, six related landscape metrics were selected: (1) Percentage of landscape (PLAND), (2) Number of patches (NP), (3) Largest patch index (LPI), (4) Mean patch area (AREA_MN), (5) Patch density (PD), and (6) Proximity index (PROX_MN). A brief description of those landscape metrics used in study was given in Table 2. Those descriptions could be also found at user's guide of FRAGSTATS™ [31].

Table 2. Landscape pattern metrics description [29, 31].

Index	Description	Unit	Range
PLAND	Percentage of landscape-equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by total landscape area (m^2), multiplied by 100 to convert to a percentage	percent	$0<PLAND\leq 100$
NP	Number of patches-equals the number of patches of the corresponding patch type (class).	none	$NP\geq 1$, no limit
LPI	Largest patch index-equals the area (m^2) of the largest patch of the corresponding patch type divided by total landscape area (m^2), multiplied by 100 to convert to a percentage	percent	$0<LPI\leq 100$

Index	Description	Unit	Range
AREA_MN	Mean patch area-Average size of patches	hectares	AREA_MN≥0, no limit
PD	Patch density equals the number of patches of the corresponding patch type divided by total landscape area (m), multiplied by 10,000 and 100 (to convert to 100 hectares).	number per 100 hectares	PD ≥0 no limit
PROX_MN	Mean proximity equals the sum of patch area (m^2) divided by the nearest edge-to-edge distance squared (m^2) between the patch and the focal patch of all patches of the corresponding patch type whose edges are within a specified distance(m) of the focal patch; Average proximity index for all patches in a class	meters	PROX_MN≥0, no limit

4. Results and discussion

4.1. Land Use/ Cover Changes

Before doing any other interpretations, thematic LULC maps (1979, 1996, 2003 and 2009) were assessed their accuracy through four measurable means of error matrix: overall accuracy, producer's accuracy, user's accuracy and Kappa coefficient. A total of 300 stratified random pixels was taken for each LULC map and then checked with reference data. According to the accuracy assessment results of classified maps, the overall accuracy for LANDSAT MSS 1979, LANDSAT ETM+ 2003 and ASTER 2009 was 92.15%, 80.33%, 84.44% and 89.00% respectively; the Kappa Coefficient of those maps reached at 0.9021, 0.6921, 0.7534 and 0.8005, respectively. The results showed that LULC map derived from ASTER has higher accuracy than the others. This could be explained by the better spatial, spectral and radiometric resolution of ASTER data.

The LULC maps of study area were generated for all four years (Figure 2) and classification area statistics were summarized in Table 3. The classified areas were measured by multiplying the number of pixel with spatial resolution of remote data (i.e. 30 meters), in which the pixel number was determined after applying post-classification analysis. And then changes were defined based on the difference of pixel number between two dates. Based on Table 3, forest and urban areas were the dominant LULC classes in spatial distribution pattern. Accordingly, forest area was counted for about 64.0%, 60.0%, 61.4% and 59.8% of the total area in 1979, 1996, 2003 and 2009 respectively; meanwhile urban area was occupied 6.5%, 8.0%, 12% and 17.9% of the total area in 1979, 1996, 2003 and 2009 respectively. The surface water body covers about 2.5%, 2.6%, 2.9% and 3.1% of the total region study in 1979, 1996, 2003 and 2009, respectively. The results also showed that from 1979 to 2009 LULC units under shrub, agriculture and barren decreased from 10.1% to 9.9%, 12.4% to 7.5% and 4.5% to 1.8%, respectively.

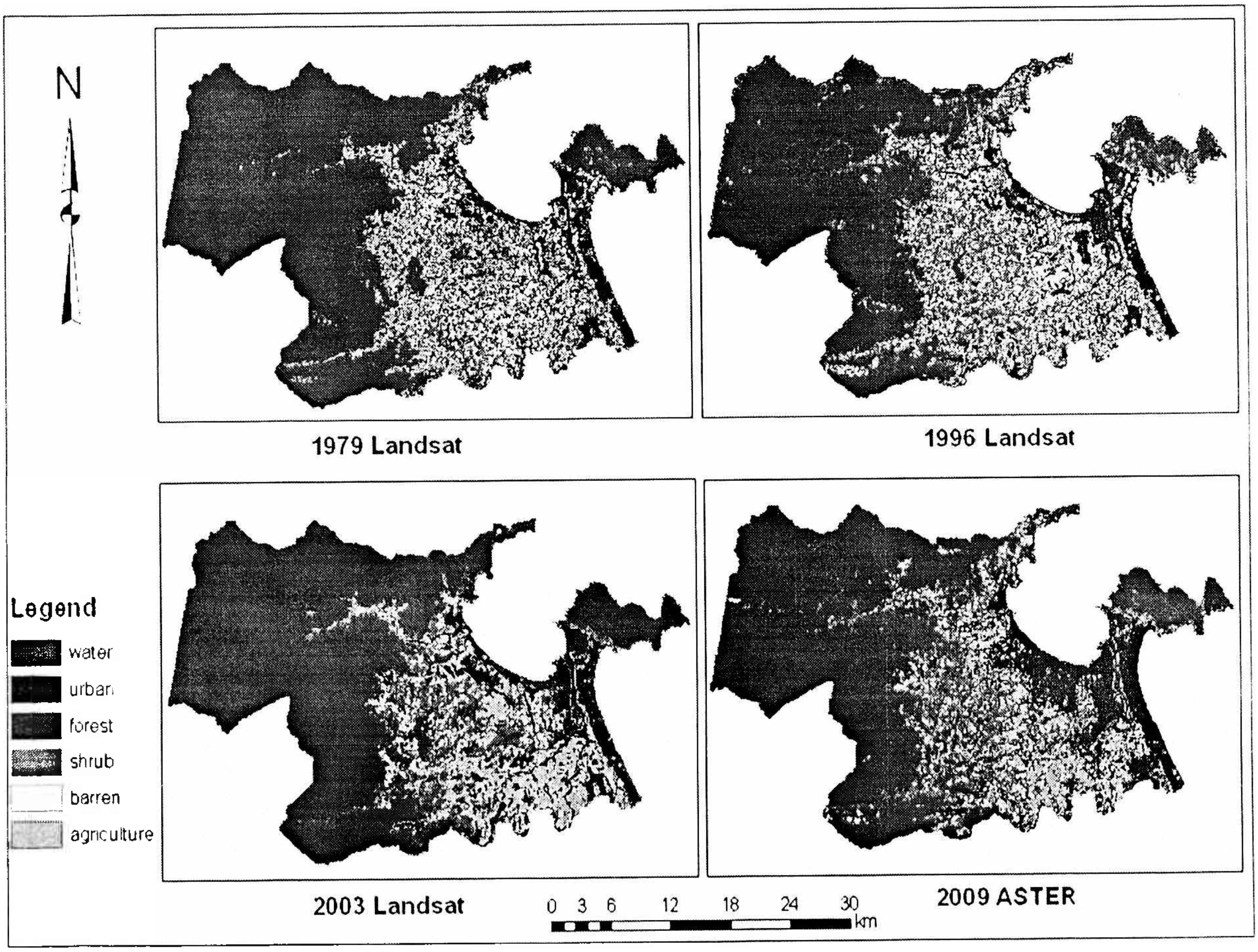

Figure 2. Land use/cover maps of Da Nang city area.

Table 3. Results of and use/cover classification for 1979, 1996, 2003 and 2009 images

LULC class	1979		1996		2003		2009	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Agriculture	12048.0	*12.4*	10416.7	*10.8*	8118.1	*8.4*	7294.7	*7.5*
Barren	4312.2	*4.5*	3680.9	*3.8*	2487.2	*2.6*	1708.9	*1.8*
Urban	6315.3	*6.5*	7791.5	*8.0*	11630.0	*12.0*	17298.5	*17.9*
Forest	61972.0	*64.0*	58126.7	*60.0*	59467.1	*61.4*	57936.2	*59.8*
Shrub	9785.2	*10.1*	14253.2	*14.7*	12335.9	*12.7*	9575.8	*9.9*
Water	2384.6	*2.5*	2548.3	*2.6*	2779.0	*2.9*	3003.6	*3.1*
Total	96817.2	*100*	96817.2	*100.0*	96817.2	*100*	96817.7	*100*

To provide a further comprehensive calculation in losing and gaining among the six LULC classes, the from-to change matrix of land use/cover in Da Nang city were created in three intervals, 1979-1996, 1996-2003, 2003-2009 and 1979-2009 (Table 4). In cross tabulation, unchanged pixels were located along the major diagonal of the matrix while conversion values of classes were arranged in descending order. As can be seen from the

Tables 4, there were small differences of area coverage of a particular class because of used different spatial resolutions for calculating LULC change from 2003 to 2009 (e.g., forest coverage in 2009 is 57936.2 hectares in Table 3 and 57935.79 hectares in Table 4c). It resulted because of using different spatial resolutions for calculating LULC change from 1979 to 2009. In fact, the 2009 ASTER image was re-sampled to a spatial resolution of 30 meters.

During the first period (1979-1996), results showed that forest, agriculture, and barren decreased strongly while urban area, shrub and water body increased, notably the raising of shrub area. Table 4(a) indicated that the expansion of shrub area was the most dramatic changes in the region whereas forest area decreased, which was the result of deforestation mainly caused by the increasing demand of timber products. Urban area grew up just 1476.2 hectares, representing 13.4% of net increase of urban area.

In 1990, the policy no timber exploitation of natural forests was promulgated by government, which could help to continue supplying materials for timbers and paper industry. Consequently, forestry productions were exploited from forest plantation [32]. Therefore, in the second period (1996-2003) forest cover extent had been slightly increased by reforestation programs with 1340.01 hectares. As can be seen from Table 4b, urban area promptly grew up 3838.5 hectares after separating from Quang Nam province and became a centrally governed city.

Table 4. Land use/ land cover transformation matrices of study area from 1979 to 2009

(Unit: hectares)

1996	1979						
	Agriculture	Barren	Urban	Forest	Shrub	Water	1996 Total
Agriculture	2910.96	1062.45	202.32	3865.05	2238.21	125.1	10416.69
Barren	657.81	481.5	573.84	986.49	832.23	142.56	3680.91
Urban	486.54	834.48	4280.67	1408.77	577.62	189	7791.48
Forest	2797.47	711.99	324.81	52197.03	1878.3	118.62	58126.77
Shrub	5016.06	984.69	655.65	3294.27	4084.56	201.69	14253.21
Water	179.19	237.06	97.02	220.41	174.24	1607.58	2548.26
1979 Total	12048.03	4312.17	6314.85	61972.02	9785.16	2384.55	
Change 1979-1996	-1631.34	-631.26	1476.63	-3845.25	4468.05	163.71	

(a) 1979-1996

2003	1996						
	Agriculture	Barren	Urban	Forest	Shrub	Water	2003 Total
Agriculture	2244.51	282.87	575.01	2165.76	2782.44	61.2	8118.09
Barren	325.98	532.08	414.09	360.45	803.7	44.91	2487.15
Urban	1127.07	985.5	5867.1	1090.71	2187.63	310.86	11629.98
Forest	4389.66	538.29	120.78	51701.94	2610.18	34.29	59466.78
Shrub	2235.96	1169.46	578.43	2572.11	5698.53	74.79	12335.94
Water	80.91	166.23	221.67	137.25	154.44	1989.45	2778.84
1996 Total	10416.69	3680.91	7791.48	58126.77	14253.21	2548.26	
Change 1996-2003	-2298.6	- 1193.76	3838.5	1340.01	-1917.27	230.58	

(b) 1996-2003

2009	2003						
	Agriculture	Barren	Urban	Forest	Shrub	Water	2009Total
Agriculture	1858.68	177.66	711	2880.63	1645.38	15.03	7294.68
Barren	86.76	121.86	148.14	860.58	464.04	24.93	1708.92
Urban	3188.7	1188.27	9025.29	739.35	2673.81	458.55	17298.54
Forest	1036.17	231.93	414.99	52503.66	3556.26	95.85	57935.79
Shrub	1833.21	656.01	808.56	2364.21	3851.46	51.3	9575.82
Water	108.27	105.48	460.89	46.71	138.33	2104.29	3003.57
2003 Total	8118.09	2487.15	11629.98	59466.78	12335.94	2778.84	
Change 2003-2009	-823.41	-778.23	5668.56	-1530.99	-2760.12	224.73	

(c) 2003-2009

2009	1979						
	Agriculture	Barren	Urban	Forest	Shrub	Water	2009 Total
Agriculture	1779.21	991.26	110.79	2394.99	1950.3	61.83	7294.68
Barren	353.07	78.3	91.8	933.93	240.48	8.73	1708.92
Urban	2975.04	1933.56	5096.7	3898.26	2789.37	581.04	17298.54
Forest	3787.38	227.52	221.58	51584.22	1928.79	89.37	57935.79
Shrub	2895.48	747.45	430.47	2834.19	2589.48	67.68	9575.82
Water	257.85	334.08	182.97	326.43	286.74	1575.9	3003.57
1979 Total	12048.03	4312.17	6314.85	61972.02	9785.16	2384.55	
Change 1979-2009	-4753.35	-2603.25	10983.69	-4036.23	-209.34	619.02	

(d) 1979-2009

Which was 35% of net increase of urban area. Whereas from 1996 to 2003, within just seven years, agriculture area reduced 2298.6 hectares, thus representing of 19.1%.

In the third period, from 2003 to 2009, forest area decreased once again (1.6% of total area in Da Nang City) due to the rapid urbanization. Agriculture area reduced 823.41 hectares within six years, which represented of 6.8%. Conversely, urban area incessantly increased and gained 5668.5 hectares, which contributed 51.6% to net increase of urban area, experienced a remarkable change of urban area with a rapid scale.

According to Table 4d, for 30 years, although forest extent fluctuated variously in different periods, this area decreased in general. Results showed that the forest area lost 10387.8 hectares of its 1979 area to other classes, in which 37.5% (3898.26 hectares) converted to urban, 27.3% (2834.19 hectares) to shrub and 23.1% (2394.99 hectares) to agriculture. From 1979 to 2009, agriculture area strongly decreased 4753.35 hectares (Table 5d), representing a net decrease of 39.5%, the change of agriculture area altered considerably in different periods of time. The loss of agriculture from 1979 to 2009 was mainly caused by the encroachment of urban and forestation. According to Table 5d, agriculture area lost 2975.04 hectares to urban area and 1392.39 hectares to forest, representing 60.3% and 29.3% of total decrease in agriculture land use, respectively. Based on statistic, 10983.69 hectares of urbanized area in this period was calculated, which was nearly twofold the coverage of urban area in 1979, thus representing an increase of 140% (10983.69 hectares). Analyzing the component of the conversion of growth in urban area, 33.5% was converted from forestry, 26.1% from agriculture and 21.5% from shrub. This also resulted because of the growth of economic after applying Doimoi policy. As can be seen in Figure 5. gross domestic product (GDP) of Da Nang city increased steadily from 1990 to 2009, with an annual growth of GDP of 10.3% (higher than nation's annual growth of GDP 7.2%). In addition, the increase of population in Da Nang city could be seen as another reason for urban expansion, in which population increase from 679.7 thousand in 1997 to 890.5 thousand in 2009, representing an increase of 31%. Based on Figure 3, the difference of spatial distribution of urban area could be clearly observed by the years. In 1979, the urban area dispersedly located along the costal line. By 2003, this area was expanded more concentrated along coastal zone and moved toward Sontra peninsula. From 2003 to 2009, the urban expansion changed the direction from costal toward in land.

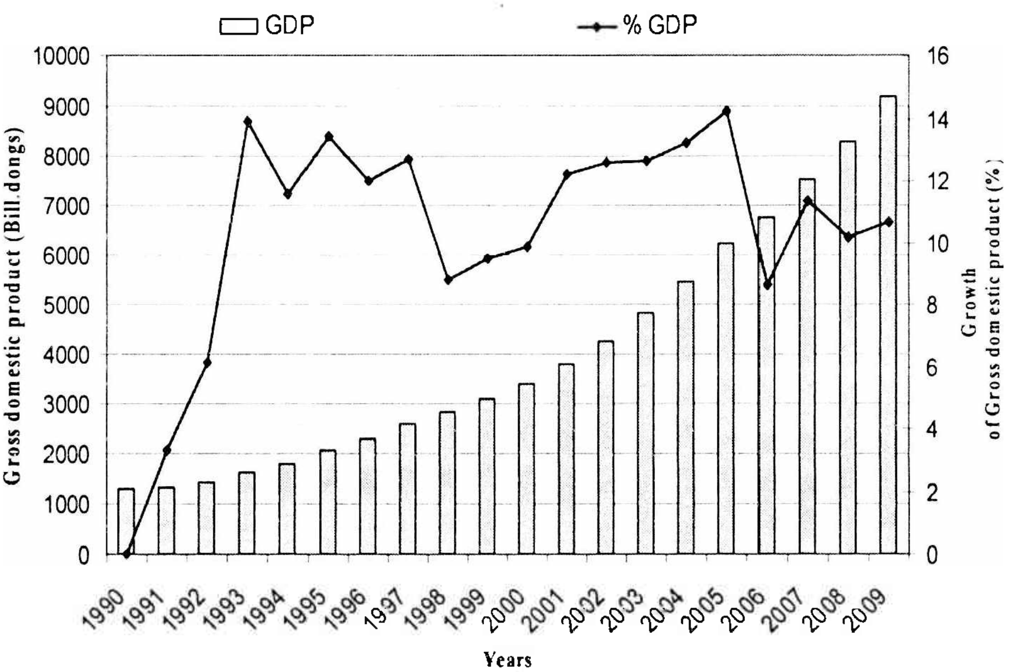

Figure 5. Gross domestic product and its growth in Da Nang city from 1990-2009.

4.2. Fragmentation Analyses

From LULC maps in 1979 and 2009, three most changing classes (agriculture, urban and forest) were chosen to compute spatial landscape matrices at class level by means of FRAGSTATS software (Table 5). In Da Nang city, forestry area presented as the dominance class of landscape. This could be identified by the largest patch index (LPI), a specific measure used for observing the dominance of a land cover type. Compared to agriculture and urban area, the largest patch index (LPI) of forest area is highest at rate of 29.4% and 29.5% in 1979 and 2009, respectively. The statistic of forestry showed that the percentage of landscape

(PLAND) index decreased from 36% to 33.2% and the number of patches (NP) decreased from 2,180 to 1,554 during the whole period from 1979 to 2009. Whereas the mean patch area index (AREA_MN) increased from 28.4 hectares to 38.0 hectares, which is supported by the increasing of the mean proximity index (PROX_MN) from 2670.1 metersto 17985.4 meters. In this case, those forested patches have been lower isolation and more contiguous in the domain of spatial distribution.

In regards to agriculture area during the period 1979-2009, the number of patches (NP) increased from 1,240 to 3,051, the mean patch area (AREA_MN) decreased from 10.0 hectares to 2.1 hectares and the mean proximity (PROX_MN) decreased strongly from 491.2 meters to 24.2 meters. These values revealed that agriculture class in 2009 were more isolated than it in 1979.

The spatial analysis of urban areas showed the significant increasing of the percentage of landscape index (PLAND) from 3.7% to 10.1%, the number of patches (NP) from 682 to 1771, the largest patch index (LPI) from 1.0% to 4.6%. These indexes evidenced that the expansion of urban areas also concentrated on existent urban. Finally, the growth of mean proximity (PROX_MN) from 67.1 meters to 1728.6 meters and of the patch density from 0.4 to 1.0 patches per 100 hectares indicated that urban class distributed in landscape configuration in 2009 more clear than in 1979.

Table 5. Metrics of landscape structure for selected indices at the class level, 1979 and 2009.

Class	PLAND (%)	NP (#)	LPI (%)	AREA_MN (ha)	PD (#/100ha)	PROX_MN (m)
1979						
Agriculture	7.0	1240	2.7	10.0	0.7	491.2
Urban	3.7	682	1.0	9.2	0.4	67.1
Forestry	36.0	2180	29.4	28.4	1.3	2670.1
2009						
Agriculture	3.6	3051	0.3	2.1	1.7	24.2
Urban	10.1	1771	4.6	10.2	1.0	1728.6
Forestry	33.2	1554	29.5	38.0	0.9	17985.4

5. Conclusions

By using the remote sensing and fractal analysisa, this paper describes the analysis of LULC and landscape change in the Da Nang city, Vietnam in the period 1979-2009. The analysis carried out found that a notable decrease of agriculture and forest because of conversion to urban land during the span of 30 years has taken place. For further understanding, key landscape indices were set for three main classes to perform the different changes in landscape structure in the surroundings of Da Nang city. The dynamic change of class indices revealed the break-up of this area into smaller patches. However, except agriculture, patches of forestry and urban tended to have a uniform landscape configuration. Accordingly, urban area showed the expansion in a concentrated way. The study explored the changes of land use/ land cover and spatial distribution of landscape in Da Nang city. This would help the decision maker and local authority having an overlook in this area, from which strategies in land use planning could be considered.

References

[1] OECD, *Competitive Cities in the Global Econom*. 2006, OECD, Paris.

[2] UN, *State of the World's Cities 2008/2009: Harmonious Cities*. 2008, United Nations Human Settlements Programme, Nairobi, Kenya

[3] OECD, *Cities and Climate Change*. 2010, OECD publishing, http://dx.doi.org/10.1787/9789264091375-en.

[4] OECD, *Regions at Glance 2009*. 2009, OECD, Paris.

[5] Angel, D.P., et al., *The drivers of greenhouse gas emissions: What do we learn from local case studies?* Local Environment: The International Journal of Justice and Sustainability, 1998. **3**(3): p. 263-277.

[6] Collier, U., *Local authorities and climate protection in the European union: Putting subsidiarity into practice?* Local Environment: The International Journal of Justice and Sustainability, 1997. **2**(1): p. 39-57.

[7] Collier, U. and R.E. Löfstedt, *Think globally, act locally? : Local climate change and energy policies in Sweden and the UK*. Global Environmental Change, 1997. **7**(1): p. 25-40.

[8] DeAngelo, B.J. and L.D.D. Harvey, The jurisdictional framework for municipal action to reduce greenhouse gas emissions: Case studies from Canada, the USA and Germany. Local Environment: The International *Journal of Justice and Sustainability*, 1998. **3**(2): p.111-136.

[9] Harvey, L.D.D., *Tackling urban Co2 emissions in Toronto*. Environment, 1993. **35**(7): p. 16-20.

[10] Lambright, W.H., S.A. Changnon, and L.D.D. Harvey, *Urban reactions to the global warning issue: agenda setting in Toronto and Chincago*. Climate Change, 1996. **34**: p. 463-478.

[11] McEvoy, D., D.C. Gibbs, and J.W.S. Longhurst, *The Prospects for Improved Energy Efficiency in the UK Residential Sector*. Journal of Environmental Planning and Management, 1999. **42**(3): p. 409-424.

[12] Wilbanks, T.J. and R.W. Kates, *Global change in local places:How scale matters*. Climate Change, 1999. **43**: p. 601-628.

[13] Dewan, A.M. and Y. Yamaguchi, *Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to promote sustainable urbanization*. Applied Geography, 2009. **29**(3): p. 390-401.

[14] Turner, B.L., *Local faces, global flows: The role of land use and land cover in global environmental change*. Land Degradation and Development, 1994. **5**(2): p. 71-78.

[15] Braimoh, A.K. and T. Onishi, *Geostatistical techniques for incorporating spatial correlation into land use change models*. International Journal of Applied Earth Observation and Geoinformation, 2007. **9**(4): p. 438.

[16] Myint, S.W. and L. Wang, *Multicriteria decision approach for land use land cover change using Markov chain analysis and a cellular automata approach*. Canadian of Remote Sensing, 2006. **32**(6): p. 390-404.

[17] Sun, Z., R. Ma, and Y. Wang, *Using LANDSAT data to determine land use changes in Datong basin, China*. Environmental Geology, 2009. **57**(8): p. 1825-1837.

[18] Hathout, S., *The use of GIS for monitoring and predicting urban growth in East and West St Paul, Winnipeg, Manitoba, Canada*. Journal of Environmental Management, 2002. **66**(3): p. 229-238.

[19] Ning, J., et al., *Land use change and ecological environment evolution in Taihu Lake Basin*, in *International Conference on Geoinformatics 18th, 2010* A.C. Yu Liu, Editor. 2010: Beijing, China.

[20] Kamusoko, C. and M. AniYa, *Land use/cover change and landscape fragmentation analysis in the Bindura district, Zimbabwe*. Land Degradation and Development, 2006. **18**: p. 221-233.

[21] Jensen, J.R., *Introductory digital image processing: a remote sensing perspective*. 3nd ed, ed. n. Edition. 2005, 3nd Edition, NJ: Prentice-Hall.

[22] Canty, M.J., *Image analysis, classification and change detection in remote sensing with algorithms for ENVI/IDL*. Second ed. 2010: Taylor and Francis.

[23] Nielsen, A. A. K. Conradsen, and J. Simpson, *Multivariate alteration dectection (MAD) and MAF postprocessing in multispectral, bitemporal image data: new approaches to change detection studies*. Remote Sensing of Environment, 1998. **64**: p. 1-19.

[24] Canty, M.J. and A.A. Nielsen, *Automatic radiometric normalization of multitemporal satellite imagery with the iteratively re-weighted MAD transformation*. Remote Sensing of Environment, 2008. **112**(3): p. 1025-1036.

[25] Anderson, J.R., et al., *A land use/cover classification system for use with remote sensor data.* US Geological Survey Professional 1976: p. 964: Sious Falls, SD.

[26] Mengistu D. A. and Salami A. T., *Application of remote sensing and GIS inland use/land cover mapping and change detection in a part of south western Nigeria.* African Journal of Environmental Science and Technology, 2007. **1**(5): p. 99-109.

[27] Reis, S., *Analyzing Land Use/Land Cover Changes Using Remote Sensing and GIS in Rize, North-East Turkey.* Sensors, 2008. **8**: p. 6188-6202.

[28] Diallo Y., Hu G., and Wen X., *Applications of Remote Sensing in Land Use/Land Cover Change Detection in Puer and Simao Counties, Yunnan Province.* Journal of American Science, 2009. **5**(4): p. 157-166.

[29] Keleş, S., et al., *Urbanization and forest cover change in regional directorate of Trabzon forestry from 1975 to 2000 using LANDSAT data.* Environmental Monitoring and Assessment, 2008. **140**(1): p. 1-14.

[30] Esbah, H., et al., *Analyzing landscape changes in the Bafa Lake Nature Park of Turkey using remote sensing and landscape structure metrics.* Environmental Monitoring and Assessment, 2009. **165**(1): p. 617-632.

[31] McGarigal, K., SA Cushman, MC Neel, and E Ene. *FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/fragstats.html.* 2002.

[32] Van Loi, N., *Use of GIS modelling in assessment of forestry land's potential in Thua Thien Hue province of central Vietnam*, in *GIS, Remote Sensing & Cartography.* 2008, Georg-August Goettingen University: Goettingen p. 220.