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RESEARCH, PROPOSE THE SUITABLE WATER REGIME FOR DEVELOPING REGENERATED MELALEUCA FOREST IN U MINH THUONG NATIONAL PARK

Major : Soil and water environment

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Introduction

0.1 The necessity of the research

In March 2002, there was a fire in the core area of U Minh Thuong National Park, the total area of fire was 3.212ha. The natural features of the area with prolonged dry weather, forest land with many flammable materials, the forest always has a high risk of fire.

Since the forest fire up to now, due to the water regime management keeping up at high levels in the long-term to prevent forest fire that maked a change in the habitat gradually, the ecosystems under the forest canopy changed. Therefore, the task of water management is very important for developing Melaleuca forest ecosystem after fire. Water management is to perform a series of action to control water at a suitable level that facilitates the development of plant and animal species, helps melaleuca trees and other plants develop normally in the ecosystem nevertheless, these actions must meet the criteria for forest fire prevention, fire protection and proper habitat maintenance.

Research on the formation and development of Melaleuca forests, especially after fire, shows that U Minh Thuong National Park cannot be well protected without good water management. So that the implementation of this research is very necessary in the present time.

0.2 Objectives, subjects and scope of research

a) *Objectives of the research*

- Evaluate the growth of regenerated Melaleuca forests at various submerged levels since forest fire up to now.
- Determine the suitable water regimes to develop regenerated Melaleuca forests and prevent forest fire in the National Park.
- Propose the appropriate water management solution for the

core zone of the National Park.

b) *Subject of the study:* The research subject of the dissertation is the suitable water regime for developing regenerated Melaleuca forest after fire in U Minh Thuong National Park.

c) *Scope of the research:* The area of regenerated Melaleuca forest with burning area in 2002 is 3.212 ha, located in the core zone of 8.003 ha of U Minh Thuong National Park.

0.3 The approach of the dissertation

Approach through forest management practices; Approach inheritance of scientific and technical results, the existing databases; and approach through water management methods on the principle of integrated use.

0.4 The scientific and practical meaning of dissertation

a) *Scientific meaning:* Address the major issue of water regime and ecosystem habitat on typical seasonal inundated peatlands. Research results contribute to the protection and sustainable development of Melaleuca forests in U Minh Thuong National Park.

b) *Practical meaning:* The research results offer managers more information on sustainable development in U Minh Thuong National Park. Propose the suitable water regime, suggest the irrigation system and structures to the consultants for having more data in water management properly with the current habitat of National Park. The research results can be consulted for management in others National Park with the same condition.

0.5 The new contributions of the dissertation

Determine a pratical water regime for developing regenerated Melaleuca forest on peatland in U Minh Thuong National Park as a basis for regulating water regimes reasonably. The results are simulated by using the visual map "*Area distribution according to* *suitable wetland habitats*".

Select the appropriate starting times for suitable water regimes throughout the year, based on the calculation of rainwater resources with different rainfall frequencies. The water storage period is determined annually from September 11th for the year of low water (frequency of 75%), from October 1st for the year of average water (frequeny of 50%) and from October 21st for the year of high water (frequency of 25%). Initially, a suitable water management solution was proposed to develop the core area of Melaleuca forest in the National Park.

The results of the dissertation on the reasonable management of water regimes for regenerated Melaleuca forests in U Minh Thuong National Park have raised the issue of water regulation for the Melaleuca forests of the South Vietnam to a higher level, to solve well the ecological environment for developing Melaleuca forest ecosystem and avoiding forest fire in the dry season.

Chapter 1

Literature review

1.1 Natural characteristics

The study area is in the tropical monsoon climate region with high temperature throughout the months of the year. Rainfall is distributed unevenly, resulting in 5 dry months and 7 wet months. From these climate features, in low-lying terrain conditions formed the typical forest land ecosystems with seasonal flooding.

1.2 The water regulating system

The system of structures in the National Park is underdeveloped so there is no coordination of synchronous water regulation, leading to high water levels in the forest.

1.3 Water management in U Minh Thuong National Park

Fresh water for growth and forest fire protection is identified primarily from rainwater. Therefore, the solution for storing fresh water in the National Park is very necessary. Due to the uneven terrain and the one-step water management at high levels in the period of 2002-2009, some lowland areas were inundated deeply. Water management in the core zone of the National Park from 2010 up to now has been transformed by the partition of three separate zones for management by elevation (Zone A, zone B, and zone C).

- *Assessment of the practical water management*

Water levels data collected from the U Minh Thuong National Park Management Board [3] [20] [32] [38] are divided into 3 different periods for evaluation: Prior to the fire incident in March 2002; after forest fires until the end of 2009; from 2010 to 2016. The collected result is the average monthly water level $\overline{h}_{th}$ (cm) over time. The data are transferred via the comparison is national height at Hon Dau station.

Water management before 2002: The highest water level is $\overline{H}_{max}$=154cm, equivalent to 1.820 ha (≈22% area) is not submerged all year round. Lowest water level $\overline{H}_{min}$=87cm corresponding to 2.375ha (≈30% area) submerged all year round; Thus, there will be 3.808ha (≈48% of area) seasonally inundated. Average water level $\overline{H}_{nam}$ = 132cm, nearly equal to the average elevation Z_{tb} = 133cm. The period that the water level is below the average elevation is 6 months.

Water management since 2002 has changed considerably compared to before the forest fire, and water levels are much higher. Demographically, the flooding area year-round increased from 30%

to 50% (2003-2009) and remained at 44% (zone C) (2010-2015). There is almost no time that the water level is below the average elevation.

➢ *Determine the water loss in Melaleuca forests*

Results from the literature [18] have identified the water evaporation and leakage in the melaleuca forest in 5 dry months is 51,4 cm. If subtracting the rainfall, the water level decreases in 5 dry months ≈32cm. According to the formula (1.1), calculate the correlation through evaporation, the water depreciation in the rainy season will be 2,77mm/day (without precipitation).

1.4 Researches relating to water regime and ecological environment

The study of the dissertation is the suitable water regime for the requirements of ecological environment and forest fire prevention, therefore the researcher mentioned the results of related researches: Hoang Van Thang, Le Dien Duc [30] " wetland classification system of Vietnam "; CARE [3] "Integrated research on many topics such as ecological environment, vegetation, animals, land, hydrological regime ..."; Le Minh Loc [12] "Rapid assessment method of biomass and impact of inundation depth on Melaleuca forest biomass on peat and alum soil"; Pham Xuan Quy [19] "Study on some silviculture characteristics of Melaleuca cajuputi in Mekong Delta"; Pham Trong Thinh [34] "assessing the impact of forest fires on U Minh Thuong National Park"; Vuong Van Quynh [18] "the measures to prevent and overcome the consequences of forest fire for U Minh area"; Vuong Van Quynh, Tran Van Thang, Tran Quang Bao [20] [1] "water management for forest fire prevention and conservation in U Minh Thuong National Park" and "appropriate flooding regime to ensure fire prevention and maintain the development of Melaleuca forests in U Minh Thuong and U Minh Ha National Park"; Luong Van Thanh, Pham Van Tung [26] "Review, ecological overview of U Minh Thuong National Park and recommend the conservation solutions"; Trần Văn Thắng [32] "influence of flooding regime on vegetation at U Minh Thuong National Park"; Pham Trong Thinh [36] "Planning for conservation and sustainable development of U Minh Thuong National Park until 2020"; Some studies on the growth of Melaleuca trees by Phung Trung Ngan and Chau Quang Hien [15], Ho Van Phuc [21], Nguyen Thanh Binh [2], Pham The Dung and Vu Dinh Huong [6]; Richard B. Primarck [22] "biological basis of conservation"; Markus Schmidt, Helge Torgersen, Astrid Kuffner and others [16] present "global perspective on biodiversity"; Doran, J.C. and Gunn, B.V. [45] "study on the distributional and ecological features of melaleuca trees"; Smathi [57] [58] "Study on structure and growth of Melaleuca forest"; Yamanoshita Takashi [59] "Study on the effect of environment on the growth of Melaleuca forest"; Takeshi [60] "Research on Melaleuca forest biomass".

1.5 Evaluate the overview part

Terrain elevation in the core zone of the National Park varies unevenly, the elevation difference between large areas is a difficult condition for the water regime management. The dry season has almost no rain, with a large amount of evaporation, which leads to high water demand.

An analysis to clarify the current water management situation in the National Park was conducted prior to the forest fires up to now. The results show that water management after fire is keeping at a very high level. Water regime has changed the proportion of submerged area corresponding to year-round floodplain habitats predominate, the seasonal floodplain habitat has been reduced and the average inundated time in the year has increased.

There are many studies related to water regime and ecological environment in the National Park. Some of the studies refer to water regimes for forest fire prevention but have not come to the end or are not satisfy. A number of studies have proposed a system of structures to regulate water regimes but have not yet elaborated the scientific basis for construction, positioning and technical calculation. Therefore, the researcher has found that further research is needed to more clarify the water regimes for regenerated Melaleuca forests in National Park, including: water levels in the forest by the space and over time of the year; water resources from rain to meet water demand; the time of the year begins to accumulate rainwater and the limitation of water storage; and system of structures with management solutions to regulate water appropriately for the National Park.

Chapter Two
Methodology and research contents

2.1 Research contents

Study to determine the reasonable water level in space (each zone in the National Park) and time of the year; Research on rain water resources to meet water demand in the year; Research to identify the times of the year to begin storing rain water to obtain a suitable water regime; Study system of structures and management solutions for regulating water regime reasonably.

2.2 Methodology

2.2.1 Research to evaluate the silvicuture characteristics of rehabilitated melaleuca forests in U Minh Thuong National Park

➢ *Scientific basis of silvicultural surveys and measures*

To facilitate the determination of the regeneration capacity of Melaleuca forests, in this dissertation, it is divided into 3 levels of influence of submerged to survey are: 0 ÷ <30cm; 30 ÷ 60cm; and> 60cm. [1] [2] [12] [20]

According to [28] [29]. In this dissertation, the focus is on conducting research on "capturing the growth condition, the growth and development regulation as well as the productive capacity of forests". Indicators to be conducted: specify sample plots, forest density, standard trees; forest reserve; forest biomass. Survey to measure the individual trees in sample plots: determine the average tree height, the average canopy diameter ($D_{tán}$), the average stem diameter at 1,3 m ($D_{1,3}$).

➢ *Method for silvicultural surveys and measures*

- Divide the regenerated Melaleuca forest according to the submerged depth;
- Define sample plots: Select the sample plots density is 15 plots, corresponding to 3 submerged levels (5 sample plots for one inundated level), area of 500m^2, size 20x25m. Determine the peat layer thickness of each plot.
- Investigate the individual trees and analytical trees: the stem diameter at 1,3m ($D_{1,3}$); the tree height (H); the canopy diameter ($D_{tán}$); Fresh biomass: shell, unshelled wood, branches, leaves, roots.

(*Note*: $\overline{H}$ *(m)* is the average tree height in the sample plot; h_i *(m)* is the height of the ith plant of the sample plot (i belongs to domain n);

n (tree) is the total number of trees in the sample plot; *N (tree/ha)* is the density of forest; n_{otci} *(tree/ha)* is the density of trees in the sample plot i[th]; n_i *(tree)* is the number of trees in the i[th] sample plot (i belongs to domain a); *a (plot)* is the number of sample plot; s_i *(ha)* is the area of the i[th] sample plot; $\overline{V}$ (m^3) is the average volume tree, $f_{1,3}$ is the coefficient of trunk figure at chest height).

- Determine average tree height: $\overline{H} = \frac{\sum_1^n h_i}{n}$ (2.1)
- Determine the average canopy diameter (Dtán)
- Determine the average trunk diameter at 1,3m ($D_{1,3}$)
- Determination of forest density: $N(cây/ha) = \frac{\sum_1^a n_{otci}}{a}$; $n_{otci}(cây/ha) = \frac{n_i}{s_i}$ (2.2)
- Define forest reserves: M (m^3/ha) = N. $\overline{V}$ (2.3)

  $\overline{V}(m^3) = \frac{\Pi}{4}.\overline{D}_{1,3}^2.\overline{H}.f_{1,3}$; $f_{1,3}$=0,45 (2.4)
- Identify standard trees.
- Study the Melaleuca forest biomass through collecting data in 15 sample plots at different submerged levels. Building relationships between biomass components with $D_{1,3}$ based on the 8 default regression functions in statistical software Statgraphics Centurion XVII. From there, choose the most appropriate correlation function to calculate.

2.2.2 Research the water management plan

➢ *Water management based on the current infrastructure plan*

Maintaining the plan status with the current infrastructures to find a reasonable water management option is always a priority. However, as analyzed in the sections 1.2 and 1.3, the National Park has a system of structures that does not meet the requirements. The National Park has changed in terms of subdivision, water management but not yet effective. Therefore, it is necessary to adjust the subdivision and add the structures for water regimes management more rational.

➢ *<u>Reasonable water management based on the re-selection of subdivision option and supplementation of infrastructures</u>*

Redistricting of forest management zone and supplementation of infrastructures for rational water management is necessary in the coming time in U Minh Thuong National Park. The task is to overcome the limitations that the current infrastructure system does not meet requirements for the growth of melaleuca trees, the conservation of biodiversity and forest fire prevention.

2.2.3 Research to determine reasonable water regime

➢ *<u>Scientific basis for determining the reasonable water regime</u>*

Based on the actual requirements of water management at National Park, the identified water regime should meet a number of specific requirements:

- For the growth of melaleuca trees: the flooding water level shall not exceed 40-60cm and the maximum flooding time shall not exceed 6 months/year.
- Conservation of biodiversity. The habitat is not flooding year-round by 20% of the area; seasonal flooding of 50% of area; year-round flooding of 30% of the area; the period that water level is under average elevation is over 6 months/year. The period that water level lower 30 cm than the peatland surface is no more than 3 months continuously each year.
- Water management for forest fire prevention: the underground water level at the driest time must be kept at a distance of ≤ 50cm from the ground surface and the proportion of areas with high risk of fire shall not exceed 20% of the area.

Scientific basis for choosing the hydrological calculation data:

There is no meteorological station in U Minh Thuong National Park area. Therefore, the author selected Rach Gia station about 46km away from study location with data series for 31 consecutive years (1985 ÷ 2015) for calculating.

➢ *Methodology to determine proper water regime*

- *System Analysis Method*: Using the systematic analysis theory in analyzing and evaluating the research object as an overall object composed of many components and elements that are interrelated with each other and with the environment in a complicated way.
- *Statistical analysis method in hydrology:* The method for calculating precipitation corresponding to design frequencies by Pearson III, has been written into software and is now widely used.

2.2.4 Research to propose the system of structures and management solution for regulating water regime

➢ *Scientific basis for suggesting the system of structures*

In order to regulate the water regime reasonably, there should be an irrigation system as a supporting tool. Responsibilities: extra water drainage; Water storage in the area according to the suitable water regime; Water regulation reasonably between zones; The structures must be environmentally friendly, limiting the change of natural landscape, not losing the typical ecological features, easy to build, easy to manage and operate.

➢ *Method for hydrological calculation*

According to the QP.TL.C-6-77 "Rules for the calculation of design hydrological features", the relationship between the total volume W (m^3) and the flow rate Q (m^3/s) is:

$W = 86400\sum^{t_2} Qi$; $W_P = 10^3 H_P . \varphi . F$; $Q_P =$ (2.15) (2.16) (2.17)

➢ *Hydraulic calculation methods for determining the size of* *structures*

Determine the sluice aperture: Using hydraulic curriculum published by Water Resources University (2005), the formula for calculating flow rate through sluice (for inundated flow regime sluice). The formula looks like this:

$$Q_C = \mu .\ \omega_d . \qquad (m^3/s) \qquad (2.18)$$

Determination of spillway size: Use of Hydraulic regulation of spillway QP.TLC-8-76 of Ministry of Agriculture and Rural Development (applicable to free flow regime). The formula looks like this:

$$Q = mb\sqrt{2g}Ho^{3/2} \rightarrow b = \frac{Q}{mHo\hat{}3/2\sqrt{2g}} \qquad (2.19)$$

2.3 The conclusion of Chapter two

The analysis provides a method for studying the silvicultural characteristics of Melaleuca forest at different submerged levels (0 ÷ <30cm, 30 ÷ 60cm and> 60cm) from the surveys data of regenerated Melaleuca forest with the indicators: forest density; standard trees; forest reserve; and forest biomass.

The analysis provides a research study scheme to determine the appropriate water regime with scientific basis as the water regime for: growth of melaleuca trees; biodiversity conservation; and forest fire prevention.

Identify the research methodology to propose system of structures. Irrigation structural system is a supporting tool to achieve high efficiency in regulating the water regime reasonably: drain the excess water; water storage; water regulation between zones; ... The results have given the methods of calculating structures according to standard code.

Chapter Three
Study results and discussion

3.1 The silviculture indicators of regenerated melaleuca forest

Conduct the survey on regenerated melaleuca forest after fire in 4 periods. Investigate in 15 standard plots at different times: The 1^{st} period in April 2009, when melaleuca forests regenerated for 7 years [26]; The 2^{nd} time in April 2012, when melaleuca forests regenerated for 10 years; The 3^{rd} period in April 2014, regenerated for 12 years; The 4^{th} period in April 2016, regenerated for 14 years.

Evaluate the results:

- The low submerged level 0 ÷ <30 cm had the best growth rate $D_{1,3}$, H_{vn}, $H_{đc}$ và $D_{tán}$, gradually decreased at higher flooding levels through 4 surveys.

- The density of Melaleuca trees regenerated after forest fire is closely related to the submergence level and diameter of the tree, recorded:

+ At low and average flooding level, the density of regenerated Melaleuca tree was highest when the forest was 7 years old and gradually decreased in the following years until the Melaleuca forests regenerated for 14 years. Then the diameter of the tree increased from 5,2 cm to 9,2 cm and from 3,3 cm to 7,1 cm.

+ At deep flooding levels, the density of regenerated trees increased over time from 8.700 trees/ha when Melaleuca forest regenerated for 7 years to 9.990 trees/ha for 14 years. Diameter increased from 3,2cm to 4,4cm.

+ The density of regenerated trees was highest when the Melaleuca forests regenerated for 7 years with 14.282 trees/ha corresponding to the shallow flooding level from 0 ÷ 30cm.

- The higher the level of flooding, the higher the rate of average, bad and fallen trees.

- Regarding the reservation of regenerated Melaleuca forests: At a shallow flooding level of the Melaleuca forest, the highest reserve is available and decreases at higher flooding levels. Forest reserve increases with time of regeneration. The lowest average volume was 40,19 m^3/ha when Melaleuca forest regenerated for 7 years and increased to 131,03 m^3/ha when Melaleuca forest regenerated for 14 years.

- Regarding the biomass of regenerated Melaleuca forest: At a shallow flooding level, the Melaleuca forest biomass has the highest number and decreases at higher flooding levels.

From the above evaluation, it shows the strong influence of water level on the growth of Melaleuca forests, at low inundated level the regenerated Melaleuca trees developed at highest rate. Indicators on the growth, the reservation and biomass of regenerated Melaleuca forests through flooding levels clearly demonstrated.

3.2 Dividing zone intended for water management for melaleuca forest

3.2.1 Analysis of current status and zone planning

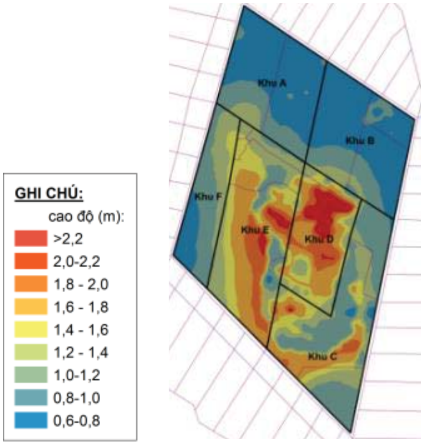
Curent status of subdivision: The division into 3 zones from 2010 up to now has not met the requirements. This is part of the reason that recent water levels are always at high level and difficult to control.

Zone planning: Zone E is kept intact. Zone F does not redistribute but changes its view of regulating water regime. Zone C and Zone D have many inadequacies and need to be re-divided.

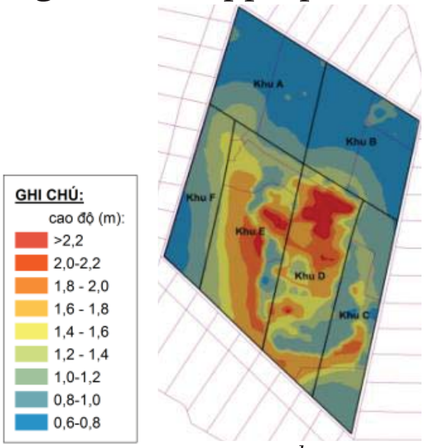
3.2.2 Select the zoning option

The researcher provided two different plans for partitions C and D as compared to planning as mentioned in this study for choosing a more appropriate solution, as shown in Figure 3.18 and Figure 3.19.

Review and compare the advantages and disadvantages of 2 zone planning options and overcome the limitations in the planning, to choose option 1 with more advantages, more appropriate.



The 3.18. The 1st zone planning



The 3.19. The 2nd zone planning

3.3 Calculation to determine the reasonable water regime

3.3.1 Calculate the area distribution by the altitude of selected option

Zones A, B, E, F remain unchanged, only zones C and D are adjusted. Results of calculating the characteristic parameters are shown in Table 3.9.

Table 3.9 Elevation distribution by zones according to selected option

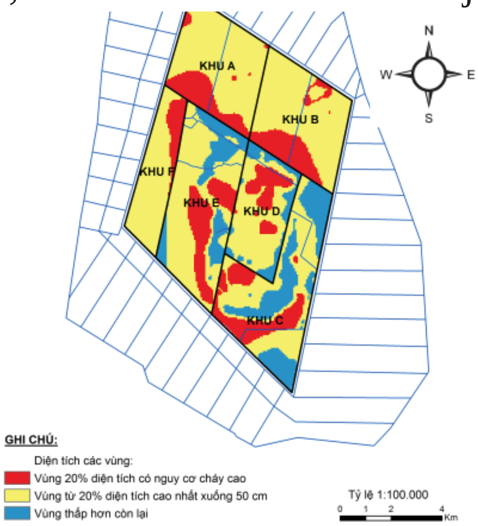
No.	The ground elevation	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F
1	Largest (m)	1,20	1,37	2,15	2,29	2,21	1,41
2	Smallest (m)	0,68	0,69	0,71	1,19	0,68	0,81
3	The average (m)	0,83	0,83	1,11	1,54	1.34	1,00

3.3.2 Calculation to determine the reasonable water level

Determine the water level corresponding to the forest area with high risk of fire 0% ($H_{0\%}$): With the maximum limitation of 50cm, corresponding to the lowest water level will be lower than the highest forest land elevation (Z_{max}) is 50cm, it is estimated that the

National Park will cover an area of 5.946 ha (equivalent to ≈74%) below the water level need to control and be in danger of flooding the whole year. Compared with the requirement for biodiversity conservation of ≈30%, the proportion of area is inundated too much, need to adjust the water level.

Determine the water level corresponding to the forest area with high risk of fire 20%: Considering 20% of the area is limited, calculated the corresponding elevation $H_{20\%}$ of each zone. Determine the next area with a water level lower than 50cm. Areas are higher than this limit will not be flooded and seasonally inundated, while the lower ones will be at risk of flooding throughout the year (Figure 3.25). As a result, Zones A, B and F do not have flooding area all year round; Zone C has 122 ha (≈7% of the area); Zone D has 169 ha (≈ 17% of the area) and zone E is inundated with 236 ha (≈14% of the area). Total area is lower than the lowest water level and is at risk of flooding all year round is 527 ha, ≈7% of the total area of the core zone. Compared to the requirement of ≈30%, the flooding area is too small, the water level must be adjusted.



The 3.25: Map of distribution area by the water level corresponding to high risk of fires 20%

Propose reasonable water level at the driest time (in April):

Consider water level corresponding to the limit 30% of the total area of the whole core zone of the National Park is floodplain habitat throughout the year, the researcher analyze and present the flooding levels for each zone, as follows: Zone A and B are 25%; Zone C is 35%; Zone D is 25%; Zone E is 25%; Zone F is 35%. The results are shown in Table 3.13.

- Area with high risk of fire each zone is <20% area of its zone. The total area with high risk of fire is 410ha, about 5% of the total area of core zone of the National Park, less than 20% compared with the requirement of forest fire prevention. So that, the elevation of water level corresponding to the flooding area proposed in April meets the requirements of forest fire prevention.

- Total area tends to flooding all year round is 2.256 ha, corresponding to 28% of the total area of the core zone of the National Park, compared with the requirement to ensure biodiversity conservation in the year-round floodplain habitat is ≈ 30% so that the flooding area rate has agreed with the requirements.

Table 3.13. The parameters corresponding to proposed rate of inundated area

No.	Sector	Total area (ha)	The region with trends that flooding year-round			Water level higher than control level 50cm (m)	Area with high risk of fire	
			Proposed rate (%)	Correspon ding area (ha)	Correspon ding water level (m)		Area (ha)	Rate (%)
1	Zone A	1.349	25%	337	0,73	1,23	4	0%
2	Zone B	1.374	25%	344	0,73	1,23	50	4%
3	Zone C	1.773	35%	621	0,98	1,48	177	10%
4	Zone D	992	25%	248	1,39	1,89	129	13%
5	Zone E	1.740	25%	435	1,10	1,60	44	3%
6	Zone F	775	35%	271	0,94	1,44	7	1%
	Total	*8.003*		*2.256*			*410*	

<u>Computation to determine the appropriate water level at the end of rainy season:</u>

The water level at the end of the rainy season should be determined to ensure that the water level meets the requirement at the end of the dry season. According to [18] the water loss in 5 months of dry season is ≈32cm (6,4 cm/month). The researcher determined the water level that required to be stored in the zones at the end of the rainy season (on November 30th) in Table 3.14. The end of the rainy season is defined as the time of the highest water level in the year during the water regime regulating procedure.

Table 3.14: The proposed governing water level for the zones and corresponding areas

No.	Sector	The region with trends that flooding year-round			The region with trends that no flooding year-round			The region with trends that seasonal flooding		
		Water level in April (m)	Flooding area (ha)	Rate (%)	Water level on November 30th (m)	No flooding area (ha)	Rate (%)	Water level (m)	Seasonal flooding area (ha)	Rate (%)
1	Zone A	0,73	337	*25*	1,05	125	*9*	0,73-1,05	887	*66*
2	Zone B	0,73	344	*25*	1,05	137	*10*	0,73-1,05	894	*65*
3	Zone C	0,98	621	*35*	1,30	411	*23*	0,98-1,30	741	*42*
4	Zone D	1,39	248	*25*	1,71	289	*29*	1,33-1,71	455	*46*
5	Zone E	1,10	435	*25*	1,42	542	*31*	1,10-1,42	763	*44*
6	Zone F	0,94	271	*35*	1,26	90	*12*	0,94-1,26	413	*53*
	Total		*2.256*	*28*		*1.594*	*20*		*4.153*	*52*

<u>Assess the calculation results:</u>

- With the highest water level at the end of the rainy season, calculated the no flooding area corresponding for the whole National Park is 1.594 ha (≈20% of the total area). Compared with the requirement of ≈20% to ensure biodiversity conservation, the ratio of no flooding area meet high requirements.

- The area between the highest and the lowest water level is the seasonal inundated area, calculated as 4.153 ha (≈52% of the total area). Compared to the requirement of ≈50% to ensure the conservation of biodiversity in seasonal floodplain habitats, the proportion of seasonal flooding area meets the requirement.

From the proposed water level data, a map of proposed distribution area by suitable floodplain habitat is constructed (Figure 3.26).

Figure 3.26 Map of proposed distribution area by reasonable floodplain habitat

3.3.3 Research to determine the suitable water regime in the year

Proper water regime is the fluctuation of water level over time of the year of the sectors to ensure the full requirements. Based on the monthly rainfall data series for 31 consecutive years (1985 ÷ 2015) of Rach Gia station, using the rainfall calculation method corresponding to design frequencies according to Pearson III for calculation.

In order to maintain the period of the year that the water level below the average elevation is ≥6 months/year, according to the requirement to satisfy the growth of Melaleuca trees, it is necessary to determine the starting time when the water level is lower than the average elevation, and the minimum period ends after 6 months. With the average water loss in dry season of 6,4 cm/month [18], control water level in April as proposed (see Table 3.14) in the zones, reversed calculation to determine the water level below the average elevation in the zones from Febraury 15th. The researcher identified the minimum period that ends after 6 months is approximately on August 15th annualy.

The end of the time of maintaining the water level below the average altitude that the water level is equal to the average elevation. This date is determined after August 15th every year. Compare the highest water level required and the average elevation of each zone to determine the storage water level. The average water level loss in the rainy season is 2,77 mm/day (not including rainfall). The calculations for different water storage periods from September 1st to November 30th, determine the water level loss over time. From the water level loss over time in the rainy season periods and the required storage water level of each zone, determine the storage water levels in the period from September 1st to November 30th.

From the calculation of water resources from rainfall according to the frequencies and the number of days of water accumulation, the rainfall is calculated according to the time of water accumulation at the end of the rainy season with the design rain frequencies.

According to QP.TL.C-6-77 convention, the year of low water is the year coresponding to design rain frequency of 75%, the average water level year corresponding to the design rain frequency of 50% and the high-water level year corresponding to the design rainfall frequency of 25%. Combine the water storage requests with the ability to respond water demands from rain, identified the annual water storage period on September 11th for low water year, on October 1st for the average water year, and on October 21st for high water year. At that time, the period that the water level in the year below the average elevation is ≈ 7 ÷ 8,5 months, satisfied the requirement.

In the case of years with extreme weather condition, the rainfall is very low, corresponding to the rainfall frequency ≥90%. If it is predictable, it is advisable to increase the starting time for water storage in early September. The duration of non-flooding time still ensures ≈6,5 months.

Assemble the calculation results, analyze and evaluate, the researcher proposed a reasonable water regime for each zone at some important milestones time in the year as shown in Table 3.20.

Table 3.20: Reasonable water regime recommends for each zone by time over year for low water level year

No.	The water level (m)	Day/Month							
		31/1	*28/2*	*31/3*	*30/4*	*30/4-11/9*	*11/9*	*30/11*	*31/12*
1	Zone A	0,92	0,86	0,79	0,73	0,73-0,83	0,83	1,05	0,99
2	Zone B	0,93	0,86	0,80	0,73	0,73-0,83	0,83	1,05	0,99
3	Zone C	1,17	1,11	1,04	0,98	0,98-1,11	1,11	1,30	1,24
4	Zone D	1,58	1,52	1,46	1,39	1,39-1,54	1,54	1,71	1,65
5	Zone E	1,30	1,23	1,17	1,10	1,10-1,34	1,34	1,42	1,36
6	Zone F	1,13	1,07	1,01	0,94	0,94-1,00	1,00	1,26	1,20

Note: - With average water year, September 11th replaced by October 1st

- With high water year, September 11th replaced by October 21st

3.4 Propose system of structures

3.4.1 Layout of the system of structures

Arranging the system of structures in the most suitable positions to accomplish the proposed tasks, shown in Figure 3.27.

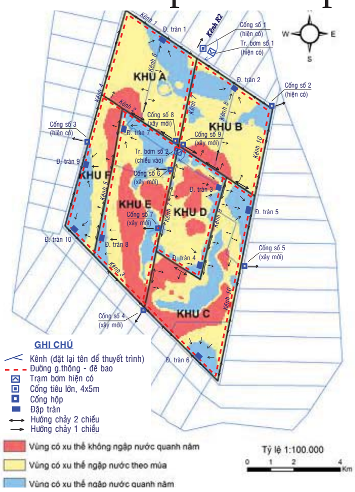


Figure 3.27: Map of proposed layout of the system of structures

3.4.2 Calculation of structural hydrology

Based on the rainfall data of 1, 3, 5, 7 days maximum of series of 31 years of Rach Gia station, calculated according to the Pearson III, determined the rainfall corresponding to the frequencies. With the characteristics of melaleuca trees can widthstand high flood tolerance and long duration of flooding, the maximum 3 days rainfall data in 2003 (corresponding to the frequency of precipitation ≈ 4%) was chosen as the typical rainfall causing submergence in the area, on that basis calculate the flood flow rate from which determine the size of the structures. The results of calculating the total flood volume, flood flow rate in the zones corresponding to rainfall in 2003 given in Table 3.23.

3.4.3 Hydraulic calculation to determine the dimensions of structures

Table 3.24: Proposed dimensions of drainage sluice and intake sluice

No.	Content	BxH (m)	Note
I	Drainage sluice		
1	Sluice number 1	4x5	*Having*
2	Sluice number 2	2x3	*Having*
3	Sluice number 3	2x3	*Having*
4	Sluice number 4	3x4	*Addition*
5	Sluice number 5	4x4	*Addition*
II	Intake sluice		
1	Sluice number 6	2x3	*Addition*
2	Sluice number 7	2x3	*Addition*
3	Sluice number 8	2x3	*Addition*
4	Sluice number 9	2x3	*Addition*

Table 3.25: Proposed dimensions of spillway

No.	Zone	Set up position	H_o (m)	Q (m^3/s)	B_{cal} (m)	B_{pro}(m)
1	Zone A	*The spillway 1*	0,32	13,3	50,7	50
2	Zone B	*The spillway 2*	0,32	13,5	51,6	52
3	Zone C	*The spillway 5*	0,32	9,9	37,6	38

		The spillway 6	0,32	9,9	37,6	38
4	Zone D	*The spillway 3*	0,32	4,9	18,7	20
		The spillway 4	0,32	4,9	18,7	20
5	Zone E	*The spillway 7*	0,32	8,6	32,6	33
		The spillway 8	0,32	8,6	32,6	33
6	Zone F	*The spillway 9*	0,32	6,7	25,6	26
		The spillway 10	0,32	6,7	25,6	26

3.5 Solutions for management, reasonable water regulation

3.5.1 Operation and water regulation procedures

Water storage and drainage; Additional water supply

3.5.2 Operational schedule of the system of structures

The most important activity of the system of structures is to determine the time to set the crest elevation to achieve a reasonable water regime.

Table 3.26: Proposed crest elevation according to reasonable water level over time

No.	Crest elevation	The crest elevation (m)		
		Lowest – on April 30th	On August 15th	Highest – on September 11th
1	The crest elevation of zone A	0,73	0,83	1,05
2	The crest elevation of zone B	0,73	0,83	1,05
3	The crest elevation of zone C	0,98	1,11	1,30
4	The crest elevation of zone D	1,39	1,54	1,71
5	The crest elevation of zone E	1,10	1,34	1,42
6	The crest elevation of zone F	0,94	1,00	1,26

Note: - With the average year of water, September 11th replaced by October 1st

- With the high-water level year, September 11th replaced by October 21st

3.6 The conclusion Chapter three

Analyze the silviculture characteristics of regenerated Melaleuca forests through forest survey data at three different flooding levels over four surveys and obtained the results: inundated levels have a strong influence on the growth of Melaleuca forest; the lower the flooding level, the better the regenerated Melaleuca trees, the higher the growth, reserve and biomass of the forest.

The partition scheme has been selected in the research result. Separate the areas with high terrains, thick peat layer and well-developed Melaleuca forests (zone D, E) to protect these zones from the risk of forest fire. Discrete the low-lying terrain areas (zones A, B, C, F) separately for water management to help Melaleuca forests have conditions for ecological restoration.

The calculation results proposed "Map of proposed distribution area by reasonable floodplain habitat" to apply for the National Park.

The results show that the "reasonable water regime proposed for each zone over time in the year", with emphasis on the starting time for reserving rainwater from the annual rainfall in the National Park is on September 11^{th} for the low water level year, on October 1^{st} for average water year and on October 21^{st} for the high-water level year.

The system of structures has been proposed in the results and the layout of structures has been chosen, the location of the structures is suitable for each zone as well as the whole National Park.

It has introduced the process of operating and regulating the water in the water storage and water drainage activities of each zone. Introduce additional water supply activity with the use of natural conditions to transfer water from high terrain areas to low terrain zone, transfer water from the area of little water requirement to the area of high water demand (zone D to zone C and zone E to zone F, ...).

Make the operational schedule of some main structures such as the time of setting up the crest elevation for water accumulation but also water drainage, meeting the required water level suitable for each zone. In particular, three periods of concern are: the lowest crest elevation – on April 30th; the crest elevation corresponding to average elevation - on August 15th; and the highest crest elevation for the years of low water level – on September 11th, for the average water level year – on October 1st, for high water level year - on October 21st.

Calculated results provide the technical parameters of the structures. Construct of technical drawings in 3D models, on the basis of the proposed structures to refer to the practical application, including two types of structures: sluice and spillway.

The conclusions and recommendations

<u>The conclusions:</u>

1) The research results have shown that after forest fire, U Minh Thuong National Park has many big changes. High water retention solution to prevent forest fires have made the ecology of Melaleuca forest changed. The situation of submerged forests with alum is gradually changing and characterizes the ecosystem of lakes and swamps.

2) The surveys, assessment results of the growth and development of regenerated Melaleuca forest clearly show the strong effect of flooding level on the growth of Melaleuca forests.

- At the shallow flooding rate of 0 ÷ 30cm, the highest diameter growth and height development of regenerated Melaleuca forest and decrease gradually at higher flooding levels.
- The density of regenerated Melaleuca trees in the forests after fire is closely related to the submerging level and diameter of trees. As the diameter increases to a level, the density of the

trees tends to decrease. The highest density of regenerated tree was observed when melaleuca forests regenerated for 7 years and corresponding to a shallow flooding level of 0 ÷ 30cm.

- The reserve of Melaleuca forests increases with time and inversely proportional to the inundating level.
- The biomass of regenerated Melaleuca forests is highest at shallow submerging level of 0 ÷ 30cm and gradually decreases at higher flooding levels. The difference in biomass between flooding levels is highest after 7 years, decreasing progressively and less fluctuation after 14 years.

3) The research result determined the proposed reasonable water level for controlling Melaleuca forests of the zones in the core area of the National Park by the time of the year. The times for controlling water level are: the highest water level at the end of the rainy season, ensuring the non-submerged habitat throughout the year ≈20% of the total area; the lowest water level at the end of the dry season, ensuring the submerged habitat year-round around 30% of the total area. Control water levels reasonably corresponding to ≈5% area of the core zone of the National Park at high risk of fire. The results have been mapped to propose a suitable distribution of floodplain habitat for the core zone of the National Park, so that GIS technology and satellite imagery can be applied to manage the water regime reasonably.

4) Identified suitable water management regimes for each zone to meet the proposed requirements: (i) suitable water regime for the growth of Melaleuca trees; (ii) appropriate water regime for biodiversity conservation, including the creation of suitable habitats and the protection of peat layers; and (iii) appropriate water regime for forest fire prevention. Calculate the water resources from the rain

with the frequencies, calculate the ability to meet the water demand and the storage water levels need for each period to ensure ≥ 6 months/year that regenerated melaleuca trees develop well, determine the time of water accumulation matching to the design rainfall frequency in hydrological year. The annual water storage period is determined from September 11th to November 30th for the low water year, for the average water year from October 1st to November 30th and for high water level year from October 21st to November 30th. In very drought years, it is possible to predict the need to increase the water accumulation on September 1st, if not predictable, but the amount of water needed at the end of the rainy season must be supplemented with water from outside, the additional pumping time is from November 1st to December 31st. The highest water level time in each zone in the year is at the end of the rainy season, which should be reached on November 30th every year. The lowest water level time in each zone each year is at the end of the dry season, which should be achieved on April 30th every year.

5) An irrigation system has been proposed to manage and regulate water regimes in the core zone of U Minh Thuong National Park, with the task of draining excess water, reserving water, regulating water, and replenishing water. Selected structures are easy to construct, easy to manage and operate, friendly to the environment, making a little change to the landscape of natural ecological environment. Provide the procedure of operating and regulating water in the water storage and drainage activities of each zone. Set up the operational schedule of some main structures such as time to set the crest elevation of spillway to meet the required water level suitable for each zone. Build up the technical drawings of structures as reference for practical application.

The recommendations:

The results of the dissertation should develop more research on the amount of water loss in the National Park during the rainy season with changes in temperature, humidity, vegetation, evaporation, rainfall, water level, compared to the dry season for more accurate application in water level calculations. It then determines when to start storing water in the rainy season more accurately.

Further research on forest fire prevention and control solutions that have not been mentioned, integrating between appropriately water regime management and proposed water levels for divided zones as presented in this study and the measures for forest fire prevention and control to protect U Minh Thuong National Park from potential forest fires.

Proposals for irrigation systems: location, type of structures, size, operational management procedures… should be consulted, reviewed and calculated in detail for inclusion in the practical water management application in the National Park.

Some research results of the dissertation can be referenced, used as a compilation and water management document for others National Park of similar nature. In addition, it can be used as a reference and teaching material for students on water resources exploitation and management.

LIST OF PUBLICATIONS

[1]- Pham Van Tung, Thai Thanh Luom (2013), *Strategic solutions to resolve water demand from coastal wetlands and islands in the dry season in Vietnam*, Journal of Agriculture and Rural Development, 12/2013.

[2]- Pham Van Tung, Thai Thanh Luom, Le Viet Khai (2013), *Research on the regeneration of Melaleuca forests under changing in hydrological conditions on the different soils in U Minh Thuong National Park*, Journal of Agriculture and Rural Development Rural Development, 12/2013.

[3]- Pham Van Tung, Luong Van Thanh (2016), *Water management in U Minh Thuong National Park since the forest fire occurred in March 2002 and impacts on forest ecology*, Proceedings of the Science and Technology of Southern Institute for Water Resources Research in 2016.

[4]- Pham Van Tung (2016), *The silviculture characteristics of regenerated Melaleuca forests in U Minh Thuong National Park since the fire occurred in March 2002 up to now*, Proceedings of the Science and Technology of Southern Institute for Water Resources Research in 2016.