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REDUCTION OF NUTRIENT CONTENTS BY HARVESTING NATURAL WETLAND VEGETATIONS

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Abstract: The effects of harvesting wetlands vegetation on nutrient contents entering Layang reservoir, in Masai Johor were investigated. Total Phosphorus (TP), Total Dissolved Phosphorus (TDP) and Nitrate-N levels at the harvesting site, both upper and bottom layers were lower compared to the control site and the inflowing river. The monthly percentage removals of TP, TDP and Nitrate-N fluctuated noticeably, ranging from 20% to 89%. Percentage removals were also higher after harvesting operation compared to before harvest. The percentage removal is highest when the shoots are young.

Keywords: *Harvest; Reservoir; Phosphorus; Nitrate-N; Wetlands; Removal.*

Abstrak: Kesan penuaian tumbuhan tanah bencah ke atas kemasukan nutrien ke dalam takungan air Layang di Masai, Johor telah dikaji. Paras Jumlah Fosforus (TP), Jumlah Fosforus-Terlarut (TDP) dan Nitrat-N di tapak penuaian, pada kedua-dua lapisan atas dan bawah lebih rendah berbanding tapak kawalan dan sungai. Peratus penyingkiran bulanan juga adalah lebih tinggi selepas penuaian berbanding sebelum penuaian. Peratus penyingkiran paling tinggi berlaku ketika pucuk tumbuhan adalah muda.

Katakunci: *Tuai; Takungan Air; Fosforus; Nitrat-N; Tanah Bencah; Penyingkiran.*

1. Introduction

There are several strategies being identified to control non-point pollution which are degrading the downstream water bodies. The strategies proposed by the United States Environmental Protection Agency (USA-EPA) as described by Olem (1990) include the best management practices (BMPs) and wetlands restoration and creation. The BMPs strategies include zoning, erosion control practices, maintaining vegetative cover, tillage conservation, terracing, contour farming and proper fertilizer application. Wetlands restoration by harvesting hydrophytic vegetation has been identified by several investigators as one of the possible control strategies to amplify nutrient removal. Suzuki et. al. (1989) found large removals of nitrogen and phosphorus through shoot harvesting. Wetlands harvesting is strongly recommended especially for aging wetland systems.

Non-point source pollution especially from nutrients inflow into reservoirs need to be controlled to decelerate the reservoir eutrophication process. Total Phosphorus concentration at the Layang reservoir has increased considerably from 0.03 mgl^{-1} in 1992 to 0.19 mgl^{-1} in 1996 (Strategy Tegas Sdn. Bhd. Pers comm.). Che Nyan Husain et al (1993) reported TP concentrations between 0.06 mgl^{-1} and 1.1 mgl^{-1} at the Layang reservoir. The nutrients observed at the Layang reservoir are associated with fertilizer application for orchid and vegetable farming. The objective of this study is to evaluate the effect of plant harvesting on pollution loading, specifically phosphorus and nitrate in the Layang River wetland systems. Wetland restoration by harvesting hydrophytic vegetation was performed to amplify nutrient removal.

2. Materials and Methods

2.1 Site Description

The Layang wetland systems are the transitional zones located between the Upper Layang watershed and their downstream reservoir systems. The Upper Layang watershed and the wetland systems are located approximately within 1°30' N and 1°36' N and 103°50' E and 104°00' E. The Upper Layang watershed is one of the major sources of runoff into the Layang reservoir (Figure 1). The Upper Layang reservoir is located about 40 km north east of Johor Bahru.

There are six river systems in the Upper Layang watershed (Figure 1). Most of the rivers are fairly dry or unfilled during dry weather except for Sg. Layang, which has a continuous notable flow throughout the year. The unfilled rivers are shrouded with tall grasses and scattered bushes and water discharges are observed during heavy rainfall only. The growth of hydrophytic wetland plants

such as cattail (*Typha latifolia*) and reeds *(Phragmites communis*) were observed especially along the downstream reach of the Layang river. The Layang watershed is covered with palm oil and rubber trees with primary forest occupying only a small portions of the area. The remaining land is mainly used for commercial agricultural and flower plantation. The type of vegetation being grown are mainly orchid, white cabbage, coriander and spinach.

2.2 Methods

Wetland section with an area of 120m x 50m, about 10% of the total wetlands area was harvested. The wetlands area during the harvesting time was estimated to be approximately 500m x 120m. The wetland plants were cut using a grass-cutter operated from a boat. Water samples were taken from three stations identified as S(I), S(C) and S(H) located in the river and within the wetland area (Figure 1 and Table 1). The locations of these stations were randomly selected; however, there were observable variations in terms of the system characteristics between the stations. The water samples were taken at the upper and bottom layers. The samples were collected monthly from October 1999 to September 2000. Samplings were performed towards the stream sides of the wetland area as Cirmo and McDonnell (1997) had indicated that these are the focal point for nutrient activities. A small boat (dinghy) was used to transport the sampling team and equipment during high water level. Brown bottles were used to prevent light penetration and Coleman containers packed with ice cube were used for sample preservation. The pH and dissolved oxygen levels were determined using Horiba Water Quality Checker. The samples were analyzed immediately upon arrival at the Universiti Teknologi Malaysia's (UTM) Environmental Laboratory. The samples were stored at about 4^{o}C if analysis was not carried out upon arrival. The water samples were analysed for TP, TDP and Nitrate-N using DR 4000 Spectrophotometer (Hach Co., CO 80539-9987, USA). Water analysis was done according to the Standard Methods as described (APHA 2000). Plant tissue analysis was carried out using colorimetric method by Rouser et. al. (1969).

Table 1. System characteristics and location of sampling station

Stations Abbreviation	Station Characteristics and Location
S(I)	Along the Layang Inflowing River
S(H)	Wetland areas – Harvest station
S(C)	Wetland Areas - Control station

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3.0 Results and Discussion

The plant harvesting operation was performed at the Layang River wetland systems on April 16, 2000 and July 20, 2000. The plant harvesting operation has reduced the TP, TDP and Nitrate-N contents in the river-wetland systems as shown in Figures 2 to 7 and percentage removal in Table 2. The phosphorus levels from the harvested site- S(H), both at the upper and bottom layers were lower compared to the control site - S(C) and the inflowing river (SI). The nitrate-N levels (Figures 6 and 7) were also lower at the harvested site, both for the upper and bottom layers. The monthly percentage removal efficiency (Figures 8 and 9) was calculated based on the values at the inflowing river and wetland systems and expressed as percentages of inflowing river. The monthly percentage removals for TP, TDP and nitrate-N at the harvesting site were higher than the control site. The monthly percentage removals of TP fluctuated noticeably, ranging from 20% to 85% as shown in Figures 8 and 9. The monthly percentage removal of TDP and Nitrate-N were comparable to TP, also ranging from 20% to 89%. The percentage removals of TP, TDP and Nitrate-N were higher at harvested site than control site (Table 2). Percentage removals were also higher after harvest compared to before harvest.

Many researchers have shown reduction in lake nutrient concentration following plant harvesting (e.g. Sloey et al, 1978); Suzuki et al, 1989; Gersberg et al, 1984; Hosoi et al, 1998; Breen, 1990; Alam, 2001. Sloey et al (1978) were able to remove 30-50 $kgha^{-1}$ of phosphorus in bulrush (*Scirpus)* marsh by monthly harvesting. Breen (1990) indicated that the phosphorus in the above ground constituted 44.9% of the total input after harvesting. Harry and Bellinger (1990) managed to remove a maximum of 7% of the phosphorus input by harvesting. Periodical and routine harvesting strategy is necessary for a long term water quality improvement of the downstream reservoir system especially for a reservoir with algae-related problems. The nutrient removal efficiency is affected by factors such as hydraulics or wastewater inflowing loadings rates and detention time (Yang and Xu, 1995; Bhamidimarri et al, 1991). Yang and Xu (1995) found that the variation of the hydraulic inflowing loadings rates and the detention time have great impact on the growth of wetland nitrifying microorganisms, thus affecting the efficiency of nitrogen and phosphorus removal. Bhamidimarri et al (1991) observed that the nutrient removal efficiencies improved once the water level depth was restored at 0.3 m. Water level fluctuations were abrupt during this study which tissue caused the variation in the removal efficiency. A further study on the factors affecting the removal efficiency is recommended

Another observation which could be noted from the result is the fluctuation of the nutrient levels. It was observed that the percentage removal of TP at the upper layer increased in May 2000 and August 2000, one month after the harvesting

operation (Figures 8 and 9). However, reductions in TP (bottom layer) and Nitrate-N (upper layer) were not noticeable. This observation suggests that the percentage removal is highest when the shoots are young. Hosoi et al (1998) found maximum level of nitrogen and phosphorus in wetland plants in their early growth and decreased with the growing period. They observed that the maximum average height of living shoots was achieved when the total sunshine duration reached 500 hrs or 40 days after harvesting. Suzuki et al (1989) reported that the younger tissue has higher nutrient concentrations and reduced with maturity. Phosphorus levels decline more rapidly with maturity compared to nitrate in their study. The harvesting operation reduced the phosphorus levels in the river-wetland systems. The observation on the plant leaves nutrient content (Figures 10 and 11) agrees with the above result. The TP and TN levels in plant leaves were higher at the harvesting site compared to control site.

Hosoi et. al (1998) reported that nutrients were removed from the wetlands more than two times greater by harvesting twice a year rather than once a year. Suzuki et. al. (1989) also indicated that the total plant biomass obtained by double harvesting was 0.5 kgm^{-2} greater than the maximum obtained if shoots were harvested only once in the growing season. They also indicated that double harvesting could remove 0.4gm^{-2} more phosphorus than the highest amount removed if shoots were harvested once a year. Bhamidimarri et al (1991) reported that the nutrient uptake by plants is likely to be minimal unless there is periodical harvesting. According to Alam (2001) multiple harvesting is promising for increasing the possibility of long term control of aquatic vegetation. This suggests that over a long term it is possible to reduce accumulation of nutrients in the Layang Reservoir if continuous generation of younger shoot can take place.

There are also several contradictory opinions on the disadvantages of wetland harvesting operation. Wieder et al (1989) stated that one primary disadvantage of harvesting wetland plants in the temperate is the relatively shorter favorable weather for effective operations. They also found that plant harvesting to remove wastewater contaminants is less effective. Reed et al (1988) stated that routine harvesting is not necessary as this operation will affect the oxygen transfer capacity of the wetland plants. As the removed plants have no or low economic value the disposal would incur additional cost.

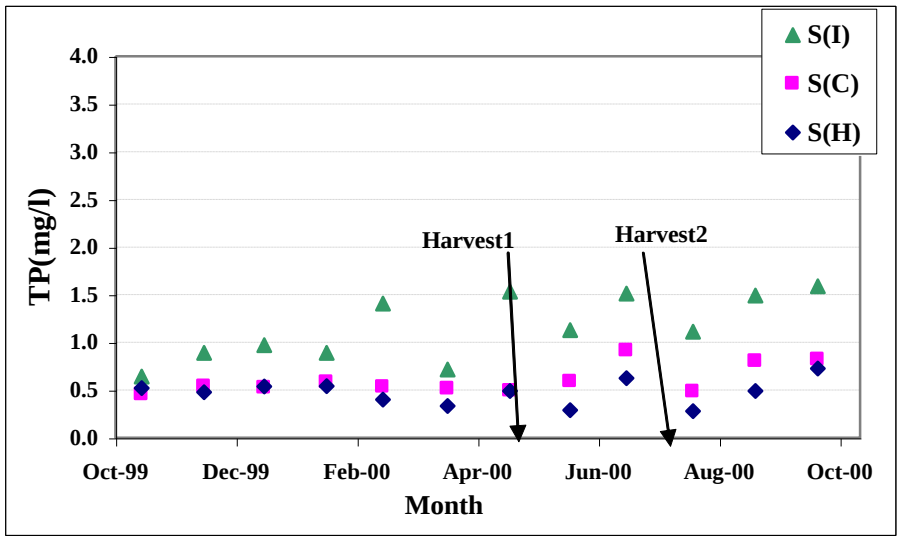

Figure 2 : TP concentration (mgl^{-1}) reduction at Layang River-Wetland Systems (Upper Layer). S(I) – inflow river S(C) – control site S(H) –harvested site

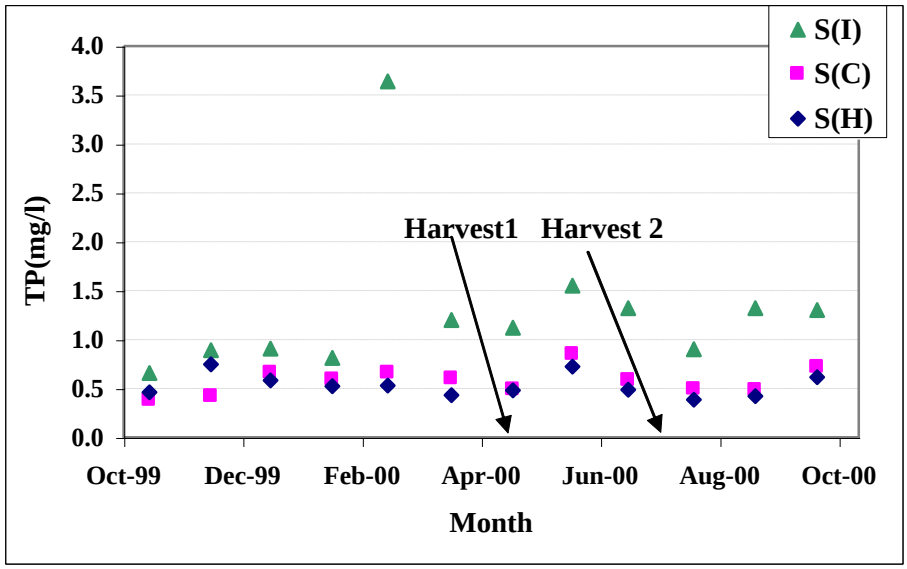

Figure 3 : TP concentration (mgl^{-1}) reduction at Layang River-Wetland Systems (Bottom Layer). S(I) – inflow river S(C) – control site S(H) –harvested site

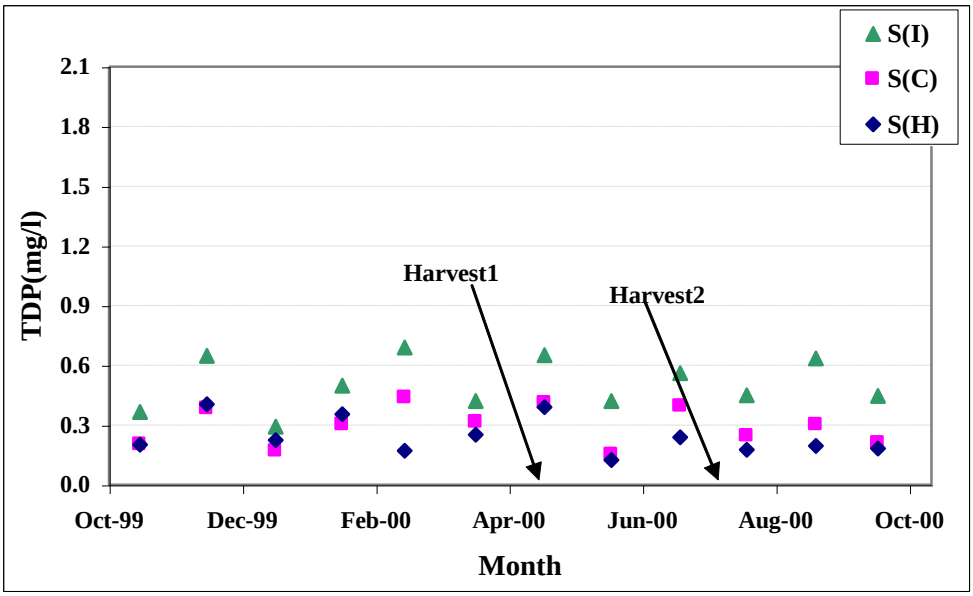

Figure 4 : TDP concentration (mgl^{-1}) reduction at Layang River-Wetland Systems (Upper Layer). S(I) – inflow river S(C) – control site S(H) –harvested site

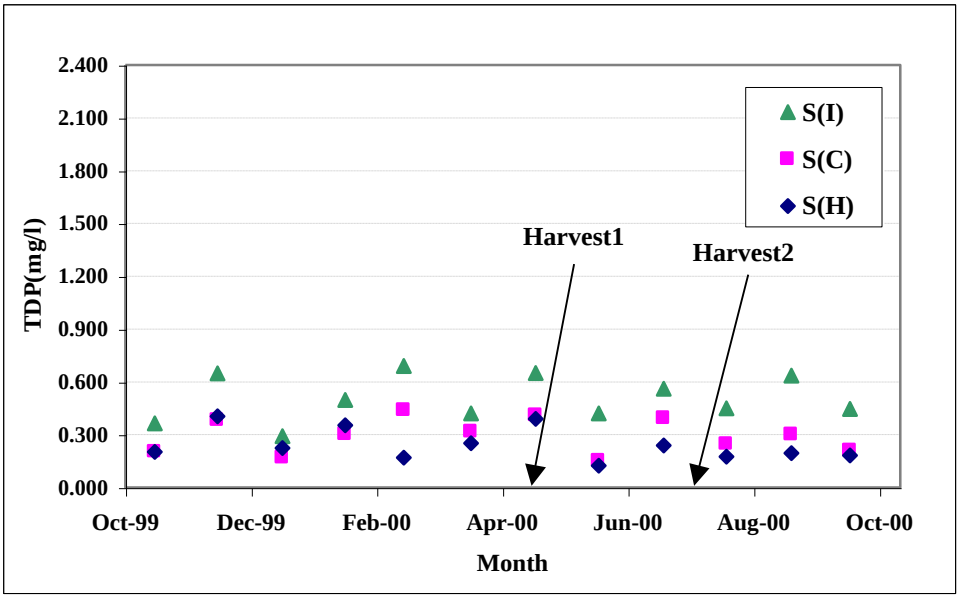

Figure 5 : TDP concentration (mgl^{-1}) reduction at Layang River-Wetland Systems (Bottom Layer). S(I) – inflow river S(C) – control site S(H) –harvested site

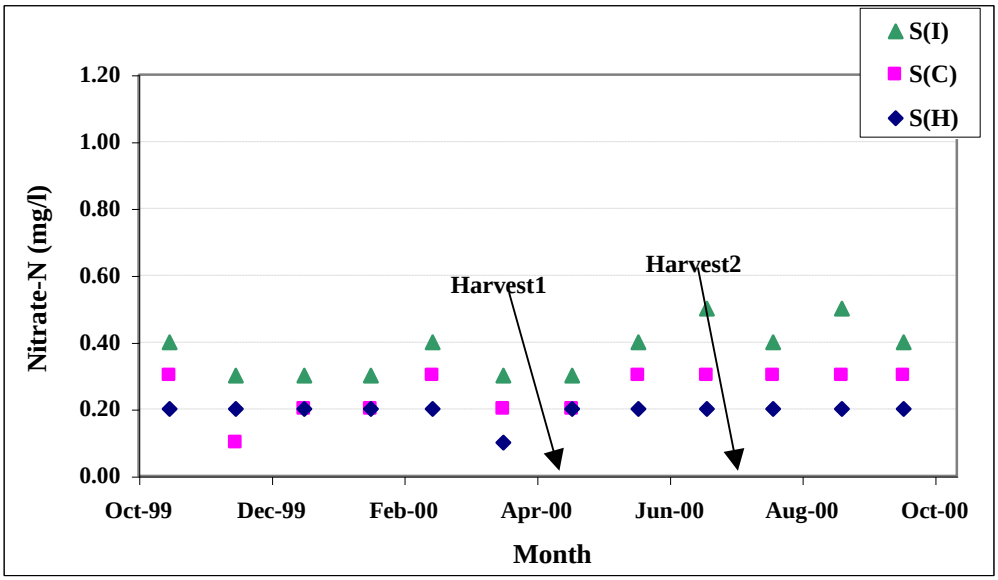

Figure 6 : Nitrate-N concentration (mg/l) reduction at Layang River-Wetland Systems (Upper Layer)
S(I) – inflow river S(C) – control site S(H) –harvested site

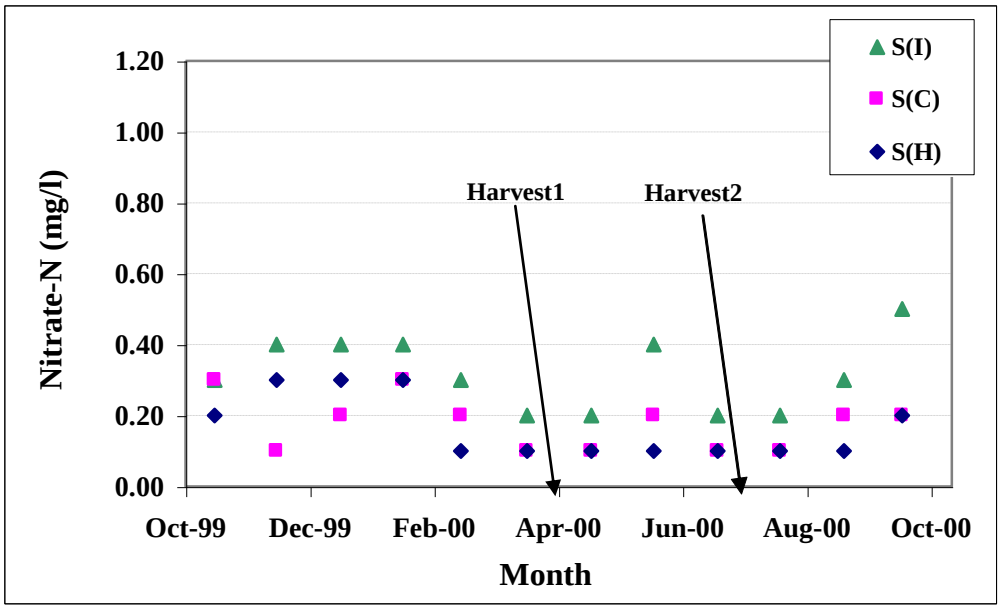

Figure 7 : Nitrate-N concentrations (mgl^{-1}) reduction at Layang River-Wetland systems (Bottom Layer). S(I) – inflow river S(C) – control site S(H) –harvested site

Table 2a : Percentage removals of TP, TDP and nitrate-N(Before Harvest)

	Harvested Site			Control Site			Mean diff.
	Min	Max	Mean	Min	Max	Mean	
TP Upper	19.10	71.57	45.76	28.10	62.40	40.05	5.71
TP Bottom	16.07	85.40	44.53	26.91	81.87	46.75	-2.22
TDP Upper	23.02	75.36	41.64	24.76	44.38	37.97	3.67
TDP Bottom	1.51	89.29	52.37	29.33	61.38	43.89	8.48
Nitrate-N Upper	33.33	66.70	44.44	25.00	66.70	36.11	8.33
Nitrate-NBottom	25.00	66.67	37.56	0.00	75.00	38.88	-1.32

Table 2b : Percentage removals of TP, TDP and nitrate-N(After Harvest)

	Harvested Site			Control Site			Mean diff.
	Min	Max	Mean	Min	Max	Mean	
TP Upper	54.56	74.82	66.26	39.40	67.91	51.04	15.22
TP Bottom	52.76	68.18	58.70	44.62	63.48	51.76	6.94
TDP Upper	40.00	70.48	59.59	29.64	63.81	46.91	12.68
TDP Bottom	25.00	83.27	49.14	21.43	61.98	39.78	9.36
Nitrate-N Upper	33.33	60.00	50.56	25.00	40.00	31.38	19.18
Nitrate-NBottom	50.00	75.00	58.61	33.00	60.00	48.88	9.73

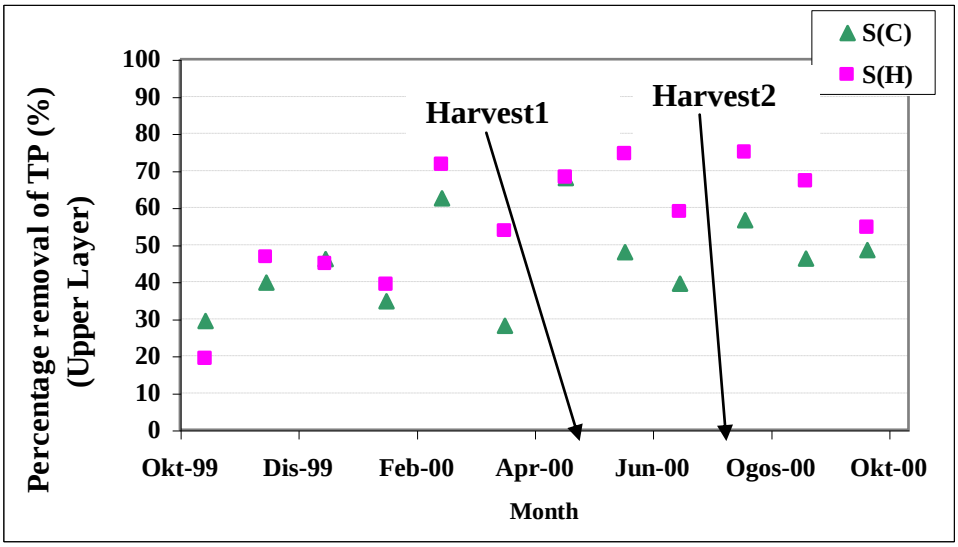

Figure 8 : Percentage reduction of TP at Layang River-Wetland Systems (Upper Layer). S(C) – control site S(H) –harvested site

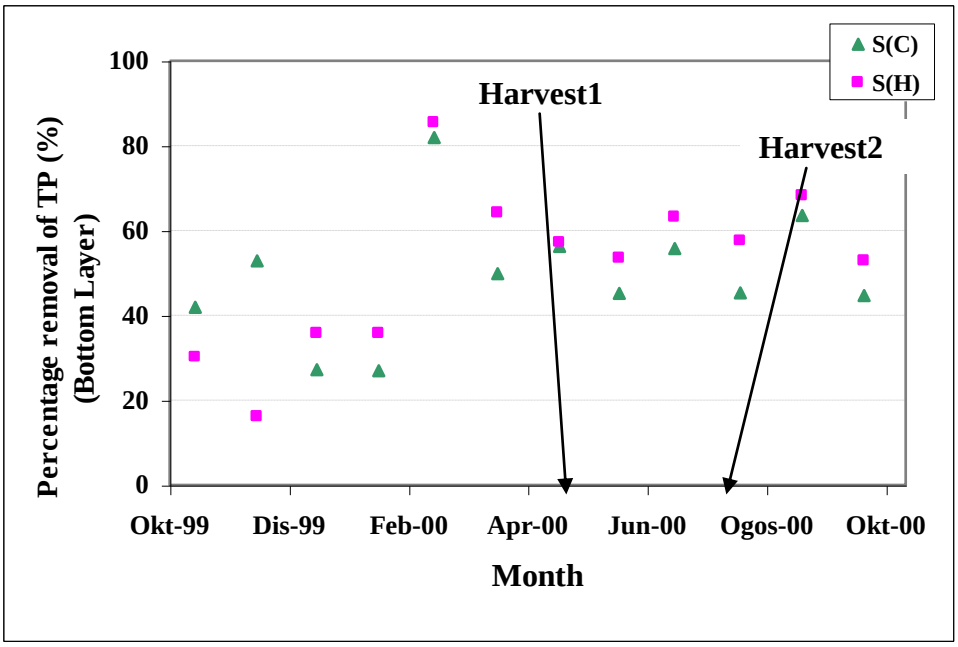

Figure 9: Percentage reduction of TP at Layang River-Wetland Systems (bottom layer). S(C) – control site S(H) –harvested site

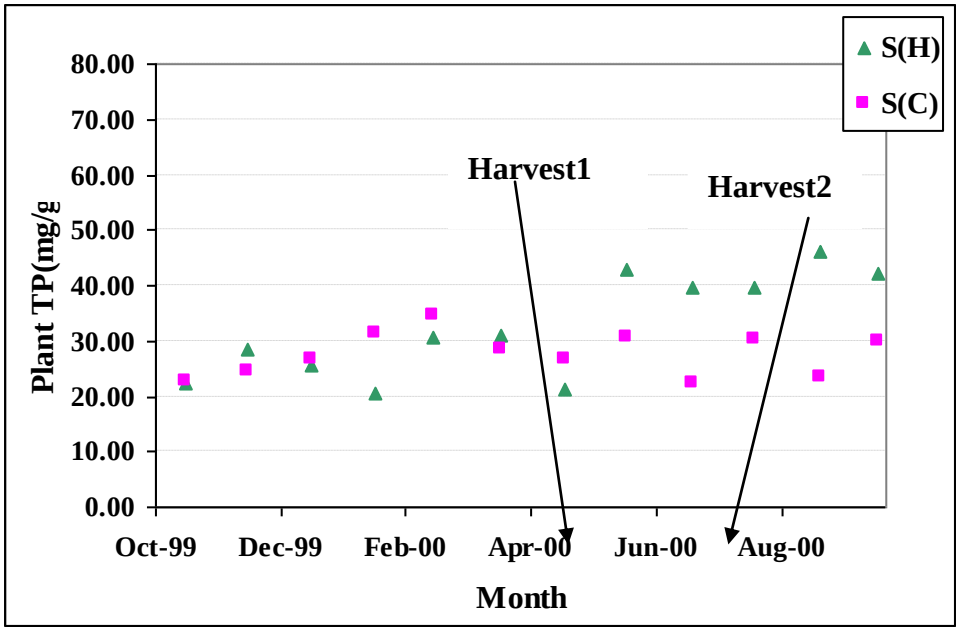

Figure 10 : TP concentrations (mgg^{-1}) in Plant Leaves. S(C) – control site S(H) –harvested site

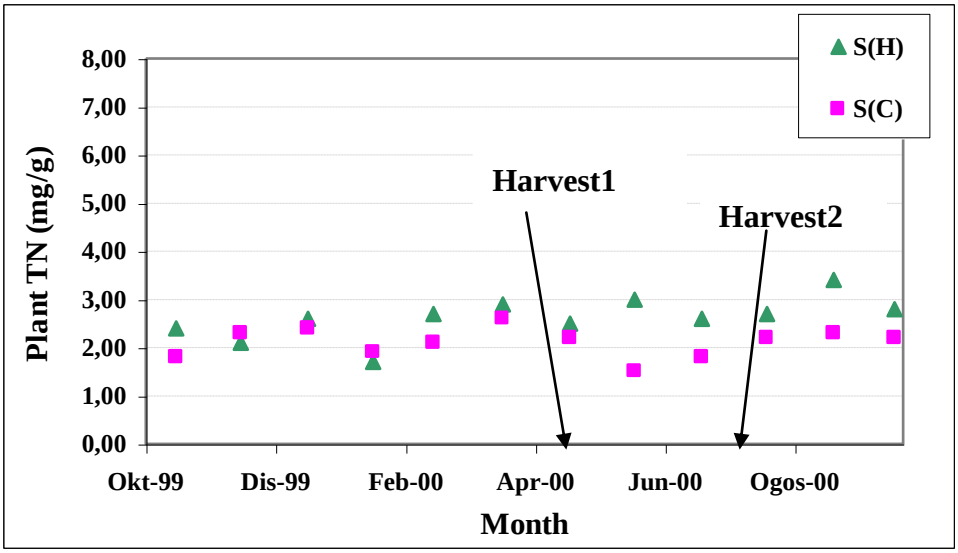

Figure 11: TN concentrations (mgg^{-1}) in plant leaves. S(C) – control site S(H) – harvested site

4.0 Conclusions

Wetland harvesting has been identified as one of promising control strategies for nutrients – TP, TDP and Nitrate-N inflows into the Layang Reservoir. Concentrations of TP, TDP and Nitrate-N in water were lower at the harvested site compared to control site and inflowing river. The nutrient contents in plant leaves were higher after harvesting compared to before harvesting. The Layang wetland systems should be harvested twice a year.

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