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THE WATER MANAGEMENT AT TRAM CHIM NATIONAL PARK, VIETNAM

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ABSTRACT

Tram Chim is a remnant wetland of the plain of reeds that drained prior to reunification. Tram Chim was most well known for being home to the Eastern Sarus Crane (*Grus antigone sharpii*) and many other water birds. One of the most essential things here is how to control the water levels effectively. Keeping the water too long and the water levels too high can destroy the ecosystem in Tram Chim while drying up the water and making the area too dried cause fire problems. The first objective was to analyze the hydrology of Tram Chim through a water budget and by assessing the variability and connectivity. The second objective was to survey the types of soils present and understand the processes involved. We found the water velocity at Tram Chim was close to zero. The pH values at Tram Chim indicate that water levels at unit A4 have kept too dry for too long, causing acid soils to oxidize, creating acid water when the wet season occurs. Due to this problem, many managers at Tram Chim attempt to restore the hydrology by regulating the water management in Tram Chim National Park.

Keywords: Tram Chim, sarus crane, soil, hydrology, fire, *melaleuca*, acid sulfate soil, rice, *eleocharis*, *ischaemum*, wetland

INTRODUCTION

Tram Chim National Park is a remnant wetland in the historic Plain of Reeds, a depression that seasonally flooded by the Mekong River prior to reunification. U.S. and French forces, degrading the Plain of Reeds, drained the wetlands. Tram Chim is also in the sedimentary ancient riverbed that formed gradually a system of small crisscrossed shape canals and the direction of flow does not follow a clear direction, surrounded by high terraces in the west and northwest of the old alluvial terraces.

The potentially acid sulfate soils exposed to the air and oxidation of pyrite in the sediment resulted in a large drop of the pH and an increase of the concentration of ferrous iron and sulphate in the soil. (Hanhart, 1997). During monsoon season, water from the Mekong would flow in quickly through channels rather than at its pre-disturbance, slow, sheet flow pace.

(Meynell, 2012). Water pooled on the surface and in some cases, the younger acid sulfate soils would become reduced and the reduction process, particularly the reduction of ferrous iron, would consume the acidity, increasing the pH closer to 7. The more developed acid sulfate soils would fail to reduce the acidity, causing the water to also become acidic (Hanhart, 1997). The combination of a new water regime and increased acid caused vegetation to shift to communities less desirable as food for the native fauna, including the Eastern Sarus crane (*Grus antigone sharpii*) which prefers the tubers of Eleocharis (*E. orostachys, E. dulcis, E. atropurpurea*). The acid soils were also unable to support rice farming for the Mekong Delta's people. A need for sustainable farming and a desire to return the Sarus crane to Tram Chim are two of the main goals that eventually led to the formation of Tram Chim National Park in 1985 (Barzen, 1994). A dike 7,000 ha created to restore the area's original function of a small part of the 750,000 ha plain of reeds as a resource to the people. In 1988 several U.S. scientists entered into an agreement with the Vietnamese government to try and further restore the area to return its function as a resource for the Eastern Sarus Crane and several other migratory and water birds (Barzen, 1994).

Study area

Figure1: Vegetation map of Tram Chim National Park, Quoi May 2006

Tram Chim established as a National Park (1998) in Tam Nong District, Dong Thap

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Province in the Mekong Delta. Tram Chim is a closed basin and a completed ecological zone including high shelves, mounds, and rivers surrounded in the south – western part of Vietnam; including 7,313 ha of wetland (with 6 discrete zones, namely A1 – 4,939.8 ha, A2 – 1,120.8 ha, A3 – 41.8 ha, A4 – 730.5 ha, A5 – 434.1 ha and Administration – 46 ha). Division A1 has the largest area, and topography of this zone shifted toward lower from the northeast to the southwest.

Division A2 average ground elevation of 1.3 to 1.4 m.

Division A3 average ground elevation l, 6 m.

Division A4 average ground elevation of 1.3 to 2.3 m.

Division A5 average ground elevation from 1.3 to 1.5 m.

The site is 40 km from Cao Lanh City, the provincial capital of Dong Thap Province. Cao Lanh is located 120 km west and slightly south of Ho Chi Minh City (former Saigon). The range of seasonal hydrological regime of the Mekong River on the topography and landforms created biological diversity and uniqueness of the Plain of Reeds in general and in particular Tram Chim National Park. It provides habitats for 130 plant species and supports a large number of water birds like herons, egrets, storks and ibises and some rare species such as Black – necked Storks, Lesser Adjutants and Greater Adjutants. Most notably, Tram Chim provides habiat for Sarus Cranes, an endangered bird species listed in the IUCN red book (UNDP/IUCN/MRC/GEF, 2005). Due to its biodiversity values, Tram Chim was Vietnam's first wetland national park and has nominated by Vietnam's Government to be a Ramsar wetland site (Buckton et al., 1999).The site is generally plain with an average elevation of 1.2 m above mean sea level: minimum 1.0 m above mean sea level, maximum 1.4 m above mean sea level.

Tram Chim National Park is located in the deep basin of The Plain of Reeds. The average height of the park ranges from 0.9 m to 2.3 m above mean sea level. Characteristic of The Plain of Reeds region is vast swamps filled with determination of organic vegetation in brackish water accumulated during the period of swamp waters, clay mud accumulated pyrite (FeS2) revealed close formation of heavy alkaline soils with high levels of toxins are difficult to renovate. Due to the heterogeneous terrain, the regulatory regime of wetlands during the dry season is very important for the conservation of biodiversity, mangrove forest fire and grassland.

The topography of the site is shallow basin, which slopes to the south – east, parallel to the Mekong River, to the north – east, perpendicular to the Mekong River,, and to the south – west, perpendicular to Vam Co River. The landscape of the park comprises of grasslands, open water, channels, and *Melaleuca* forest. These vegetation types, especially the wet grasslands in Tram Chim contain some typical vegetation communities of the Plain of Reeds. They are the best sample for the rare floodplain components of the bioregion that are not likely found elsewhere in Indochina. Tram Chim is one of the very few places in the region where the Brownbeard Rice (*Oryza rufipogon*) communities are likely to service to any extent and, therefore, one of the most important sites for the conservation of wild rice in Vietnam. Tram Chim is also famous for the population of Sarus Crane (*Grus antigone sharpie*) (VU) which inhabits the national park during the dry season. The fish in Family *Cyprinidae* and *Notopteridae* with 39 species recorded prefer deep river and moves to shallow wetland in breeding season. The other groups are fish in Family *Channidae* and *Anabantidae* with 25 species recorded prefer shallow wetland). The wetlands of Tram Chim National Park are also an important source of food, spawning grounds, nursery and migration paths on which fish stocks, within and outside the wetlands (Bao, Phommavong, Tien, & Yoorong., 2001).

The fire problems in recent years

An important issue in the management of Tram Chim National Park is fire problem. Impact of high-intensity fire had created urgency in the government agencies and society. The fire caused damage to wetland ecosystems, such as destruction of vegetation and peat, reducing organic layer on the surface, increasing surface erosion, reduction of individual animals ... But with fire frequency and intensity appropriate to have an active role in maintaining and enhancing the biodiversity of wetland ecosystems, especially in herbaceous plant communities. For a number of woody plant species (such as *eucalyptus* ...), forest fire frequently and intensively in appropriate conditions will become favorable for regenerating of seeds and buds. Fire also plays

an important role as a source of nutrients for aquatic species with organic matter mineralization. If not burned, organic matter accumulates a faster pace and the ground will enhance to the sufficient extent to form different ecosystems. Thus, in an appropriate extent, fire is a natural ecological factor that is necessary for the conservation of biodiversity of herbaceous plant communities in particular and wetland ecosystems in general.

For wetland ecosystem in Tram Chim National Park, fire is a factor of two aspects: harmful and beneficial. The downside is clear. But the meaning of the fire ecology of the ecosystem in Tram Chim is a dry phase and wet phase, a floating season and a season-arid land, mangrove forest and flammable grassland, far less concerned research. Meaningful study of fire ecology is complex problems not only for the Tram Chim even for Vietnam and around the world. While not control actively the fire and the benefit of preventing harmful effects of fire is very important, the fire prevention and fighting of mangrove forests and dry grasslands remains a problem. According to the Tram Chim National Park, in 2006 – 2011, fire always occurs in the mangrove forest and grassland; the fire and extent of damage are different. However, the ecological effects of fire on wetland ecosystems in general and in particular in Tram Chim have not studied to find out.

Causes of problems in Tram Chim

In nature, Tram Chim has six dry months and six flooded months. Even from January to April, wetlands have dried up some places. Keeping flooded even during dry season degrades biodiversity. The native species will lose their habitats, decrease regenerative abilities. Native ecosystems weaken and lead to the contamination of invasive species. Ecosystem breaks and makes the susceptible animals facing with dangerous predators.

Tram Chim has a criss-cross canal system that helps the water to flow out in the flood season. Although the canals can localize the temporary fire and supply water when the fire occurred, it also decreases the soil moisture rapidly when the water levels drop in the dry season due to the rapid evaporation. The loss of vegetation's cover declines the moisturizing effect of flooded forest. Forest can be vulnerable to dry up after a short period of drought. Tram Chim is an ecosystem accumulate burning materials significantly. One hecta of 10 years mangrove forest can produce about 10 tons of dried leaves and twigs. The area of grassland is larger than melaleuca forest. The fields of dense grass supply 40 tons of burning materials every year easily when the grass dries. The more water kept the fire risk is higher.

Keeping water levels high in Tram Chim controls the fire at the moment, but accumulating organic matter, creating greater fire risk in the future. Previously, the flood spills over the area, take away the organic layer of dense grass or under the mangrove canopy. Currently, the dike keeps the water. The organic layer that should be gone accumulates thicker every time. In addition, the canals retain the water during dry season and reduce the level of decomposition of organic matter in mangrove forests and grasslands. This is the underlying cause of large forest fires, which cannot control.

Fires are also caused by people living around Tram Chim National Park and their intrusion into the area, and then accidentally catching fire, leading combustion, or because some people burned deliberately by contradiction. More than 40,000 people live around national park as potential risks that may cause fire at any time during the annual dry season.

Goal and Objectives

Our goal is to determine if the present water management strategy affects to the water and soil of the highly manipulated floodplain wetland of Tram Chim. The first objective is to analyze the hydrology of Tram Chim through a water budget and by assessing the variability and connectivity. The second objective is to understand the types of soils present at Tram Chim how they form and the processes that affect them today.

METHODS

We will use three methods to analyze the hydrology at Tram Chim. We will create a water budget, assess the variability and assess the connectivity at Tram Chim. We will find figures for the water budget for inputs and outputs and attempt to balance the equation.

Water Budget

Direct measurement techniques can use in wetlands to determine all contributing factors of the water budget, but we did not perform

these techniques. We used values from previous studies.

$\Delta S = P + SW_{in} + GW_{in} - ET - SW_{out} - GW_{out}$

Figure 2: Water Budget explanation

Water Variability

Water budgets vary within and among years. Variation in water budgets over time will cause plant and animal species to vary. The water levels at Tram Chim used to have a certain amount of natural variability that helped to sustain this biologically diverse ecosystem. In contrast, today the water levels and variability are highly managed by a system of canals and dikes. We will use water quality measurements of pH, temperature and TDS as well as analysis of soil cores to determine how current management affects the variability at Tram Chim. Tram Chim has 8 gates and a surrounding dike as shown in Figure 2. We used a Thermo Scientific Orion 4 Star portable water quality meter to determine the pH, TDS and temperature.

Water Connectivity

We used a Rhodamine dye test to determine the velocity of water flow at Tram Chim near a water control gate between A2 and A4. Understanding the connectivity of Tram Chim is important for those charged with public safety or others having interest in transient water quality problems can predict the time of arrival and passage time of a noxious substance released or spilled upstream (F.A Kilpatrick and J.F Wilson, Jr. , 1982).

RESULTS

Water budget

Tram Chim is a floodplain, which affected by the 2 seasons: dry season and wet season. During each season, the amount of water in and water out are significantly different. For this water budget, we used yearly estimates only, which we found in earlier studies.

$(P - ET) + (SW_{in} - SW_{out}) + (GW_{in} - GW_{out}) = \Delta S$

$(1400 - 1397) + (1863 - 2200) = \Delta S = -334$

The total amount of water output at Tram Chim is 334 mm more than the amount of water input in a year. The groundwater component of the budget was and remained insignificant relative to the other water balance components (Beilfuss, 1991). In dry season, evaporation happens remarkablly and frequently. The water on the surface does not occur (except some places where people keep the level of water high). The amount of water in is less than that of water out. In the wet season, precipitation is dominant with heavy rain, floods and this makes the surface water move. The amount of water in is greater than the amount of water out.

Connectivity, Dye Test

Figure 3: Dye Test results

It can be seen from the line chart that the velocity of water on the surface at Tram Chim is dramatically different during the period surveyed. The highest numbers recorded after 500 seconds. However, the velocity changes significantly into negative values, reaching the lowest level (-0,129cm) at 1124 seconds. After that, velocity tends to be positive levels. Overall, velocity moves slowly during the period surveyed. These figures change from positive values to negative values. We can assume from this data that there is very little connectivity at the time the data taken. Most likely, this is because the gates closed and it is not the monsoon season.

pH and TDS

Table 1: Water quality in Tram Chim Water quality testing at Tram Chim revealed a distinct difference between units A1, A4, and unit A2. Units A1 and A4 had higher pH, ranging from 6.05-6.56. Unit A2 exhibited lower pH, ranging from 3.65-3.79. TDS reported at Tram Chim are quite high. The highest point is found in TC8 (1397mg/l), being nearly 20 times higher than the lowest in TC6 and TC11.

Table 1 shows a dramatic difference between samples. In TC8, the value of pH is very low (3.65) while TDS takes the first place (1397mg/l). There is an opposite trend in TC6 and TC11. TC11 reported in Melaleuca forest, having 72mg/l of TDS and 6.05 of pH.

Soil

Within the scope of Tram Chim National Park, the main soil types follow:

Gray on ancient alluvial soil distribute in the north and the high terrain. Land with lightweight, porous, mechanical components and poor nutrition in low-lying areas usually affected by acidity.

Potential ASS: topographical distribution is in low-lying, low, wet, anaerobic conditions. Surgical morphology is blue gray, dark gray or dark gray and decomposed residues of plant.

Land with severe components, high rate of clay, the whole operation was grey, accumulates organic, acidic (pH 1.5-2), and the transferable levels of aluminum (Al^{3+}) in height are doubled in the depths.

ASS activity: distribution is average terrain and rapid drainage. Land with severe components, percentage of clay is high (> 50percentage), soil is acidic (pH <3.5), organic content and high total nitrogen, but phosphorus concentrations and total phosphorus are low of iron but high of aluminum. At Tram Chim, the top two layers were dark, wet, with oxidized roots and brown mottles indicating oxidized iron. Jarosite was present also, but much earlier in the profile at 20cm. The last five layers were all moist, dense clay with jarosite throughout, exhibited by yellowish brown and red mottles. Additionally at Tram Chim, we observed the flooded soils in unit A2. We did not collect a soil core, but we observed a deep layer of dark, organic matter, submerged by water. This soil exhibited an odor that we identified as H_2S from the highly reduced conditions.

Directive plants on acid sulphate soils have many communities: *Eleocharis dulcis*, *Eleocharis ochrostachyo*, *Lopiromia articulata*, *Phragmites karka*. Etc... Plants are directive on the average acidity: *Panicum repens*, *Eleocharis dulcis*, *Cyperus tagetiformis*. Etc... The diversity preservation of the vegetation, which preserved their living conditions: topography, soil, wetland regime, is important activities for the first biodiversity conservation of wetland ecosystems in the Plain of Reeds generally and in Tram Chim National Park particularly.

Table 1: Water quality in Tram Chim

TRAM CHIM WATER QUALITY			
Location	Temperature	pH	TDS(mg/l)
TC1	27.8	6.44	112
TC5	30.7	6.28	160
TC6	30.3	6.56	67
TC7	30.7	5.62	157
TC8	34.8	3.65	1397
TC9	35	3.77	857
TC10	34.3	3.79	768
TC11	29.9	6.05	72

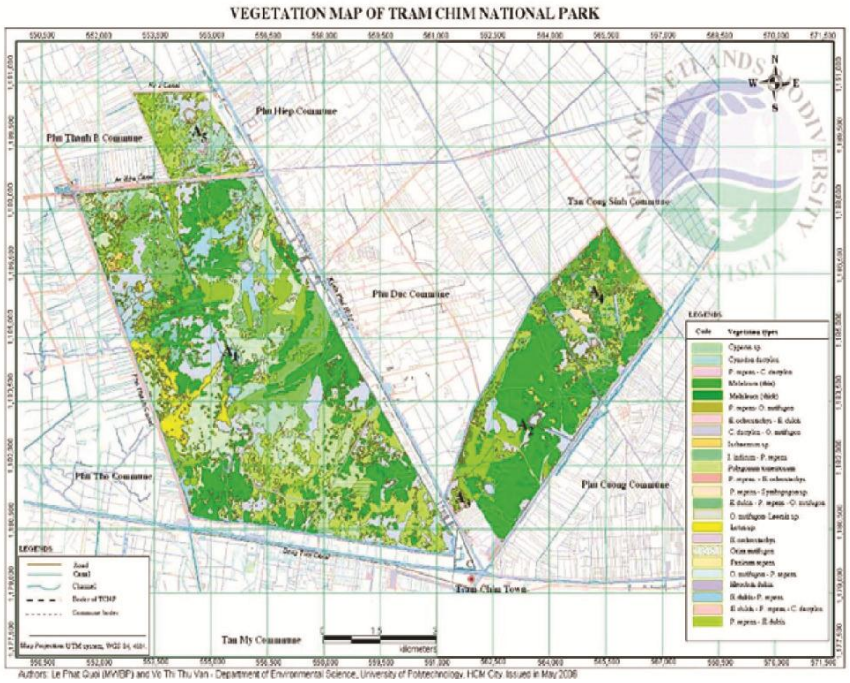
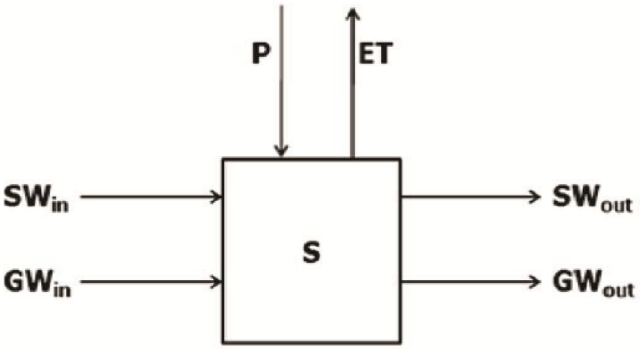


Figure1 vegetation map of Tram Chim National Park Quoi May 2006



ΔS = change in volume of water storage
P = Precipitation
ET = Evapotranspiration
SW_{in} = Surface water inflows
SW_{out} = Surface water outflows.
GW_{in} = Groundwater inflows
GW_{out} = Groundwater outflows

Figure 2: Water Budget explanation

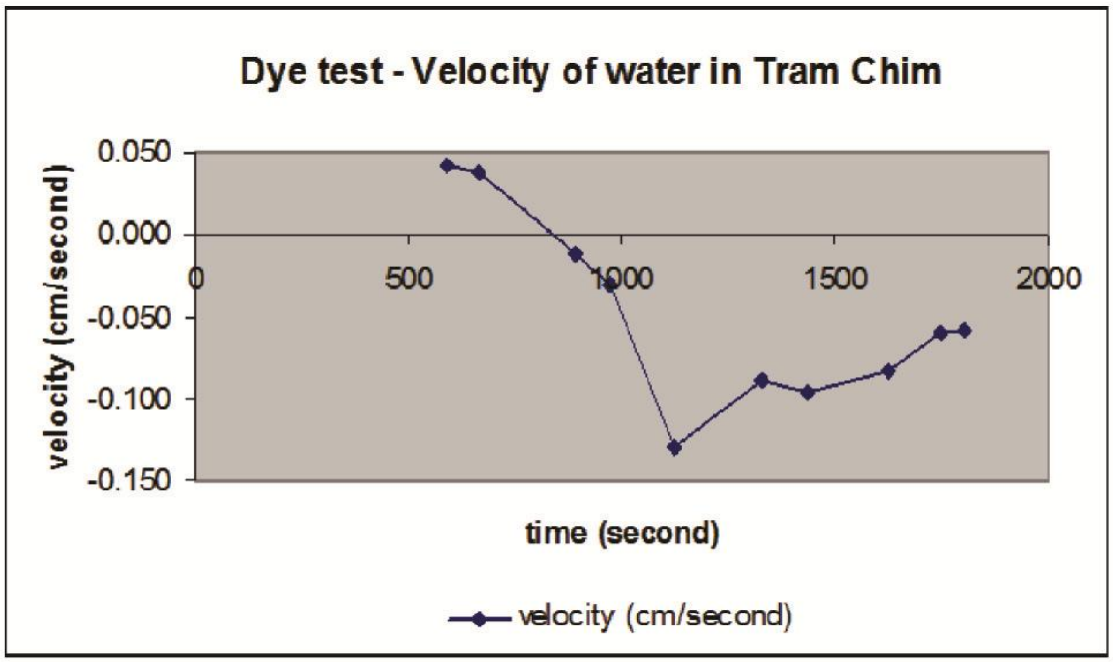


Figure 3: Dye Test results

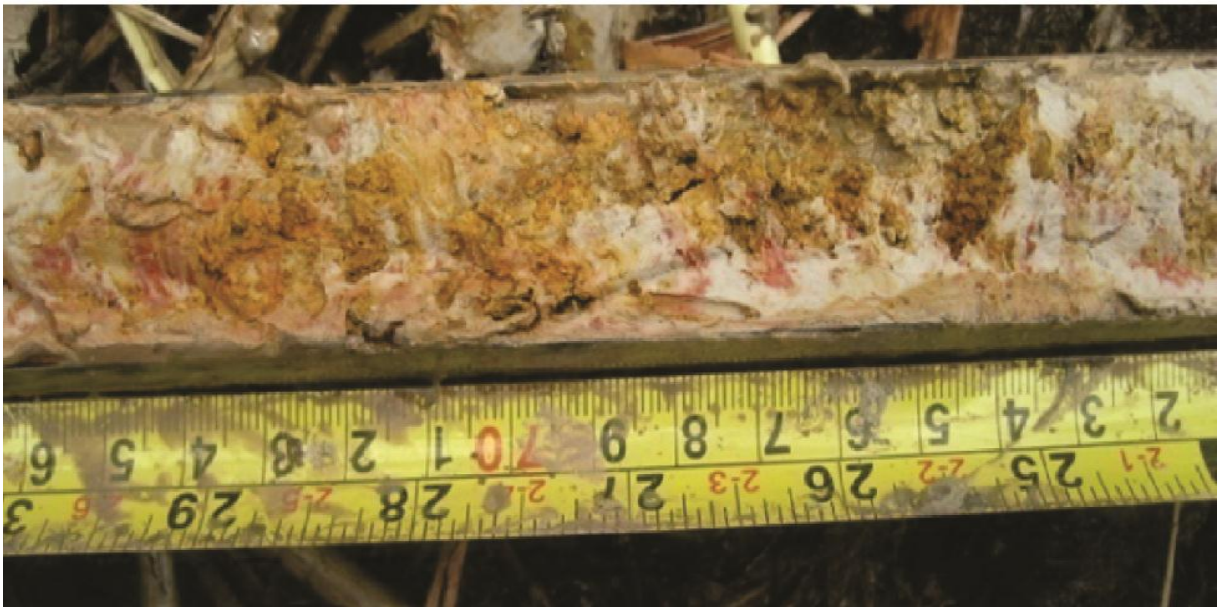


Figure 4 Acid Sulfate Soil at Tram

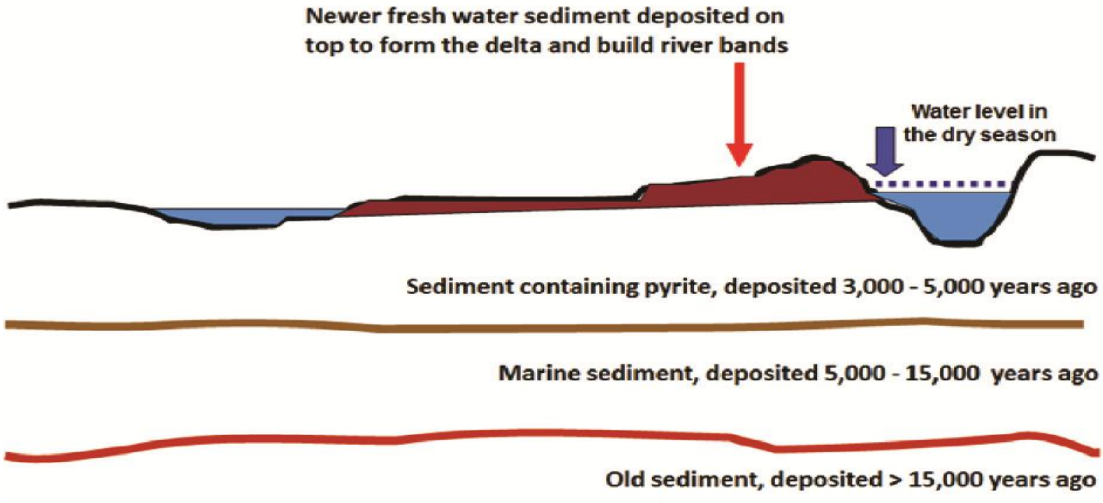


Figure 5: Formation of soils in the Mekong Delta (NI 2012)

DISCUSSION

Hydrological characteristics

In the dry season, when the temperature increases significantly, the evaporation goes up quickly. Overland surface water movement between Tram Chim and its surrounding area occurred only during the peak flooding season. The amount of precipitation in the wet season is greater than that of evaporation because the floodwater from Mekong River and Bassac River flows through the flood control channels, which alters the flow of floodwater and bring sediment to the floodplain. Groundwater is considered ø because of low hydraulic conductivities of marine clay substrate (10^{-5} – 10^{-8} md^{-1}) and negligible elevation gradients across the wetland (1:50 000), the groundwater component of water budget was and remained insignificant relative to the other water components. Prior to disturbance, high groundwater maintained throughout the dry season in the floodplain. Under current measured conditions, floodplain water levels were more than 1m below the soil surface at Tram Chim (Barzen, 1994).

The pH of water in units A1 and A2 is closer to 7, ranging from 6.05 – 6.56 because of one of two possible reasons. First, the acid sulfate soils are buried deeper and have not been oxidized. Second, water has been stable on the surface for a long time and the soil is highly reduced. The pH of the water in unit A4 is highly acidic, ranging from 3.65 – 3.79. This is likely because the area has kept too dry for too long and the acid sulfate soils have oxidized. Using the dikes to control the water in Tram Chim in some fields can cause several problems. Drying and subsequent oxidation of the rootzone results in several oxidation reactions, mainly of ferrous to ferric iron:

$$Fe^{2+}_{(sol)} + \frac{1}{4}O_2 + \frac{5}{2}H_2O \xrightarrow{ox} Fe(OH)_3 + 2H^+$$

This process releases H^+, resulting in a drop of pH and subsequent increased solubility of Al_{sol}, Re-submergence triggers a strong, but temporary, increase of the $Fe^{2+}_{(sol)}$. (Hanhart, 1997). This problem can be seen clearly throughout the soil profile, with the existence of *jarosite*.

Hydrological regime of the Plain of Reeds in Tram Chim dominated by the flow of Tien River, tidal river, precipitation and terrain conditions. Hydrological regime in the Plain of Reeds is 2 opposite seasons: the flood season (also called a floating season) and dry season, leading to excessive water or lack of water. The flood season usually lasts from July to December, the flood's peak usually occurs in late September or early October. Flooding time is usually about 4-5 months and about 2-3 m depth.

Hydrography is the main control of ecosystem in the Plain of Reeds. Since ancient times, the Plain of Reeds is surrounded by high mounds along the border Cambodia and Tien river, so be called "the closed flood." In the rainy season, water from the Mekong Delta spills over Cambodia, combines with local rainfall and inundates low-lying areas. Flood water levels remain high for a prolonged period of seven months. When the floodwater recedes, the water levels around wetlands dry slowly by evaporation, plant transpiration and drainage occurring naturally in the dry season. In the end of the dry season, some areas remain flooded, while other parts, the water surface is still on the ground and the soil is still moist due to capillary moisture of the soil. Only the new high sand dunes dry completely. The Plain of Reeds is the deepest and the longest flooded area of the Mekong Delta. Today, the irrigation canal systems and drainage channels have grown thickly and The Plain of Reeds is no longer "the closed flood" again. However, this is well protected by Tram Chim National Park and has preserved the natural typical habitats of the Plain of Reeds.

The fluctuation of seasonal hydrologic regime based on geomorphic conditions builds up the biodiversity of the Plain of Reeds; the distinctive patterns of habitat areas preserved in Tram Chim National Park. The Plain of Reeds has formerly known about reed fields because there are many meadows and reed swamps covered areas. The grassland habitat types are included *Eleocharis*, *Panicum*, *Triticum* and wild rice. The distribution of plant communities depends on terrain elevation, flood depth and duration of flooding. Grassland communities often appear in areas where higher than 0.85 m above the sea level, but *Eleocharis*, *Panicum* are often dominated places lower than 0.75 m above the sea level.

Characteristics of soil

TDS in Tram Chim recorded is great. This may be because of the interference of animals. They come and stay for a determinative time and leave organic matter, which contains ions. These ions are in the water and make TDS of water high.

Figure 4: Acid Sulfate Soil at Tram Chim

The soils of the Mekong River Basin contain four basic layers. The old sediment deposited more than 15,000 years ago. The second layer in the profile is a layer of marine sediment deposited between 5,000-15,000 years ago. The third layer in the profile formed when sediment-filled fresh water, rich in Iron from the Mekong mixed with saline water rich in SO_4 and formed pyrite, FeS_2, under anaerobic conditions. The top layer of the profile is the more-recent, fine, clay sediments deposited by the Mekong during the wet season. (Ni, 2012). The pyrite-containing sediment from 3-5,000 years ago is found at 20 cm depth at Tram Chim.

Figure 5: Formation of soils in the Mekong

This deposition can be explained by the geomorphology and resulting flow patterns in the monsoon season. Tram Chim is located in a depression area surrounded by uplands to the northeast and the natural levee of the Mekong River in the south and west. When the wet season causes the River to overflow its banks, it pools in the basin at Tram Chim. This process occurs slowly with the larger sand and silt particles settling out first before reaching the basin. When the water finally reaches Tram Chim it sits on the surface for a long time, allowing the finer clay particles to settle. The fast-moving water drops the larger sediment particles out first at higher speeds, followed by the smaller, clay particles, which take more time to settle.

The highly reduced and submerged soil at Tram Chim in unit A2 are a result of the water levels, which managed to be higher for several reasons. This area is kept wetter to foster growth of species that require more water. The depth is also maintained at this higher level to prevent fire. This is a concern because the presence of such a large amount of organic soils would burn very hot and for a very long time.

Wetland management regimes in Tram Chim National Park

Natural History of the Plain of Reeds is a model of ecological synthesis between the geomorphology, hydrology and wetland creatures. Hydrology or flooding regime is an important factor for the conservation of wetland ecosystems in general and in Tram Chim National Park in particular. Hydrological regime in Tram Chim National Park depends on the hydrological regime of the Plain of Reeds. Hydrological regime of the Plain of Reeds depends on the following factors: the flow regime of the Mekong River, Tidal regime of the South China Sea, the rainfall regime in the Plain of Reeds; natural terrain conditions, and activities and economic development of society. These factors have changed over the previous, thereby affecting the Tram Chim National Park.

Previously, the hydrological regime in Tram Chim National Park was managed by two methods: open method, i.e. the natural hydrological regime, and managing methods by regulating water sewer systems. Tram Chim National Park divided into 5 different management areas (A1-A5), each surrounded by the canal and dyke systems with a total length of about 70 km. In each region the channel depth and width is vary. The whole area is often flooded about 6 to 7 months every year in flood season, from late June to December, the flooding to 2-3 m. The wetland management mode to as close to natural laws as possible, which means creating a natural alternating between dry mode and wet mode to create the shape and structure of wetland vegetation water. In recent years, all 5 zones of Tram Chim National Park are managed by a system of drains and water spillway. Specifically, A1 zone six culverts, drains Zone 2 A2, A3 3 tribute; A4 Zone 1 and 1 culvert spillway, the spillway area A5 1.

Management Recommendations

We have two recommendations for Tram Chim. The first is the water on unit A2 allowed to drain more often. This would facilitate decomposition of the thick organic debris that is now present. This debris is susceptible to fire and the thicker it becomes, the greater the risk. We understand that the timing of these drawdowns is crucial and suggest that this happen before the wet season but not in the driest part of the dry season.

The second recommendation is that unit A4 be allowed to hold water more often to keep the acid sulfate soils from being exposed and oxidizing. This area has extremely acidic water and needs to build an organic layer to protect those soils from exposure. Perhaps if some sediment rich water could let in, the sediment could settle in the existing vegetation.

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