Evaluation of current situation of melaleuca forest in the U Minh Ha national park, Vietnam under the situation of climate change and proposed solutions for conservation and sustainable development

V H Thi Thanh1*, P P Vu Hoang1, K H Trong1, P P Ho Thanh1

1Hochiminh City University of Natural Resources and Environment (HCMUMRE), Vietnam

* httvan@hcmunre.edu.vn

Abstract: U Minh Ha National Park (UMHNP) is one of the important biosphere reserves in Vietnam, this park still has a pristine ecosystem like natural melaleuca forest on peatland in the core zone of UMHNP. Melaleuca forest is not only economic revenue for native people but also the habitat for all the species in UMHNP. However, facing to current climate change and fire prevention of UMHNP has made the growth of melaleuca forest get some negative effects. Melaleuca cajuput can grow in a wetland if the depth of water is not high and waterlogged duration is not last long. If the water depth is over 50 cm and waterlogged duration is more than 5-6 months the roots of this land will be damaged. Currently under the condition of climate change, in the dry season, the high temperature and prolonged heat make the herbaceous and liana vegetation die and form burning materials. Unevenly distributed rainfall combined with prolonged heat increases the risk of forest fire, especially in the last months of the dry season. To prevent forest fires, the U Minh Ha national management board always maintains high water levels in canals, maintaining high water levels for a long time reducing the risk of forest fire but also makes peat land dilated leads to the fallen of Melaleuca trees. At the same time, at the beginning of the rainy season, heavy local rainfall led to the phenomenon of alum in this area. This research has shown the current state of U Minh Ha National Park under climate change status and proposed some measures to help Melaleuca forest grows sustainably.

1. Introduction
U Minh Ha is one of the three remaining peat swamp forests in the Mekong Delta (along with U Minh Thuong in Kien Giang Province and Tra Su in An Giang Province). This is an essential protected area to ensure the recovery of endemic species of peat swamp ecosystems. The alum-flooded Melaleuca forest ecosystem is a highly endemic ecosystem with many species recorded in Vietnam’s Red Data Book.

U Minh Ha National Park is also considered a living ecology museum of plants in the freshwater ecosystem of the Mekong Delta region. Melaleuca forest in U Minh Ha - Ca Mau Province is not only a valuable resource to biodiversity but it is also one of the remaining carbon sinks and peat mines in Vietnam. This is not only a region of high diversity with its many extremely valuable endemic species, but it is also an area that serves as a carbon sink to mitigate climate change [1].
Many studies in recent years clearly show the impact of climate change has increased the risk of forest fires worldwide. The number of forest fires has increased almost three times since 1990\cite{2}. Studies of climate change models have shown that the risk forest fires increased by 50% in many places, sometimes even 2 to 3 times, mainly due to rising temperatures. Forest fire, under the impact of climate change, makes protecting the forest in general and protecting the Melaleuca forest ecosystem in particular face extremely difficult challenges not only for managers but also for researchers. This is also a direct threat to the Melaleuca forest ecosystem of U Minh Ha National Park. Besides, changes in microclimate factors will negatively impact the development and growth of U Minh Ha forest.

2. Area and methodology

2.1. Research Area
U Minh Ha National Park is located in the southern part of Ca Mau Province, 30 km north of Ca Mau City. Covering the area of 8527.8 ha, U Minh Ha National Park is located in the territory of the 2 districts U Minh and Tran Van Thoi.

Geographical coordinates:
- From 9°12’30” to 9°17’41” north latitude.
- From 104°54’1” to 104°59’16” east longitude.

2.2. Methods of data collection
Collect secondary data about:
- The ecological situation, natural and environmental factors in U Minh Ha National Park.
- Current status of Melaleuca forest in U Minh Ha National Park.
- Thickness and distribution of peat layer, maintenance water level and plan to maintain the water level in U Minh Ha National Park.

The survey, verify and quickly assess forest ecological status\cite{3}:
- Make plans with the support from forest rangers, technicians and staff of U Minh Ha National Park to accurately identify the locations affected by fires, areas of biodiversity and endemic species.
- Carry out quick inspection by monitoring sections with a below 100m flying system
- Conduct a short-term survey at affected sites. Collect information on the environment, flora, soil, and water.
- Time for conducting the survey: 7/2018.

2.3. Data analysis
Microsoft Excel was used as tools to synthesize, analyze, calculate data and graph.

3. Results and discussion

3.1. Biodiversity

3.1.1. Plants. U Minh Ha National Park has 249 plant species belonging to 82 families. Among them, the ones with most abundant species are Cyperaceae (29 species), Poaceae (27 species), Asteraceae (19 species), Rubiaceae (10 species), Amaranthaceae (8 species) (Refer table 1). However, most of this group is composed of herbaceous plants which are mainly concentrated in the forest floor which are mainly represented by two types of habitats (wetland savana and canal) and water canal (11% of the national park area). The rest of the national park is the habitat of Melaleuca cajuputi (89% of the national park)\cite{1}. 

2
Table 1. A table with number of species of plant families in U Minh Ha National Park.

| No. | Family               | Number of species | Quantity |
|-----|----------------------|-------------------|----------|
| 1   | Cyperaceae           |                   | 29       |
| 2   | Poaceae              |                   | 27       |
| 3   | Asteraceae           |                   | 19       |
| 4   | Rubiaceae            |                   | 10       |
| 5   | Amaranthaceae        |                   | 8        |
| 6   | Euphorbiaceae        |                   | 6        |
| 7   | Myrtaceae            |                   | 6        |
| 8   | Convolvulaceae       |                   | 5        |
| 9   | Cucurbitaceae        |                   | 5        |
| 10  | Acanthaceae          |                   | 5        |
| 11  | 72 other families    |                   | 129      |

(Source: Ca Mau Province Environmental Planning Report, 2008)

The group of plants indicating acidic soils such as Eleocharis ochrostachys or Phragmites karka dominates in the group of plants under the understory layer. Besides, vines which are able to grow on the cajuput bodies such as Stenochlaena palustris, Cayratia trifolia also grow very well under the forest canopy. The initial assessment of the research team when observing from the fire station in the National Park area shows that the forest canopy composition has high uniformity in each area. The structural characteristics of the melaleuca forest are quite consistent with each region through forest management and rehabilitation as a basis for this result. Forest canopy is structured by Melaleuca in the process of new recovery and development, the canopy layer is mainly composed of perennial Melaleuca groups.

Melaleuca forest is planted on 7051 ha of acidic soil and natural Melaleuca forest on peatland covers an area of 1289.6 ha. At the time of the survey, in June 2018, this is the time of the first phase of the rainy season, almost all the areas have high humidity (> 80%, measured at 12 pm). However, on the cajuput bodies, there are vines of herbaceous which are dead from the lack of water in the dry season. The system of wind and swirls in increasing intensity, as well as the dramatic increase in density of vines climbing the Melaleuca trees, are the basis for the process of collapsing Melaleuca forests on peatland, which originally has a weak ground platform.

The flora of U Minh Ha National Park shows the characteristics of Melaleuca forest ecosystem on alum submerged land. In the process of restoration, Melaleuca is the only species that has reduced the competitiveness of other woody groups but created a living space for vines species and ferns. The new Melaleuca forest ecosystem will create new carbon pools for sedimentation and future peat regeneration, contributing to climate change mitigation.

3.1.2 Animal

Based on the reports, U Minh Ha National Park has 36 mammal species belonging to 13 families and 8 orders. There are 10 amphibian species belonging to Anura and 3 families. There are 37 reptile species belonging to 2 families: Squamata and Testudinata. The National Park has 37 species of fish belonging to 19 families (Refer table 2). Two species of fish, Clarias batrachus and Chitala ornata, are in the Red Data Book of Vietnam and are at the T level (threatened) [1].
Table 2. A table with animals in U Minh National Park.

| Class      | Number of species | Number of families | Number of orders |
|------------|-------------------|--------------------|------------------|
| Animal     | 23                | 12                 | 7                |
| Birds      | 91                | 33                 | 15               |
| Reptile    | 36                | 16                 | 3                |
| Amphibians | 11                | 5                  | 2                |
| Total      | 161               | 66                 | 27               |

(Source: Ca Mau Province Environmental Planning Report, 2008)

3.2. Climate change situation in Ca Mau province

Based on scientific studies, the Mekong Delta is extremely sensitive and vulnerable to climate change. According to the 2016 RCP8.5 scenario, the average increase in temperature in the Mekong Delta is around 3.0 - 3.5°C. If the sea level rises by 100cm, 38.9% of the Mekong Delta area will be flooded and the damage will be extremely high without the adaptation measures and mitigation of climate change impacts (RCP8.5: ink sea level rise from 51-106cm) [4]. Ca Mau is affected by almost all impacts from climate change through all manifestations, in which extreme climatic phenomena are likely to have the greatest impact including droughts and floods.

3.3. Melaleuca plant physiology in the state of climate change

3.3.1. Melaleuca tree physiology. *Melaleuca cajuputi* is a species with a wide ecological range. *Melaleuca* usually grows well in estuarine, coastal and moist tropical areas. The maximum average temperature for *Melaleuca* to grow well is 31-33°C and the average minimum temperature is 17-22°C, the average rainfall is about 1300 -1700 mm a year. *Melaleuca* is a perennial plant that likes light and thin canopy [5]. For heavy alum areas like U Minh Ha National Park that is a wetland area with the long dry climate in the hot season, melaleuca is almost the only species that can adapt [5]. *Melaleuca* tolerates acidic soil conditions but do not really grow in alum conditions due to the decline in the absorption ability of their root in soil with a lot of H+ ion [6]. *Melaleuca* is submerged but would be inhibited if the water level is too high and the duration of flooding is too long. *Melaleuca* trees grow normally on shallow submerged alum soil below 50 cm and the annual flooding period does not last more than 5-6 months over 70 cm and when the annual flooding period lasts more than 8 months, the growth of Melaleuca begins to be inhibited. The growth of melaleuca is clearly affected in deep-water environments and year-round flooding. [6]

Plants that have been inundated for long periods of time can damage the root system [7], which leads to a lack of oxygen exchange [8]. *Melaleuca* roots are flooded from 2 to 4 months does not prevent Melaleuca from growing normally. From 4 - 8 months, it will grow slowly and over 8 months the *Melaleuca* can be degraded [9]. *Melaleuca* has the ability to withstand the harsh conditions of the environment through a very long time of evolution and natural selection.

3.3.2 Climate change affects the growth and development of Melaleuca trees

3.3.2.1. Rising temperatures. Studies of meteorological models warn droughts to be more severe in coastal areas during the dry season. Moreover, the highest average temperature during the dry season will increase from 33-35°C to 35-37°C. This will increase the evaporation process in wetlands and increase the evapotranspiration through the leaves of the *Melaleuca* forest ecosystem. This process will quickly deplete the area's water resources, increase the risk of fire and reduce firefighting capacity because of the low water level at the end of the dry season and at the beginning of the rainy season [10]. An increased of temperatures increase the possibility of lethality in plants and therefore, increase the amount of combustion material. In addition, the depletion of water will cause potential alum layers to
be activated, making the soil become more acidic, leading to a decrease in plant growth, reducing the viability of aquatic and animal species and harm the terrestrial animals.

3.3.2.2. Unevenly distributed rainfall
Studies have warned of an increase in high-intensity rainfall and long-term droughts along with a decline in early rainfall of about 10-20%[11]. Combined with the process of heat enhancement, the region will face an inevitable demand for storing water. The process of storing water combined with locally heavy rain will cause alum phenomena to increase the toxicity of soil and water in the region. Increasing alum and reducing pH in the area will cause *Melaleuca* to be inhibited and difficult to grow.

The El Niño phenomenon also significantly affects the groundwater and the risk of forest fire on peatland, especially in the dry season, the decrease of more than 40 cm below the ground increases the likelihood of forest fires. With the increasing frequency of El Niño phenomena, there will be a great risk for the region in general and for the *Melaleuca* forest ecosystem. Because U Minh Ha National Park has the advantage of being located inland and with the surrounding dike system, it is not affected by the influence of saltwater intrusion. At the same time, U Minh Ha National Park can actively regulate water resources as a major advantage to the region's climate change. However, climate change still leads to a lack of water in the dry season, a combination of prolonged droughts and horizontal drainage of peat on a large scale due to the extensive canal system that will cause water loss in the area to happen extremely fast. As a result, peat soil will become dry and more likely to lead to forest fires. To prevent forest fires under climate change conditions, U Minh Ha National Park still must maintain high and prolonged water levels. This, although helping U Minh Ha National Park to prevent fire more effectively, bring along the downside of the ecosystem, especially *Melaleuca* forests, being badly affected.

The survey found that the prevention of the National Park from being affected the hazards of forest fire was carried out from the beginning of the rainy season when the water level in the canals was still high at the time. Water level monitoring and evapotranspiration indicators are taken very seriously. Through this, the fire prevention and fighting capacity of the area is very high, and the issues of planting and regenerating are also carried out continuously for many years to increase the resistance of *Melaleuca* forest ecosystem.

The survey showed that areas of heavy acidic soils (pH <4.5) were periodically flooded and suffered from the lack of oxygen for long periods of inundation due to water retention to preserve the forests. There is an area that holds water for up to 8 months due to the low and potentially fire-prone area characteristics that are no longer an appropriate ecological environment for young Melaleuca trees. This makes the amount of regenerated melaleuca and young trees become very limited, the possibility of encountering young melaleuca forests is almost nonexistent. The empty area filled with dry clay due to past fires has led to the inhibition in the development of the plant groups, herbaceous plants and vines always exist in the form of dry and fresh plants in high density creating the ability to provide materials for high fire which makes the fire difficult to extinguish if it breaks out. Although the National Park has now managed to control the problem of a forest fire, the potential threats to the preservation of the ecosystem of the National Park pose new challenges, especially in the context of climate change.

3.4. Solutions for conservation and sustainable development of Melaleuca flora

3.4.1. Management solutions. Enhancing the knowledge of local people and officials on ecology and factors that affect *Melaleuca* forests in order to raise support and agreement with the people in the process of forest development and preservation. Improving the management capacity of the national park not only for forest fire prevention but also in the process of advocacy and development of the ecosystem with a regard to the lives of the people in the region.

Combining community interests and the benefits of the Park, strengthening cooperation between the Park and the people and sharing the responsibility of keeping forests with the people to ensure the harmony and sustainability of the combined forest fire prevention and biodiversity conservation.
3.4.2. Technical solutions

U Minh Ha National Park needs to study solutions to manage and regulate water resources in the direction of combining biodiversity conservation and forest fire prevention. Applying research and technology techniques to manage the process of ecosystem development in combination with operating models of water management domestically and internationally to find the most suitable solution for the Park. Generally evaluating and constructing irrigation works to ensure adequate water for fire prevention and fire fighting as well as the distribution of water resources in accordance with the development cycle of Melaleuca forest ecosystem.

Combining the process of reforestation on rehabilitated forest parts with ecological support for natural areas to protect the biological integrity of the ecosystem. Evaluating the process of recovering or reducing the thickness and distribution of peat soil as well as studying the ability to recover peat layer to increase the ability to absorb and retain water for the region through ecological measures. Study the possibility of planting a special protective forest layer around the core zone to protect the natural Melaleuca forest ecosystem on peatland.

4. Conclusion

Melaleuca trees can tolerate and adapt well as well as wide ecological amplitude, but the thickness of peat layer, the level of water, and the duration of flooding still pose a significant influence on the growth and development of Melaleuca trees. In the face of the risk of climate change and the pressure of increasing forest fire potential resulting from climate change, sustainable measures should be taken in the process of forest fire prevention and fire fighting. In which, technical measures need to have agreement and support of the people, so the measures applied to manage forests and increase awareness of the people are put in the top priority.

Facing the situation of climate change and the risk of loss of Melaleuca forest ecosystems along with the re-release of sediment carbon in peat soil, measures to keep forests and develop forest ecosystems in harmony with fire prevention and fighting capabilities by the canal system should be studied and proposed. The management of water resources becomes important and requires practical research and application to ensure the effectiveness and sustainability of forest fire prevention and control and to ensure the role of the National Park as a biodiversity conservation area.

Acknowledgements

This research was supported by the Ministry Project, Project Number: TNMT.2018.05.10 from the Ministry of Natural Resources and Environment and Mr. Nguyen Tan Truyen, U Minh Ha National Park, Ca Mau for his support during the work.

References

[1] Vietnam Environment Protection Agency 2003 Report on peatland management in Vietnam, Ministry of Natural Resources and Environment p 16

[2] Johann G G and Nikola N 2009 Proc. of the European and Mediterranean Workshop Climate change impact on water-related and marine risks (Murcia) p 26

[3] Ramsar Convention 2006 Guidelines for the rapid ecological assessment of biodiversity in inland water, coastal and marine areas. Secretariat of the Convention on Biological Diversity (Montreal, Canada, CBD Technical Series no. 22 and the Secretariat of the Ramsar Convention, Gland, Switzerland, Ramsar Technical Report no. 1)

[4] Ministry of Natural Resources and Environment 2016 Climate change and sea level rise scenarios for Vietnam p 187

[5] Hong T T T, Long N B, Ni D V and Be N V 2015 Can Tho Uni. J. Sci. 40 92
[6] Nguyen N T, Saneoka H, Suwa R and Fujita K 2009 *Trees*. **23** 649
[7] Crawford R M M 1992 *Adv. Ecol. Res.* **23** 93
[8] Armstrong W, Brandle R and Jackson M B 1994 *Acta Bot. Neerl.* **43** 307
[9] Anh N N 2005 *Proc. on Hydrology of the Mekong Delta and its relationship with forest fire management on wetlands/ Managing water and fire in flooded special-use forests with Melaleuca forests in the Mekong Delta* p 26
[10] Tuan L A and Suppakorn C 2009 Climate change in the Mekong River Delta and key concerns on future climate threats. *DRAGON Asia Summit*, Seam Riep, Cambodia p10.
[11] Peter C and Greet R 2008 *Climate Change & Human Development in Vietnam: A case study for the Human Development Report 2007/2008* (Oxfam and the United Nations Development Programme) p 25