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RESTORATION OF PEATLAND ECOSYSTEMS AND BIODIVERSITY IN U MINH REGION OF MEKONG DELTA, VIETNAM

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SUMMARY

Remaining petlands distributed mainly in U Minh region of Lower Mekong Delta and they have protected as national parks: U Minh Ha and U Minh Thuong National Parks. Since 2010, an appropriate management of fires and water has applied resulted in no forest fires and ecosystems restored significantly. Some previously species of fauna and flora, which disappeared due to forest fires and inappropriate management from 2002 to 2009, were recorded their back presence in 2014. The inventory showed total 14 species of animal and 17 species of plants, which are in IUCN and Vietnam Red Books, were restored in peatland habitats. Some waterfowls (Leptoptilos javanicus, Pelecaniformes, Plegadis falcinellus) have begun choosing peatland forest and grassland habitats as breeding sites. Peatland ecosystems showed the higher density of peatland Melaleuca forests, the lower the number of plant species and vice versa, which resulted in various plant biodiversity index (H') and species evenness (J'). Average H' value of very spare to spare Melaleuca forests varied from 0.78 - 1.70, and species evenness J' = 0.49 - 0.77, while seasonally inundated grasslands ecosystems increased significantly after applying appropriate management (H'= 0.43 up to 1.93 and J' from 0.42 up to 1.0). Restoration of Peatland Melaleuca forest plays an important role in carbon storage and absorbance of carbon dioxides from the atmosphere. The corresponding estimated carbon storage and Co_2-e in Melaleuca forests are of 27.80 tons/ha and Co_2-e is of 102.04 tons.ha^{-1}. Then the total amount of carbon storage and Co_2-e of melaleuca forest estimated are 318,949.949 tons and 1,170,546.312 tons in both national parks. An appropriate management of water and fires is one of the activities has resulted in the successful restoration of ecosystems and biodiversity in peatlands of U Minh region, and UMTNP recognized as ASEAN Heritage Park (2013) and RAMSAR site in 2015.

Keywords: *Peatland, carbon dioxide, ecosystems, biodiversity, Melaleuca*

INTRODUCTION

Tropical peatlands are widely distributed throughout Indonesia, Malaysia and several other countries in South East Asia. Peat swamp forests are unique habitats for flora and fauna, containing a high proportion of endemic species (Page *et al.,* 1999). Peat swamp forests are ombrotrophic wetland ecosystems that sequester carbon into vegetation and, especially, into peat below the forest floor. The woody peat formed in these ecosystems is rich in C (about 56 % on a dry mass basis) and the peat deposits can be several meters thick over vast areas, making tropical peatlands globally important C-stores (Page *et al.,* 2011). In addition, peatlands represent globally significant stores of soil carbon that have been accumulating for millennia and currently, peatlands globally represent a major store of soil carbon sink for carbon dioxide and source of atmospheric methane (Maria S., 2008).

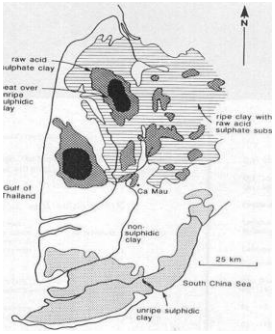

Figure 1: Two peatland areas remained in U Minh region, Lower Mekong Delta

A comparatively small area of peatlands in Vietnam compared to its regional neighbors. They were found in many parts, however mainly located in U Minh region (Fig.1) where was designed as two national parks: U Minh Ha National Park (UMHNP) and U Minh Thuong National Park (UMTNP). Inappropriate management resulted in large-scale peatland loss during past decades, estimated that more than 64,000 hectares of 1962 (VHP, 1974) down to 11,744.19 hectares of 2013 (Quoi, 2014), and ecosystems degradation of peatlands with major environmental and social impacts in U Minh region located in Ca Mau and Kien Giang Provinces.

Most of the peatlands in U Minh region were covered by Melaleuca and mixed forests, which are important natural ecosystems with high value for biodiversity conservation, climate regulation, and water supplies to communities in the dry season. The peatland complex ecosystems play a special role in maintaining biodiversity as a result of habitat isolation in U Minh region.

This paper, used data collected from APFP (2013), SEAPeat Project (2014) and SNV (2015), focuses on restoration of ecosystems and biodiversity resulted from reasonable hydrological management in peatland U Minh region, including UMHNP and UMTNP. Estimation of capable carbon storage and carbon dioxide equivalent (CO_2) absorbed from the atmosphere by forest also is discussed within.

METHODOLOGY

The multi-satellite imagery of SPOT 5 and Landsat TM7 (2006, 2009, 2010, and 2013) was used to identify the ecosystems and plant communities. The observation was conducted on a total area of 61,314.20 ha in peatland U Minh region, however, there were total 643 observed sites were done in two parks.

At each observation site, different size quadrats, of which 1 x 1m^2 and 10 x 20m^2 random quadrats for grasslands and forestlands respectively, were used to observe species occurrences, species dominant, parameters of forest trees (stem density, basal area) used to estimate the amount of carbon dioxide (CO_2) sequestration in Melaleuca forest.

Evenness of species by Peilon Method is applied, which given by J‘ = H/logS.

Species diversity in plant communities is calculated by biodiversity index (H') of Shannon - Weiner (1949).

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Dominant species is applied by Simpson's dominance index λ, which is given by

$$\lambda = \sum_{i=1}^{n} \left(\frac{ni}{n} \right)^2$$

To estimate carbon content and carbon dioxide equivalents (CO_2-e) absorption by forest, calculation was applied with following steps: average biomass, the amount of carbon stored in plant biomass per area, amount of CO_2 absorbed from the atmosphere by forest trees. The method of NIRI (Norman, 2015 after NIKI, 2001) was used to estimate carbon stored in the tree and CO_2 absorption from the atmosphere by forest.

RESULTS AND DISCUSSION

A large area of peatland was considered for satellite interpretation and the survey to record the presence of peatlands in U Minh region. Base on the result of satellite interpretation and on the ground surveys, once there was a wide distribution of peatland in U Minh region (61,314.20 ha), however, a large area of peatland was destroyed by human activities and natural factors, hence, there is the only small area of peatlands, with 9,174.37 ha, being present mainly in U Minh Ha region and UMTNP (Tab. 1). Except peatlands remained in the national parks, there is still a considerable area of peatlands in the buffer zone of UMHNP, with 2,296.57 ha, while only several small patches of peat soils were identified in that of UMTNP.

Table 1: The peatland areas in U Minh region, Lower Mekong Delta of Vietnam.

Peatland Sites	Previous peatland area (ha)	Remaining Peatland (ha)
U Minh Ha region (Ca Mau province)	35,654.20	5,943.04
U Minh Thuong NP (Kien Giang province)	25,660.00	3,231.33
Total	61,314.20	9,174.37

Ecosystems and biodiversity

From 2000 to 2002, the water level dropped more than 85 cm from soil surface in the dry season was main causes of forest fires resulted in damages of the large-scale area of peatlands that was about a quarter and two-third of peatlands in UMHNP and UMTNP respectively, which caused a forest ecosystems degradation and a significant decline of biodiversity (UMTNP, 2005, UMHNP, 2004).

Since the end of 2003 to 2006, in order to control the forest fires, the water level was kept high throughout the year has caused degradation of ecosystems and biodiversity, especially that of Melaleuca forest habitat in UMTNP. Under the advice of environmentalists and the consent of local authorities, an integrated management of water and fire has been applied in peatlands resulted in effectively restoring the ecosystem and biodiversity since 2010. Area of forest restored in both parks up to 13,564.03 ha, which was however not uniform in density. In UMTNP, Melaleuca forest restored up to 5,504.78 ha, and seasonally inundated grasslands, which disappeared after forest fires in 2002 and then affected by a prolonging high water level, restored significantly up to 765.32 ha (Tab. 2).

Table 2: Changes of ecosystems in UMTNP (Kien Giang Province) from 2006 to 2014

Ecosystems	The year of 2006	The year of 2009	The year of 2011	The year of 2014
	Area (ha)	Area (ha)	Area (ha)	Area (ha)
Melaleuca forests	3,904.16	4,440.87	4,460.78	5,504.78
Grasslands	2,772.50	0.00	1,447.69	765.32
Aquatic swamps	1,126.74	3,393.37	1,912.80	1,551.17
Tall grass - shrubs	141.80	142.55	142.55	142.55
Total area (ha)	7,945.20	7,976.79	7,963.82	7,963.82

Peatland ecosystems are restored simultaneously with the abundance of plant species recorded with 176 plant species (belonging to 62 families) in UMHNP and 254 species (belonging to 64 families) in UMTNP (APFP, 2013 and SNV, 2014). Some waterfowl *(Leptoptilos javanicus, Pelecaniformes, Plegadis falcinellus*) have begun choosing peatland forest and grassland habitats as breeding sites. The fragmentation of forests is a general consequence of forest fires and inappropriate management which has occurred in peatland forests, which were restored by planting, mainly Melaleuca, and natural regeneration resulted in the forest covered in various tree densities (Fig 2, Fig. 3, and Fig. 4).

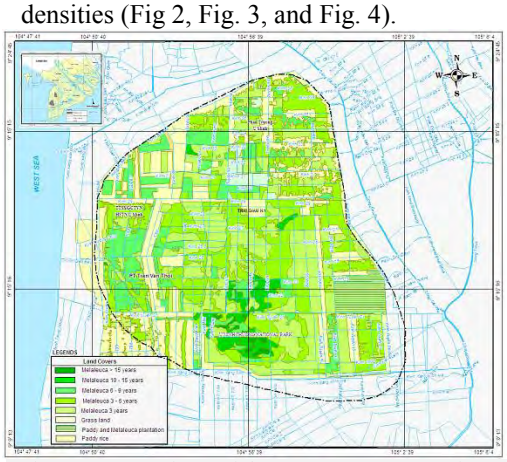

Figure 2: Forests in U Minh Ha area (Ca Mau Province)

Figure 3: Peatland forests in UMHNP (Ca Mau)

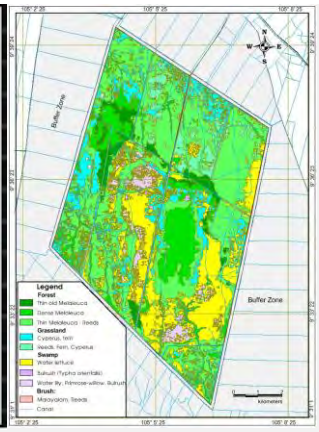

Figure 4: Peatland forests in UMTNP (Kien Giang)

The direct comparison of biodiversity among various forest densities that are from partial clearance to dense forests has received much attention. The high density of Melaleuca forest caused inadequate space and light indispensable for photosynthesis for other plants species developed. Therefore, the densities of Melaleuca forest affected to the number of plant species within it.

Numerical classification revealed a highly diverse pattern of variability in the forest examined. Most of forest plantation is single species forest by Melaleuca, while mixed forests in peat domes dominant by diversity of indigenous species of trees; therefore, value of biodiversity index (H') of mixed forests (H'= 0.85-1.27) in peat dome is higher than that of single Melaleuca forest (average H'= 0.53) (Tab. 3). Biodiversity index is quite low in dense Melaleuca plantation (H'= 0.17- 0.95) (Tab) while this value is high in dense natural Melaleuca forests in UMTNP (H' value is up to 1.75) (Tab. 4). The result showed the forests restored may deliver conserve levels of biodiversity but it rarely matches the composition and structure of the original forest cover in U Minh peatlands where the forest was fired completely from 2000 to 2002.

The analyzed data showed the number of plant species started increasing as the plant density below 4,600 trees.ha^{-1}. As forest tree density decreased simultaneously with the increase in a number of plant species, this resulted in the biodiversity index (H') in sparse to average density forests were higher than that in dense forest (Fig. 5, Fig. 6, Fig. 7, and Fig.8). The higher density of peatland Melaleuca forests, the lower the number of plant species and vice versa (see Fig. 5 and Fig.7). However, the highest number of plant species recorded was not more than 13 species at each observed plot in spare forest. The structural features of peatland forests are a greater abundance and diversity of lianas that could be caused by the competition of dominant lianas and herbaceous species of *Stenochloena palustris, Blechnum serrulatum*, *Cayratia trifolia* that thrived and then overrode other species.

Table 3: Ecosystems and Biodiversity Index in U Minh Ha National Park (Ca Mau Province)

Ecosystems	**No of sites**	**S**	**N**	**d=S/√N**	**H'**	**λ**	**J**
Dense forest	15	3 - 11	130 - 240	0.23- 0.86	0.17 - 0.95	0.00 - 0.06	0.10 - 0.52
Average forest	96	2 - 8	73 - 156	0.19 - 0.68	0.18 - 1.17	0.00 - 0.21	0.13 - 0.57
Spare forest	72	3 - 10	92 - 142	0.31 - 0,98	0.39 - 1.27	0.03 - 0.25	0.36 - 0.65
Very spare forest	278	3 - 13	11 - 112	0.34 - 1.44	0.08 - 2.20	0.13 - 0.97	0.08 - 0.92
Grassland	66	3 - 12	4 - 105	0.29 - 2.27	0.17 - 2.13	0.10 - 0.92	0.15 - 1.03

Table 4: Ecosystems and Biodiversity Index in U Minh Thuong National Park (Kien Giang Province)

Ecosystems	No of sites	S	N	d=S/√N	H'	ʎ	J
Dense forest	21	2 - 7	37 - 137	0.23 - 0.81	0.12 - 1.75	0.20 - 0.95	0.18 - 0.96
Average forest	22	3 - 8	48 - 140	0.34 - 0.85	0.81 - 1.81	0.18 - 0.38	0.51 - 0.96
Spare forest	14	4 - 7	66 - 122	0.41 - 0.74	0.57 - 1.63	0.23 - 0.56	0.92 - 0.41
Grasslands	35	2 - 8	11 - 64	0.26 - 1.05	0.91 - 1.58	0.24 - 0.94	0.21 - 0.98
Aquatic swamp	24	1 - 7	30 - 71	0.13 - 0.98	0.00 - 1.75	0.21 - 1.00	0.00 - 0.95

The transition from Melaleuca forest community to grassland community is very sharp due to the environmental condition. Some species of *Stenochloena palustris, Blechnum serrulatum* and *Phragmitex karka* were dominant in the grassland communities and *Stenochloena palustris* which had covered up to 75% of the grasslands. Due to grasslands recently restored and being competitive the dominant species of fern, therefore, biodiversity index varied from 0.17 – 2.20, and evenness of species was among species (J= 0.15 - 1.03). The high values of biodiversity index recorded in some areas of grasslands, where dominant by species of Cyperaceae (H' = 1.67 - 1.91). Swamps occupied by aquatic vegetation communities in various species. Some areas covered by very high density of species of *Typha angustifolia* or *Pistia stratiotes* (95% to 100%) that have very low biodiversity index (H'= 0.00 - 0.03), while the other aquatic communities have high diversity index (H‘ = 0.18 -1.75) and evenness (J = 0.21 – 0.95).

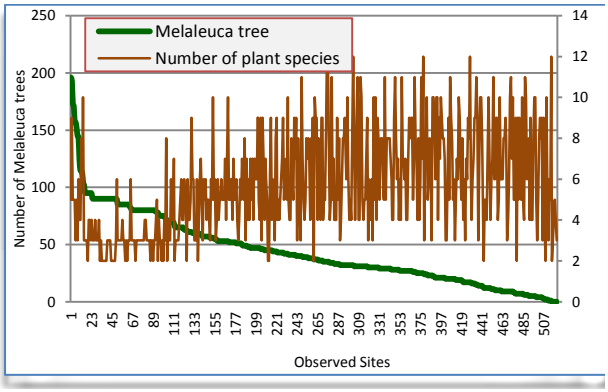

Figure 5: Densities of Melaleuca trees and a number of the plant species in peatland forests in UMHNP. (Ca Mau)

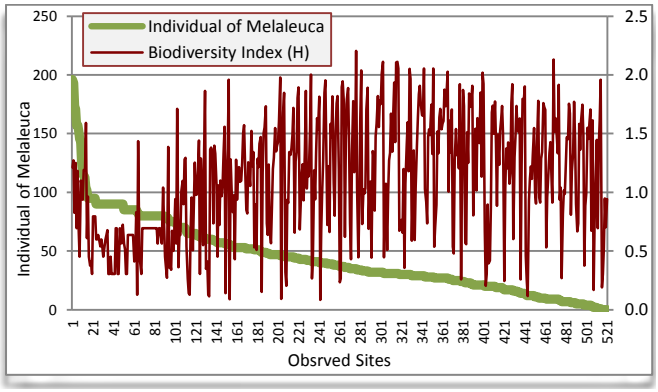

Figure 6: The density of Melaleuca forest and Biodiversity Index (H') in peatland forests in UMHNP.

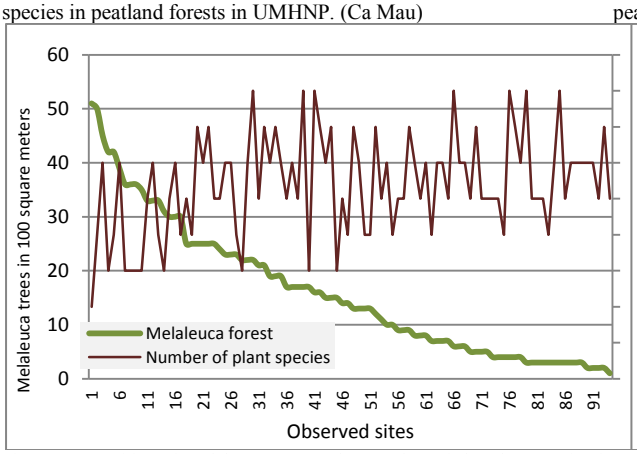

Figure 7: Densities of Melaleuca trees and a number of the plant species in peatland forests in UMTNP (Kien Giang province)

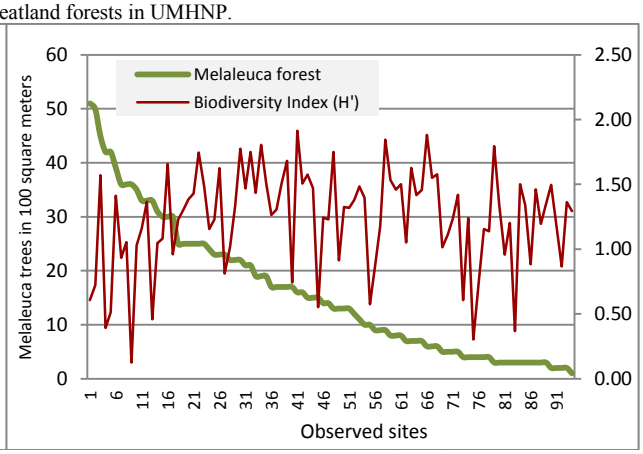

Figure 8: The density of Melaleuca forest and Biodiversity Index (H') in peatland forests in UMTNP (Kien Giang Province)

Carbon storage and carbon dioxide sequestration in peatland forests

Melaleuca forest and plantation dominated in both parks are generally dense and highly productive, and density-dependent mortality is to be expected by the park managers. Amongst other tropical forests, Melaleuca forest is carbon stores, and it is considered as carbon dioxide sinks when it has increased in the area. The Melaleuca forest density, which increased in middle age but decreased in mature age of trees, varied from 5,250 trees.ha^{-1} in dense forests and reduced gradually to 360 trees.ha^{-1} in the very spare forest, in which the different forest densities resulted in the various amount of forest biomass estimated (Tab. 4 & Tab. 5).

Total biomass estimated of Melaleuca forest and plantation, including above-ground biomass, roots, and the forest floor, is of 655,657.939 tons, in which total amount of carbon estimated is of 318,949.949 tons stored in

tree tissues and equivalent to 1,170,546.312 tons of CO_2-e sequestration in Melaleuca forests (Table 4, Annex 4 and 5). Due to forest areas has been restored in UMTNP since 2010, the total low biomass, which resulted in the lower amount of carbon and carbon dioxide than those in UMHNP. In UMHNP forest, the average carbon content stored is of 27.80 tons.ha-1 and equivalent to 102.04 tons.ha^{-1} CO_2-e in sequestration. Similarly, a study on carbon adsorption capacity of Melaleuca forests in UMHNP by Vinh (2013) showed average carbon content stored is of 26.90 tons.ha^{-1}.

Table 4: Carbon stored and carbon dioxide equivalent in sequestration in the forest for two parks.

Parameters	UMHNP	UMTNP	Total
Forest area (ha)	8,059.25	5,504.78	13,564.03
Total biomass (tons.area^{-1})	448,147.65	207,510.289	655,657.939
Carbon content (t.C.ha^{-1})	27.803	18.848	-
Carbon dioxides equivalent (tCO_2-e.ha^{-1})	102.038	69.173	-
Carbon content (tons.area^{-1})	218,929.320	100,020.629	318,949.949
Carbon dioxide equivalent (CO_2-e)(tons.area^{-1})	803,470.604	367,075.708	1,170,546.312

In the buffer zone, a land cover map showed Melaleuca covered in a large area; therefore estimates of 277,044.107 tons of carbon (equivalent to 1,016,751.872 tons of CO_2-e) were stored in the standing stock of plantation (Quoi, 2010). However, provincial forest report of 2010 showed a significant decrease of forest land that has been converted to agricultural land; therefore, this has resulted in decrease a large area of forest resulted in the decrease of the amount of C stock and CO_2-e sequestration in the buffer zone.

CONCLUSION

The peatlands remained only a relatively small area in the U Minh region, the Lower Mekong Delta. A significant area of peatlands was known as national parks aiming to conserve ecosystem and biodiversity of peatlands. Unsuitable water management, however, caused to peatland degradation resulted in serious damage to ecosystems and biodiversity. The water management in UMHNP peatlands has not been as expected. The water level dropped down deeper 85 cm from the surface in the dry season, which made it easier for forest fires and oxidation of peat materials.

Melaleuca forest covered predominantly in peatlands in both national parks, however, Melaleuca plantation dominated in the buffer zone of the UMHNP. High biomass estimated of Peatland Melaleuca forest resulted in a considerable amount of carbon and carbon dioxide equivalent sequestration. Thus, if the forest fire, there will be a large amount of carbon content loss and CO_2 equivalent released into the atmosphere.

The application of integrated management of water and fires in peatlands has restored ecosystems and biodiversity, and forest fire risks limited. The success of peatland management in UMTNP has been recognized as an ASEAN Heritage Park (AHP) in 2013 and Ramsar Site in 2015.

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