PEATLAND MANAGEMENT – EXPERIENCE AND RESEARCH FINDINGS IN ASEAN PEATLAND FOREST PROJECTS (APFP) PILOT SITE AT BESTARI JAYA, SELANGOR, MALAYSIA

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Abstract

Peat swamp forests (PSF) are tropical moist forests where water logged soils prevent dead leaves and wood from fully decomposing, which over time creates a thick layer of acidic peat. Large quantities of carbon are stored in tropical peat lands due to the large amount of organic matter in their soils. These peat lands might also become significant sources of CO_2 resulting from human activities and forest fires. The changes in forest cover and percentage or amount of carbon stock annually could be differentiated or calculated using mathematical models. The use of satellite imagery has been reported to be a useful tool for peatland management. Results from remote sensing methods could provide local or global estimates of carbon stocks in forests. This technology can fill in the gaps where inventory information is unavailable. Consequently, this approach was used to estimate the changes in carbon stocks for a pilot site under the ASEAN Peatland Forests Project (APFP). The pilot site was located within the Raja Musa Forest Reserve (RMFR), Selangor, Malaysia. APFP covers an area of about 4,000 ha of which about half (2,000 ha) while the rest comprise a mixture of other land uses. In this project, satellite images of 1989, 2001 and 2010 were used to determine the changes in the extent of PSF and aboveground carbon stocks. It was found that in 1989, the total PSF of APFP pilot site had lost about 342,756 tonnes of aboveground carbon stocks from the year 1989 (387,266.60 tonnes) to 2001 (44,510.42 tonnes) due to several episodes of forest fires. However, the aboveground carbon stocks started to recover back due to natural regeneration as it increased about 57,337 tonnes (56%) from the year 2001 to 2010 (101,847.49 tonnes). Based on the results from this study, it was recommended that the recovery of the site be enhanced through rehabilitation or assisted regeneration. This paper elaborates further on changes in vegetation and carbon stocks from year 1989 to 2010, some reasons due to changes and other related to aspects of protection.

Keywords *: peatland – management – carbon stock – aboveground – remote sensing*

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Introduction

Peat swamp forests (PSF) are tropical moist forests where water logged soils prevent dead leaves and wood from fully decomposing, which over time creates a thick layer of acidic peat. These forests are normally located immediately behind the coastline and extends inland along the lower reaches of the main river systems. It is well recognised that the PSF are a significant carbon sink for the earth (ESA 2003).

Recognition of the function as carbon sink as it gained an importance in recent years due to the implication of raised CO_2 levels in contributing to global warming. Large quantities of carbon are stored in tropical peatlands due large amount of organic matters in its soils. It was estimated that 5,800 tonnes of carbon per ha can be stored in a 10-metre deep peat swamp compared to 300-500 tonnes per hectare for other types of tropical forest (UNDP 2006). Tropical peatlands, besides acting as stores of carbon, actively accumulate carbon in the form of peat. Because decomposition is incomplete, carbon is locked up in organic form in complex substances formed by incomplete decomposition. Drainage of peat swamps destroys this useful function and may contribute to global warming through the release of CO_2 into the atmosphere.

Currently, there is a tremendous amount and diversity of efforts being carried out related to forest and carbon accounting with a variety methods used for measurement. Remote sensing methods could provide local or global estimates of carbon stocks in forests. This technology can fill in gaps where inventory information is unavailable. Remote sensing applications could be very valuable in carrying out assessments of how climate change might be having an impact on forests by tracking major disturbances, changes in the growing season, and Net Primary Productivity (NPP). Carbon accounting is needed to support the objectives of international agreement to mitigate global climate change (UN 1998). In conjunction with other spatial datasets such as climate, soil type, and tree height, forest coverage is important for the carbon cycle model (DeFries *et al.* 2000).

Nonetheless, the peat lands might also become significant sources of CO_2 resulting from human activities and forest fires. The occurrence of forest fires is not new in the ASEAN region and is still an important issue relates to environment and health. The devastation seems to be critical in drier periods of *El-Nino/Southern Oscillation* (ENSO) episodes. In Malaysia, forest fires pose a major threat to the management and conservation of peat lands which at this stage has been very much reduced in extent and quality (Samsudin & Ismail 2003, Ismail *et al.* 2011). Forest fires have not only directly destroyed the flora and fauna of the peat land ecosystem, but their resulting haze is also detrimental to health and contributes to the accumulation of green house gases in the atmosphere. Records have shown that most of the forest fires occur during the prolonged annual dry spells between the months of January to March, and June to August. The fire occurs sporadically in the natural forests, particularly in the degraded PSF. The root cause seemed to be human interventions, either as a result of their negligence or uncontrolled use of fire coupled with unplanned agricultural activities.

There are also significant extent of PSF found in Selangor. Out of a total of 250,129 ha of permanent forest reserve (PFR) which is equivalent to 33.1% of total land area of Selangor in the year 2010, the PSF covers an area of about 83,000 ha (**Table 1**). PSF in Selangor are found in six forest reserve (FR) in the Districts Forest of Pantai Klang (South and North Kuala Langat FRs and Sungai Karang FR) and Hulu Selangor (Raja Musa FR). These PSF are recognized as having important functions i.e. regulate sound environment such as flood and climate change control, supply water for domestic consumption and farming areas, and biodiversity conservation (Zulkifli *et al.* 1999).

Table 1 Different types of forest in Selangor for the year 2010

Forest types	Total (ha)
Dryland	136,859.45
Peat swamp	82,890.38
Mangroves	18,998.00
Forest plantation	11,381.00
Total (ha)	**250,128.83**

Source: Forestry Department Peninsular Malaysia (FDPM) 2011

Project site

This project is in the peatland area of ASEAN Peatland Forest Project (APFP) at the pilot site which partly covers Raja Musa Forest Reserve (RMFR), Selangor, Malaysia. The APFP pilot site is located in the southern part of RMFR (**Figure 1**), covering an area of about 4,000 ha. The RMFR with an extent of 23,486 ha, is located in the North Selangor Peat Swamp Forest (NSPSF) in the north western part of Selangor .Prior to its gazettement as permanent reserved forest in 1990, RMFR was part of stateland forest and was intensively subjected to logging since 1950s. The site is located inside the following corners of coordinates [Malaysian Rectified Skew Orthomorphic (MRSO) Projection]:

Upper left	:	371 813.1	382 944.3
Upper right	:	380 629.8	382 944.3
Lower right	:	380 614.4	378 383.2
Lower left	:	371 813.9	378 398.3

The forest is heavily disturbed and the forest stand has only of low to medium density tree stocking. Under the "Integrated Management Plan of the NSPSF (2001 – 2010)", 70% of RMFR was classified as production forest, 27% as forest sanctuary for wildlife and the remaining 3% as research forest (JPNS 2000).

In general, RMFR support tree species with small to medium sized crowns, typically reaching 30 m in height. Emergent trees are scattered throughout the area. Kempas (*Koompassia malaccensis*), Meranti bakau (*Shorea uliginosa*), Kedondong (*Santiria* spp.), Kelat (*Syzgium* spp.) and Ramin melawis (*Gonystylus bancanus)* are the dominant tree species within the forest. Part of the north-east corner of RMFR is known for its high water table as it is located near the peat dome in the central RMFR and dominated by palms and pandanus. Another 2,000 ha of APFP pilot site is located outside the RMFR where main landuses are agricultural areas and stateland PSF.

The major issues with regards to the management and conservation of RMFR are forest fires and encroachment. The occurrence of forest fire is closely related to the heavily drained and degraded condition of the forest areas in RMFR. RMFR suffers from ear frequent fires almost every year particularly during prolonged dry spells in the months of February until March and June until August. The other issue related to RMFR is encroachment. Illegal occupation of government lands was rampant from the late 1990's up to mid 2000's. The degraded condition of the forest land due to burning provided an excuse for illegal settlers to encroach into the forest reserve for settlement and agriculture. Nevertheless, these areas are outside from the APFP's pilot site. Efforts have been undertaken by the Selangor State Forestry Department to address the illegal encroachment problems. Consequently, several individuals forcefully evacuated from the affected sites within RMFR and these areas have now been allocated for forest rehabilitation activities.

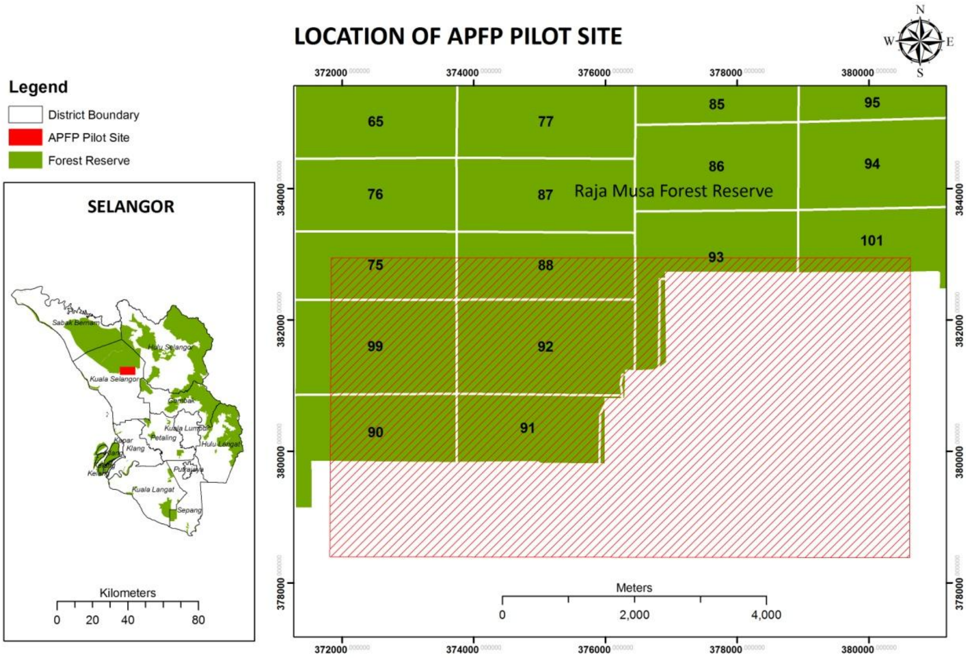


Figure 1 Location of APFP pilot site

Data types

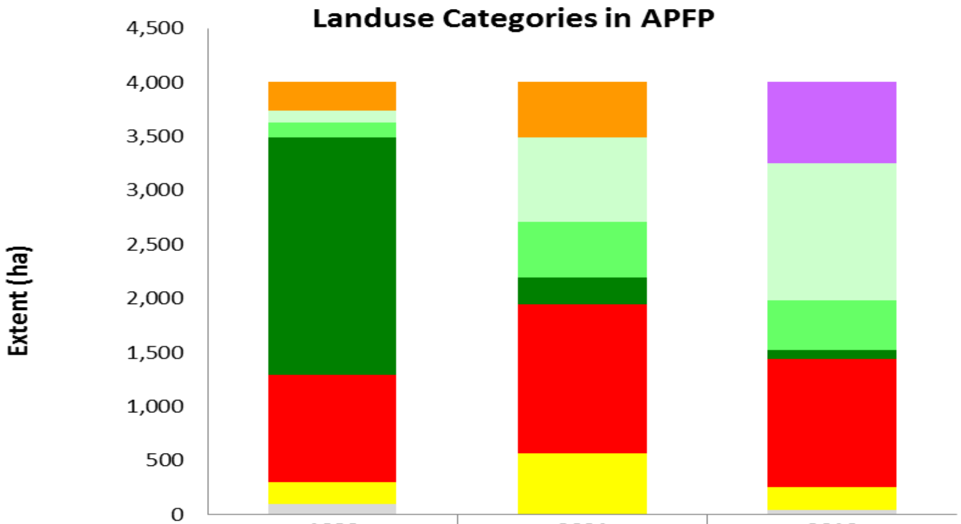
Two types of data were used in this study namely secondary and satellite data. Secondary data comprised external forest reserve boundary, compartment boundary and external APFP boundary based on existing forest data of 1999 (JPNS 2000). These were all acquired from Selangor State Forestry Department. In order to detect the changes in carbon stocks and the availability of satellite images, satellite data comprising Landsat-TM and SPOT-5 imageries over the years 1989, 2001 and 2010, were used as shown in **Table 2**.

Table 2 Satellite data used in the study

Year	Satellite	Date of image	Spatial resolution (m)
1989	Landsat-TM	07/02/1989	30
2001	Landsat-TM	09/12/2001	30
2010	SPOT	24/01/2010	5

Landuse classification in the APFP

Landuse classification was applied to the satellite images to identify and classify the extent of landuse/land cover classes in the study area. By using an appropriate classification algorithm, several classes of landuse of the pilot site of approximately about 4,000 ha have been classified and the extent of each landuse category was quantified (**Figure 2**). In additional to the different landuse classes, the pilot area itself was categories into three categories according to its tree density in NDVI (Normalised Difference Vegetation Index); namely low, medium and high tree stand. NDVI is found ranged from 0.1-0.5 in the peat swamp forest. This range was divided into three, which are (i) 0.1-0.2, (ii) 0.2-0.3 and (iii) 0.3-0.5, that represent low, medium and high, respectively. This categorization was useful to provide information of on tree and carbon stocking as well as the impact of series of forest fires occurred. The tree stand in the study area was considerably dense before the forest fire event as indicated on the satellite image for 1989. The classification results were spatially mapped as shown in **Figures 3 – 5** for the years 1989, 2001 and 2010 respectively.



	1989	2001	2010
Oil palm plantation	0.00	0.00	760.35
Shrubs	269.82	513.36	0.00
Tree Stands: Low	105.24	788.70	1,266.97
Tree Stands: Medium	140.72	512.40	452.69
Tree Stands: High	2,200.61	244.22	83.74
Mining sites	986.72	1,378.84	1,188.95
Grassland	203.52	568.53	212.00
Cleared land	99.42	0.00	41.35
Total:	4006.05	4006.05	4006.05

Figure 2 Landuse classes in the pilot site on different years (1989, 2001 & 2010)

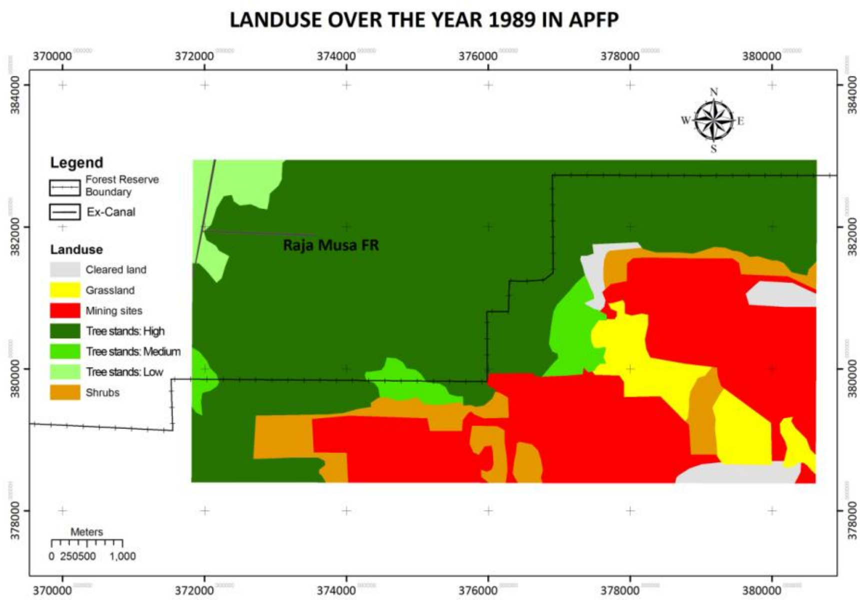


Figure 3 Landuse classes in year 1989

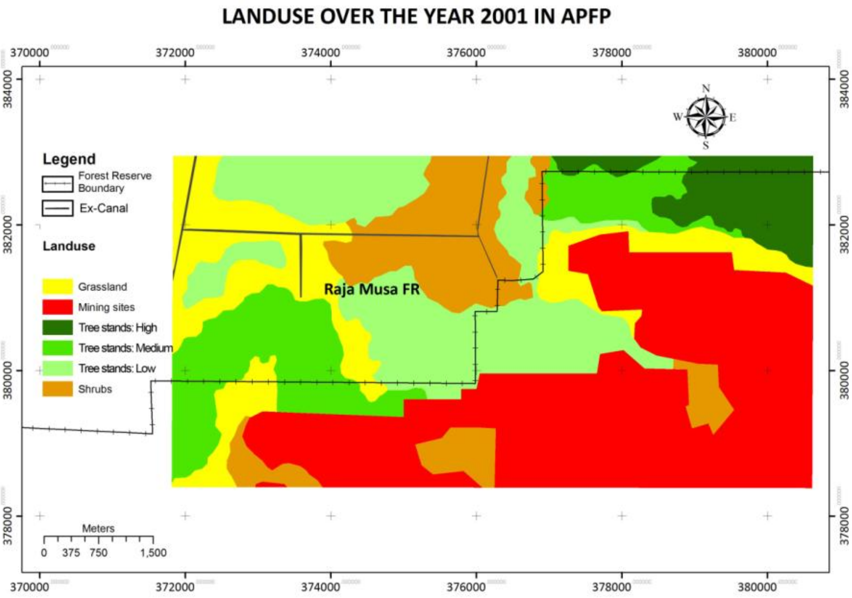


Figure 4 Landuse classes in year 2001

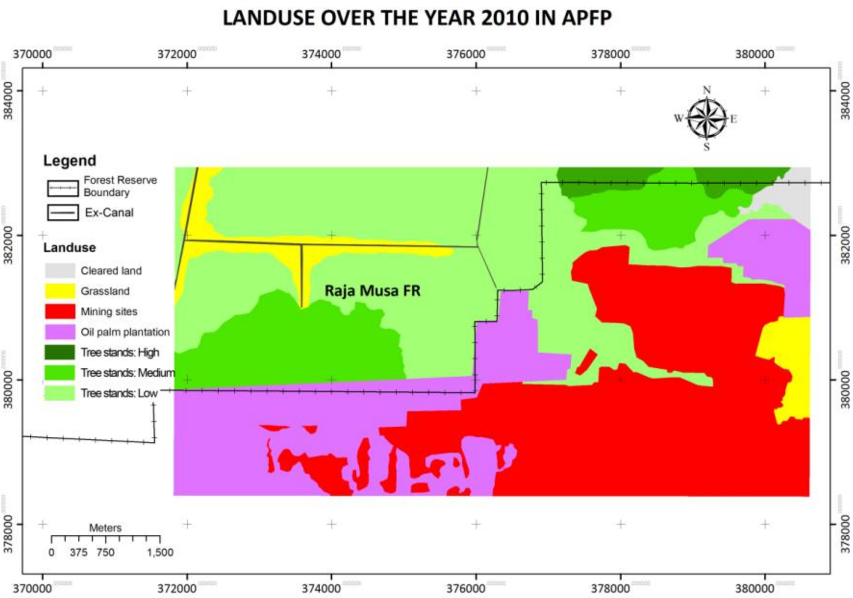


Figure 5 Landuse classes in year 2010

From the satellite data it was found that oil palm plantation only appeared on the satellite image in the year 2010. It occupied about 760 ha fringing the central horizontal line of the APFP pilot site. Another landuse class that occupied a significant extent of pilot site is mining areas. These mining areas were probably PSF sometimes ago. However they were converted into water bodies and grassland areas after they were left abandon following the completion of the mining activities were completed. These mining sites are dominant in the southern part of APFP pilot site.

Forest area that was pristine in the APFP pilot site occupied about 2,447 ha (61%) in the year 1989. However they were significantly reduced to 1,545 ha (39%) in the year 2001. This was due to the series of forest fire in which turned the part of forest areas into grassland and shrubs. However, some of these affected areas have regenerated back into PSF thus increasing the total extent of forest area to 1,803 ha (45%) in 2010.

Aboveground carbon stocks in APFP

This project used secondary data to estimate aboveground carbon stock in the APFP pilot site due to limited resources available for field inventory. This was the optimum effort feasible within the short time frame of this project. A more detailed and precise calculation of the carbon stocks would require long-term measurements and detailed forest inventories. An additional uncertainty is that the resolution of the remote sensing data used (i.e. 30 x 30 m) does not allow further detailed assessment.

A set of ground inventory data adopted from JPNS (2000) was used to generate aboveground carbon stock prediction equation over the study area. Landsat-TM image over the year 2001 was used to perform this process. Since only standing volume (m^3 ha^{-1}) was given, the parameter has been converted to total carbon stock by using the following equation (simplified from IPCC, 2006):

$$C = A \times V \times BCEF \times CF$$

Where,

C	total carbon in carbon stock, in t
A	area of land of certain land use class, in ha
V	merchantable growing stock volume, in m^3/ha
BCEF	biomass conversion and expansion factor
CF	carbon fraction of dry matter [the carbon fraction (CF) of dry matter was chosen to be 50%, as recommended by IPCC]

The ground data set and the generated NDVI from the satellites images is listed in **Table 3** and the correlation between these two parameters at corresponding locations is shown in **Figure 6.**

Table 3 Ground inventory data and generated NDVI from satellite image

Compartment	Estimated standing Volume (m^3 ha^{-1})*	Aboveground C stock (t ha^{-1})	Mean NDVI (Year 2001)
75	79.36	66.27	0.2722
88	79.36	66.27	0.2357
90	60.89	50.84	0.1561
91	79.36	66.27	0.2585
92	0.00	0.00	0.0009
93	79.36	66.27	0.2936
99	0.00	0.00	0.0000
101	60.89	50.84	0.1959

*Note: Measurement was made in the year 1999 for the trees ≥ 15.0 cm DBH, JPNS (2000)

The NDVI was used as the indicator/predictor for the aboveground carbon stocks in the study area. This index can be generated from both Landsat and SPOT image, which enabled the carbon stock estimation over the time series of satellite images. The aboveground carbon stock estimation that have calculated based on the satellite images have successfully shown the distribution over the certain years and further allowed carbon stock changes assessment in the APFP pilot site. However, these results include some level of uncertainty that need to be assessed. Therefore, a field survey was conducted in the study area to determine estimation error and accuracy of the estimated aboveground carbon stock for the purpose validation and verification.

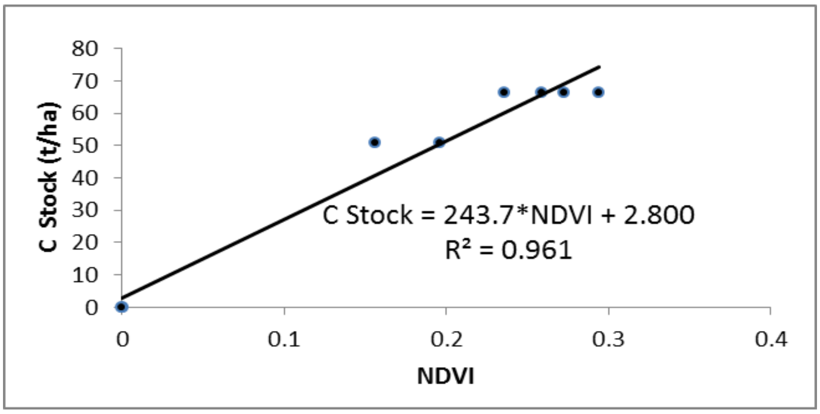


Figure 6 Relationship between aboveground carbon stock and NDVI

Causes of aboveground carbon changes

The NDVI images that were converted to aboveground carbon stock have allowed the calculation of total aboveground carbon stock in the study area over the three series of years. It was found that the total aboveground carbon stock in APFP area has lost about 342,756 tonnes from the year 1989 to 2001 due to the series of forest fire. However the aboveground carbon stock started to recover back as it increased about 57,337 ha from the year 2001 to 2010. The distribution of carbon stocks in the PSF in APFP pilot site that ranged from 80 – 184 t ha^{-1} in year 1989 has decreased to 0 – 40 t ha^{-1} in the year 2001 and increased back at the range from 20 – 40 t ha^{-1}. The statistics of assessed aboveground carbon stock in APFP pilot site is shown in **Table 4** and its trend of changes is shown in **Figure 7**.

Table 4 Basic statistics of assessed aboveground carbon stock in APFP

Year	Minimum (t ha^{-1})	Maximum (t ha^{-1})	Mode (t ha^{-1})	Average (t ha^{-1})	Total (tonne)
1989	0.00	154.61	124.61	96.67	387,266.60
2001	0.00	61.11	37.38	11.11	44,510.42
2010	0.00	70.00	36.78	25.42	101,847.49

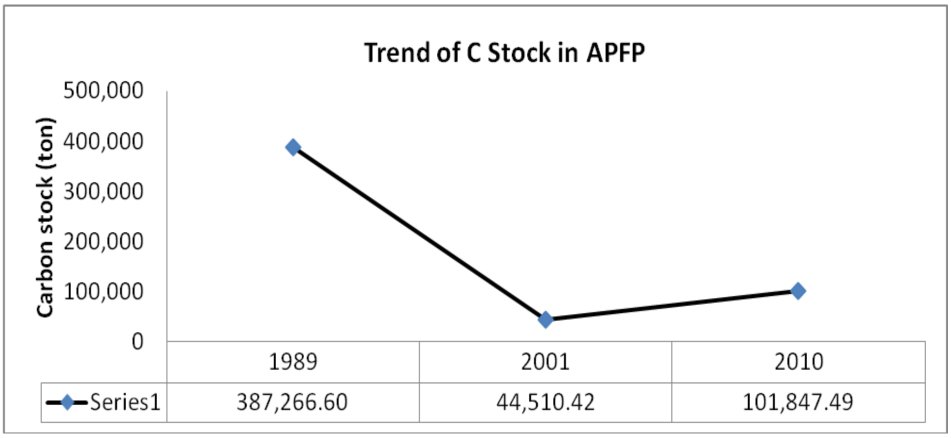


Figure 7 Trend of changes in aboveground carbon stock in APFP from 1989 to 2010

The study shows that the series of forest fire events occurred in forest areas have caused considerable amount of carbon lost. This carbon lost can occur within short period of time during the fires episodes, but the forest ecosystem has to take tens of years to recover the carbon storage. **Figures 8 – 10** show the spatial distribution of aboveground carbon stock for the years 1989, 2001 and 2010. In addition, aboveground carbon stock changes of the APFP pilot site from the year 1989 to 2010 is shown in percentage in **Figure 11**. Most of the central and south west areas were totally (100%) changed due to the land conversion from forest area to oil palm plantation (outside the forest reserve).

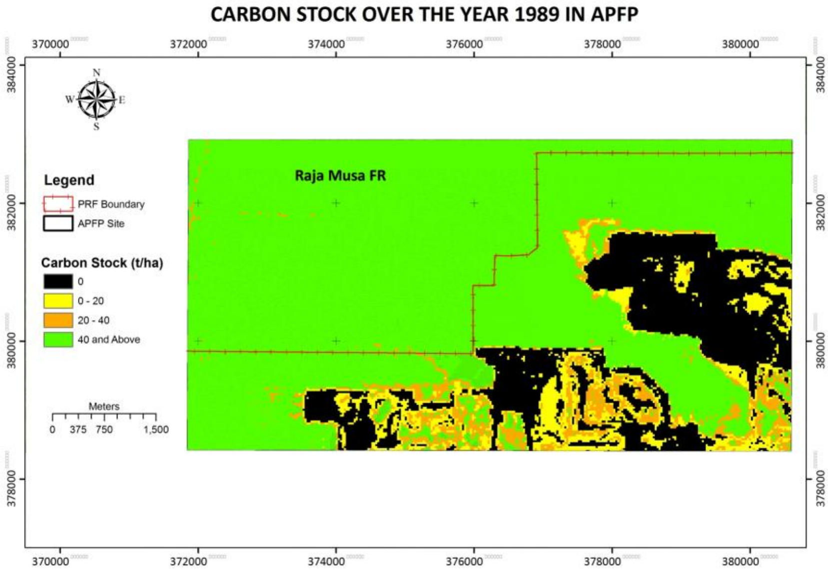


Figure 8 Distribution of aboveground carbon stock in year 1989

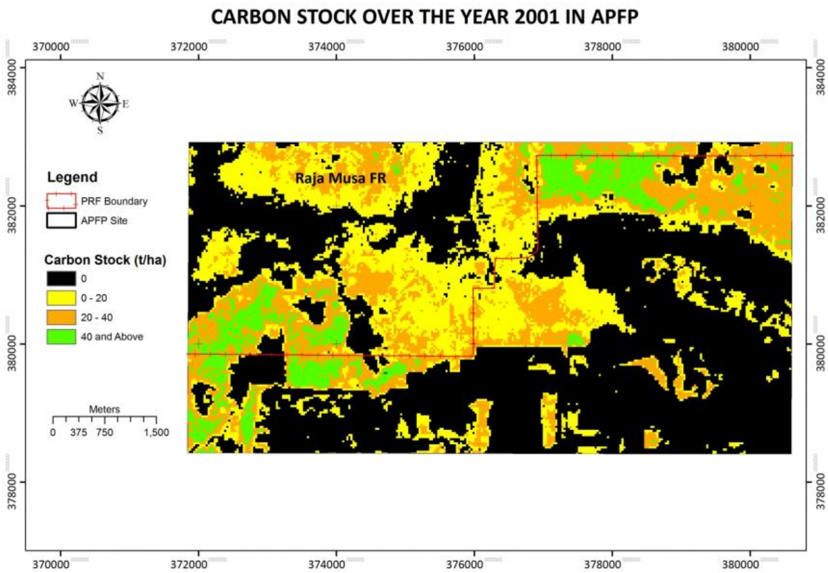


Figure 9 Distribution of aboveground carbon stock in year 2001

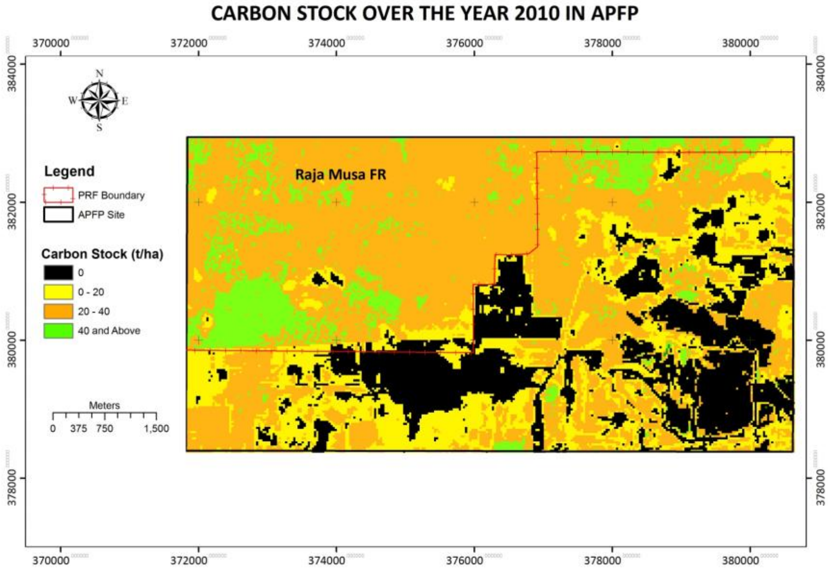


Figure 10 Distribution of aboveground carbon stock in year 2010

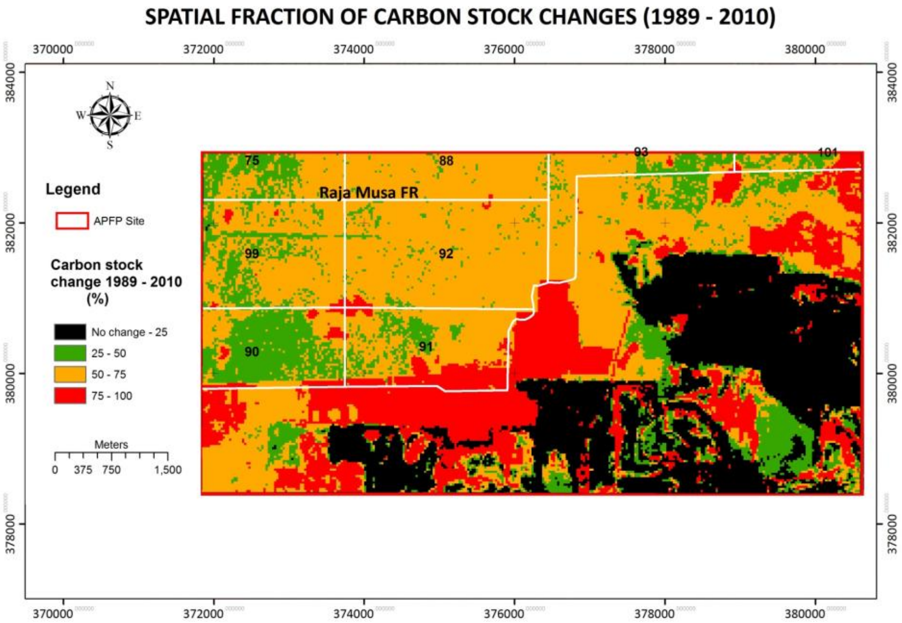


Figure 11 Fraction of aboveground carbon stock changes between year of 1989 and 2010

Conclusions

Remote sensing technology has proven to be successful in relatively short duration in estimating aboveground carbon stock over the certain years. The methodology was used to estimate the aboveground carbon stock changes in the PSF areas of APFP pilot site at RMFR, Selangor of Malaysia. Validation and verification results showed that estimation error and accuracy of the calculation are of acceptable levels. The method adopted in this study has been found to be a cost-effective way to estimate the aboveground carbon and its pattern of changes. Detail field inventory in term of ground vegetation is needed for more accurate estimation of the aboveground carbon, nonetheless, provided field inventory data for all investigated years are also available to compare their pattern. Field inventory in the APFP pilot site if conducted would only be able provide estimates of the current vegetation information to be used for estimate the current carbon stock.

Based on project's findings, it was found that total aboveground carbon stock in PSF areas of APFP pilot site has lost about 342,756 tonnes from the year 1989 (387,266.60 tonnes) to 2001 (44,510.42 tonnes) due the forest fires in this area. However the aboveground carbon stock started to recover back as it increased about 57,337 ton from the year 2001 to 2010 (101,847.49 tonnes). Study by Istomo (2006) found that about 20.1% of aboveground carbon in PSF is belowground carbon. Therefore as for 2010, the total vegetation carbon of PSF in the APFP site was about 122,318 tonnes (aboveground = 101,847 tonnes, belowground = 20,471 tonnes) or about 11.35 t ha^{-1} (total area of PSF for 2010 ~ 1,803 ha). The low stocking of vegetation carbon stock was because more than 70% of total PSF areas consisted of open areas with very little vegetation in the APFP pilot site for year of 2010. As for comparison, an intact PSF in Pekan FR, Pahang could stock vegetation carbon at about 414.6 t ha^{-1} (Khali Aziz *et al.* 2009).

Recommendations

This study has provided useful information on the changes in C stocks in the study site for a 20 year period. Some useful lessons and experience were gained. Consequently the following recommendations is proposed:

i. Forest fire was found as the main threat to the PSF areas in the APFP pilot site. Therefore, it is suggested permanent water level station be installed to measure water table and create buffer zone of forest reserve to prevent and control fires. It is suggested that the APFP project conduct special study to develop forest fire management plan that will have forest fire prevention measures.
ii. Implement of fire preventions measures for the APFP pilot site particularly good water management (canal blocking) strategies.
iii. Increase the number of regular monitoring by forestry department's personnel particularly during dry season in It would be good to get the involvement of local community fire brigade;
iv. Conduct detail carbon assessment for PSF areas in the APFP pilot site including its soil via field inventory in order to determine total carbon stock of the area;
v. Conduct comprehensive rehabilitation program particularly in open PSF areas inside the RMFR to assist their regeneration, prevent fires and increase the carbon stock;
vi. Assign the APFP pilot site as model for long-term management site for peat land in Malaysia. It is an ideal site to show good coordination and cooperation of stakeholders for integrated management of the peat lands. It also can be a suitable place for a Centre of Excellence for Peat land in Malaysia;
vii. Provide training to the staff of JPNS in the management of PSF as well in controlling and preventing forest fires in PSF; and
viii. Conduct assessment of aboveground carbon stock for the whole Raja Musa FR or even all PSF forest reserve in Selangor by using the remote sensing technologies in order to estimate their contribution on stocking of carbon for environment stability.

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