Historical land use and land cover changes, 1989-2011, in Phuket, Thailand

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Abstract

This study aimed to investigate historical land use and land cover changes, 1989-2011, in Phuket, Thailand. Based on data collected from the satellite images of Landsat 4 TM (1989) Landsat 7 ETM+ (2000) and THEOS (2011), using geographical information system and remote sensing. During this 23-year period, forests and agricultural lands, as expected, decreased with the extensive expansion of urban areas throughout Phuket, particularly on the coastal lines of the west coast of the Island. In the period of 12 years (1989-2000), forests decreased by 7.53 sq.km (4,700 rai), and thereafter, 11 years later from 2000 to 2011, forests dramatically decreased by 23.37 sq.km (14,600 rai). It indicates severe deforestation by a factor of 3.5. Meanwhile, mangrove forests decreased in the first period of study and then increased, pointing out effective mangrove-planting campaigns by local conservationists. Built-up areas have replaced all types of land use, including beaches, coconut trees, paddy fields, water bodies, para rubber, mangrove forests, and forests. There are the needs for more housing to accommodate an increasing of population from tourism activities. These findings are the basis for future land use planning policy in Phuket with a consideration of tourism development and environmental protection.

Key Word: Land use and land cover, Change Detection, Remote Sensing and Geographic Information System, Phuket

1. Introduction

One element of achieving land use planning is an understanding of the history of land use and land cover changes (LULCC) at a particular location. In the past, such information would be very difficult to obtain due to costly and time consuming. Today, an integration of remote sensing technology and geographic information system has made it possible to examine the historical LULCC effectively and precisely (Choptum, 2008; Jirakajonkul, 2009). A number of studies on the historical LULCC have reported causes and effects of the changes. Population growth and policy-based development are key factors regulating LULCC (Verburg et al. t., 1999), resulting in deforestation for urbanization and agricultural expansion and losses of biodiversity (Barbieri and Carr, 2004;). These information can assist policy and decision makers for future land use management concerning a balance between developments and natural conservation and sustainability (Wen and Shao, 2005).

Phuket is the world famous tourist destination, so called "Pearl of the Andaman" (Chaiyarat, 2006). It contributes about 30% of Thailand's tourism income. Historic land use change was accounted for by the transformation of mining industries to tourist business sectors. Developments of tourism activities have been initially driven by the Fourth National Economic and Social Development Plan during 1977-1981 and subsequent series of national plans. Since then, Phuket's economy is relied on the tourism growth.

This study aimed to study 23-year changes in LULCC of Phuket during 1989-2011, using GIS and RS. This would be useful as the basis for land use planning in the future with regard to the balance of the ecosystem and biodiversity.

2. Material and Methods

2.1 Study Area

The Phuket province is situated in southern region of Thailand, covering 543 sq.km (Fig. 1). Phuket province, located in the Andaman Sea. The island is mostly mountainous with a mountain range in the west of the island from the north to the south. The mountains of Phuket form the southern end of the Phuket mountain range. Climate is defined as the tropical monsoon.

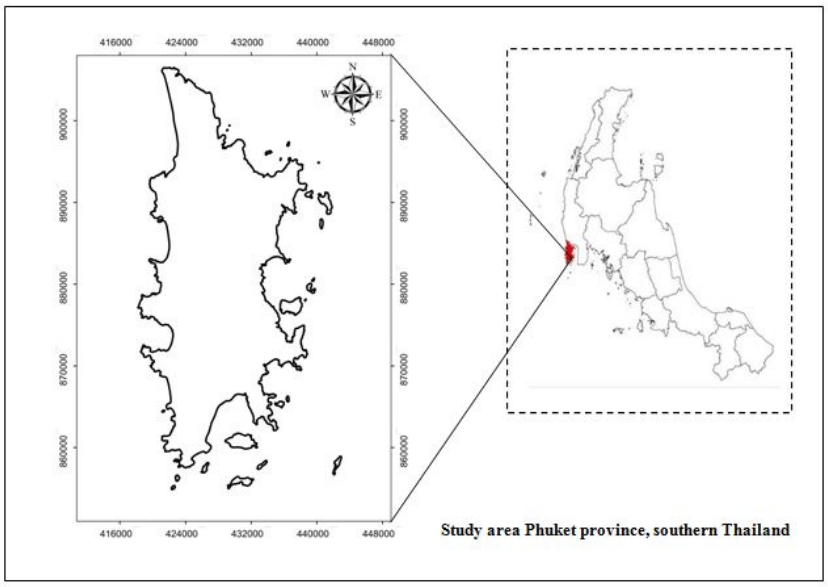

Figure 1: The study area of Phuket province, southern Thailand

2.2 Data Set

The satellite images used in the study were the Landsat-4 TM image in 1989 Landsat-7 ETM+ image in 2000 obtained from the USGS Earth Resources Observation and Science Center. The datasets with 30 m resolution were acquired on 15 February 1989 and 27 December 2000, respectively. The THEOS image in 2011 was obtained from the Geo-Informatics and Space Technology Development Agency of Thailand. The dataset with 15 m resolution was acquired on 28 February 2011.

2.3 Methods

Pre-image process**:** At this stage, the satellite images were adjusted both the discrepancy resulting from the influence of the atmosphere and image enhancement**.** The reference coordinates UTM WGS 84 zone 47N was used to the images. The resolution images satellite THEOS with 15 m and Landsat satellite images with 30 m. So, adjust resolution of the image use method image sharpening. Using the Panchromatic band of Landsat satellite images with 15-meter resolution satellite image adjustment. A resolution of 15 meters, which is equivalent to the THEOS satellite images to study in the land use.

Classification: At this stage, a preliminary study of land use classification using unsupervised classification and K-mean clustering was performed. Twelve land use types; mangrove forest, forest, para rubber, coconut trees, paddy field, water body, beach, built-up area, bare land and other, aquaculture, oil palm and pineapple were classified. The supervised classification with maximum likelihood method was then applied to classify different land use types.

Accuracy assessment: In this process, overall accuracy and Kappa coefficient will be tested (Choptum, 2008).

Change detection: Change detection was then employed to detect the differences between each pair of land use maps. The comparisons were divided into three periods: 1989-2000, 2000-2011, and 1989-2011, respectively.

3. Results

Overall accuracy of land use classification of Landsat 4 TM (1989), Landsat 7 ETM+ (2000), and THEOS (2011) satellite images was 89.14 %, 91.66 %, and 91.93 %, respectively, and the Kappa coefficient 0.85, 0.90 and 0.87. Divided into 9 categories for year 1989, land uses consisted of mangrove, forest, rubber, coconut trees, rice, water body, beach, built-up area, and bare land and other. Aquaculture lands were observed in 2000 whereas oil palm and pineapple were found in 2011. Historical LULCC of Phuket is shown in Table 1 and Figure 2. Change detections for the periods of 1989-2000, 2000-2011, and 1989-2011 are shown in Tables 2-4, respectively.

Table 1 Land use and land cover changes of Phuket between 1989 and 2011 in square kilometers.

Land use/Year	1989	2000	2011
Mangrove	24.01	14.98	42.45
Forest	106.95	99.42	76.05
Water body	20.82	14.50	14.16
Paddy field	10.34	52.18	23.54
Para rubber	223.32	171.02	181.84
Bare land	14.81	15.29	13.17
Beach	6.85	14.98	5.62
Coconut trees	49.46	45.05	32.96
Built-up area	42.03	55.13	101.14
Aquaculture		29.67	13.94
Oil palm			21.56
Pineapple			19.25
Cloud	41.47	40.57	
Shadow	2.49	2.65	

Forest

In the period of 1989-2000, forests decreased by 7.53 sq.km (4,700 rai). The forest was replaced by para rubber (25.45%). From 2000 to 2011, forests dramatically decreased by 23.37 sq.km (14,600 rai) and were converted to para rubber (36.10%) and oil palm (8.38%).

Mangrove forest

In the late 19th century, mangrove forests decreased by 9.03 sq.km and were transformed to aquaculture areas (16.73%), particularly shrimp farming. In early 20th century, the mangrove forests increased 27.47 sq.km pointing out effective mangrove-planting campaigns by local conservationists.

Para rubber

Para rubber agriculture decreased by 52.3 sq.km during the first period whereas it increased by 10.82 sq.km in the later period.

Water body

Water bodies declined to 6.32 sq km. during 1989-2000, and were changed to aquaculture areas (16.77 %), and there after decreased by 0.34 sq.km during 2000-2011.

Paddy field

For the first duration, paddy fields increased by 41.84 sq.km and then decreased by 28.64 sq.km in the second period.

Built-up area

From 1989-2000, built-up areas increased by 13.10 sq.km. These area replaced coconut trees (20.71%) and beach areas (22.22%). During 2000-2011, a number of built-up areas were evident with an area of 46.01 sq.km, for the replacement of beach areas (29.89%), bare lands (28.43%), paddy fields (26.02%), aquaculture (25.73%) and coconut trees (22.03%).

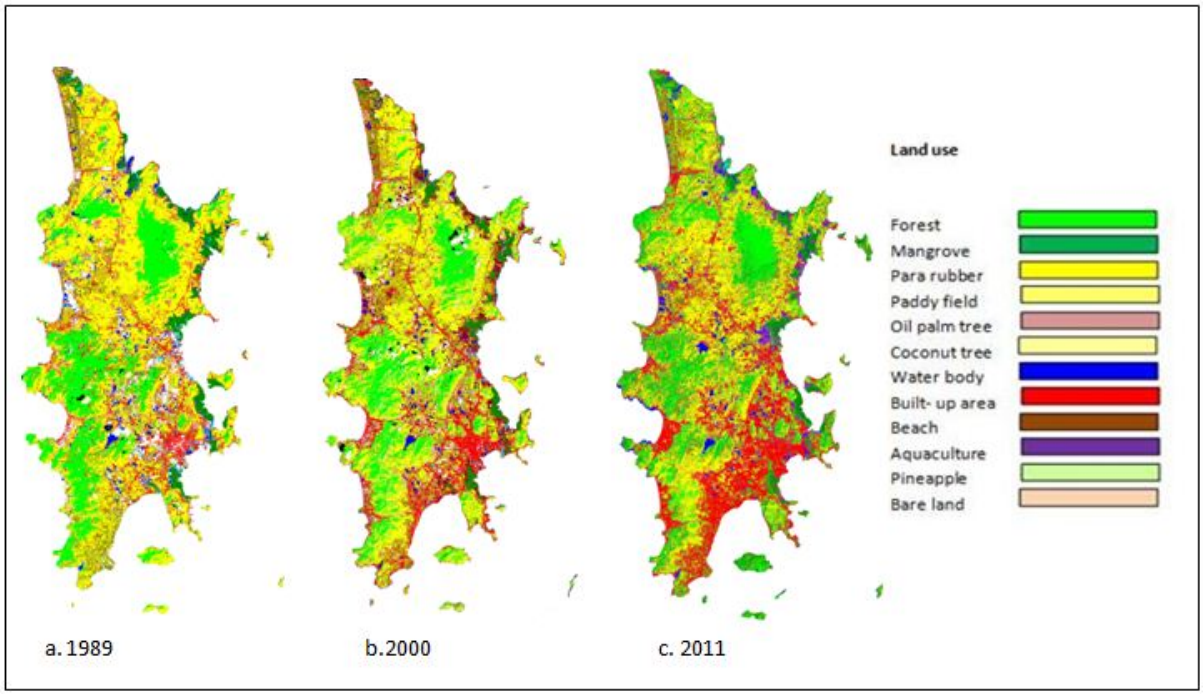

Figure 2: Maps of land use classifications of Phuket province; (a) Land use 1989 (b) Land use 2000 and (c) Land use 2011

Table 2: Comparison of land use changes between 1989 and 2000 in term of area percentage.

2000/1989	1	2	3	4	5	6	7	8	9
1: Mangrove forest	49.90	0.05	0.36	0.05	0.59	0.61	4.35	0.44	0.16
2: Forest	3.24	60.51	9.71	2.35	4.00	7.43	10.03	1.60	2.86
3: Para rubber	2.61	25.46	49.73	10.14	22.98	19.23	5.48	1.93	43.68
4: Paddy field	2.27	1.55	10.25	45.07	15.74	10.70	4.19	12.10	17.68
5: Coconut tree	8.52	3.96	8.83	8.12	15.84	9.88	5.65	5.86	9.07
6: Built-up area	8.60	1.11	6.75	8.36	20.71	30.52	5.31	22.22	8.30
7: Water body	0.34	0.02	0.11	0.20	0.24	0.29	27.01	1.68	0.08
8: Beach	4.02	0.20	1.32	3.69	2.76	3.71	3.34	10.94	1.78
9: Bare land	0.21	0.42	2.85	6.53	4.26	2.86	0.65	7.32	5.35
10: Aquaculture	16.73	0.91	2.74	6.39	4.87	6.17	16.77	16.38	2.64
Changes	50.10	39.49	50.27	54.93	84.16	69.48	72.99	89.07	94.65
Difference	- 37.60	- 7.04	- 23.42	404.77	- 8.92	31.16	- 30.84	118.76	3.24

Table 3: Comparison of land use changes between 2000 and 2011 in term of area percentage.

2011/2000	1	2	3	4	5	6	7	8	9	10
1: Mangrove forest	48.92	8.13	4.91	3.5	7.75	5.64	8.73	6.25	2.65	11.76
2: Forest	12.16	35.62	12.81	4.43	8.4	3.15	7.65	3.21	4.48	5.49
3: Para rubber	6.85	36.1	47.63	30.27	32.7	16.29	10.2	11.83	31.01	15.82
4: Paddy field	0.3	2.05	4.99	8.53	4.54	3.85	2.11	3	6.44	3.21
5: Coconut tree	4.38	2	4.14	8.37	8.9	9.68	5.21	7.43	8.34	8.93
6: Built-up area	9.57	3.32	9.43	26.02	22.03	42.56	14.41	29.89	28.43	25.73
7: Water body	5.15	0.37	0.67	2.01	1.48	2.06	19.59	4.21	2.53	6.71
8: Beach	0.34	0.28	0.83	1.87	1.2	0.91	0.97	1.1	1.65	1.4
9: Bare land	0.95	0.73	2.12	4.03	3.22	2.76	1.74	2.51	3.81	3.28
10: Aquaculture	4.35	0.35	0.88	2.95	2.39	4.28	5.4	4.34	3.28	7.46
11: Pineapple	0.37	2.11	5.21	5.3	3.47	1.89	1.03	1.38	4.74	1.65
12: Oil palm tree	0.19	8.38	5.41	1.63	1.85	0.65	0.41	0.48	1.77	0.74
Class Changes	51.08	64.39	52.37	91.47	91.1	57.44	80.41	98.9	96.19	92.54
Image Difference	183.56	-21.44	7.35	-54.85	-25.49	85.08	5.33	-62.18	-13.88	-52.38

4. Discussion

Our study of LULCC in Phuket for 23 years (1989-2011) disclosed that built-up areas have replaced all types of land use, including beaches (37.2%), coconut trees (27.35%), paddy fields (24.51%), water bodies (17%), para rubber (15.5%), mangrove forests (10.58%) and forests (1.95%). There are the needs for more housing to accommodate an increasing of population. Our result is similar to that occurred in Chiang Rai, Lamphun and Chaing Mai provinces (Sangchayosawat, 2005).

Phuket forest conservation areas have been replaced by para rubber agriculture and oil palm plantation. There was an evidence that during the first 12-year period of study 1989-2000 the forests decreased by about 7.53 sq.km (4,700 rai), and 11 years later (2000-2011) decreased by threefold and a half, accounting for 23.37 sq.km (14,600 rai). This issue is a global problem and is in need to be solved (Mon et al., 2012). Authorities involved should pay more attention on this issue. A serious action should been made to prevent further forest encroachment in the future.

Table 4: Comparison of land use changes between 1989 and 2011 in term of area percentage.

2011/1989	1	2	3	4	5	6	7	8	9
1:Mangrove forest	40.31	8.8	4.78	1.78	4.5	4.39	10.27	3.05	1.43
2:Forest	10.85	40.23	8.92	2.09	3.99	6.39	9.64	3.84	5.51
3:Para rubber	9.93	34.71	42.83	24.51	27.35	24.83	19.09	16.87	43.41
4:Paddy field	0.6	1.54	5.28	12.86	5.33	4.63	2.92	4.36	7.41
5:Coconut tree	4.89	1.64	5.34	9.66	9.33	8.66	6.48	9.95	6.35
6:Built-up area	10.58	1.95	15.15	28.71	31.8	33.04	17	37.2	15.92
7:Water body	5.61	0.15	1.25	1.7	1.58	1.98	11.58	5.15	1.57
8:Beach	0.56	0.12	1.02	2.56	1.31	1.18	0.93	1.42	1.62
9:Bare land	1.26	0.4	2.63	5.6	3.56	2.72	2.14	3.72	3.89
10:Aquaculture	5.42	0.14	1.74	2.95	2.6	4.07	4.73	6.33	2.2
11:Pineapple	0.59	1.61	5.08	6.02	3.52	2.39	1.88	2.18	7.21
12:Oil palm tree	0.43	8.56	4.14	0.91	1.15	2.58	1.53	0.72	2.78
Change	59.69	59.78	57.17	87.14	90.67	66.96	88.42	98.58	96.11
Difference	76.79	-26.74	-17.67	128.01	-32.65	140.57	-32.11	-17.9	-11.11

In addition, the development of the economy is another factor that affects the growth of the city. The Pearl River Delta region of China has a rapid rate of economic growth accelerated by the government policy, resulting in significant changes in land use. An increase of urban areas over 300% between 1988 and 1996 was marked with a decrease in agricultural areas (Seto et al., 2002; Weng, 2002). The growth of city is also associated with infrastructure availability. A paved road would have been followed by the settlement of community due to the convenience of commuters (Keratikasikon et al., 2007). After the construction of the Tinnasulanon Bridge and the construction deepwater port of Songkhla province, community residents have a new settlement along the road parallel to the Highway 408 (Boonnarong, 2009). In Phuket, urban expansion and development have been chiefly driven by tourism activities and policies at local, regional, and national levels.

5. Conclusions

Historical land use and land cover changes in Phuket, Thailand, have been largely regulated by tourism-economic developments in according to the national economic policies. A rapid growth of urban expansion and development with a number of tourist accommodations and residential housings under constructions is a result of the policy-driven development. Consequently, forest conservation areas dramatically decreased by a factor of 3.5 during the early 21st century, compared to that in the late 20th century. This raise a concern about developments without conservation planning or a failure in land use management. Therefore, we suggest that an increasing conservation effort should been made to protect natural resources in the region, and a strict land use policy and regulation should be carried out in practices.

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