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Detection of Land Use Change Using the R Program (A Case Study of Phuket Island, Thailand)

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Abstract: Urban growth is an important topic that developers around the world need to assess because of expansion of the city which directly affects adjacent areas. After land reform was initiated in 1987 by Remote Sensing data (RS), developers became aware of the study of land planning and land policy. Although, Geographic Information System (GIS) Software can be used in detecting land use change, there is the need to pay the license cost. Nowadays, geographers have been able develop GIS Programs such as Map Windows GIS and Quantum GIS for detecting land use change. However, some techniques are not available with the free software. The main purpose for investigating land use change was to show loss and gain in areas and also to show the basic statistics. This study examines the use of GIS in land use change mapping for Phuket Island from 1967 to 2009. Secondary data from the Thai Department of Land Development was appropriate for analyzing land use change. Researchers used the data from supervised classifications to classify the RS data. For the analysis of land use categories change, the digitization approach was used. The computation was based on the actual number of observations for land use data on Phuket by free software, the R Program. Three categories of land use change were investigated: forest, agriculture and urban; quantitative analysis changed using a bubble plot matrix. The study illustrated the increasing trend of urban growth in tourist areas which directly affect the forest area on Phuket Island. Land use changes from one category to another have been clearly represented by map format using a scale of 1:1000.

Key words: Land use, Phuket Island, urban, agricultural, forest, GIS freely available, software, R Program

INTRODUCTION

Land use change has been investigated in many countries by geographers. In the past, researchers argued about how to best monitor land use change whether to use the survey or remote sensing system (Hill, 1984). When the remote sensing data provided high accuracy, land use change was investigated (Yang and Qiao, 2010; Strand *et al*., 2002; Weng, 2002; Sadr and Rodier, 2012; Lammeren *et al*., 2009). After land reform was initiated in 1987, by RS, land use change was investigated by use of high technology. The majority of the researchers used the remote sensing data to investigate land use changes.

Several researchers studied land use changes and the causes that affected the quality of human life. For example, the changes to urban land use represent a particular land use intensification because the change affected the good life of the population especially in the increasing urban area. The disorder from globalization has used up a lot of resources especially the land. That has directly affected the natural resources such as the growth of urban area in Shenzhen which has disturbed the ecology system. In the northeast of China, interference of natural resources, especially in the forest area by deforestation has affected the biodiversity of the tourist industry. Researchers also need to know where to allocate the recourses to achieve the highest benefits and plan accordingly to fit the problem of the environment. The pattern of change from forest area to urban was also studied by Jim and Liu (2001). They investigated whether the association between land use and trees (forest) was related to the culture, history, biodiversity and pattern of change in Guangzhou City, China. Moreover, they found an important characteristic: the land use scale showed that the old districts conserved the forest area more than new districts. Hascic and Wu (2006) studied how forest land use change affected drinking water where water from catchment areas with a large portion of forests is of higher

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quality. Kurt (2013) studied the land use change of Black Sea coastal regions in Istanbul. Agricultural and forest areas have changed to urban areas and the particular urban area has increased to 122%. Recently, Muma studied the effects of the change from forest to agricultural area in Canada. The agricultural land use has resulted in an inversion of hydrological effects and a decrease in forest cover.

In Thailand, land use has changed rapidly since 1980. The Thai Department of Lands has been regularly surveying and recording land use in hundreds of small plots in every province since 1967. These data contain a lot of valuable information about Thai history and culture development that is not available elsewhere and tends to be forgotten and lost. Such information is also valuable to planners and developers. Ramesh (1989) focused on the land use in Chang Mai area by secondary classification data from aerial photographs. Nine groups of land use have been classified, the result showed that urban area has increased to other land use categories and maximum agriculture has been converted to urban land use over a 12 years period. In the West of Thailand, Raine (1994) studied land use change in Chanthaburi Province which is a coastal zone, especially the agricultural area changes in each category. It was estimated that deforestation decreased from 1975 to 1989.

Now, Thailand still owes its development to an agricultural base and some to the heavy industry. The important products such as rubber, rice, minerals and palm trees are the natural resources that helped power the growth of Thailand's economy including tourism, especially in the southern part. However, that has had a direct effect on land use.

Researchers investigated this on Phuket Island which is one of the provinces of Thailand that has grown faster than other regions. Since, the opening of tourist areas and many projects around Phuket City, Phuket has developed; the most active zone of economic development is the city of Phuket which is adjacent to forest area.

This study presents land use change of Phuket Island and especially focuses on the R Program. Land use was classified broadly as natural (forest and grassland), farm (agriculture and fish farming) and urban (village, city and other developed land including mines) based on GIS of Phuket Island. The majority of researchers used license software such as AreGIS, AreView, MapInfo, Intergraph, IDRISI, SAGA, GIS, etc. The essence of detecting land use change involves detecting the change and showing it on graphic or thematic map. Licensed software can detect land use change but it is costly. Nowadays, geographers have been able to develop GIS Programs such as MapWindows GIS and Quantum GIS but the limitation is that some techniques are not available for free. So, analysis was made possible by the R Program (R Development Core Term, 2012) which is free to use software. The program used the secondary data and transformed it to digital data (Grid-point) by digitization. The program can display the thematic map the same as licensed software which illustrated the loss and gain corresponding to statistical display. Researchers will show land use changes with a bubble plot matrix, it's easy to understand the changes in such a manner. Moreover, the result will provide qualitative statistics. Land use change can provide valuable resources for analyzing what happened in the past and for planning and forecasting for the future.

MATERIALS AND METHODS

The study used the remote sensing data as the basic data. The data in shape-file in analog format from remote sensing was based on a thematic map. In this study, the steps for the study of land use change will be shown in Fig. 1.

The area of study: Phuket Island is located between latitude 7°53'N and longitude 98°24'E. Neighboring provinces are Phang Nga and Krabi and since Phuket is an island, it has no land boundaries. It is situated off the west coast of Thailand near the Andaman Sea.

In 2009, land use categories in the study area covered forest, urban, agriculture farm, rubber and mine. The total area of Phuket Island is 576 km^2. In 1967, accounted forest area was 41.13% whereas urban area was 12.66% and agriculture area was 46.21%. Agriculture areas, especially rubber, play an important role in the economy of Phuket Island including mining for export products (Fig. 2).

Geometric correction (coordinate shift): Geometric correction is the process of digitally manipulating image data such that the image's projection precisely matches a specific projection surface or shape. Researchers need to project the thematic map to the same position as land use data from 1967 to 2009. The thematic data from the Landsat image were geo-referenced to a digital map using a bilinear transformation (Fig. 3).

Detection land use by digitalization: The analysis of land use changes, raster and polygonal shapes are the majority that geographers used to study. Although, a polygonal shape can provide thematic maps a display of patterns for a given year, the data is difficult to analyze because the polygons change. Digital (raster) can provide clear land use change and is more suitable to analyze change

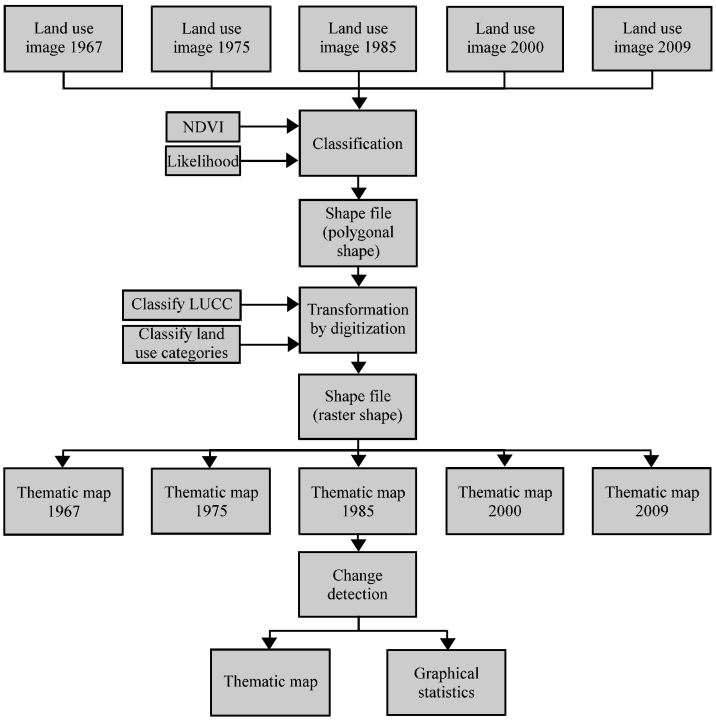


Fig. 1: Conceptual framework of research

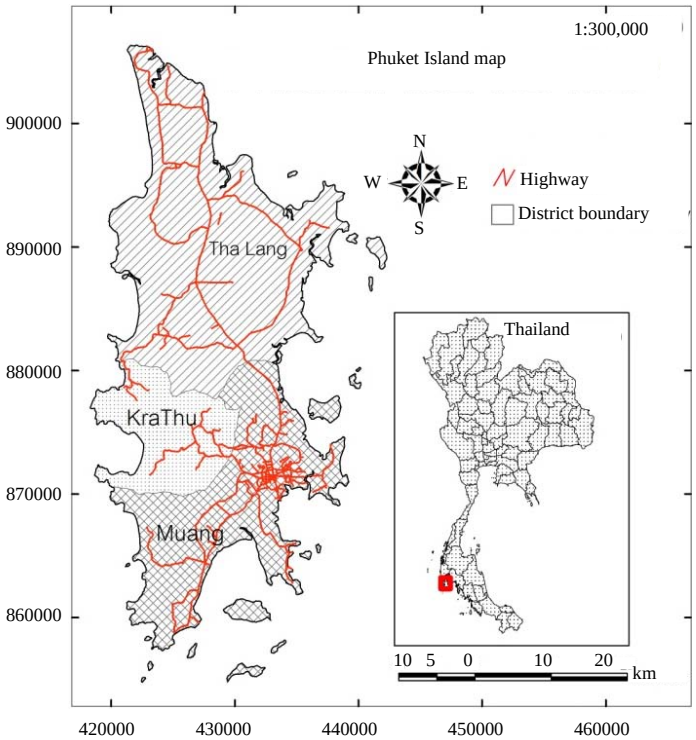


Fig. 2: Phuket Island map body

detection. Thinnukool extracted the classification data and reformed digital data by the digitalization concept.

The concept was an idea for the representation of a point on land use map. Researchers used the concept to

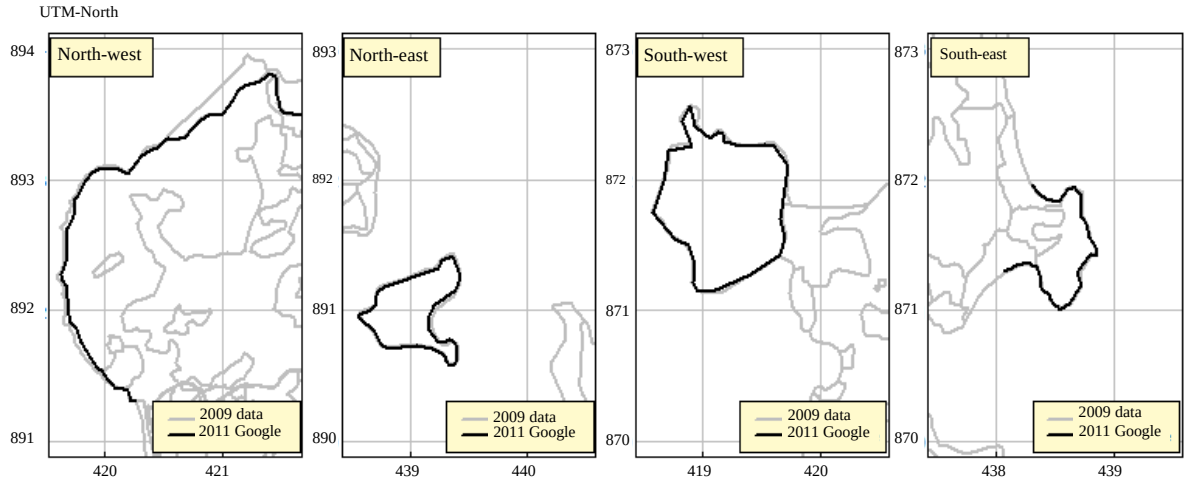


Fig. 3: Geometric correction shows the coordinates around Phuket Island which comparison land use data between 2009 and 2011 (Google Earth)

convert the polygonal data by grid-point data to digital data. The computation from digitization, for connecting from the polygonal coordinates to those based on the grid, involves assigning grid points to polygons.

The image transformation from polygonal data to digital data by digitization is a command used to convert meters to kilometers. P_{43} is land use data (polygonal form) including field plotID, x, y, DESEng and LUcode which are recorded in txt. file. This program takes the form:

Program command (Convert to km^3):

```
Require: Read txt. land use data (polygonal form)
1: p43data$x <-p43data$x/1000
2: p43data$y <-p43data$y/1000
3: p43xy$x <-p43xy$x/1000
4: p43xy$y <-p43xy$y/1000
```

Geometric correction: This proposed process is used for the p43 to fix the mistake of positioning in the thematic map.

Program command (Geometric correction):

```
Require: Read txt. land use data (polygonal form)  (**constant value 0.31 and 0.24)
1: p43xy$x <- p43xy$x-0.31
2: p43xy$y <- p43xy$y+0.24
3: p43data$x <- p43data$x-0.31
4: p43data$y <- p43data$y+0.24
```

Remove holes plot: This is proposed to remove some plots in the thematic map which provides only one type of occupation in one polygon.

Program command (Remove holes plot):

```
Require: Read txt. land use data (polygonal form)
1: p43data$hole <- 0*p43data$plotID
2: rxya <- NA+p43xy[1,]
3: (j in p43data$plotID) {rxyj <- subset(p43xy, p43xy$plotID == j)
4: rxyjNA <- subset(rxyj, is.na(rxyj$x))
5: (dim(rxyjNA)[1]>0) ptID1 <- min(rxyjNA$pointID)
6: rxyj <- subset(rxyj,rxyj$pointID<ptID1)
7: p43data$hole[p43data$plotID == j] <- 1
8: rxya <- rbind(rxya, rxyj)
9: p43xy <- rxya[-1,]
```

Assign gird point: The computational method for connecting from the polygonal coordinates to those based on grid point, this program takes the command line.

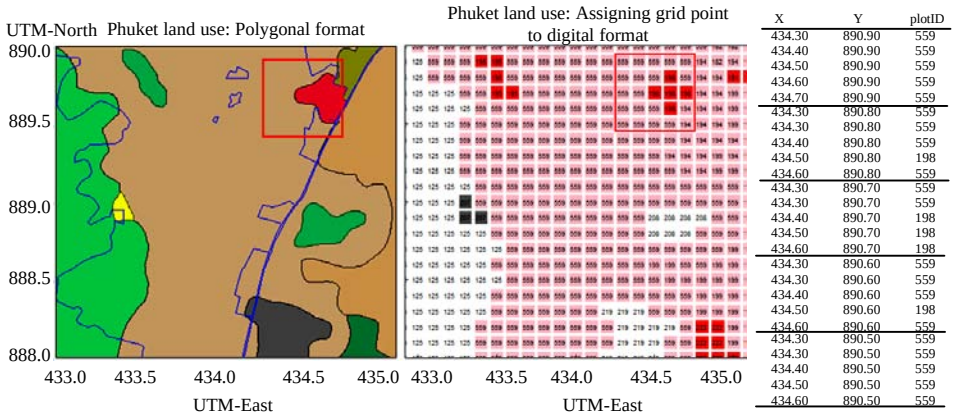
Program command (Assign gird point):

```
Require: Read txt. land use data (polygonal form)
1: plotIDs <- 0*pt.x
2: (j in c(1:571))
3: pol <- subset (p43xy, p43xy$plotID == j)
4: pol.x <- pol$x
5: pol.y <- pol$y
6: point.in.polygon (pt.x, pt.y, pol.x, pol.y) -> grid
7: plotIDs <- ifelse(grid == 1, j, plotIDs)
```

Apparently, following the command was used to compute the polygonal form to digital form, Fig. 4 illustrated the thematic map by grid point and showed the new data structure (Right panel).

The conversion of polygonal representation to digital data in Fig. 4, right panel was a data structure of an example of 5×5 grip-points that indicated in the rectangle of middle panel.

The research has contributed a digital thematic map (raster) of preliminary studies of land use change. In order to detect and assess land use change with digitization, Fig. 5 shows land use loss and gain in the sample area. An important thing in land use change is the Land Use Code/land Cover (LUCC) which is a description of land use categories.



X	Y	plotID
434.30	890.90	559
434.40	890.90	559
434.50	890.90	559
434.60	890.90	559
434.70	890.90	559
434.30	890.80	559
434.30	890.80	559
434.40	890.80	559
434.50	890.80	198
434.60	890.80	559
434.30	890.70	559
434.30	890.70	559
434.40	890.70	198
434.50	890.70	198
434.60	890.70	198
434.30	890.60	559
434.30	890.60	559
434.40	890.60	559
434.50	890.60	198
434.60	890.60	559
434.30	890.50	559
434.30	890.50	559
434.40	890.50	559
434.50	890.50	559
434.60	890.50	559

Fig. 4: The digitization involves converting the polygonal data in analog form (polygonal format) to digital form by grid-point

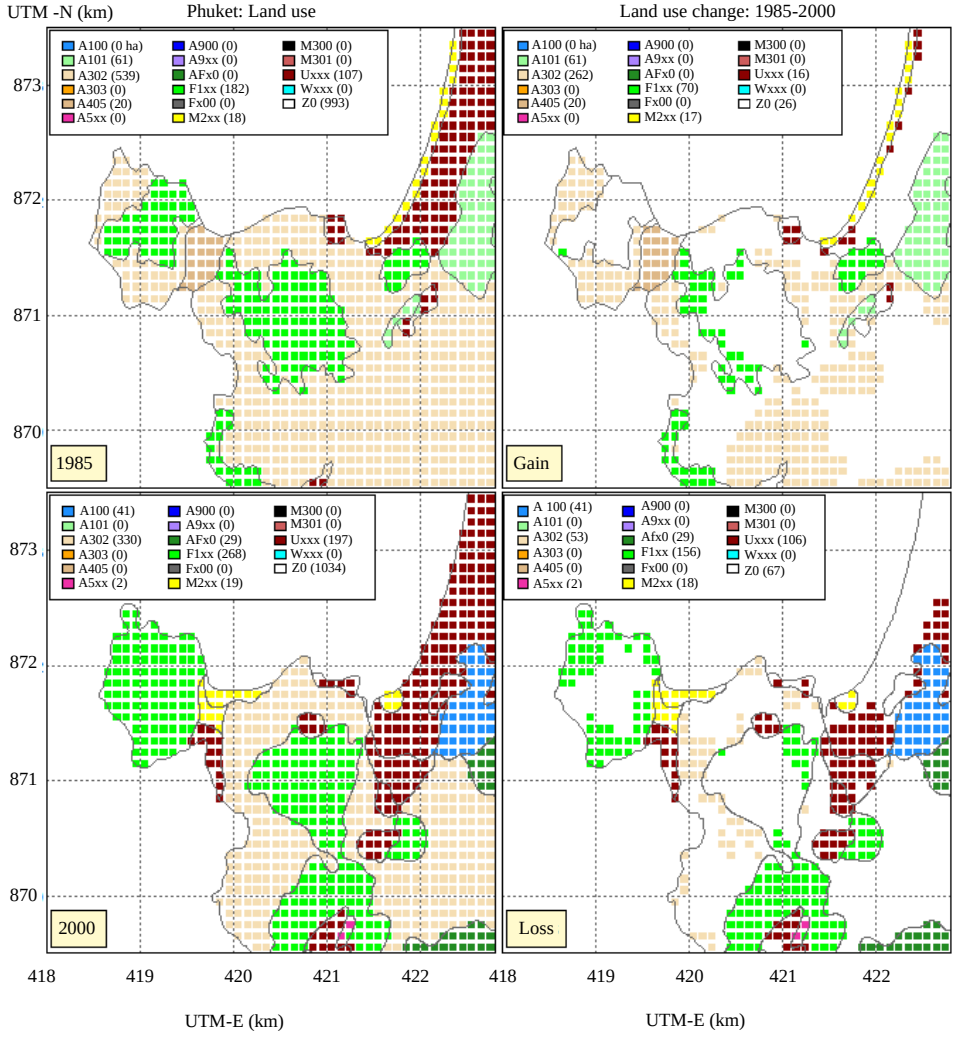


Fig. 5: The thematic map was useful to illustrate land loss and gain of land use change detection. Note that the first row of panels demonstrated land use occupancy of land use type. The top right panel showed land use gained from 1985 to 2000 and bottom right show the land use loss in 1985 (compare with 2000)

Table 1: Land use code and land-cover

LUCC	Descript	LUCC	Descript	LUCC	Descript
A100	Abandoned paddy-field	A502	Truck crop	M402	Beach
A101	Rice paddy	A503	Floricultural	U100	City, town, commercial
A205	Pineapple	A703	Poultry farm house	U200	Allocated land project
A205-A302	Pineapple/Para rubber	A704	Swine farm	U201	Lowland village
A219	Sweet potato	A900	Abandoned Aqua-cultural land	U201-A401	Lowland village/Mixed orchard
A301	Mixed perennial	A902	Fish farm	U300	Institutional
A302	Para rubber	A903	Shrimp farm	U401	Airport
A303	Oil palm	F101	Dense evergreen forest	U404	Harbor
A305	Teak	F106	Mangrove forest	U502	Factory
A401	Mixed orchard	F107	Beach forest	U601	Recreation area
A401-A405	Mixed orchard/Coconut	M102	Scrub, grass and scrub	U602	Golf course
A404	Rambutan	M200	Wetland	W201	Reservoir
A405	Coconut	M300	Abandoned mine	UN	unclassified
A408	Cashew	M304	Soil pit	XX-XX	Ratio 50/50%

Thinnukool managed LUCC in Thailand and explained the problem to define the LUCC change since land use in 1967 has been replaced by new LUCC. The modification of LUCC is supported by the new LUCC in sub-class, Table 1 demonstrated the LUCC of 1967 to 1985 which were re-organized in the same pattern as the LUCC in 2000.

An experimental test was been used for an example area in North West of Phuket. Figure 5 shows loss and gain is area from 1985 to 2000, A302 (539 ha in 1985) rubber gained remained at 262 ha and A101 remained at 61 ha and urban area gained 16 ha in 1985 to 2000. While in 2000, A302 had a loss from 1985 to 2000 which was 53 ha and urban areas had a loss which was 106 ha. However, the loss of the land was not a real loss because the area remained within the island and the land changed to other types.

RESULTS AND DISCUSSION

Land use for Phuket Island, since 1967 to 2009 is depicted by five panels of mapping which were constructed through digitization interpretation. Land use categories were classified by the type of land use. Therefore, land use types in Phuket Island are more than the three types which have been managed for detecting important areas, especially forest areas because they have direct effect on biodiversity, daily life and natural balance. Researchers classify thematic land use map in three categories such as natural (F) (mainly forest, grassland and beach), farm (A) (including agricultural and fish farming) and development (U) (including the city, villages, institutional and recreational land and mines).

The majority of land, in 1967 was found to be covered by forest and decreased in the successive years. The agricultural areas increased in the following years: 1975, 1985, 2000 and only in 2009 the agricultural area decreased because in 1985 to 2000 the majority of agricultural areas started changing to mining areas while some mining areas were also converted to abandoned mining areas. Other land use categories such as urban areas were small in number in every year. In order to see occupation of land use type of Phuket thematic map, it is useful to show the total land use during 5 periods. Urban areas decreased from 1967 to 1985 but had a slight increase in 2009. This was caused by the change from agricultural area to urban area by property investment. To see where land use changes occurred from one type to another type (Fig. 6).

Change in land use is effectively summarized in a cross-tabulation giving area (ha) or percentages of land use categories from one period to the next. These numbers can be displayed as a bubble plot matrix (note that darker colors show changes and lighter colors denote no change). Researchers used bubble plots to show variation of the land use change for each of three categories: natural (mainly forest, grassland and beach), farm (including agricultural and fish farming) and development (including the city, villages, institutional and recreational land and mines). Converting shape files comprising polygonal boundaries to more tractable gridded 1 ha sub-plots simplifies analysis, enabling straightforward creation of bubble plot matrices and corresponding thematic plots to highlight changes in land use patterns. For example, researchers found that in the park area, north of Phuket City changes from surveys in 1967, 1975, 1985, 2000 and 2009 had similar patterns except for the period when land devoted to urban use increased from 1975 to 1985 but substantially decreased in 1985 to 2000. This occurred because almost all the mining industry ceased and returned to natural and farm land.

In Fig. 7, it can be found that the area of forest land continued to reduce, especially the south of Phuket. Forest occupied a large area of land, especially in 1975 to 1985 but tends to decrease in time. Regarding the total

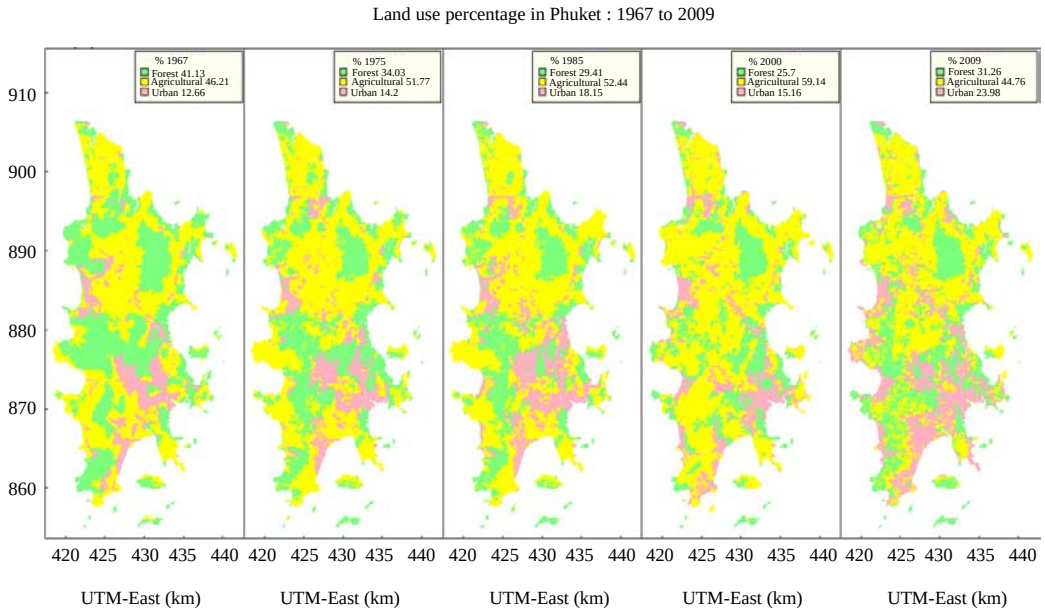


Fig. 6: Summary of occupation of land use type of Phuket from 1967 to 2009 in the three types of groups

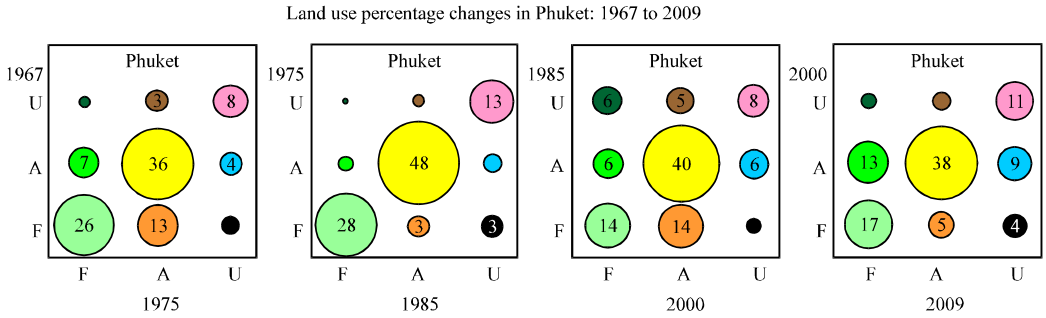


Fig. 7: Change in land use is effectively summarized in a cross tabulation giving area (ha) or percentages of land use categories from one period to the next. These numbers can be displayed as a bubble-plot matrix as above (Note that darker colors show changes and lighter colors denote no change)

urban areas from 1967 to 1975, the number of the urban areas did not change (28%) and increased in next period, from 1985 to 2000 (14%).

There was an increase again from 2000 to 2009 of 17%. The coverage of agricultural and fish farming (A) areas in four periods were large in number but the trend of change to urban decreased. In the first period, 1967 until 1975, the agricultural area changed to urban area (4%) then from 1975 to 1985 (2.5%) after that from 1985 to 2000 (6%) and lastly from 2000 to 2009 (9%).

Focusing on the number of forest areas from first period (1967 to 1975) to the fourth (2000 to 2009), to see where changes occurred, thematic maps were useful. Figure 8 showed how land use changed during those four periods. Panel one showed the land use change from 1967 to 1975 whereas panel 2-4 showed land use change in 1975 to 1985, 1985 to 2000 and 2000 to 2009, respectively.

The reduction in forest area was less in the period of years from 1985 to 2000, the forest area was mainly converted into agriculture area. In the 2000 to 2009 period, the land use type has the largest number of urban land during all 4 periods. The dominant area is Patong beach, an important area in Phuket Island which is 20 km^3 of the island. The area has been constructed into infrastructure, commercial area, hotels, etc. To see land use change, Fig. 9 and 10 will explain the type of land use change during the past 42 years.

Figure 10 shows the land use change over the 42 years study period; 20 km^3 around Patong beach. The

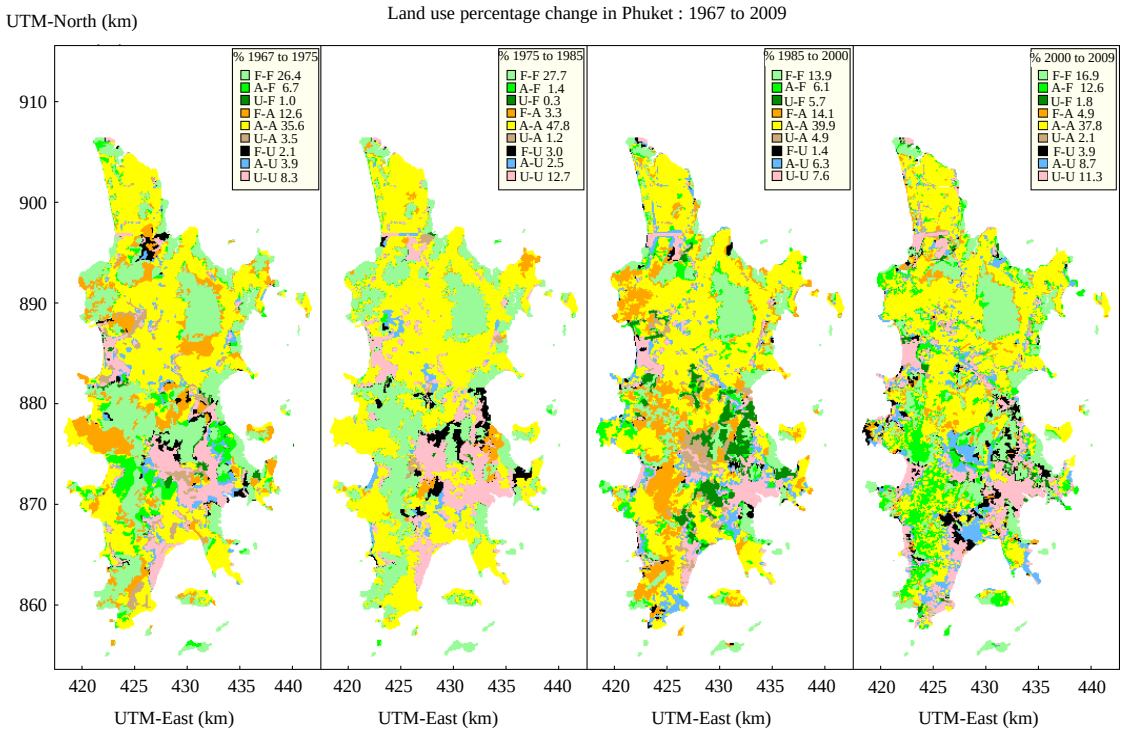


Fig. 8: To see where changes occur, thematic maps are useful. The map below uses the same colors as in the bubbleplot matrix. Note that the number of land-use changes in 4 panels corresponds with bubbleplot matrix

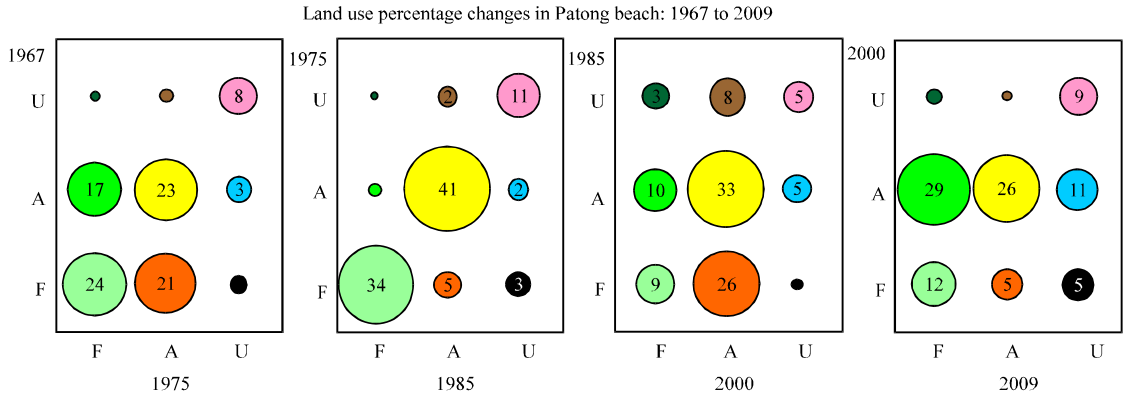


Fig. 9: Land use change surrounding Patong beach displayed as a bubble-plot matrix as follows in four periods which corresponds to Fig. 10

21.0% of this study area during 1967 to 1975 was changed from forest to agriculture with greater changes in 1985 to 2000 periods. An important point to consider is the change from urban reclaimed to forest from 1985 to 2000. Tin mining has been a major source of income for the island since 1980 when the mining activity ceased, the area changed from abundant mining to forest area. Along Patong beach, there was a change to urban and a small area change from forest to urban in the 2000 to 2009 period. The increasing demand from tourists has brought about substantial changes in the coastal areas of Phuket. According to the report of Wong (1998), upland resort development has resulted and will continue to have negative impacts on the coastal environment in Southeast Asia. Moreover, in 2009, the Tourism Authority of Thailand (TAT) reported that numbers of hotels in the southern part of Thailand are 25% more than the rest of the regions. The demand of construction of new hotels and resorts has grown and that is a direct cause which affects land use on Phuket in the tourist areas.

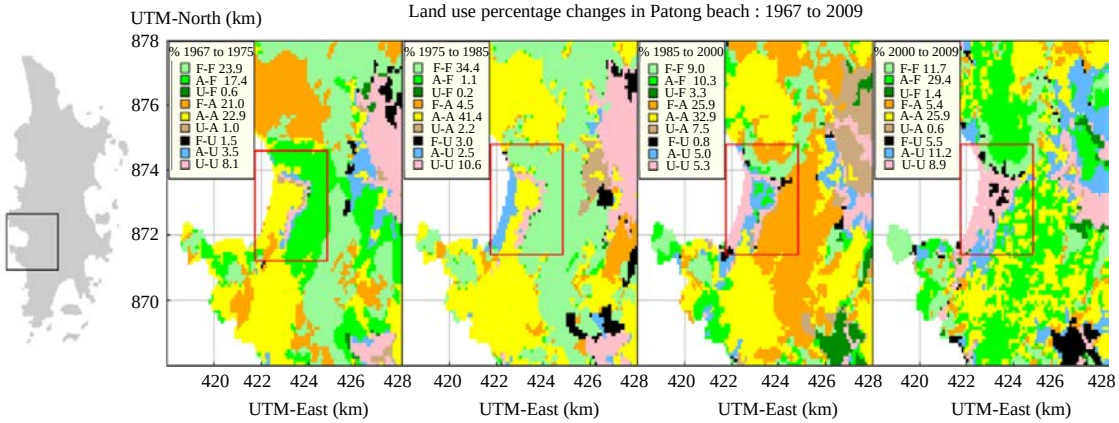


Fig. 10: The map on the extreme left of Phuket Island, with the rectangular box, indicates the thematic map for Patong beach. Thematic maps for land use change surrounding Patong beach are 20 km^3 in area

CONCLUSION

This study presents the results of land use changes for measuring GIS data with respect to digitization based on GIS data which was computed by freely available software with no license fees. This computation is based on the actual number of observations for digitizing to compute land use data of Phuket from 1967 to 2009. Researchers used bubble plots to show variation of the land use change for each of three categories corresponding with a thematic map. The results show the proportion for land use change from year to year whereas the bubble plots show the simple statistics where the developer, planner and geographer can understand the result.

Land use is quite important for Phuket Island due to the constantly increasing urban area. Agricultural areas and forests are quite important for a crowded city, however, human encroachment and commercial projects have impacted locally, mostly because of the construction in the tourist areas. Based on this study, it can be concluded that future study is needed to monitor land use change in the long term and high statistical analysis is needed to predict the land use change.

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REFERENCES

Hascic, I. and J.J. Wu, 2006. Land use and watershed health in the United States. Land Econ., 82: 214-239.

Hill, R.D., 1984. Land use change. Geoforum, 15: 457-461.

Jim, C.Y. and H.T. Liu, 2001. Patterns and dynamics of urban forests in relation to land use and development history in guangzhou city, China. Geog. J., 167: 358-375.

Kurt, S., 2013. Land use changes in Istanbul's Black Sea coastal regions between 1987 and 2007. J. Geog. Sci., 23: 271-279.

Lammeren, R.V., J. Houtkamp, C. Colijn, M. Hiferink and A. Bouwman, 2009. Google earth based visualization of land use scenario studies. Proceedings of the GSDI 11th Conference, Spatial Data Infrastructure Convergence: Building SDI Bridges to Address Global Challenges, June 15-19, 2009, Rotterdam, The Netherlands.

Raine, R.M., 1994. Current land use and changes in land use over time in the coastal zone of Chanthaburi Province, Thailand. Biol. Conserv., 67: 201-204.

R Development Core Team, 2012. R: A Language and Environment for Statistical Computing. The R Foundation for Statistical Computing, Vienna, Austria.

Ramesh, B., 1989. Urban land use change detection using sequential aerial photographs and spot image case study: Chiangmai, Thailand. J. Indian Soc. Remote Sens., 17: 101-108.

Sadr, K. and X. Rodier, 2012. Google Earth, GIS and stone-walled structures in southern Gauteng, South Africa. J. Archaeol. Sci., 39: 1034-1042.

Strand, G.H., W. Dramstad and G. Engan, 2002. The effect of field experience on the accuracy of identifying land cover types in aerial photographs. Int. J. Applied Earth Obs. Geoinf., 4: 137-146.

Weng, O., 2002. Land use change analysis in the zhujiang delta of China using satellite remote sensing, GIS and stochastic modeling. J. Environ. Manage., 64: 273-284.

Wong, P.P., 1998. Coastal tourism development in Southeast Asia: Relevance and lessons for coastal zone management. Ocean Coastal Manage., 38: 89-109.

Yang, G. and G. Qiao, 2010. Data processing method for current land use using GIS Technology. Proceedings of the 2nd International Workshop on Education Technology and Computer Science, March 6-7, 2010, Wuhan, China, pp: 511-514.