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# Identification of impacts, some biology of water hyacinth (*Eichhornia crassipes*) and its management options in Lake Tana, Ethiopia

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**ABSTRACT**

The study was conducted from July, 2013 to July, 2015 in the North-Eastern part of lake Tana. Six sites were selected from Fogera, Libokemkem and Dembia districts based on water hyacinth infestation and free area. Plant sample was collected from infested areas using quadrant and different parameters were recorded using sensitive balance and tape meter. The physical parameters were measured *in situ* using YSI 556 multi-probe system, while the chemical parameters were carried out using a portable water analysis kit. Zooplankton and phytoplankton samples were collected by 80 and 50 µm mesh net filtering device. Moreover, structured questionnaire, focuses group discussion, key informant interview has been used to collect some quantitative and qualitative data. 104 plants/$m^2$ and 8.216 ± 0.45 kg fresh weight/$m^2$ which equals 82,160 kg/ha or 82.16 tones/ha fresh weight can be harvested during the dry season of a year. But 583 plants/$m^2$ which equals 270,000 kg/ha = 270 tones/ha fresh weight can be harvested during the wet season of a year. The present assessment also noted that no major management strategy had been employed in the infested water body areas, despite many efforts had been applied by the community and the government. Water hyacinth poses serious problems on the community living around Lake Tana by affecting fishing process, farmland, livestock and the environment of in a variety of ways.

**Keywords:** Control strategies, infested area, fishing, native species, nutrient load.

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## INTRODUCTION

Water hyacinth (*Eichhornia crasspies*) is widely recognized as the world's worst aquatic weed. Originally exported from its native Amazonian basin because of its attractive flowers, the species rapidly established and spread throughout tropical, subtropical and warm temperate regions of the world (Julien et al., 1999). It was indicated that this weed forms a dense impenetrable mats across water surface, limiting access by man, animals and machinery. Moreover, navigation and fishing are obstructed, and hydropower, irrigation as well as drainage systems become blocked. The weed was first introduced into Africa through Egypt sometimes between 1879 and 1882 (Friend, 1989). It has been recognized as the most damaging aquatic weed in Ethiopia since its first presence in 1965 (Stroud, 1994; Rezene, 2005). It has been recognized its presence in lake Tana in 2011 (Tewabe, 2015). Even though several efforts have been made by different parties, its expansion increased year after year. Therefore, there is a need to study some of its biology, impact on water quality, biota and current management options. Thus, the present study aimed to (1) examine some biology and biomass at different periods of a year; (2) identify its impact on water quality, fishing activities and over all socio-economic challenges in the community; (3) identify current management options and ways taken by the assigned parties and check its effectiveness and identify its drawbacks; and (4) identify its distribution, area coverage and direction from water hyacinth inception area perspective.

## MATERIALS AND METHODS

The study was conducted from July, 2013 to July, 2015 in the North-Eastern part of lake Tana. Sampled sites chosen were from Fogera, Libokemkem and Dembia woreda and two sampling sites were selected from each woreda based on water hyacinth infestation and water hyacinth free area. Plant sample was collected from infested areas using quadrant and different parameters were recorded using sensitive balance and tape meter.

### Measurement of physico-chemical parameters

Dissolved oxygen (DO), pH, specific conductance ($K_{25}$), total dissolved solid (TDS), Salinity (sal) and Temperature (T) were measured *in situ* using an instrument model YSI 556 multi-probe system.

Measurements of Ammonia ($NH_3$-N), Phosphate ($PO_4$-P), Nitrate ($NO_3$-N) and Total hardness were carried out using Photometer Systems for Water Analysis; a portable water analysis kit with model Palintest transmittance display photometer 5000. Nutrient analyses were made in the shore area immediately after sample collection using water samples filtered through Whatman GF/C.

### Plankton sampling

Water samples were collected from each sampling station up to a depth of 1 m using a 10 L bucket. Zooplankton and phytoplankton samples were collected by 80 and 50 µm mesh net filtering device. Collected specimens immediately fixed with 4% formalin and were fixed using Lugol's iodine solution respectively. Identification of plankton was carried out under a binocular biological microscope (model, Olympus CHS) and enumeration was made using standard procedures according to Lind (1979). Dry weight of water hyacinth has been analyzed following the procedures of solar drying system. The social and quantitative data were collected by using structured questionnaire, focused group discussion, key informants interview.

### Statistical analysis

The collected data was analyzed by both qualitative and quantitative approaches. Descriptive statistics such as frequency, mean, percentage, standard deviations were also used. In addition, one-way analysis of variance (ANOVA) were employed by using SPSS version 20 software.

## RESULTS AND DISCUSSION

During dry season sampling in 1 m × 1 m = 1 $m^2$ there was 13 batches/$m^2$ area of water hyacinth with in a batch there was 8 individual plants which implies 104 plants/$m^2$ and 8.216 ± 0.45 kg fresh weight/$m^2$ this equals 82,160 kg/ha = 82.16 tones/ha fresh weight can be harvested during the dry season of a year. In the contrary during the wet season with in 1 m × 1m = 1 $m^2$ it is found that 55 batches and 27± 0.61 kg fresh weight/$m^2$ was recorded. In each batch there were a mean number of 10.6 plants. 583 plants/$m^2$. 270,000 kg/ha = 270 tones/ha fresh weight can be harvested during the wet season of a year. As a result, batches of water hyacinth root, leaf and petioles part has been dried and its dry weight found to be 84.36, 62.5 and 92.11%, respectively.

The highest plant population count (308 plants/$m^2$) was recorded in Koka Dam followed by Lake Koka (298 plants/$m^2$), Lake Ellen (274 plants/$m^2$), Lake Elletoke (268 plants/$m^2$), Afer Gedeb (261 plants/$m^2$), Tare and Awash (211 and 186 plants/$m^2$) according to Firehun et al. (2014).

### Trends of water hyacinth coverage

Area coverage of water hyacinth has been increased at alarming rate. Its coverage at the inception period in 2011 was about 80 to 100 ha (Tewabe, 2015). After a year it can cover about 20,000 ha (BoEPLAU, 2012) (Figure 1). Even if tremendous amount of human labour, time and money has been exerted each year by both surrounding community and government, its coverage continues to escalate up to 50,000 ha in the subsequent years (Anteneh et al., 2015) (Figure 2).

Due to lack of knowledge about the biology of the plant, the measure to avoid or reduce the water hyacinth from and around the Lake has failed. If it is required to eliminate water hyacinth from the Lake, it needs complete clearance including individual plant fragments tissues. However, the measures taken by bureau of environmental protection and other concerned stakeholders are not like this. Figure 3 showed that the Water hyacinth infestation current status on the shore of Lake Tana estimated to be ca. 34500 ha by May, 2015.

Most of the farmers and governmental bodies merely collect certain amount of water hyacinth with high cost and deposit somewhere, mostly around the shoreline. On the other day, the expansion of the weed become aggravated because during the disturbance each fragile part of the plant to most part of the area through wave and others. In addition, site selection to deposit the harvested weed biomass is inappropriate. Drained input fertilizer and other agricultural influents from crop cultivated land and the catchment area of the lake aggravates water hyacinth to over dominate other floras. Therefore, shore area floras which would be important fish breeding grounds and livestock forage source in the vicinity become damaged. (Table 1)

Values of physico-chemical parameters measured in this study are shown in Table 2. Except DO, $NO_3$, $NO_2$ and $NH_3$, higher mean values were recorded in the weed infested site. However, there were no statistically significance difference between the weed infested and non-infested sites.

Floating water hyacinth mat may have profound influence on diurnal temperature fluctuation (Mehra et al., 1999). Mironga et al. (2012) also reported that due to the presence of dense water hyacinth mat, which blocks the exchange of heat between the lake surface and the atmosphere and heat generated from decaying organic

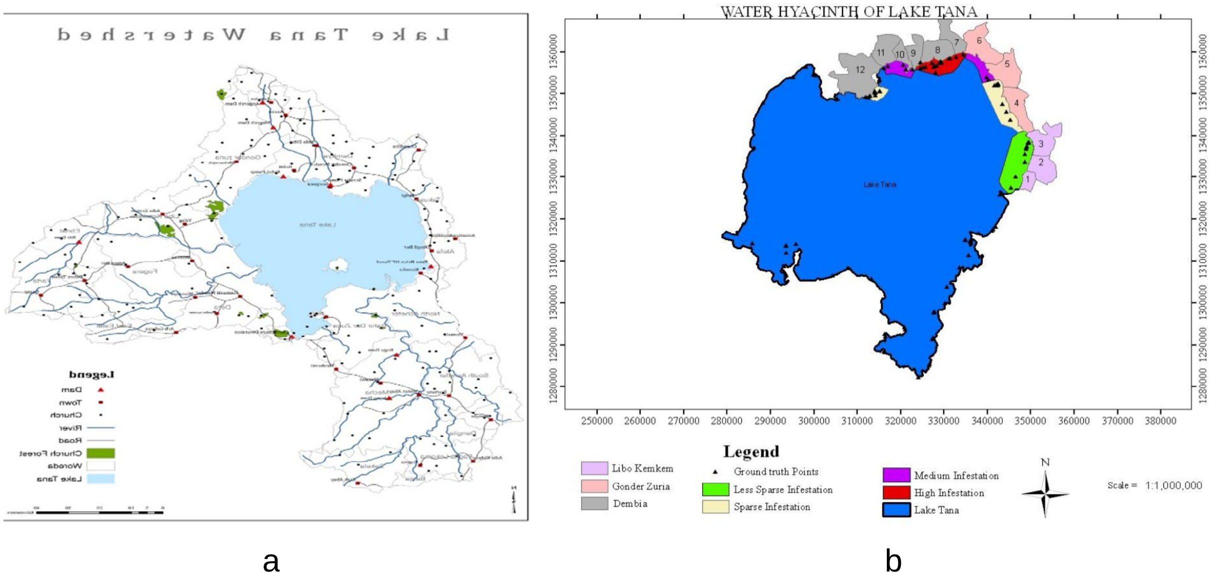


**Figure 1.** Water hyacinth infestation coverage during 2011 (a) and during 2012 (b).

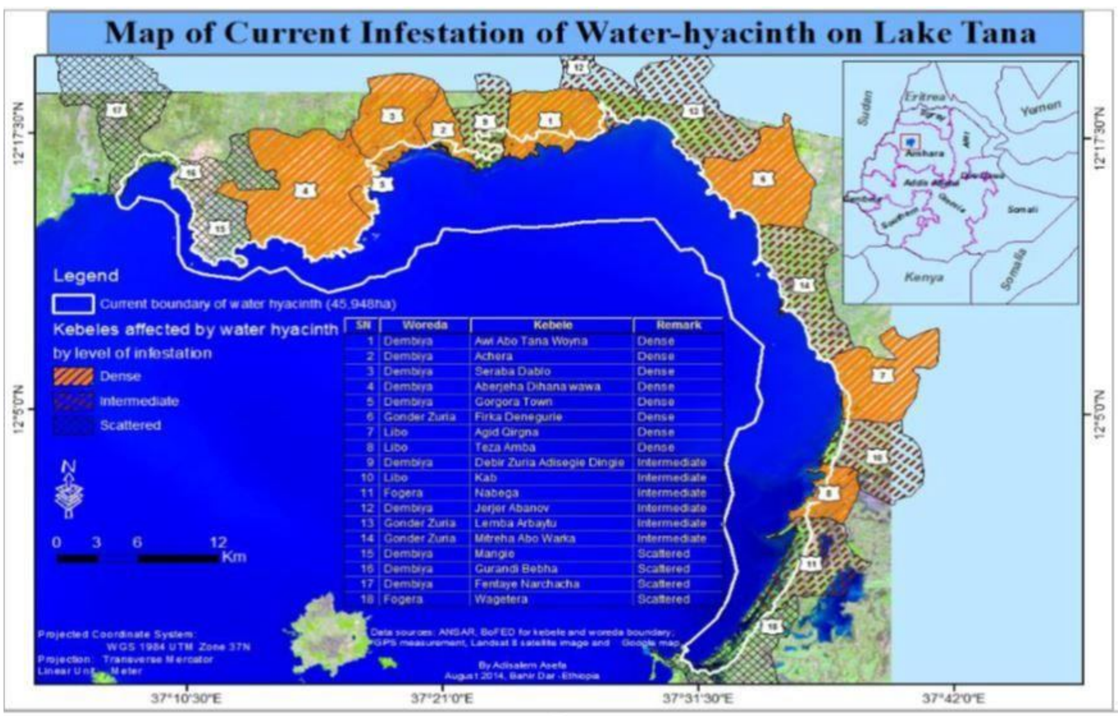


**Figure 2.** A map showing the 50,000 ha water hyacinth infestation kebeles and woredas during August 2014 survey (Anteneh et al., 2014).

matter from water hyacinth, temperature increases slightly. With the increase in temperature, the dissolved oxygen level under water hyacinth shows a decreasing trend; owing to primarily the metabolic activity of epiphytic organisms (Mironga et al., 2012) and the general water property, that is, warmer water holds less oxygen than colder water (Kelly and Linda, 1997).

According to Roger and Davis (1972), the uptake of nitrogen by water hyacinth is 5 to 10 times as rapidly as phosphorous. As a result, the weed can competitively exceed other aquatic macrophytes and algal species. Among the identified taxa Bacillariophyceae was dominant in both sites (Figure 4). Contribution of Euglinophyceae, chlorophyceae and Cyanophyceae to

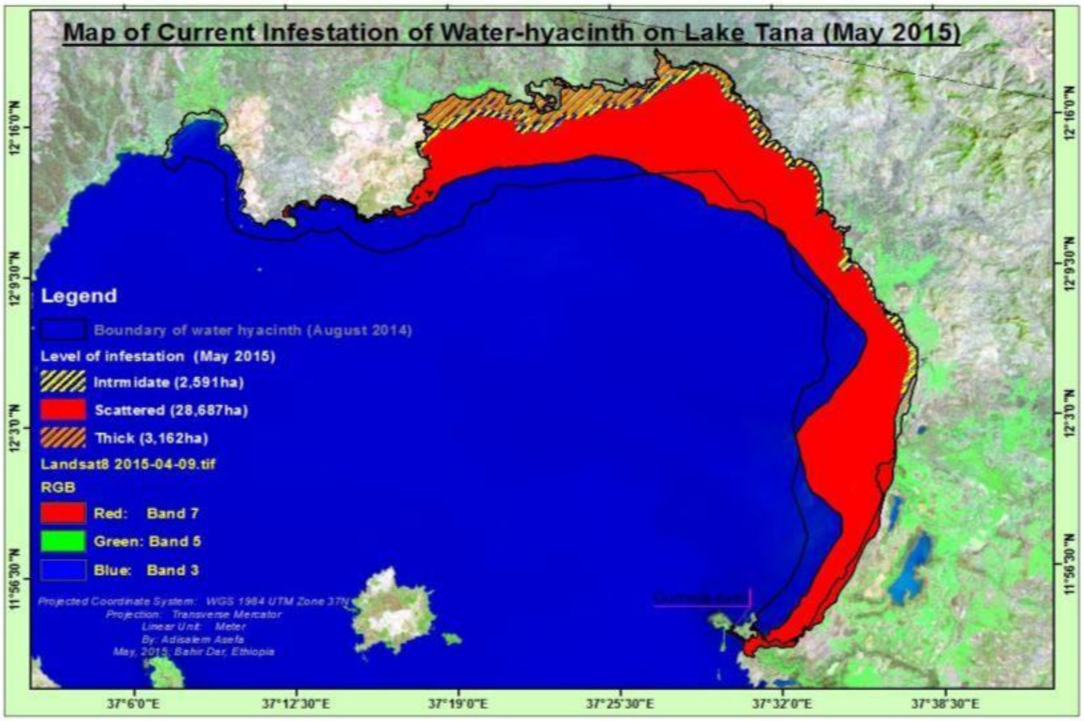


**Figure 3.** Water hyacinth infestation current status on the shore of Lake Tana estimated to be ca. 34500 ha (May, 2015).

**Table 1.** Root, leaf and petioles measurement of water hyacinth during dry and wet seasons of a year.

| Period | Root mean length (cm) | Root mean weight (g) | Leaf mean length (cm) | Leaf mean width (cm) | Leaf mean weight (g) | Petioles mean length (cm) | Petioles mean weight (g) |
|---|---|---|---|---|---|---|---|
| Dry season | 76 ± 2.12 | 222 ± 6.11 | 9.5 ± 1.23 | 12.3 ± 3.32 | 48.5 ± 5.43 | 19.6 ±1.19 | 287.6 ± 1.55 |
| Wet season | 58±3.21 | 1840 ± 7.62* | 8.7 ± 2.33 | 12.1 ± 2.23 | 172 ± 4.22* | 17.1 ± 1.13 | 725 ± 12.62* |

*$P < 0.05$.

**Table 2.** Physico-chemical analysis.

| Parameter | Weed infested site | Non-infested site | P value |
|---|---|---|---|
| | Mean ± SD | Mean ± SD | |
| Temp (°C) | 25.57 ± 3.4 | 24.12 ± 1.95 | 0.346 |
| PH | 7.64 ± 0.56 | 7.61 ± 0.34 | 0.915 |
| DO (mg/l) | 5.34 ± 0.87 | 5.99 ± 0.67 | 0.140 |
| S. Cond. ($K_{25}$) (μs/cm$^3$) | 168.57 ± 43.7 | 138.7 ± 44.6 | 0.230 |
| TDS (g/L) | 0.109 ± 0.03 | 0.092 ± 0.03 | 0.306 |
| Sal. (g/L) | 0 .0757 ± 0.022 | 0.064 ± 0.022 | 0.356 |
| $PO_4$ (mg/L) | 1.31 ± 1.25 | 0.46 ± 0.39 | 0.184 |
| $NO_3$ (mg/L) | 1.49 ± 0.65 | 1.53 ± 0.51 | 0.908 |
| $NO_2$ (mg/L) | 0.0066 ± 0.005 | 0.0196 ± 0.023 | 0.210 |
| TH (mg/L) | 92.5 ± 21.1 | 91.2 ± 43.9 | 0.950 |
| $SO_4$ (mgL) | 3.83 ± 2.9 | 2.4 ± 1.3 | 0.351 |
| $H_2S$ (mg/L) | 0.030 ± 0.014 | 0.023 ± 0.024 | 0.578 |
| Alk. (mg/L) as $CaCO_3$ | 87.5 ± 29.4 | 74.0 ± 32.6 | 0.489 |
| $NH_3$ (mg/L) | 0.046 ± 0.076 | 0.096 ± 0.14 | 0.469 |

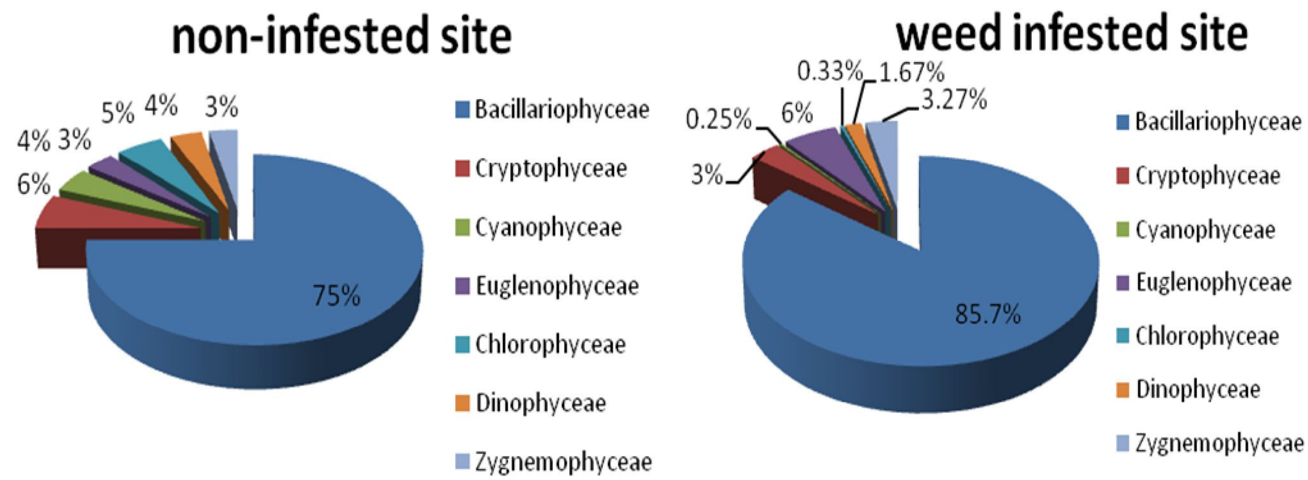


**Figure 4.** Percentage contribution of phytoplankton taxa to the total phytoplankton counts.

the total phytoplankton density were relatively low in the weed infested site. However, higher density of the majority of identified phytoplankton taxa were observed in the weed infested site.

On the other hand, the occurrences of higher species diversity were observed in the non-infested sites, according to Almeida et al. (2006), water hyacinth has selectively inhibited planktonic green algae in a shallow lake. The reduction in photosynthetic activity beneath the mat as well the limiting supply of oxygen from the weed itself results in decreased dissolved oxygen concentration in the water column (Mironga et al., 2011; Meerhoff et al., 2003).

From the total count of zooplankton, density of copepod was higher in the weed infested site, while rotifer was contributing a lot in the non-infested site. Rotifer contributed 65% in the non-infested sites followed by copepod (23%) and cladocera (12%), but, in the weed infested sites copepod contributed 51% followed by Rotifer (39%) and Cladocera (10%).

### Effect of water hyacinth on fishing

Water hyacinth provides highly complex habitat structure by restricting the growth of other submersed macrophytes. This modification and habitat complexity at the surface of the water are likely affect fishes and other invertebrate’s habitat (Meerhoff et al., 2003). In agreement with a study by Villamagna and Murphy (2010) and Kateregga and Sterner (2009), water hyacinth can greatly affect fish catch rates because mats of water hyacinth can block access to fishing grounds clogging and damaging eye of net, and increasing costs (effort and materials) of fishing. Furthermore, water hyacinth tears gill nets and damage boat’s motor which accrue to cost of fishing.

Fishers invest extra time in detaching water hyacinth parts from gillnet after catching. Fishers put gillnet in non-infested area but when the wave starts the fishing gear becomes covered by water hyacinth, therefore the gill net is lost. Loss of gill net could result in additional labor and fuel cost for finding their fishing gear and repair damaged gillnet. In the area of severe infestation, fishing is difficult especially around the shore area, this could strongly affect fishers that use artisanal fishing boat. Generally, area infested by water hyacinth has reduces efficiency of fishing in the study area.

### Effects of water hyacinth on livestock

The study areas are known by potentially rich dairy cattle breeds known as Fogera breeds. The shore area of Lake Tana is rich in submersing grass (including hippo grass) which feeds lots of cattle for the surrounding inhabitants. However, due to expansion of water hyacinth and its competition with the native species the submerging grasses and other native species becomes devastated. These affect a lot of cattle which are directly and indirectly dependent on the grass around the lake. As shown in Table 3, some respondents purchase supplementary feeds for their cattle because the grass on the grazing lands around the lake has been destroyed by the invasive water hyacinth. (Figure 5)

### Effect of water hyacinth on crop production

Mat of water hyacinth during flooding and wave time makes rice production frustrating by totally covering the rice field. There was also one thing that most of the interviewed farmers gave strong emphasis that water hyacinth makes the farmland more compacted due to its long root that makes the farm land difficult to plough. The collected water hyacinth (heap) has noticeable impact on

**Table 3.** Effect of water hyacinth on fishing, cattle and farmland.

| Parameter | N | Min. | Max | Mean | Std. Dev. |
|---|---|---|---|---|---|
| Extra hour for detaching from the gear and boat | 20 | 1 | 12 | 5 | 3.53 |
| How much you incur for fishing gear damaged | 16 | 200 | 5000 | 1721.7 | 1470.07 |
| Birr you allocate for purchase animal feed | 18 | 300 | 5000 | 1240 | 1223.46 |
| How much you incur for cow medication | 20 | 50 | 200 | 120 | 63.51 |
| How many times you clean your farm land for sow teff | 20 | 1 | 5 | 2.7 | 0.95 |
| Labour required to clean "timad[1]" of land per day | 20 | 4 | 60 | 19.2 | 17.65 |

[1] A unit of measurement of land which 1 timad equals to 0.25 hectare.

**Figure 5.** Grazing land infested by water hyacinth.

farm management because they took large place and make the farmland fragile (Figure 6). Farmers in the study areas sow crops when the water starts to shrink with simple adjustment of the plot.

Unlike the last five years, managing the farmlands for recession agriculture has become labor intensive due to infestation of this invasive weed. After the water shrinks, water hyacinth stay on the farm by penetrating its long root to the ground, therefore farmers clean their farmland for planting crop by family and employed laborers. Farmers spend a large amount of time and money for managing weeds when they prepare their farm land for recessional agriculture. Water hyacinth invades smother grazing lands at an alarming rate which directly or indirectly harm livestock. Land and water managers incur significant amount of costs for material and labor costs to control or reduce rate of expansion of the weeds.

Based on the survey (Table 3), 19 laborers in average are required to clear 0.25 ha of land for recession agriculture, which were not needed before water hyacinth infestation. The other challenge associated with infestation of water hyacinth is where to put the collected water hyacinth. Farmers put the collected water hyacinth as a terrace from many places and around the boundary of their land (Figure 6). However, heap of water hyacinth makes the plot or farmland fragmented and difficult to manage.

## Water hyacinth and the ecosystem

Water hyacinth invasions change the natural diversity and balance of ecological communities. These changes threaten the survival of many plants and animals because

**Figure 6.** Farmlands overcrowded by heap of removed water hyacinth.

a b

**Figure 7.** Collected water hyacinth burned after dried (a) and water hyacinth that hinders swimming and boat (b).

the weeds compete with native plants for space, nutrients and sunlight. Water hyacinth also reduces biological diversity, impacts native submersed plants, alters immersed plant species by pushing away and devastating them, and also alter animal communities by blocking access to the water and/or eliminating plants the animals depend on for feed. (Figure 7)

Water hyacinth has prominent effect on the environment by restricting the growth of other submersed and emergent macro-phytes and loss of native habitats. The weed also affects diversity, distribution and abundance of life in aquatic environments in the study area. In addition, water hyacinth leads to de-oxygenation of the water and enhances evapo-transpiration, thus affecting all aquatic organisms. Moreover, the death and decay of water hyacinth vegetation in large masses create anaerobic conditions and production of lethal gases. Generally, water hyacinth in combination with so many others anthropogenic activities (Asmare et al., 2016), is a severe problem for Lake Tana and the surroundings. Therefore, it needs immediate and appropriate measures before things become irreversible.

## CONCLUSION

The coverage of water hyacinth during 2011 was approximately 80 to 100 ha. Eventually, it spreads into eastern part of the lake and reaches ca. 50,000 ha. The impact of water hyacinth on water quality was not significant. The present assessment also noted that no major management strategy had been employed in the infested water body areas, despite many efforts had been applied by the community and the government. *Eichhornia crassipes* remains a major lake Tana ecosystem problem, especially in fisheries, irrigation, transportation, hydropower and ecotourism sectors.

## RECOMMENDATIONS

1. Multidisciplinary research: their effects on the aquatic systems, potential benefits to both humans and other organisms; relationship with submersed vegetation, cattle health and farm productivity should be carried out.
2. Control strategies should take into account the potential effects on the flora and fauna found in the water body.
3. Harvested water hyacinth has to be put into valuable use.
4. Manual control method which currently applied should be revised based on the biological nature of the plant.
5. Integrated approach has to be implemented such as manual, mechanical, chemical and biological methods through scientific procedures.
6. There is need for improvement of land use management in the catchment and along the rivers so as to reduce silt and nutrient loads.

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