Towards the Conservation of Sungai Santi Catchment: Monitoring of Land Use and Vegetation Density of Mangrove Areas

(Ke arah pemuliharaan kawasan tadahan Sungai Santi: Pengawasan guna tanah dan kepadatan kawasan tumbuhan hutan paya bakau)

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ABSTRACT

This paper presents analyses of the land use and land cover change of the Sungai Santi catchment area. The purposes of this study were to delineate mangrove and other land use and land cover and to detect and develop land use masp in catchment aresa over the past 17 years. The NDVI method has been applied to observe the vegetation density of mangrove areas. Landsat TM and SPOT 5 imageries with a combination of ERDAS Imagine 8.4 and Arc View/Arc GIS software were used to detect spatial and temporal changes in land use and vegetation density between the years 1991 and 2007. Sungai Santi catchment experienced multiple changes of land use of varying degrees in 1991 and 2007. Results showed that agricultural land of oil palm and mixed agriculture, water bodies, and forest increased in this area, compared to mangroves and urban areas which decreased by 15.8 % (350 ha) and 23.4 % (223.3 ha) respectively. A land use change matrix indicated that the reduction of mangrove areas was due to an increase in water bodies and forest areas. NDVI method indicated six vegetation density values and the most dominant value was (0.4 – 0.5) which recorded 989.9 ha in 1991 and 981 ha in 2007. Even though the NDVI change matrix depicted a significant transition of 144.1 ha display from (0.4 - 0.5) to (0.5 - 0.6) in 2007, there low vegetation density occurred near the main river. The results showed that on-going land use change and deforestation of mangrove areas can be controlled through strict management of land conversion, and as for the mangrove forest, it has to be through total protection by law. This goal can be achieved by improving the Permanent Forest Reserve law and commitment to adopting a sustainable resource policy.

Keywords: Land use and land cover; NDVI; Catchment; Mangrove

ABSTRAK

Makalah ini menerangkan analisis perubahan guna tanah dan litupan tanah bagi tadahan Sungai Santi. Tujuan kajian ini dijalankan adalah untuk menilai serta menerangkan hutan paya bakau dan guna tanah yang lain,

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dan untuk membentuk peta guna tanah di kawasan tadahan dalam tempoh 17 tahun. Kaedah NDVI diaplikasikan untuk mengawasi kepadatan tumbuhan bagi kawasan hutan paya bakau.Imej satelit Landsat TM dan SPOT 5, dan kombinasi perisisan ERDAS imagine 8.4 dan Arcview/Arc GIS digunakan untuk mengesan perubahan masa dan ruang guna tanah dan kepadatan tumbuhan hutan paya bakau antara tahun 1991 dan 2007. Tadahan Sungai Santi mengalami pelbagai perubahan guna tanah pada kadar yang berlainan. Keputusan menunjukkan tanah pertanian yang merangkumi tanaman kelapa sawit dan tanaman campur, kawasan air, dan hutan mengalami pertambahan keluasan, berbanding penurunan keluasan direkodkan sejumlah 15.8 % (350 ha) bagi tanah hutan paya bakau dan 23.4 % (223.3 ha) bagi kawasan pembangunan. Matrik perubahan guna tanah menunjukkan kebanyakkan pengurangan kawasan hutan paya bakau adalah disebabkan oleh pertambahan keluasan kawasan air dan hutan. Kaedah NDVI mendapati enam kepadatan tumbuhan diperolehi dan nilai yang dominan dicatatkan oleh (0.4 – 0.5) dengan keluasan 989.9 ha pada tahun 1991 dan 981 ha pada tahun 2007. Walaupun matrik perubahan kepadatan tumbuhan yang signifikan direkodkan sejumlah 144.1 ha oleh peralihan dari (0.4 – 0.5) hingga ke (0.5 – 0.6), namun kehadiran beberapa kawasan kurang ditumbuhi oleh tumbuhan dikesan di sekitar kawasan sungai utama pada tahun 2007. Keputusan menunjukkan perubahan guna tanah yang berlaku dan nyah hutan paya bakau boleh dikawal dengan melalui pengurusan yang ketat terhadap perubahan status guna tanah dan perlindungan undang-undang bagi hutan rizab kekal. Matlamat ini boleh dicapai dengan menguatkan lagi perundangan berkaitan dengan rizab hutan kekal dan komitmen dalam menerapkan polisi kelastarian sumber.

Katakunci: Guna tanah, Litupan tanah, NDVI, Catchment, Mangrove

INTRODUCTION

Studies show that anthropogenic activities alter the Earth's surface and have a profound effect upon the natural environment thus resulting in observable patterns in land use and land cover (LUCC) over time (Turner & Mayer, 1994; Geist & Lambin, 2001). LUCC is the outcome of natural and sosio-economic factors and their utilization by man in time and space. Therefore, understanding LUCC and the factors that contribute to them are very important in order to predict global environmental changes due to the demands of an increasing population (Sharifah Mastura, 2006). The advanced concept of vegetation mapping has greatly increased research on LUCC thus providing an accurate evaluation of the health of the world's vegetation.

Over the past few years, data from Earth sensing satellites has become vital in mapping the Earth's features and infrastructures, managing natural resources and studying environmental change. Remote Sensing (RS) and Geographic Information Systems (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of Earth and an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity (Wilkie & Finn, 1996).

According to Bosch and Hewlett (1982), the reduction of forest cover will increase water yield and the practice of conserving vegetation density or forest cover will decrease water yield. Response to treatment of forest was highly variable and for the most part, unpredictable. Mangrove forests and the types of coastal ecosystems in the tropical zone play an important role not only for the biogeochemical cycle but also for human demand and economic activities. In terms of this study, the mangrove forest is one of the vegetations that cover Sungai Santi catchment. Therefore, attempts will be made in this study to map the status of land use and land cover of Sungai Santi catchment with an additional focus on vegetation density of the mangrove area. The data obtained can be useful for management practices and the sustainable development of catchment areas.

STUDY AREA

Sungai Santi is located near the Sungai Santi Forest Reserve, east Johor, Malaysia. The river is flows near Kampung Gambu, Kampung Punggai, Kampung Setajam, Bandar Penawar and Felda Adela. The Sungai Santi catchment area is fed by two main rivers; Sungai Santi and Sungai Sebina. Both rivers are typical of riverine mangrove ecosystems found in Peninsular Malaysia. Mangrove diversity remains high in both areas with a total 18 true mangrove and 13 mangrove-associated species recorded in Sungai Santi. The main agricultural activity in this area is oil palm cultivation, dominating almost the entire region. The rapid growth of oil palm plantations contributes to the multiple conversions of land use and land cover changes. Productive mangrove forests are mainly in the upper parts of the catchment area, of which a certain extent has already been converted to the agriculture of oil palm.

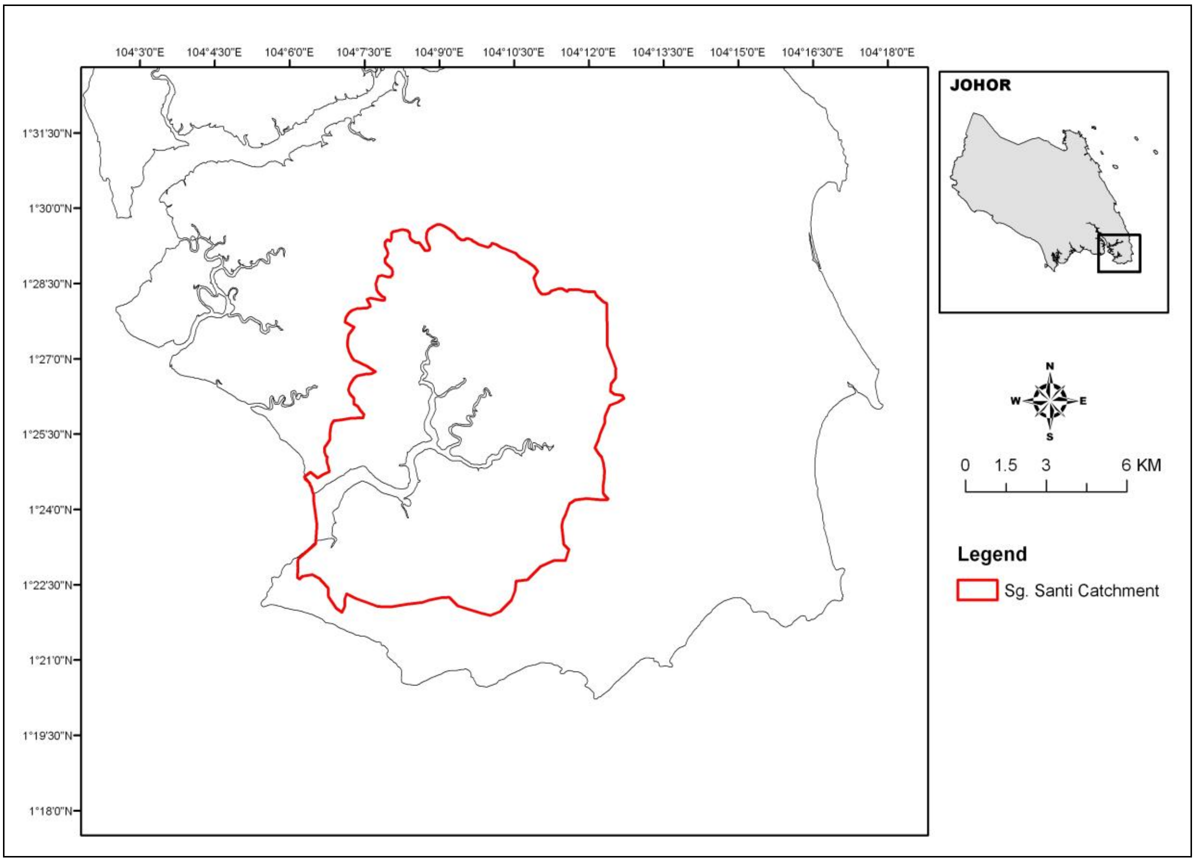

Figure 1: Sungai Santi catchment area in east Johor

METHODS

The land use mapping procedure used for the Sungai Santi catchment is grouped into six categories, each chosen to reflect the broad hydrological conditions of the water catchment area. These include, but are not limited to impervious surfaces, permeable and semi permeable surfaces and water bodies. Table 1 shows the details of the land use classification as well as a description for the catchment study area.

Landsat TM (1991) and SPOT 5 (2007) imageries were chosen for this study and processed using ERDAS Imagine 8.4 image processing software in conjuction with ArcView/Arc GIS. Figure 2 illustrates the process in accordance with the method outlined. Supervised classification was then carried out on the image using the Gaussin maximum likelihood method followed by post classification processing to smothen out certain pixels so that the determination of land use areas through statisticalmethods could be carried out as accurately as possible. Land use and land cover were plotted statistics for each land use and land cover category were generated. The spatial distributions of land use and land cover changes were also mapped.

The Normalised Density Vegetation Index (NDVI) method has been used to assess changes in the density of canopy trees and plants throughout the catchment and also focuses on mangrove forests between 1991 and 2007. The use of this method provides information on areas with a high density of vegetation cover to areas that have low plant density or are not covered by any plant. The NDVI ranges between - 1 and + 1. Apart from vegetation, other features show either negative or zero values. The formula used is as follows:

$$NDVI = (NIR - R) / (NIR + R)$$

There are seven identified plant densities; a dark green color represents a distance value of 0.3 to 0.6 (40% - 60%). A light green color is indicative of a distance value of 0.1 to 0.3 (10% - 30%) representing sparse vegetation. Areas with no vegetation and water bodies are represented by a white patch and the value recorded is zero or less than zero.

Table 1: Land use classification of Sungai Santi catchment

Land Use Classification	Description
Water Bodies	Rivers.
Mangroves	True mangrove and mangrove-associated species.
Forest	Low land forest and grassland.
Mixed Agriculture	Coconut and golf courses.
Palm Oil	Mature trees and seedlings.
Urban	Towns, housing, aquaculture pond, and recently cleared areas.

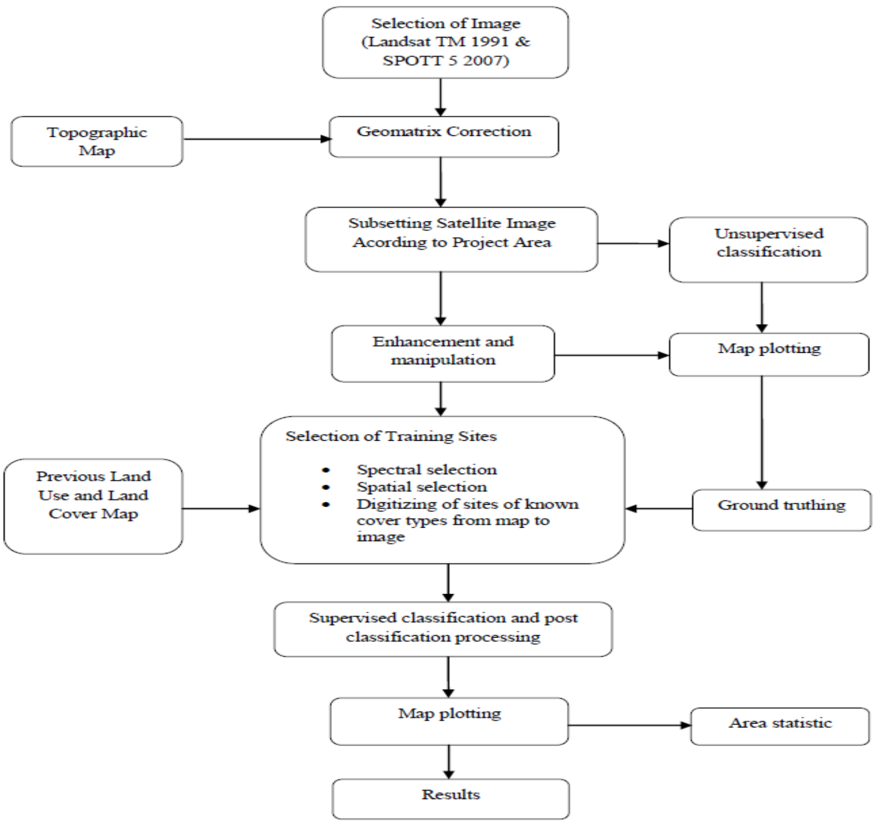

Figure 2: Outline of satellite imagery processing to determine land use classification

RESULT AND DISCUSSION

Land Use Changes of the Sungai Santi Catchment Area Figures 3 and 4 shows the land uses of the Sungai Santi catchment area in 1991 and 2007 using Landsat TM and SPOT 5 satelite imageries. By comparing the land use categories between the two periods, a land use change matrix model was developed as shown in table 2 and summarized in table 3.

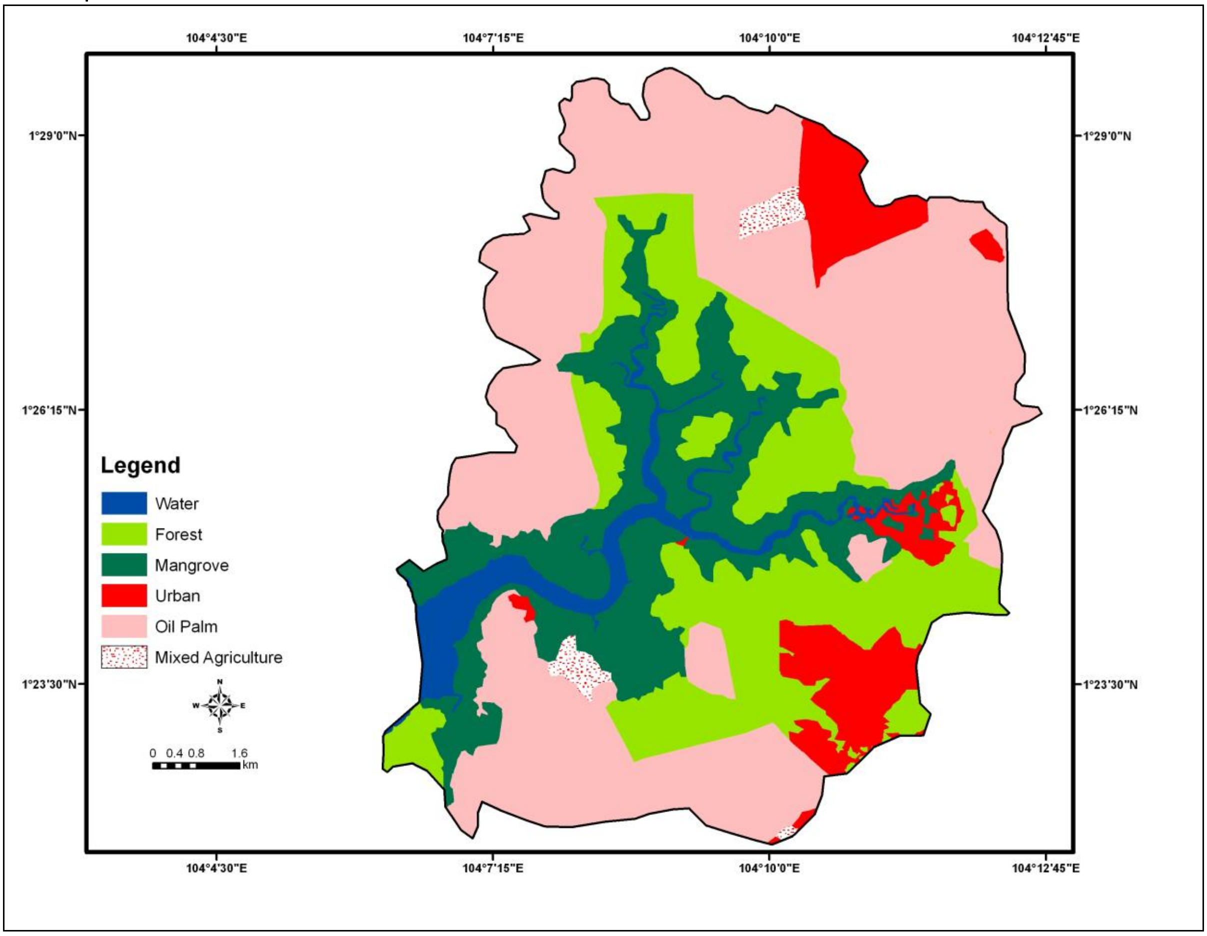

Figure 3: Classified image of land use of Sungai Santi catchment in 1991

The results showed that water bodies increased by 91.6 ha between 1991 and 2007, while a different trend is shown in mangrove areas with a reduction of 350 ha (Table 4). Other land use categories showed fluctuations at each annual interval. In terms of size, oil palm dominated the whole catchment area every year with percentages of between 45.8% and 46.2%, and gained in size by 42.3 ha in 2007. This shows that oil palm is a major contributor to the economic resources of local residents in the study area. Forest occupied 21.9 % of the sub-catchment in 1991 increased to 23.5 % in 2007. Another category of land use that experienced an incrase was mixed agriculture. It expanded from 137.2 ha to 382.3 ha due to the development of golf courses in 2001. Urban areas represented 8% of the sub-catchment in 1991. However, in 2007, the urban areas declined to a total of 259 ha. This is because bare areas that were cleared for development in 1991 were converted to grassland in 2007.

As mentioned earlier, water bodies and mangrove areas showed opposing trends between 1999 and 2007. This situation is evidenced by a 263 ha conversion of mangrove areas to forest areas (Table 3). This indicates that mangrove forests in the study area experienced a displacement or shift to lowland forests. According to Watson (1982), the existence "dry land mangrove" marks the beginning of the transition or displacement of mangroves to lowland forests. However, the role of mangrove plant displacement to lowland forest needs to be in the focus of further studies. Additional rivers in the study area receive tidal water, and this factor may contribute to the evolution of the mangrove forest. In addition, riverbank erosion is also believed to contribute to the reduction of mangrove stands. This scenario is evidenced by the increase of water bodies to 17.6 % between 1991 and 2007. Although mangrove trees dominate the entire river bank area and should be able to reduce erosion, movements generated by passenger boats that link Johor and Singapore have slightly increased erosion in these areas. This can be seen in the 88.6 ha change of mangrove forest to water bodies. Furthermore, a close examination of the 2007 map shows that some mangrove areas were also converted to fish ponds, further contributing to the overall change to urban areas with a total of 79.2 ha.

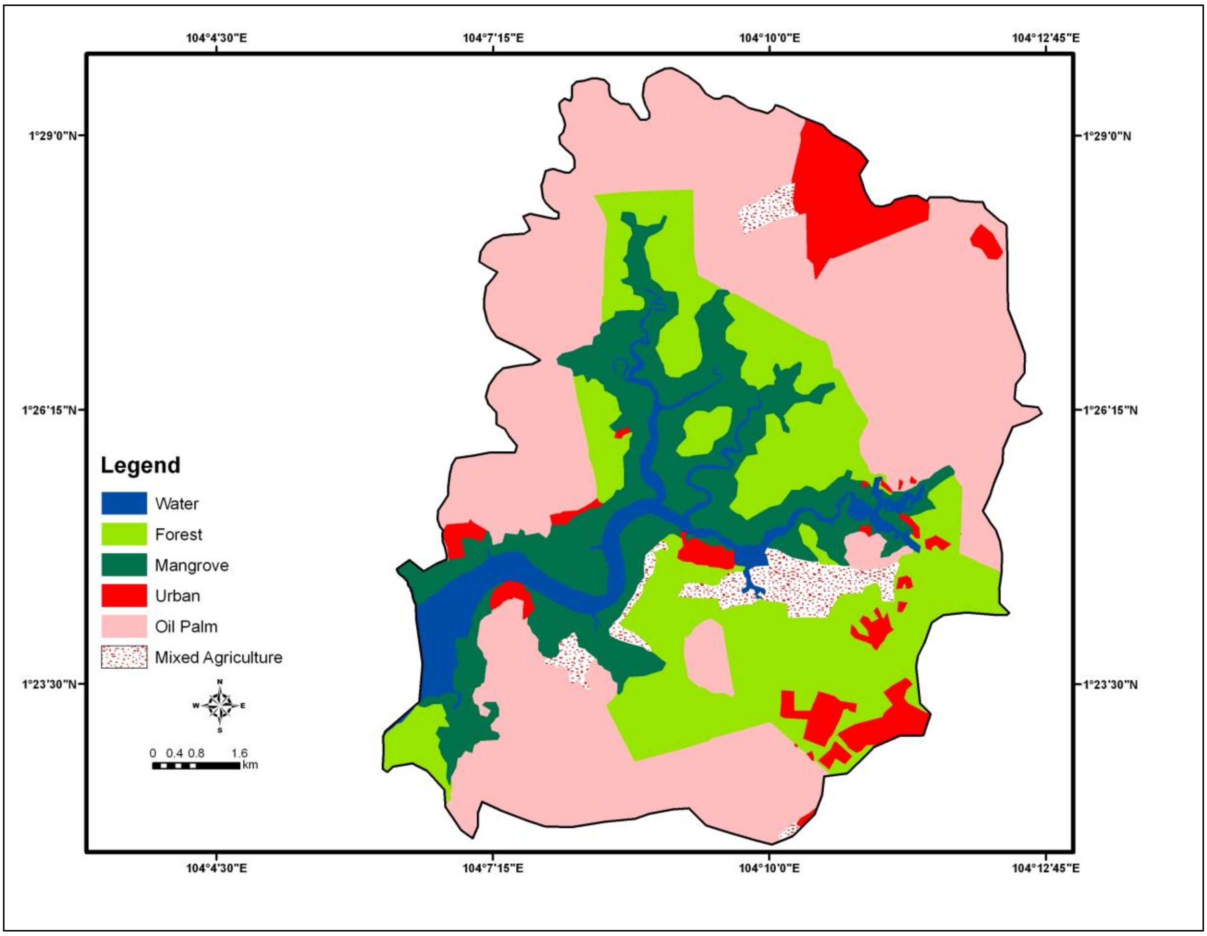

Figure 4: Classified image land use of Sungai Santi catchment in 2007

At the same time, a total of 44.7 ha of mangrove forest were converted to oil palm and 57.8 ha were recorded as a change to mixed agriculture. The changes in mangrove stands along the river bank occurred by natural processes including displacement to forest areas (116.5 ha), bank erosion (88.6 ha), as well as human activities (102.5 ha). Although the physical changes caused by human activities such as agriculture and logging are low compared to natural forces, it may have affected the heterogeneity of the mangrove habitat in general thereby affecting organism communities in the study areas.

Table 2: Land use change matrix of the Sungai Santi catchment area between 1991 and 2007

Landuse Categories (Ha)	Oil palm	Water Bodies	Mixed Agriculture	Urban	Mangrove	Forest	Total 1991
Oil Palm	5292.9	0.1	14.8	40.4	15.2	75.4	5438.8
Water Bodies	0.0	427.1	0.6	3.1	88.6	1.0	520.5
Mixed Agriculture	42.8	0.0	87.5	6.7	0.2	0.0	137.2
Urban	34.2	28.2	1.2	478.7	22.5	388.2	953.1
Mangrove	44.7	148.3	57.8	79.2	1629.1	263.0	2222.1
Forest	66.5	8.3	220.3	121.8	116.5	2063.5	2596.9
Total 2007	5481.2	612.1	382.2	729.9	1872.1	2791.2	11868.7

Table 3: Summary of land use changes for the Sungai Santi catchment area between 1991 and 2007

Land Use Categories	1991		2007		Different	% Different
	(Ha)	%	(Ha)	%	(Ha)	(Gain / Loss)
Oil Palm	5438.8	45.8	5481.2	46.2	42.3	0.8
Water Bodies	520.5	4.4	612.1	5.2	91.6	17.6
Mixed Agriculture	137.2	1.2	382.3	3.2	245.1	178.7
Urban	953.2	8.0	729.9	6.1	223.3	-23.4
Mangrove	2222.1	18.7	1872.1	15.8	350	-15.8
Forest	2596.9	21.9	2791.3	23.5	194.3	7.5

Sungai Santi Catchment Greenness Index

Figures 5 and 6 shows the NDVI value for Sungai Santi in 1991 and 2007. By comparing the NDVI value between the two periods, a change matrix model was developed as shown in Table 4 and is summarized in Table 5.

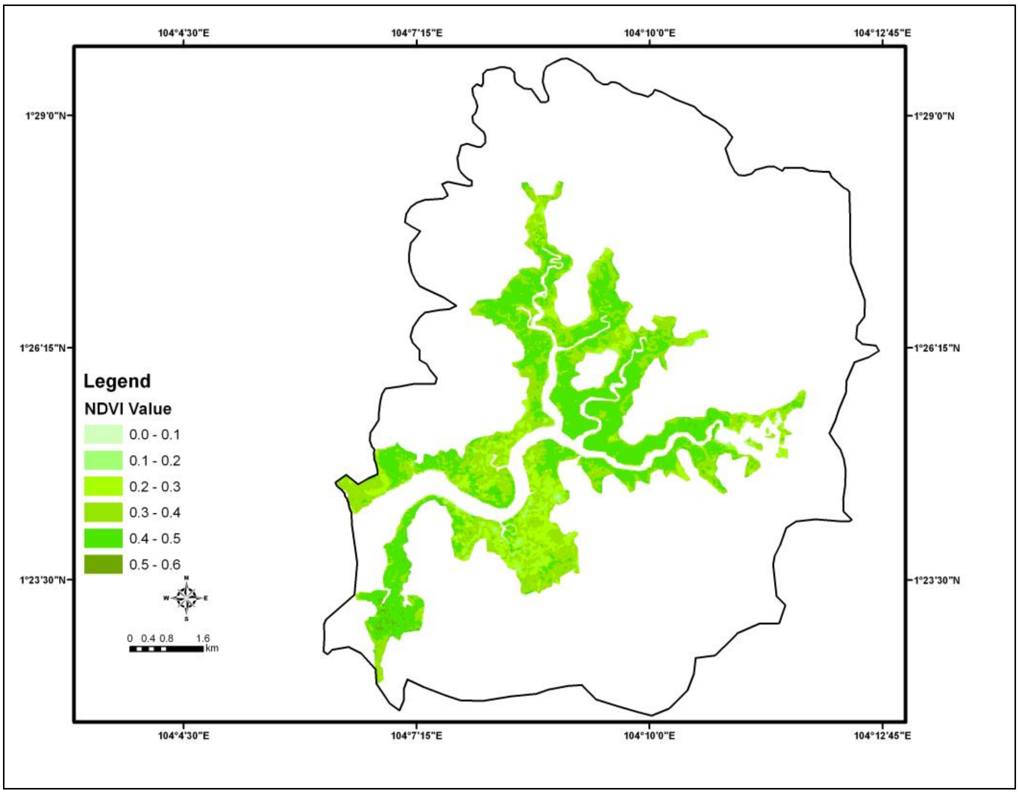

Figure 5: NDVI value composition of the Sungai Santi catchment area in 1991

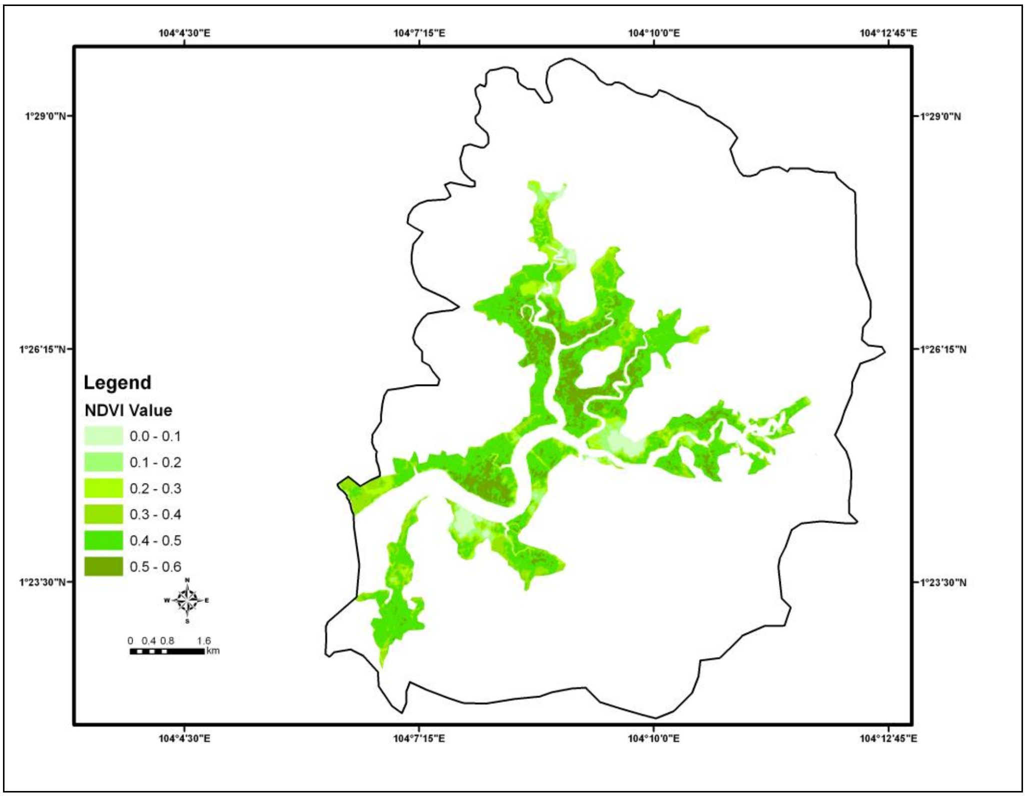

Figure 6: NDVI value composition of the Sungai Santi catchment area in 2007

There is a low NDVI value of (0.0 - 0.1) to (0.1 - 0.2), an increase in areas from 0.6 % to 4.3 % ha and 2.1 % to 4.8 % between 1991 and 2007(Table 6). Moderate vegetation density decreased by 180.3 ha in 2007, while high vegetation density decreased significantly by 509.5 ha from 831.3 ha in 1991. The mangrove areas dominated the map with an NDVI value (0.4 - 0.5) and an area of 989.9 ha (37.5 %) in 1991 but decreased to 981 ha (52.4 %) in 2007. Furthermore, a very high vegetation density was recorded at 448.4 ha in 2007 compared to 8.2 ha in 1991. These were areas further away from water bodies and were generally harder to reach and were therefore spared from rampant logging activities. During the intervening years, these areas had undergone continuous undisturbed growth. These were the areas that had registered better quality vegetation density as reflected by the indices in 2007.

Table 5 shows the NDVI value change matrix between 1991 and 2007. “No value” represents other features that were not vegetation areas. The total no value areas recorded was 243 ha in 1991, increasing to 593.1 ha in 2007. The NDVI value of (0.0 - 0.1) recorded the highest transition areas to an NDVI value of (0.4 - 0.5) with 2.9 ha converted between 1991 and 2007. Meanwhile only 0.3 ha were converted to NDVI values of (0.1 - 0.2). NDVI values of (0.5 - 0.6) showed high transitional areas to (0.4 - 0.5) with a total of 6 ha, and 0.1 ha to (0.1 - 0.2) and (0.2 - 0.3), respectively. The significant transition of 144.1 ha showed a change of (0.4 - 0.5) to (0.5 - 0.6) in 2007*,* but low vegetation densities were recorded near the main river. These are easily accessible areas and were subject to logging activities; in itself explaining the lower vegetation density of the area (Figure 5). This demonstrates that over the years, the areas that registered low NDVI values or vegetation densities had increased and at the same time more mangrove areas exhibited higher vegetation density. This is considered a very positive development and can be explained in many ways. Perhaps the most important explanation is that of better control over logging activities, particularly illegal logging.

Agricultural activities such as coconut and palm oil contribute to most of the changes in the mangroves of Sungai Santi with a total area of 102.5 ha. Land use in the study area showed a similar trend to the classes derived in a study conducted in Ghana by Tommy et al., (2002), where they found that mangrove forests in coastal areas decreased to 2605 ha, while agricultural land increased to 5087 ha. Agricultural areas were also recorded as the third largest land use area of the Ban Klang mangrove forest in Thailand (Sremongkontip et al., 2000). Although almost the entire agricultural area is located inland and away from water bodies, agrochemical pollution is possible, and thus has had negative effects on the entire water area reservoir (Hong & San, 1993). This was also demonstrated in a study conducted by Nur et al. (2001) in the mangrove forests in the Bay of Jakarta and North Java, Indonesia. It was found that pesticides or pesticide contamination occurs in the water bodies in these areas. In addition, the opening of an agricultural area requires large area of land and permanently changes the natural habitat. According to Nik Hassan et al., (2009), the existence of major areas of agricultural land contributes to soil degradation. These lead to the reduction of mangrove forests, and at the same time increases the acidity of the soil and exposes the areas to erosion and water runoff leading to increased sediment flow into nearby creeks. The accumulation of sediment increases turbidity and reduces the rate of photosynthesis of aquatic plants, thus affecting primary productivity and the food web in the area (Sharifah Mastura & Othman, 2009).

Table 4: NDVI values change matrix of the Sungai Santi catchment area between 1991 and 2007

NDVI value	No Value	0.0 -0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	Total 1991
No Value	0.0	21.3	22.6	32.8	53.3	100.8	12.3	243.1
0.0 - 0.1	7.2	0.9	0.3	0.6	1.8	2.9	0.4	14
0.1-0.2	18.5	1.6	2.0	3.2	8.0	12	2.1	47.5
0.2-0.3	125.9	8.2	10.8	24.0	54.6	85.2	22.6	331.3
0.3-0.4	257.3	18.8	23.5	39.8	124.5	301.0	66.4	831.3
0.4-0.5	182.9	29.4	30.5	50.5	79.3	473.1	144.1	989.9
0.5-0.6	1.2	0.0	0.1	0.1	0.2	6.0	0.5	8.2
Total 2007	593.1	80.1	89.8	151	321.8	981	248.4	2465.2

Table 5: Summary of NDVI values for mangrove areas for the Sungai Santi catchment area in 1991 and 2007

NDVI Value	Vegetation Density	1991 (Ha)	%	2007 (Ha)	%	Different (Ha)	% Different (Gain / loss)
0.0 - 0.1	Very Poor	14	0.6	80.1	4.3	66.2	474.1
0.1 -0.2	Poor	47.5	2.1	89.8	4.8	42.3	89.1
0.2 - 0.3	Moderate	331.3	14.9	151	8.1	180.3	-54.4
0.3 -0.4	High	831.3	37.4	321.8	17.2	509.5	-61.3
0.4 - 0.5	Moderate high	989.9	44.5	981	52.4	8.9	-0.9
0.5 - 0.6	Very high	8.2	0.4	248.4	13.3	240.2	240.23

A total of 79.8 ha of development areas existed in the study area between 1991 and 2007. Sebana Cove Resort can be seen in the 2001 map at the top of the inner estuary. Apart from the existence of this resort, it can be seen that there are few local residents' houses along the river bank. Thus, human settlement is not a major contributor to land use changes in the mangroves of Sungai Santi. This is contrary to a study done by Sremongkontip et al., (2000) that recorded 10.32 ha of human settlement between 1984 and 1995. Fish ponds constructed within the study area are far from the main water system, but their existence would indirectly lead to the release of dissolved nutrients and sediments into mangrove forests through connecting shallow creeks. Voravit and Piamsak (2003) explain that the main degradation of mangrove forests in the Gulf of Thailand was caused by the construction of fish and shrimp ponds.

Furthermore, the construction of fish ponds drives illegal logging activities and the exploitation of more forest areas to meet this demand. Hong (1995) found that nearly 100,000 ha of mangrove forest destroy by shrimp farming between 1995 to 2001 in Ca Mau province in Vietnam. He also explained that poor environmental conditions, techniques and financial resources caused shrimp farms to fail and some ponds were only used for a short period. After a few years, soil fertility began to decline leading farmers to build new ponds. The destruction of mangrove forests is caused by the desire for immediate economic benefit rather than longer term but sustainable exploitation. Even though small scale destruction of mangrove areas caused by fish farming was detected in this study, the scenario in Hong's study has not yet taken palce in the Sungai Santi mangrove forest, or in any other mangrove forest in Peninsular Malaysia.

A total of 263 ha of forest land cover was recorded in the study area; the possible outcome of mangrove succession to lowland forest. Sremongkontip et al., (2000), found that 14.5 ha of lowland forests were the result of the succession of mangroves in Ban Klang. In addition, it is believed that the existence of lowland forest areas was the result of the cultivation of mangrove stands for agricultural activities, but that the planned development for that area failed to materialise. Water bodies also increased between 1991 and 2007, probably as a result of riverbank erosion in the study area. This is evidenced by human activities and settlements along the river, contributing to other natural processes such as strong currents and soil sediment movement (Nik Hassan et al., 2009). Akosornkoae and Paphavasit (1996) found that rising sea levels in Thailand contribute to the destruction of mangrove forests. In addition, strong water currents can increase river banks degradation (Ekhwan & Haryati, 2007; Nik Hassan et al., 2009). River systems in the study area happen to be on the main route of boats and passenger ferries, therefore resulting in strong water currents that can accelerate the process of river banks erosion.

CONCLUSION

The purpose of this work was to delineate land use, land cover classes and vegetation density of mangrove areas with the passage of time in the Sungai Santi catchment area for long term monitoring and conservation. Satellite remote sensing has successfully been utilized to detect land use change dynamics in the 17-year period. Landsat TM and SPOT 5 remotely sensed images were used. Land use change detection was carried out with the Gaussin maximum likelihood supervised classification method combined with visual interpretation. The results showed that oil palm, mixed agriculture, water bodies, and forest increased in the area, compared to mangrove forests and urban areas which decreased by 15.8 % (350 ha) and 23.4 % (223.3 ha) respectively. The conversion of mangrove areas to forest was about 116.5 ha between 1991 and 2007, while 88.6 ha of the mangrove area were converted to water bodies. The NDVI method recorded a high density value of (0.4 – 0.5) with a minimal loss of density at 0.9 % between 1991 and 2007. Even though the NDVI value of (0.5 – 0.6) recorded a high density area with a total of 248.4 ha in 2007, but there were low vegetation densities occurring near the main river system. It showed that several areas have a high density of vegetation, while logging still occurrs in other parts of the mangrove area. The bigger challenge now is to maintain and further propagate the ecological well-being of the mangrove area, taking into account various on-going developments as well as those being planned for the Sungai Santi catchment area. These findings may help conservation efforts following the declaration of the Sungai Santi mangrove area as a Ramsar site and Important Bird Area (IBA); vital ecotourism areas.

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