



Sustainable Floating Vegetation Linking Cultural Identity of the Intha Farmers Responding to Deforestation on Upland Catchment

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Abstract

Erosion loads and soil sediment characteristics from the deforestation of the Kalaw catchment causes shallow water level and reduced plant nutrients in the Inle Lake aquatic ecosystems. This research aimed to address the effect of soil sediment changes both loads and quality on the practices of floating vegetation which is part of the cultural identity of Intha community. Soil sediment quality data and GIS maps were gathered from government departments and they were used to estimate the topsoil loss and household questionnaire survey were conducted in six Intha communities to evaluate the adverse impacts on Intha livelihoods. The soil sediment loads to the lake's littoral zone due to the forest cover depletion was 80,584 tons per year and their characteristics and large quantity were found affected to process of floating vegetation by using chemical fertilizers and pesticides. All respondents (n = 282) agreed that they were concerned with the adverse effects and impacts from changes in soil sediment that it had a negative impact and it was an impediment to achieving sustainable livelihoods. An Integrated Lake Ecoregion Management Plan including a livelihood development plan are required for implementation by central government so that conservation measures proposed in this research can address environmental, social and economic issues affecting the Inle Lake ecoregion. Buffer zone management should be implemented by local government in order to control high sediment loads in the lake and its flood plain area. The results provided evidence that support the improvement of ecoregion including the Intha livelihoods as a criterion for the Inle aquatic ecoregion for the sustainable management.

Keywords: Ecological function; Sedimentation; Intha livelihoods; Floating vegetation, Inle Lake

Introduction

The concept of ecoregion can contribute to the development of environmental criteria, to illustrate current environmental condition, and to maintain and restore biophysical and chemical composition in lakes [1]. For this reason, ecoregion management can be used as an important tool for the process of ecological assessment. As human are integral part of ecosystem, ecoregion management needs to integrate the role of livelihood development in order to achieve sustainable development [2]. The ecoregion is normally developed by an authority, but effects of using the ecoregions happen from activities at ground. In the Inle Lake ecoregion, ecosystem degradation poses challenges to the livelihoods of rural poor because most rural people rely mainly on natural resources, especially forest ecosystem services, for their livelihoods [2]. The Intha communities are predominant ethnic groups who have been living in littoral zone of Inle Lake and depend on the lake ecosystem services for their livelihoods [3]. They are facing challenges in achieving sustainable livelihoods when the ecosystems of Inle Lake have changed due to deforestation and high sediment loads [3].

Deforestation due to unsustainable land use practices in the catchment causes soil erosion, increased sediment, and nutrients loads in the lake [4]. There is generally hypothesized that increased destroying natural forest in the catchment areas, even as small as $<1 \text{ km}^2$, can cause an increase in sediment loads and changes of sediment characteristics [4]. Land-use management practices can have a significant effect on catchment sediment yield, and rate of runoff [5]. Sedimentation and soil erosion are indicators of mismanagement in upland catchment and consequences of deforestation which eventually causes lake sedimentation. In the upland catchment of Inle Lake, significant forest degradation was caused by mismanagement of the ecosystem. As a consequence, high sediment

loads were deposited on flood plain area of the lake through runoff from catchment.

The functions of upland forest and catchment are crucial for the lake health. In forest ecosystems, the creation of an organic forest floor, the maintenance of mineral soil organic matter, and formation of plant root networks that allow for rapid water flow from the soil surface into groundwater, are important contributions to forest hydrology and water quality of lake and streams [6]. In forested area, soil sediments are characterized by rich soil nutrients and organic materials, dissolved organic carbon and nitrogen [7–11]. In deforested area, the soil sediment characteristics change to sandy and silt, more gravels, and decreased soil nutrients and organic matter contents [12–15]. Regarding with the ecological function of Inle Lake ecoregion, the natural process of sedimentation, nutrient translocation from upland supports soil fertility on low land area of Inle Lake [16–17]. In its natural state, the Inle Lake had formed deltas on its flood plain area, and nutrient were deposited on the littoral zone of the lake through sedimentation from upland and this contributed extensively to the development of floating vegetation; cultural identity of Intha [15]. Through these ecological functions, the Intha get required soil nutrients for their floating vegetation and a good livable environment for their livelihoods. This means that the role of upland forest ecosystem is of paramount importance to the lake and Intha livelihoods.

However, that natural function has significantly changed with increased sediment loads in current time compared with the last 50 years [14]. Deforestation is the major contributors of severe sedimentation due to erosion and loss of top soil and decrease in fertility [10]. In the degraded forest area of upland catchment, the bare soil is not able to maintain water sufficiently and large sediment loads are transported into the lake through rapid runoff.

In this way, high sediment loads and soil nutrients depletion can be occurred in the lake. As a consequence, this has negative impact on the growth process of the floating vegetation process of the Intha.

The growth process of Intha's floating vegetation plots uses sediment from the bottom of the lake and aquatic plants like algae, weeds and water hyacinth from the wetland area of lake as a supportive medium/substrate. The black sediment scooped out from the lake bottom are spread over it and covered with a layer of weeds and one more silt layer. The sediment and clay alluvium from the bottom of the lake, aquatic weeds, and algae are used to enhance the fertility and nutrients for growth of floating vegetation.

The changes in the existing environmental conditions, intensive sediment loads, often cause socio-economic problems [18]. Soil nutrients come from degraded forest area cannot benefit the Intha with sustainable yields from floating vegetation. Normally, ecosystem management mainly focuses on environmental conditions. Understanding the factors that are causing ecological functions change is important to creating interventions that can implement restoration by effective management system. However, in the case of Inle Lake ecoregion, we need to consider the vulnerability of Intha livelihoods because they are highly dependent on the ecosystem services of the lake and the upland catchment. Therefore, the integration of Intha's livelihoods development in ecoregion management is quite important for the Inle Lake ecoregion. Thus, this study particularly concerned with linkage that deal with changes in ecological function and their impact on the Intha livelihoods.

Materials and methods

1) Study area

This research was conducted in the Inle Lake ecoregion which is located in Nyaungshwe

Township, southern Shan State of Myanmar with a total watershed area of 5612 km² and extends from approximately 20°15' to 20°45' N latitude to 96°49' to 96°48' E longitude [18]. The study area was selected the Thandaung stream delta of Kalaw watershed that covers an area of about 670 km² among four major watersheds, namely, Namlet, Yay Pei, Kalaw and Bilu streams. The Thandaung stream, one of the major streams flowing into the Inle Lake from Kalaw watershed which is located western part of the lake and has most of the floating vegetation areas among the Intha community occupying the delta area of stream and lake (Figure 1). The topography of Inle Lake ecoregion comprises of three sub-ecoregions which include the upland forest catchment, low land agriculture area and the lake water body. The Intha's floating vegetation area exists in a flood plain area or in the littoral zone of the lake.

The Inle Lake is a wetland habitat type supporting a rich biodiversity and traditional culture of the local Intha people. The Inle Lake ecosystem contributes several socio-economic benefits to the local people. The local people who live in Inle Lake ecoregion rely on three main ecosystems; forest ecosystem, agro-ecosystem and wetland ecosystem. There are about 38 Intha villages, the major indigenous group, who are living in the flood plain area of the lake and practicing floating vegetation agriculture, mainly growing tomato as a major cash crop.

In the study area, livelihoods of Intha community are floating vegetation, fishing, agricultural farming, wage labor, ecotourism, and small businesses. The Inle Lake is an integral part of the Intha community's livelihood, as they are dependent on fisheries and floating vegetation growing tomato to a wide extent as their major cash crop [18]. The floating vegetation supports the Intha communities with local food security, export opportunities and it also becomes main income source. Thus, this

study mainly focuses on floating vegetation as their major livelihood how it was impacted by high sediment loads due to deforestation.

The major factor threatening the ecological function of Inle Lake ecoregion was deforestation and high sedimentation which were deposited from the Kalaw catchment. The Thandaung stream delta has transported high sediment loads caused by serious erosion and major contributions of sediments to the Inle Lake [19]. Moreover, most of Intha's floating vegetation villages are located in the Thandaung stream delta. Considering these factors, the Thandaung stream delta was selected for this study. The location map of the Thandaung delta is shown in Figure 1.

2) Research methods

For prediction of sediment loads, Revised Universal Soil Loss Equation (RUSLE) [20] was applied to predict average annual soil erosion by water. It is a widely used mathematical model that describes soil erosion processes (Eq. 1).

$$A = R \times K \times LS \times C \times P \quad (\text{Eq. 1})$$

Where; A = average annual soil loss in $t \text{ ha}^{-1} \text{ a}^{-1}$, R = rainfall erosivity index, K = soil erodibility factor, L = slope length, S = slope factor and slope gradient (%), C = vegetation cover factor and P = conservation practice factor.

Regarding with an assessment of deforestation rate, LANDSAT Satellite images of land use changes in the Inle Lake watershed and GIS land use and land cover map were applied to identify vegetation cover of Inle Lake ecoregion for deforestation rate and extent of the lake water body. These GIS maps distinguish watershed area, deforested area, agricultural land, floating vegetation area and lake water surface. According to these maps, we can assess the deforestation process and spatial-temporal changes of land use and land cover in the Inle catchment as a significant challenge.

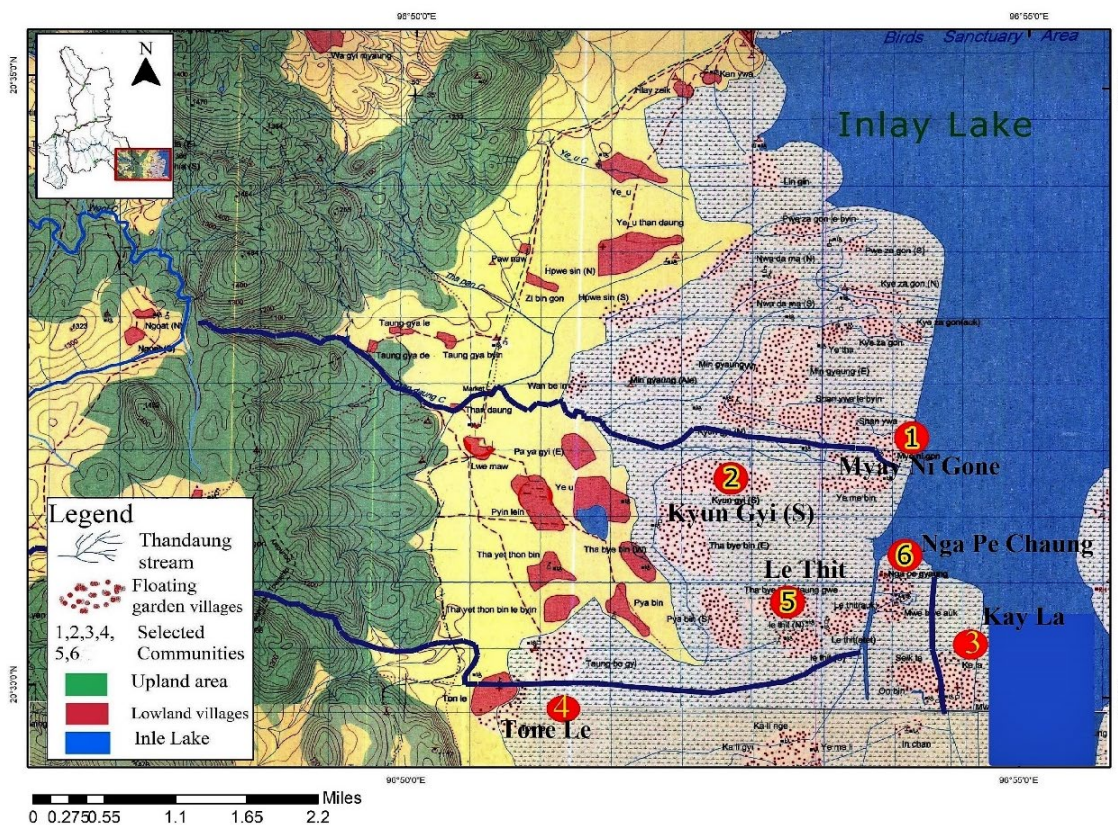


Figure 1 Locations of selected Intha communities in Nyaungshwe Township.

Social survey was conducted to know the perception of Intha's farmers about high sediment load influence on their livelihoods especially floating vegetation and how much dependency they have on the lake's ecosystem. During the field visit, household questionnaire survey and focus group discussions were carried out in the study area by using qualitative and quantitative methods (mixed method). Focus group discussion consisted of local governmental organizations (forest department, agriculture department, irrigation and water utilization), and some Non-Governmental Organizations (NGOs). For the household questionnaire survey, samples of six sample Intha communities were selected by using random sampling method. And, the sampling size for the number of respondents/households was calculated based on Yamane's formula [21] (Eq. 2).

$$n = \frac{N}{1+N(e)^2} \quad (\text{Eq. 2})$$

Where; n = the sample size, N = the size of population, e = level of precision.

By using Yamane's formula of sample size with an error 5% and with a 95% confidence level [21], calculated sample size covers the total number of households. Therefore, the number of sample sizes of households were 282 out of 964 households from 6 communities in the study area according to Yamane's formula.

Moreover, proportional stratified random sampling method was used for the calculation of proportional sample from 282 households. A formula for calculation is shown in following (Eq. 3):

$$ni = \frac{n \times Ni}{N} \quad (\text{Eq. 3})$$

Where; n_i = sample sizes of household of each village, n = total sample size, N_i = numbers of household of each village, N = total numbers of households

Descriptive statistical analysis was applied by using Microsoft Excel to compare the soil nutrients analytical data in six sample Intha villages gathered from Agriculture Department in Nyaungshwe Township and collected qualitative information of soil properties from household survey. The results are interpreted through percentages, tables, bar graphs and figures.

Results and discussion

1) High sediment loads on littoral zone of Inle Lake caused by forest degradation in catchment

The Inle Lake receives $4.56 \text{ t ha}^{-1} \text{ a}^{-1}$ and $80,584 \text{ t a}^{-1}$ of sediments from the Thandaung stream, the Kalaw catchment area of 670 km^2 . The biggest soil loss comes from agricultural land at $72,912 \text{ t a}^{-1}$ whereas $7,180 \text{ t a}^{-1}$ comes from degraded forest and 14.7 t a^{-1} from closed forest. These figures indicate the higher proportion of closed forest cover, the lesser the soil loss. Significant land-use change from forest area to agriculture land in upland catchment could be one reason for high sediment loads deposited from agriculture land.

According to the results from previous research, almost 45% of the total sediment loads from the Kalaw watershed came from degraded forest area [19]. According to Furuichi research regarding erosion and sedimentation in Inle Lake, there was estimated that total sediment inputs from the whole Inle Lake catchment were approximately $277,000 \text{ t a}^{-1}$ in littoral zone of the lake [22]. If the total sediment loads of $80,584 \text{ t a}^{-1}$ came from Kalaw watershed alone, it can be assumed that the sediment deposited from Kalaw catchment was intensive.

If sediment loads from other streams flowing into the lake were to be taken into consideration, then the total sediment loads would be much higher than this estimate and implying that livelihoods of local Intha are affected by this high sediment loads. According to household

interview, 46% of respondents noticed that high sediment loads occurred on the flood plain area and it destroyed their floating vegetation because of a decline in the water level. Therefore, high sediment loads caused by upland forest degradation have great impacts on the livelihood of Intha.

The percentage coverage of each different land use type in the Kalaw catchment are agricultural land 69.94%, closed forest 6.28%, degraded forest 3.08%, and others 20.64%. According to field observation and land use map, significant change in land use and land cover was occurred in agricultural land and forests. A total forest cover of 92 km² has diminished during 1989-2014 but the amount of forest cover loss of 115 km² is obvious in 2000-2014 [23]. Agriculture land area was increased from 60.67% in 2000 to 69.94 % in 2015, and especially floating vegetation which is invading the wetland was observed (Figure 2). Wetland area has been reduced dramatically, from 3.01% in 1989 to only 0.94% in 2014 [23–24]. From

1935 to 2000, the net open water area of Inle Lake decreased from 69.10 to 46.69 km², a loss of 32.4% during this 65-year period [25] caused by sedimentation due to deforestation in catchment and increased sediment loads on flood plain area of the lake. The following figure shows degraded forest in the catchment, crop land expansion, wetland depletion and shrinkage of lake water bodies.

In the Inle Lake catchment area, forests account for about 483 square miles of the catchment area [26]. In 2010, over 45% of natural forest cover extended in Taunggyi region, Shan State. In 2018, 7,740 ha of natural forest cover were lost. From 2001 to 2018, the amount of forest cover lost was 70,270 ha in Taunggyi, equivalent to 7% decrease since 2000. In Kalaw and Nyaungshwe Townships, percentage of land cover change is 9.43% and 6.79% of the whole Taunggyi Region [27]. The increasing forest cover loss during 2001 to 2018 is shown in (Figure 3).

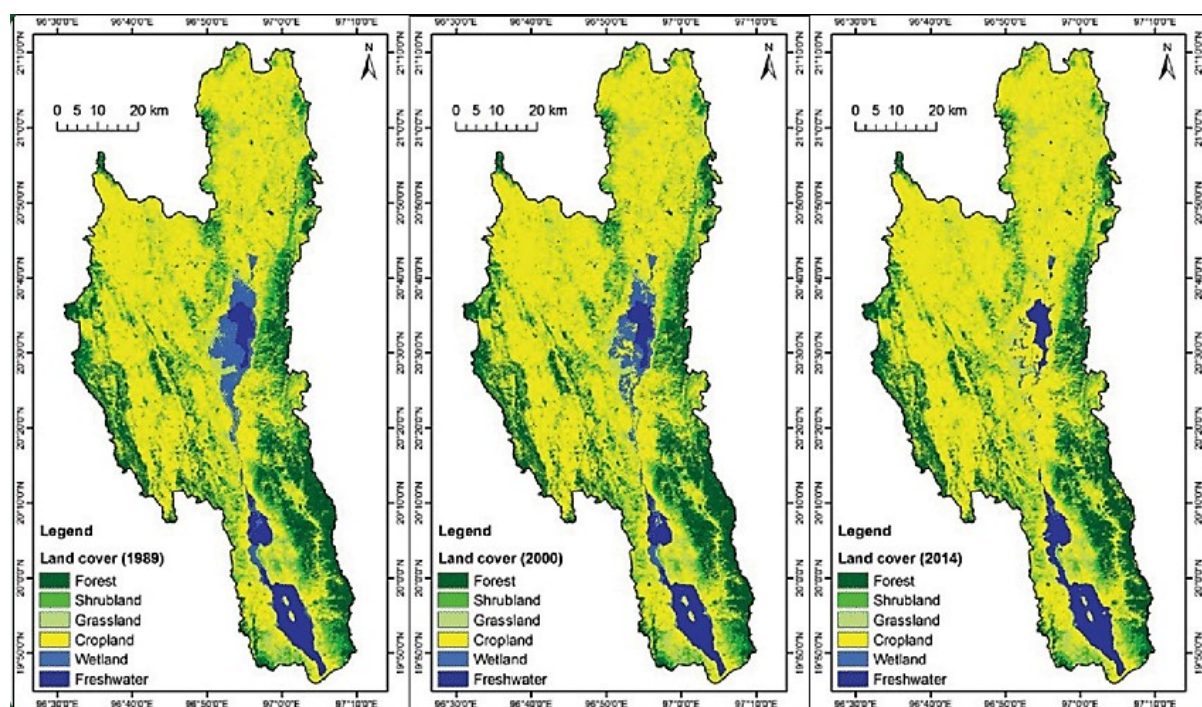


Figure 2 Spatial-temporal changes of land use and land cover in Inle catchment.

Source: [23–24]

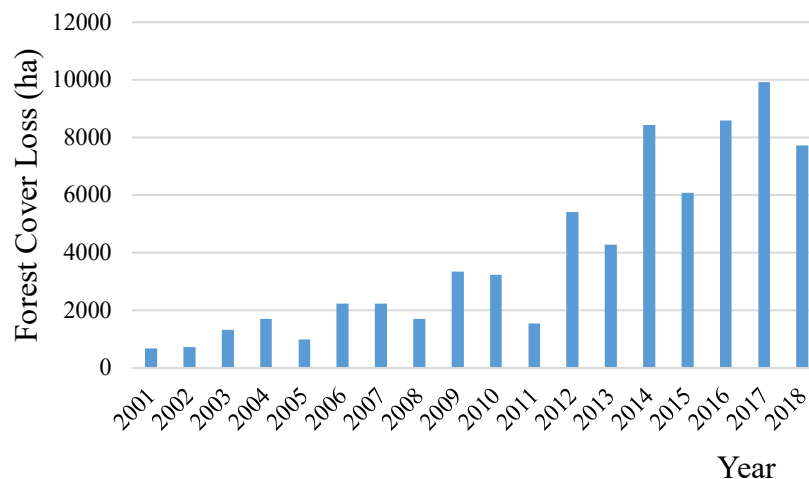


Figure 3 Increasing trend of forest cover loss in Taunggye Region, Southern Shan State.

Source: [28]

2) Effect of changing soil sediment loads and characteristics on floating vegetation

In the Inle Lake catchment, soil nutrient contents or soil fertility are of poor quality and declined by loss of topsoil, soil erosion and decrease in organic matter due to forest degradation. The Intha farmers are highly dependent on soil sediment for floating vegetation practices. The result showed that there were 86.5% of households are dependent upon the lake ecosystem for their livelihoods especially floating vegetation and fishing. Regarding the Intha farmers' perception on impacts of high sediment loads, Intha farmers (n = 282) concerned on the high sediment loads and 46% of respondents answered that high sediment loads occurred in the flood plain area and it destroyed their floating vegetation because it caused the water level to decline and floating vegetation could not float in shallow water as their roots got attached to the soil and finally it was destroyed. Thirty four percent of respondents reported that the lake water level has declined and become shallower than the past decades. And, 12% of the local people were more concerned about transportation problem because their agriculture products were transported through waterways. The waterways

were becoming shallower due to sedimentation. Damaging the water transportation system has significant impacts on Intha's socio-economic status. Moreover, most of elder people noticed that the sediment in streams carrying from the upland catchment were sandy at present time. This means that the texture of sediment changed to sandy type because of deforestation on the upland catchment.

This opinion was supported by the previous analysis research study at Mine Thaut Village Tract, eastern side of Inle Lake and it showed that the value of soil nutrients in the Inle catchment were 0.77% of total nitrogen (N), 11.80 ppm of available phosphorus (P) and 0.87 ppm of available potassium oxide (K₂O) [29]. These amounts were very low compared with floating vegetation area. An another previous social research conducted in Inle Lake region also proved that soil fertility was declined in upland and lowland zones [30]. According to the results of soil quality analysis conducted by Agriculture Department in six sample Intha villages in study area, soil nutrients: (N, P, K) contents were high in two sample floating vegetation plots while comparing with two sample plots located near the Thandaung stream flowing from upland catchment (Figure 4)

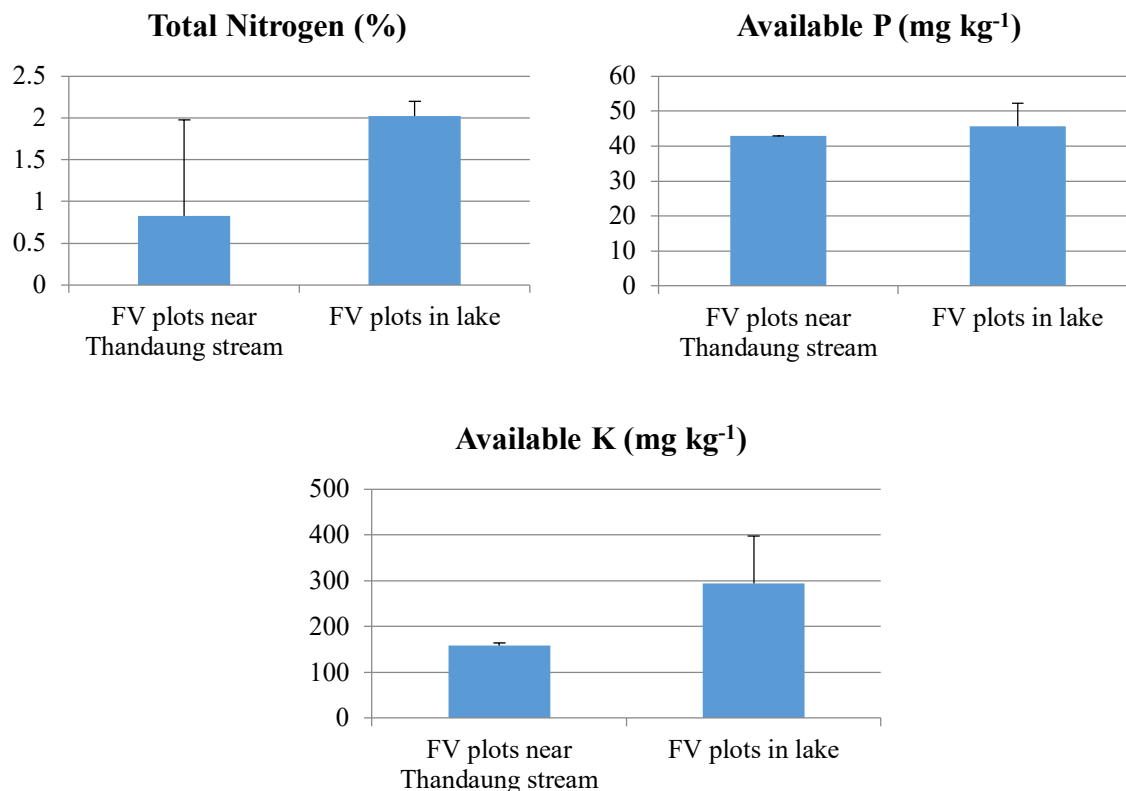


Figure 4 Soil nutrients (N, P, K) contents in different floating vegetation plots near Thandaung stream and in lake.

High content of N, P, K values could be for adding organic manure, algae, and chemical fertilizer at the time of making floating plot for vegetation. Besides, use of black silt from bottom of the lake and aquatic weeds, and agro-chemicals fertilizer, the soil is enriched with N, P, K in floating vegetation plots. According to the household interview, 100% of farmers said that they need to use fertilizer to maintain higher yields of crops and they cannot grow vegetable without adding chemical fertilizers for floating vegetation. Moreover, farmers noticed that sandy texture sediments were deposited in the Thandaung stream from the Kalaw watershed and this phenomenon negatively affected to their floating vegetation.

Among the six surveyed communities, three communities, namely Myay Ni Gone, Lae Thit and Kyun Gyi are located quite close to the Thandaung stream flowing from upland catchment, then they have encountered

significant impacts of high sediment loads and changes of sediment quality than other communities. Almost all respondents answered that the main impact of sedimentation was causing shallow water level which was destroying their floating vegetation. In these three vulnerable communities, farmers noticed that sandy texture sediments were deposited in streams at present time. Then, this situation had a negative impact on the productivity of their floating vegetation. When comparing floating vegetation yields of six Intha communities, floating vegetation yields of these three communities were lower than that of others and the total number of sample size of households were 282 out of 964 households from 6 communities in the study area (Figure 5). In the Lae Thit village, 25% of households changed floating vegetation to farm land since last 10 years ago because high sediment deposition caused shallow water level and dry land

eventually formed in such places. Then they changed from floating vegetation to other farming practices, growing other seasonal crops instead.

In the Kyun Gyi communities, 62% of households cannot support their livelihoods with floating vegetation income alone. They also changed floating vegetation to other farming practices such as growing peanuts since last 20 years because new farmland had formed and the water level had declined due to high sediment loads. Therefore, changing livelihoods was the obvious impact of high sediment loads in this community. Particularly, the impact of sedimentation in changing livelihoods from aquatic-based floating vegetation to terrestrial farming and damage of transportation waterways were found to be problematic for the Intha communities and impact on their agriculture yields as well.

Regarding the ecosystem management regardless of the livelihoods of vulnerable Intha community, the changes of soil sediments and characteristics by forest degradation in catchment caused the impact on their cultural identity, especially the process of floating vegetation. The natural process of sedimentation and nutrient translocation from upland supports soil fertility in the littoral zone of Inle Lake. In its natural phenomena, the Inle Lake had formed

deltas with fertile soil and nutrients deposited in littoral zone of the lake through sedimentation from upland which contributed to extensive development of floating vegetation; cultural identity of Intha and their economic growth. This means the linkage of changes in ecological function and culture identity of the Intha livelihoods.

In order to achieve sustainable management of Inle Lake ecoregion, inclusive ecoregion management needs to be implemented by integrating three main pillars: Environment (soil nutrients and fertility through sedimentation), Culture (Intha floating vegetation practices), and Economic (income). This implies that there is need to manage the Inle Lake ecosystem with the participation of Intha community, by formulating a livelihood development plan: Good Agriculture Practices (GAPs) for floating vegetation in order to support the lake ecosystem conservation.

Regarding the situation of soil sediment solving in Inle Lake, buffer zone management needs to be implemented by local organizations and Inle Lake conservation community. Buffer zone can trap high sediment loads transporting from upland catchment in order to protect entering into the lake as a vegetative filter and buffer prevent fluctuating water level in flood plain area of the lake.

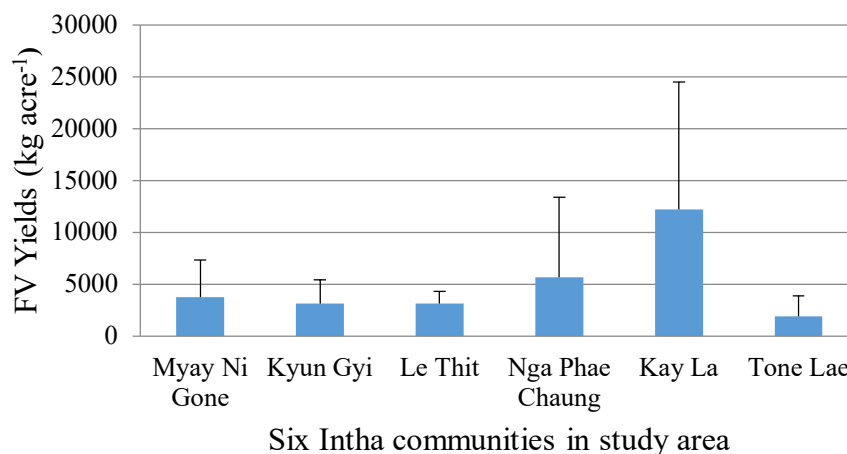


Figure 5 Comparison of average yields of floating vegetation in six Intha communities.

Soil erosion and sedimentation control measures need to be conducted by giving priority to land and water management at the catchment scale. Sedimentation in the Kalaw stream is most likely serious than in other catchments. The integrated Inle Lake ecoregion management should include protection of high sediment loads, restoration of floodplains and wetlands, catchment conservation, and sustainable agricultural practices for local livelihood development. Moreover, there is a need to raise awareness among local people about sustainable consumption of natural resources in order to help conserve and restore the lake ecosystem. Hence, some recommendations are proposed regarding to this study and further research;

- Enhancing effective catchment conservation and sustainable land use practices (Agro-forestry development) on upland catchment by local government.

- Implementing buffer zone management to control high sediment loads in lake and its littoral zone.

- Formulating Livelihood Development Plan: good agriculture practices (GAPs) for floating vegetation and set secure market for products of GAPs

- Ensure Inclusive Ecoregion Management balancing ecosystem services and the Intha's livelihood development

- Future ecoregion should include the Intha livelihoods as the criteria of Inle aquatic ecoregion development and an approach to sustainable management.

Conclusion

High amount of sediment loads and sandy texture sediments were found deposited from forest degraded area in upland Kalaw catchment because of significant land-use change from forest to agriculture land in the catchment area. The main impact of high sedimentation was causing shallow water level in littoral zone of the lake and sandy sediment which were

deposited through the Thandaung stream. This phenomenon had a negative impact on the Intha floating vegetation by decreasing yields and changing practices. Thus, changing livelihoods and floating vegetation practices were the obvious impact of high sediment loads for Intha communities. When the management of Inle Lake ecoregion was developed regardless of Intha livelihoods and their cultural identity, the vulnerable Intha people were affected since they were utilizing ecosystem services. Thus, this study indicated that the integration of Intha livelihoods in ecoregion management is required in achieving sustainable ecoregion management.

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