The International Journal of Engineering and Science (IJES)
|| Volume || 8 || Issue || 3 Series II || Pages || PP 23-29|| 2019 ||
ISSN (e): 2319 – 1813 ISSN (p): 23-19 – 1805

Estimating of Carbon Storage of Peatlands and Main Hazards Related to the Utilization and Management of Peatlands in Lower U Minh National Park, Ca Mau Province, and Vietnam

Phan Truong Khanh and Tran Thi Hong Ngoc
Faculty of Environmental Technology Engineering, University of An Giang,Vietnam
Corresponding Author: Phan Truong Khanh

--***ABSTRACT***--
Along with storing large quantities of carbon, peatlands also play an important role in the retention, purification and release of water and in the mitigation of droughts and floods. In Lower U Minh melaleuca forest, in the past peatlands have been decreasing very quicklydue to the burning forest and the agriculture activities. So, peatlands have become net sources of greenhouse gas (GHG) emissions. Changes peatlands may cause changes in net carbon storage. Currently, there is minimal carbon data for this national park. Therefore, our objectives were to measure C stocks of peatlands for this ecosystem. Forty five plots were established at a size of 1,600m^2 (40mx40m) in the plantation Melaleuca forest and in the natural Melaleuca forest. In total, 225 peat samples were collected between 2015-2017. Three measurements were obtained to determine total soil organic carbon: organic soil depth; bulk density and % organic carbon. Results showed that the thickness of the peat was ranged from 0.1m to 1.3m; C% ranged from 49.18%-50.89%. Bulk densities with a mean of 0.226 g/cm^3. Total peat carbon content with a mean of 586MgC/ha. Average Peat reserves was 1,154.31 tons/ha. We found that the carbon content of peatland in Natural melaleuca forest was 2,65 timeshigher than the carbon of the peatlands in the plantation melaleuca forest. In summary, the two peatlands differed greatly in %carbon, bulk densities, peat thickness which could be caused by the burning forest, the variation in using soil and hydrology, or alternatively to plant intensive melaleuca. The paper showed that a canal system for fire control built in the peatland area has caused many problems for this ecosystem.
KEYWORDS*: Carbon storage, Peatland, Lower U Minh National Park*

Date of Submission: 28-02-2019 Date of acceptance: 25-03-2019

I. INTRODUCTION

In nature, wet state peatlands provide vital ecosystem services. By regulating water flow, they help minimize the risk of flooding and drought and prevent seawater intrusion. In many parts of the world, peatlands supply food, fibre and other local products that sustain local economies. They also preserve important ecological and archaeological information such as pollen records and human artefacts.

Peatlands are the largest natural terrestrial carbon store; the area covered by near natural peatland worldwide (>3 million km^2) sequesters 0.37 gigatonnes of carbon dioxide (CO_2) a year – storing more carbon than all other vegetation types in the world combined [9], [12]. Peatland is distributed mainly in North America, Russia, Europe, East Asia and Southeast Asia, Caribbean, Central America, South America and South Africa [11]. Southeast Asia has 25 million ha of peatlands, which is 60% of all tropical peatlands [6], [17], [14]. Carbon is removed from the atmosphere into the plant tissues by photosynthesis and it is then stored in the dead plant remains, often over millennia, as a thick layer of peat [10]. Semi-natural and undamaged peatlands can accumulate carbon at a rate of 30-70 tons of carbon per km^2 per year [2], [20]. The lack of awareness of the benefits of peatlands means that they have been severely overexploited and damaged as a result of actions. These actions include but are not limited to drainage, agricultural conversion, burning and mining for fuel. About 15% of the world's peatlands – coverless than 0.4% of the global land surface – have been drained. This has released huge amounts of greenhouse gases, such as carbon dioxide (CO_2), from the carbon stored within peat soils [9]. Damaged peatlands contribute about 10% of greenhouse gas emissions from the land use sector. CO_2 emissions from drained peatlands are estimated at 1.3 gigatonnes of CO_2 annually. This is equivalent to 5.6% of global anthropogenic CO_2 emissions [9]. Draining peatlands reduces the quality of drinking water due to pollution from dissolved compounds. Damage to peatlands also results in biodiversity loss [9]. Recognizing the importance of carbon stored in peatlands for theglobal carbon budget, climate modelling groups have begun to integrate peatlands into stand-alone terrestrial ecosystem models (TEMs) and also TEMs that serve ESMs and global climate models (GCMs) [21].

Vietnam has a comparatively small area of peatlands compared to its regional neighbors. They are found in many parts of Vietnam, but occur mainly in the Lower Mekong Delta and are estimated to cover about 24,000ha [1]. A measurable area of peatlands in the Lower Mekong Delta and central areas of Vietnam have been exploited for uses such as for fuel and as fertilizer. These activities have resulted in many problems not only in the peatlands but in surrounding areas [1]. Peatlands are highly significant to global efforts to combat climate change, as well as wider sustainable development goals. The protection and restoration of peatlands is vital in the transition towards a low-carbon and circular economy. Immediate action worldwide is required to protect, sustainably manage and restore peatlands. This involves protecting them from degrading activities such as agricultural conversion and drainage, and restoring the waterlogged conditions required for peat formation to prevent the release of carbon stored in peat soil. Because of the importance and their large carbon stores, peatland would make ideal candidates for Reducing Emissions from Deforestation and forest Degradation (REDD+) strategies. However, there is little information or current research on the whole-ecosystem carbon storage for peatlands, especially in Vietnam. Therefore, this study "Estimating of Peat Carbon Pool and Main Hazards Related to the Utilization and Management of Peatlands in Lower U Minh National Park, Ca Mau Province, Vietnam" iscritical to evaluating the current condition of the whole-ecosystem carbon storage in Vietnam. The objective is to provide data for ESMs and global climate models, as well as proposing sustainable ways of managing peat soil in the study area.

II. METHODOLOGY

Characteristics the study area

The Lower U Minh National Parkbelongs to U Minh and Tran Van Thoi districts of Ca Mau province in Vietnam. Thetotal areaof the park is estimated to be about 8,476 ha. It is located between 9^{o}12’30” to 9^{o}17’41”N and 104^{o}54’11” to 104^{o}59’29”E (Figure1).The average temperature in the area is26.5^{0}C and the average annual precipitation is 2,360 mm. The terrain of the land is relatively flat and the average elevation varies from 1 to 1.5m above sea level. The main soil types are peat and clay with alum sub-soils dominating in water logged areas[13].

Due to the presence of dyke systems in the area, Lower U Minh National Park is not affected by the diurnal tidal of the WestSea. However, the area is floodedfrom 0.1 to 1m during the rainy seasonfor5-6months from June to November in each year. The amount of waterin the forestcan be adjusted, lowered orstoredineach zonebyregulatingwater through culverts. The vegetation of the LowerU MinhNational Park dominates with Melaleucacajuputiibelongs to Myrtaceae family [13].

III. DATA COLLECTION

Based on the forest status map combined with field surveys we selected 45 plots with a size of 1,600m^2(40mx40m) representingthe study area (Figure 2). Global Positioning System (GPS) was used to determine the coordinates and the direction of the standard plots.In each main plot 5 subplots were selected of 100m^2 (10 m x 10 m). The subplots were located at the four corners of the main plot and the fifth plot was located at the center of the main plot. Out of 45 plots, 33 werelaid in the plantation Melaleuca forest and 12 plots were laid in natural Melaleuca forest areas. Two hundred twenty five peat samples were collected during 2015-2016. The peat sampling techniques varied by depth within the peatprofile. Three measurements were obtained to determine total soil organic carbon: organic soil depth (to obtain soil volume per area), bulk density (to obtain soil mass per area) and %organic carbon (OC) (to convert mass per area to C per area). Soil depth was measured at three separate locations around each sub-plot.The depth was measured using a soil auger. The entire peat profile was coredonce at each site and were transported to the lab at the center of environmental monitoring in An Giang where they were immediately frozen (−23°C) until further analysis. All of the samples wereoven dried at 60 °C for 24h [4]. The bulk density was calculated using the mass of the dried sample divided by the volume of the wet sample [4]. The peat was analyzed for percent carbon (%C) using a Shimadzu TOC-5000 Total Organic Carbon Analyzer.

The peat C pool is calculated: peat volume (V) x carbon density (CD), where V= area x thickness (usually expressed in m^3) and CD= bulk density (BD; expressed as g/cm^3 or kg/m^3) x Carbon fraction (i.e. 50% C = 0.5 carbon fraction) [18]. Field measurements include peat thickness to determine volume and peat soil sampling to determine BD and %C in a laboratory. C stocks are usually expressed as MgC/ha. Peat reserves M (tons)= Thickness x Area x Bulk density.

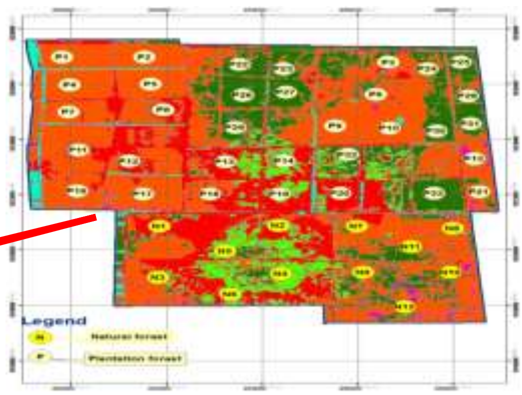

Figure 1: Location of the lower U Minh National Park (right) and Mekong Delta (left)

Figure 2: Layout of sample plots

IV. RESULTS AND DISCUSSION

Peat has made a difference in soil elevation in U Minh Ha National Park. Seventy two percent of peat area is in the range from 0.1 to 0.6m. The area above 0.6m only accounts for 28%. The ground elevation of the National Park is not uniform. The elevation of the southern section of the park is higher than the elevation of the northern section. The distribution of peat according to elevation is the basis for designing water management plans to ensure the conservation of forest ecosystems and prevention of forest fires. Peat soil is formed by incomplete decomposition of organic matter, accumulated over thousands of years due to lack of oxygen under flooded conditions. The results of drilling peat soil samples in U Minh Ha National Park, it was shown that above the peat layer was the litter layer 10-20 cm thick, that had not completely decomposed. The thick litter layer called peat is 10-130cm thick in areas of natural Melaleuca forest 1,827.8ha). This area did not burn in 2002. In another area, called the Melaleuca plantation forest (not natural melaleuca forest), there are approximately1,419.7ha of peatremaining(10-15cm thick) fire in 2002.After the fire, a substantial regrow of Melaleuca occurred and additional Melaleuca were planted by the management board.

Underneath the peat layer was a gray to brown gray clay layer, which contains a little plant litter, 1-1.5 m thick (bearing alum material). Peat land in lower U MinhNational Park is mainly distributed in areas with average ground elevation below 0.5m. In this area, the ground is low and the alum layer is shallow. Most active alum soil is distributed in the swamp. The thickness of peat layer varies greatly depending on the previous burnt status. Currently, in the U Minh Ha National Park, there exist mainly peatlands on the potential alum, peatlands on active alum.In terms of morphology, peatlands can be divided into two types: black peat is located in the deeper layer; Brown peat has a loose structure, some containsrotting wood, located just above the black peat layers. Bulk density of black peat is higher than brown peat. The black peat is usually more moist than brown peat and is difficult to burn.

Figure 3: Black peat**Figure 4:** Brown peat

In 1976, the peatland area in U Minh Ha was 20,167ha, the reserve of 153.4 million tons. In 2000, the peat land area in U Minh was 7,434ha, in 2002, the peat land decreased by 14,000ha due to big fires. From 2003 to 2010 the area of peat land remained at 6,034ha, reserves of about 13 million tons [19]. According to the survey and evaluation results of the Vietnam Department of Geological Minerals in 2015, U Minh Ha National Park has 2,658 ha of peat, the thickness of peat is from 0.5m to 1.5m. But according to our survey results in

2016-2017, the peat land area currently has 3,247.5 ha (accounting for 38.32%) of the total area of the national park with peat thickness from 10cm to 130cm. In plantations Melaleuca forest, peat soil with a thickness of 10-50cm occupies an area of 1,419.7ha, reserves of 928,484.00 tons equivalent (654.00tons/ha). Meanwhile, in natural Melaleuca forest, peat land area was 1,827.8 ha with a depth of 10-130 cm, reserves of 3,024,306.00 tons equivalent to 1,654.62tons/ha (Table 1). Thus, a total of 3,952,790 tons of peat reserves in the entire forest block. We found that the area of peat land decreased continuously from 1976 to 2017, the decrease was approximately16,920 ha (Figure 5) due to a variety of reasons including a large fire in 2002 and due to use for the purpose of growing rice and crops. The multiple forest fires and land us changes heavily contributed to the reduction of the peatlands.As a consequence of these factors, peat reserves fell sharply from 153 to 305 million tons in 1976 to 13,100,000 tons in 2010, and in 2017, the peat reserves were only 3,952,790 tons. Currently, Melaleuca have naturally regenerated and recovered on burnt peat soil area. The area of peatlands by the thickness of the peat layer is shown in Figure 6.

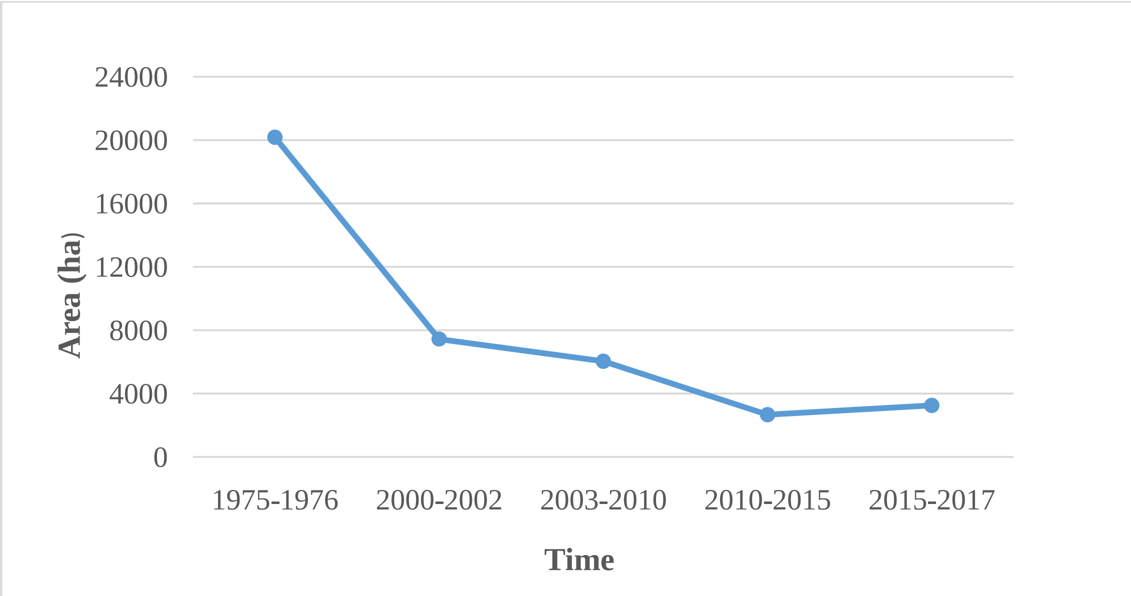

Figure5: Peat area in Lower U Minh National Park over time

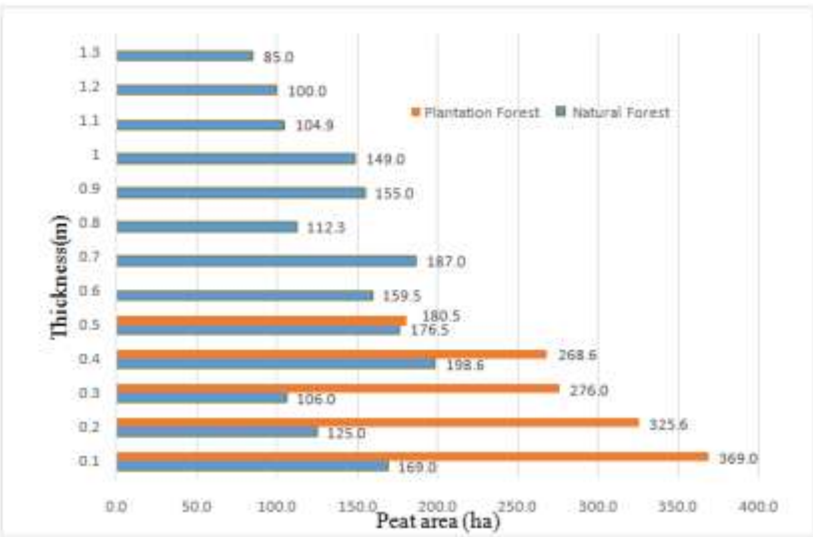

Figure 6: Peat area according to thickness in the Lower U Minh National Park in 2017.

Estimating carbon stock in peat

Peatlands of Lower U Minh National Park is tropical peat, a lot of pyrite, a range of pH fom 3.5 to 5.2; Average pH in Natural Melaleuca Forest is 4.5 and 4.7 in Plantation melaleuca forest; humus content of 46-51%; thickness 0.1m-1.3m, bulk density for the whole peat cores in Natural Melaleuca Forest 0.236g/cm^3 and 0,216g/cm^3 for Plantation Melaleuca Forest; average %C ranged 50.89% and 49.18% in the peatlands of Natural and Plantation Melaleuca forest respectively. Peat carbon density varied in peatland of Natural Melaleuca forest of12.02gC/cm^3,While an overall mean C density of 10.62gC/cm^3 in peatland of plantation Melaleuca forest. The results showed that bulk density and C content increased towards deeper peat (Figure 7). Total Peat carbon content with a mean of 851.50MgC/ha and 320.51MgC/ha for Natural Melaleuca Forest and Plantation Melaleuca Forest respectively.However, according to the results of Quoi in 2012. The average carbon content of peatland in lower U Minh is 626 tons/ha. In contrast our results showed 585,75 tons/ha. Compared to the result of Murdiyarso, 2010 mean Carbon storage in mangrove and peatland ecosystems with a mean peat depth of 45.5 ± 6.8cm was 894.3MgC/ha (higher 1,4 times our result: carbon of peatland in melaleuca forest), with a range of 558 to 1213 Mg C/ha in Tanjung Puting National Park, Central Kalimantan, Indonessia.Total carbon stocks of U Minh National Park varied 2,001,399.64 tons (1,556,365.94 tons forNatural Melaleuca Forest and 455,033.7tons for Plantation Melaleuca forest)(Table 1). The carbon content by peat thickness is shown in Figure 7.This data shows that peat in natural malaleuca forest contain very large C-pools because of the combination of large trees, denser peats and significant C storage in the upper mineral soil layers. Peatlands are extremely rich in belowground C-stocks, and it is not sufficient to keep the trees standing without maintaining natural inundation processes that prevent the oxidation of organic soils.

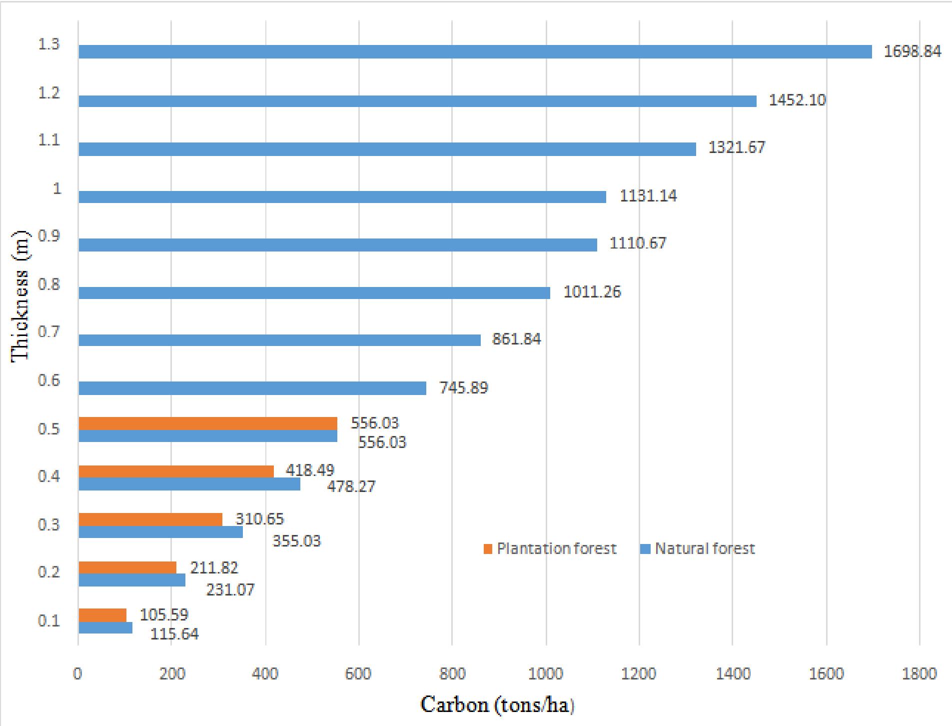

Figure 7: Carbon content by thickness of peat layer

Table1: Average (SE) peat and carbon properties in the cored peatlands of Natural and Plantation Melaleuca forest in Lower U Minh National Park.

	Natural Melaleuca Forest (n-60)	**Plantation Melaleuca Forest (n-165)**
Average thickness (cm)	88 ±3.14	37±1.63
pH	4.5 ±0.28	4.7 ±0.16
% C	50.89 ±1.35	49.18±0.79
Bulk density (g/cm^3)	0.236±0.37	0.216±0.09
C density (gC/cm^3)	12.02±0.8	10.62±0.42
Total C (MgC/ha)	851.50±35.9	320.51±27
Carbon Pool (tons)	1,556,365.94	455,033.7
Peat (tons/ha)	1,654.62	654.00
Peat reserves (tons)	3,024,306.00	928,484.00

Main hazards related to the utilization and managementof peatlands

The surface of an intact peatland is usually too wet to support a fire. However, if there is loss of moisture from the upper peat layer, both natural climatic variation and anthropogenic disturbances can increase the risk of fires. But many fires on peatlands are a direct, though often accidental consequence of land use change brought about by disturbances of the natural ecosystem. These disturbances greatly increase the risk of ignition and severe burning of both vegetation and peat. Some of the most extensive peatland fires recently have occurred on peatlands in Lower U Minh National Park that were either being used for, or were in the process of being converted to, agricultural use. Around 4,25 million tons per year of peatland were burned, which released an estimated 7,82 million tons per year of CO_2 emissions; total emissions from peat oxidation by lowering the dry season groundwater level is 182,664 tons CO_2/year [19]. Several more peatland fires occurred in this region in recently years. They have now become a frequent feature of the dry season when weather conditions provide a suitable window for the use of fire as an economical method of clearing the land. Land clearance is driven in part by recent rapid conversion of peatland to industrial-scale Melaleuca plantations. The combination of drainage, drought and abandonment has also been responsible for extensive peatland fires. Increased drainage, which occurs when canals are dug for timber transport, increases the risk of carbon loss [7]. Intensive forestry operations in tropical peat swamp forests always lead to a reduction in the capacity of the system to maintain the overall carbon store, particularly the carbon stored in peat. Carbon losses from peat are evident as the soil surface lowers in drained areas. The subsidence rate is positively related to increased depth of the water table below the peat surface [8], [3]. In the tropics, physical compaction and shrinkage comprise a substantial part of subsidence only during the first years after drainage. Up to 90 percent of long-term carbon losses measured from peat subsidence are due to oxidative decomposition [8]; [3]. In addition, about twice as much POC and DOC leaches from drained peat swamp forest as it does from intact peat swamp forests [15].

During the summer of 2016, an extreme period of high temperatures and low rainfall resulted in widespread and prolonged fires on drained peatlands in Lower U Minh National Park. Wherever they occur, peat fires are very difficult to extinguish. They are often located at some distance from roads, making it difficult to apply conventional fire-fighting techniques. In addition, the nature of thesmoldering material means that the fires can persist for weeks, or even months, burning slowly at and below the peat surface. Under very dry conditions, smouldering fires can continue to burn even following days of rain. Peat fires are a particularly large source of carbon emissions to the atmosphere when compared to the combustion of above-ground vegetation [5]. The ecologic impacts of the fires are significant in terms of the massive extent of peat forest that has burned and the near total removal of 8 – 45 year old trees. The depth of peat has been reduced by 30 – 100cm (from an estimated original 150 cm) and nearly 40% of the Melaleuca peat forest in these areas has burned (Figure 8-9).Habitat for deer, wild pigs, monkey's and hundred of bird species has been significantly altered. Fire suppression efforts have been successful, but have resulted in at least 15 kilometers of canals in the area. As part of the suppression effort, salt water has been pumped into both areas, which can lead to negative impacts on fresh water plants, organisms, and native wildlife.The canals alter the historic/natural water regime in the peat forest, causing ground water levels lower than normal, leading to the severity and extent of seasonal drying and fragment the habitat of the area. These impacts make it difficult to achieve the current land management objectives of the area.

The construction of new canals and widening of existing canals to stop current fires was a remarkable, well-coordinated, and successful effort, but canals are not the long-term solution to fire control. Because the long-term impacts of the salt water, especially if this practice is needed more often, will only compound problems that are contributing to the deterioration of the peat forest.

In short, The canals dug for use in controlling fires are problematic to the balance of the ecosystem in the area. To properly manage the park, a return to the historic natural water regime is needed. Any proposal to build additional canals for the purpose of fire control should not be implemented, as this will only increase the problems that already exist in the park.

Figure 8: Burned Melaleuca peat forest **Figure 9:** Fire consumed organic peat layer

V. CONCLUSION

The data presented in this report show that area of peatlands in Lower U Minh National Park has declined because of fires and human activities over the past several decades. We found a high of Carbon content stored in peatlands and consistent or conclusive differences in terms of C content in peatland of natural melaleuca forest and plantation melaleuca forest about thickness, % carbon, bulk density. And so there are significant differences in peat reserves and carbon density in peat per units hectare between natural Melaleuca forest and plantation Melaleuca forest.

Specifically, forest fires have caused and may continue to cause problems for peatland management and conservation in the study area recently. A canal system for fire control built in the peatland area has resulted in subsidence of peatland because of loss of water in dry season. Lower water level results in decomposition of peat materials and release high amount of carbon dioxides (CO_2) to the atmosphere.

Many aspects of both melaleuca and peatlands make them unique ecosystems. Improving their management, including wise use of resources, would enhance collateral benefits for both global and local communities.Below are some of our recommendations:

There is a need to develop a plan to access the current situation and comprehensively manage peatlands in the study area. Develop a sustainable plan to rehabilitate the Melaleuca peat forest by restoring the historic/natural water regimes. Reduce or eliminate the canals in the peat forests;Develop and implement fire management policies and strategies that support of land management policies; Educate the local residents about the importance Increase the awareness of local people on the importance of preserving the Melaleuca peat forest for it's biodiversity and wildlife benefits.

REFERENCES

[1]. ASEAN Peatland Forests Project 2010-2019. Distribution and Status of Peatlands in Vietnam http://www.aseanpeat.net/index.cfm?&menuid=123.

[2]. Billett, M., Charman, D.J., Clark, J.M., Evans, C., Evans, M., Ostle, N., Worrall, F., Burden, A., Dinsmore, K., Jones, T., McNamara, N., Parry, L., Rowson, J. & Rose, R. 2010. Carbon balance of UK peatlands: current state of knowledge and future research challenges. Climate Research, 45, 13-29. www.int-res.com/articles/cr_oa/c045p013.pdf

[3]. Couwenberg, J. & Hooijer, A. 2013. Towards robust subsidence-based soil carbon emission factors for peat soils in south-east Asia, with special reference to oil palm plantations. Mires and Peat, 12: 1–13.

[4]. Chambers FM, Beilman DW, Yu Z (2011) Methods for determining peathumification and for quantifying peat bulk density, organic matterand carbon content for palaeostudies of climate and peatland carbondynamics. Mires and Peat 7:1–10

[5]. FAO, 2014.Towards climate-responsiblepeatlands managementISBN 978-92-5-108546-2 (print). http://www.fao.org/3/a-i4029e.pdf

[6]. Fujimoto, K., Imaya, A., Tabuchi, R., Kuramoto, S., Utsugi, H. and Murosushi, T. 1999 Belowground carbon storage of Micronesian mangrove forests. Ecological Research 14: 409–413.

[7]. Hirano, T., Segah, H., Harada, T., Limin, S., June, T., Hirata, R., Osaki, M. 2007. Carbon dioxide balance of a tropical peat swamp forest in Kalimantan, Indonesia. Glob. Change Biol., 13: 412–425.

[8]. Hooijer, A., Page, S., Jauhiainen, J., Lee, W.A., Lu, X.X., Idris, A., Anshari, G. 2012. Subsidence and carbon loss in drained tropical peatlands. Biogeosciences, 9: 1053–1071.

[9]. IUCN,2017.Peatlands and climate changehttps://www.iucn.org/sites/dev/files/peatlands_and_climate_change_issues_brief_final.pdf

[10]. IUCN, 2011. Commission of inquiryPeatlands Published by the IUCN UK Peatland Programme ISBN 978-0-9570572-1-0 The report and associated Commission of Inquiry material can be downloaded from www.iucn-uk-peatlandprogramme.org.

[11]. International Peat Society, 2008. Peatlands and Climate Change. International Peat Society, Vapaudenkatu 12, 40100 Jyvaskyla, Finland.

[12]. JirenXu, Paul J.Morris, JunguoLiu,JosephHolden: 2018. PEATMAP: Refining estimates of global peatland distribution based on a meta-analysis, ISSN 0341-8162 Volume 160, January 2018, Pages 134-140. Copyright © 2019 Elsevier B.V. or its licensors or contributors. ScienceDirect ® is a registered trademark of Elsevier B.V. https://doi.org/10.1016/j.catena.2017.09.010.

[13]. Khanh, P. T., Subasinghe S.M.C.U.P. 2018. Identification of Vegetation Change of Lower U Minh National Park of Vietnam from 1975 to 2015. Journal of Tropical Forestry and Environment Vol. 7, No. 02 (2017) 10 -20. ISSN 2235-9370 Print / ISSN 2235-9362.

[14]. Komiyama, A., Ong, J.E. and Poungparn, S. 2008. Allometry, biomass, and productivity of mangrove forests: A review. Aquatic Botany 89: 128–137.

[15]. Moore, S., Evans, C.D., Page, S.E., Garnett, M.H., Jones, T.G., Freeman, C., Hooijer, A., Wiltshire, A.J., Limin, S.H., Gauci, v. 2013. Deep instability of deforested tropical peatlands revealed by fluvial organic carbon fluxes. Nature, 493: 660–663.

[16]. Murdiyarso., D, Donato, D.; Kauffman, J.B.; Kurnianto, S.; Stidham, M.; Kanninen, M. 2010. Carbon storage in mangrove and peatland ecosystems: a preliminary account from plots in Indonesia. Center for International Forestry Research (CIFOR), Bogor, Indonesia DOI:10.17528/cifor/003233.

[17]. Page, S.E., Siegert, F., Rieley, J.O., Boehm, H.-D.V., Jaya, A. and Limin, S. 2002 The amount of carbon released from peat and forest fires in Indonesia during 1997. Nature 420: 61–65.

[18]. Rodney A, 2014). Chimner&Cassandra A. Ott&Charles H. Perry&Randall K. Kolka, 2014. Developing and Evaluating Rapid Field Methodsto Estimate Peat Carbon. Wetlands (2014) 34:1241–1246DOI 10.1007/s13157-014-0574-6.

[19]. Sam Đ.Đ, 2011. Ước tính phát thải khí nhà kính từ sử dụng đất than bùn ở tỉnh Kiên Giang và Cà Mau. [Translate] Estimates of greenhouse gas emissions from peatland use in Kien Giang and Ca Mau provinces.

[20]. Worrall, F., Chapman, P., Holden, J., Evans, C., Artz, R., Smith, P. & Grayson, R. (2010b) Peatlands and climate change. Report to IUCN UK Peatland Programme, Edinburgh.www.iucn-uk-peatlandprogramme.org/scientificreviews

[21]. Yuanqiao Wu, Ed Chan2, Joe R. Melton3, and Diana L. Verseghy; 2017). A map of global peatland distribution created using machinelearning for use in terrestrial ecosystem and earth system models. Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2017-152

Phan Truong Khanh " Estimating of Carbon Storage of Peatlands and Main Hazards Related to the Utilization and Management of Peatlands in Lower U Minh National Park, Ca Mau Province, and Vietnam" The International Journal of Engineering and Science (IJES), 8.3 (2019): 23-29