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ORIGINAL ARTICLE

INVATION OF WATER HYACINTH (*EICHORNIA CRASSIPES*) IN THE SURFACE WATER OF TONDANO LAKE

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ABSTRACT: The study was conducted to examine the distribution of the invasion of water hyacinth on the lake surface Tondano. Research methods spatial approach to the analysis and interpretation process of digitization of satellite imagery application SIGs that ArcGIS 10. The data used are: Landsat satellite image of Quick bird with a spatial resolution of 0.6 meters recording in 2006 and 2011. Based on the results obtained image interpretation, the distribution of water hyacinth invasion (*Eichornia crassipes*) has grown and spread of high speed, so the plant is considered a weed that damages aquatic environments and greatly contribute to water quality, lake eutrophication and silting process. The rate of spread of water hyacinth is different in each observation station, due to differences in content of nutrients, especially nitrogen and phosphate in the water. Based on the analysis of satellite imagery interpretation and digitization of 2006 wider distribution of water hyacinth 130.77 hectares or 2.82% in 2011 and increased to 292.66 hectares or 6.32%. This means that during the period 2006 - 2011 water hyacinth increased by 161.89 ha with an average annual growth of 32.38 Ha. Based on the data rate distribution hyacinth invasion, may predict the next few years will be entirely Tondano lake surface is covered by water hyacinth management if no serious action.

KEYWORDS: Water hyacinth, spacial analysis, Lake Tondano.

INTRODUCTION

Water hyacinth (Eichornia crassipes), is a plant that floats on the surface of the water, well developed root system in shallow water. *E. crassipes* grows very fast, both vegetative and generative. Vegetative growth can be doubled twice with an interval of 52 days an area of 1 m^2, or within one year is able to cover the water surface area of 7 m^2. This plant grows in the lake Tondano spread so fast and out of control. The development of coastal lakes many community activities generate waste containing organic nutrients phosphorus and nitrogen, thus triggering the accelerated growth of *E. crassipes* and water quality and contribute to the silting of the lake. Hall Sulawesi River Region I, (2010) explains, the state Tondano lake located in the district of Minahasa North Sulawesi has an area of 4628 Ha of water or 46.28 km^2, while the volume of water based on the contours of 668.57 million m^3, if calculated from the mean depth of the water volume approximately 697.31 million m^3. Lake Tondano in 1934 still has a depth of 40 meters, a depth of 28 meters in 1974, with the passage of time in 2004 living 18 meters maximum depth, average depth means staying 12 meters.

Tondano Lake has an economic value to society, as a source of raw water for drinking and industrial water, energy sources of electricity, irrigation agriculture, fisheries, namely fish farming using floating net and trawl, livestock, mining and Tourist Lake such as fishing, boating, swimming while enjoying the natural beauty. If management is done well will be able to have a positive impact both for the government is to increase local revenues, and for the community to improve the income and well-being. Lake Tondano in terms of its ecosystem, a living place from a variety of organisms, including those that are endemic such as Nike (local name of small fish) and Payangka fish (Ophieleotris *aporos* (Bleeker)) is typical of existing fish in the lake Tondano, is spread fish in the shallow waters of

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the lake, there are also small shrimps that become *o. aporos* food sources.

Along the shallow waters of the lake, a lot overgrown with water plants, especially *Eichornia crassipes*. Distribution of water hyacinth on the surface of the water is very disturbing in terms of aesthetics as well as the ecosystem of the lake. *E. crassipes* growing on the periphery of the lake as far as 5-20 m, growing rapidly due to the abundance of nutrients containing nitrogen and phosphorus. *E. crassipes* has the ability to absorb the nutrients phosphorus good water (Xie and Yu, 2003). The growth rate of uncontrolled *E. crassipes* known as algae blooms causing the water plant is considered weed pests (Malmo, 2012; Phanankosi *et al.*, 2013). An increasing number of these plants can cause silting occurs, affecting water quality and water supply as a source of drinking water (Yirefu *et al.*, 2007). For the purpose of this study was to examine the distribution invasion of *E. crassipes* in the lake water surface by means of digitization of satellite images using the map. The results can be a reference made lake management policy programs to address the invasion of *E. crassipes* spread on the water surface of the lake Tondano.

MATERIALS AND METHODS

Location of the study is in the lake Tondano Minahasa regency of North Sulawesi. Geographical location is at position 1^0 9 '0 "- 1^0 18' 0" NL and 124^0 51 '0 "- 124^0 57' 0" EL.

This study uses a spatial approach to the analysis of spatial processes. This analysis requires land use data Tondano lake's multi temporal (Pebesma, 2012) is a map of land use in 2006 and in 2011. This study uses two maps were overlaid to determine the extent and distribution of land use change in the waters of the lake Tondano. According to O'Sullivan and Unwin (2003), map overlay is a technique that combines two or more maps. Figure 1, shows the research sites in the lake Tondano.

Figure 1: Map of the study site (source: Google Earth, 2011)

2.1. The technique of obtaining data

The data required to determine the distribution of *E. crassipes* invasion in the surface water of the lake is an extensive map Tondano, by: a) Integration of Remote Sensing Data and b) Geographic Information Systems (GIS). Remote Sensing Data used are: Quick bird satellite image with a spatial resolution of 0.6 meters in 2006 and 2011. Satellite data are then corrected with the geometric mean to determine the coordinates position, so that the position of the same image with the position on the field. Once the corrected image data is then performed interpretation and digitization process satellite imagery using an application that is ArcGIS10 SIGs. The interpretation of the results obtained by the extent of existing land use around the lake Tondano particularly broad and expansive lake *E.crassipes* cover on the water surface. To determine changes in land use required a different satellite image data in the recording.

2.2. Distribution of the surface of the Eichornia crassipes in the lake

The rate of spread of the *E. crassipes* on the surface can lead to an increase in trophic conditions in the waters, and causes a decrease in phytoplankton productivity of the lake (Mironga *et al.*, 2012). The existence of this plant blocking light sun that goes into the water and will affect the survival of aquatic biota, fauna, other aquatic plants, which then form sediment. If not controlled, Tondano lake trophic conditions will reach the dystrophic condition. *E. crassipes* will be a problem for hydroelectric power generation activity and inhibit the flow of water to the lake outlet (Sittadewi, 2008). Increased fertility of water known as eutrophication process result of many nutrients. The abundance of the nutrients nitrogen and phosphorus into the lake due to erosion, the presence of residual waste that fish feed and fish feces, domestic waste, waste transport and the activity of the people who live along the edge of the lake and watershed.

Kasam and Lail, (2008), describes the *E. crassipes* is more accurately described as a natural buffer or biofilter, as has the nature of which is able to absorb the pollutants in the water. A clump of *E. crassipes* can absorb lead (Pb) up to 96.4%, iron (Fe) 64.5% within a period of seven days or one week. Having the ability to absorb non-biodegradable organic substances contained in domestic wastewater with COD concentration of approximately 400 mg COD / L, with the fulfillment of the terms of nutrients required and the level of acidity at pH 8. In addition, the ability of *E. crassipes* to absorb Na and Cl by 9.8% and 19.3% from 228.6 mg / L

Na and 628.1 mg / L. The importance of *E. crassipes* as a natural buffer to prevent pollution by leakage of hazardous materials into the water. Phanankosi *et al.*, (2013), the results of research conducted turns *E. crassipes* also has the ability to absorb Zinc metal (Zn), nickel (Ni), copper (Cu) and selenium (Se). Other benefits include water hyacinth by Kasam *et al.*, (2008), are: a) possess biological properties as water filters of various materials or contamination by heavy metals from a variety of activities such as industry, households and agriculture, b) as a ground cover and compost in agriculture and plantations; c) as source gases include gases such as ammonium sulfate, hydrogen gas, nitrogen and methane, which can be obtained by fermentation; d) raw material fertilizer NPK plants that contain elements which are the three main elements needed plants; e) as a raw material of activated carbon; f) as the material of paper and board industry, artificial. The ability of *E. crassipes* to absorb nutrients greatly influenced the composition and concentration of nutrients in water bodies. The higher the concentration of nitrates and phosphates in the water, the faster the spread of *E. crassipes* on the surface. This means that *E. crassipes* is not entirely detrimental to the environment, because its existence is necessary, because it is necessary to control the area of supervision and restriction of the population (Weiping *et al.*, 1998; Budiharjo and Huboyo, 2007; Phanankosi *et al.*, 2013). Arfiati, (2010), explains that the presence of aquatic plants in a body of water even be a contender for the phytoplankton, especially in light reception due to the effects of shade and absorption of nitrate and phosphate. Results of research conducted showed that the difference in the ability of aquatic plants to absorb nitrates and phosphates. Plant water hyacinth (*Eichhornia crassipes*) appeared to have a higher ability to absorb phosphate is 0.34 ppm / day. Then the absorption decreases for Wood plant lettuce (*Pistia stratiotes*) 0.30 ppm / day and the lowest is the water plant Hydrilla (*Hydrilla verticillata*) of 0.29 ppm / day. The ability to absorb nitrate was different, water plants *Hydrilla* has the highest ability to absorb nitrate is equal to 1.22 ppm / day, lower absorption *P. stratiotes* plants obtained of 0.95 ppm / day, while the lowest *E. crassipes* to absorb nitrate of 0.83 ppm / day. Phanankosi *et al.*, (2013), said the negative impact of *E. crassipes* on the surface of the water which: have a fast reproduction rate, thereby increasing evaporation and reduced water and form a canopy at the water surface. In Tondano lake *E.crassipes* growth spurt in some locations there is a difference. This is attributed to differences in nutrient content. Because it is believed to be in a relatively short time if there is no other treatment of *E. crassipes* canopy will cover the waters of the lake Tondano (Moerdiyanto *et al.*, 2007). Figure 2 below shows the distribution of the rate of *E. crassipes* in the lake water surface Tondano.

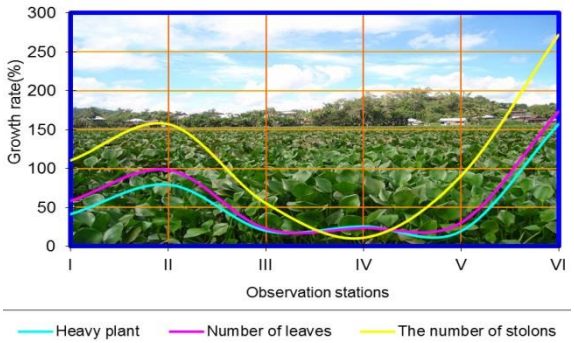

Figure 2: Growth Rate Comparison Chart *E. crassipes* (Source: Moerdiyanto *et al.*, 2007)

RESULTS AND DISCUSSION

Based on the results of the interpretation and application of satellite images digitized ArcGIS 10 showed invasion of *E. crassipes* growth from year to year, there is a significant trend change. Results digitized multi temporal remote sensing data, using Quickbird satellite imagery of 2006 and 2011, changes in land use Tondano lake waters can be seen in table-1 below. Results interpretation digitized maps of land use changes in lake waters Tondano discussed in detail in the following distribution of observation stations.

Table 1: Changes in land use in the waters of Lake Tondano Year 2006-2011

No	Land Use	Area in 2006 (Ha)	Percentage (%)	Area in 2011 (Ha)	Percentage (%)
1	Water Hyacinth	130,77	2,89	292,66	6,85
2	Pond Cages	37,61	0,83	72,75	1,70
3	Wide Water	4519.88	96,28	4268,48	91,45

Source: Results Interpretation, 2012.

3.1. Observation stations 1 and 2: Leleko estuaries, farms and tourist

Assessment of land use change Tondano lake waters at the point of observation station 1 is located at the mouth of the river Leleko. Conditions and *E. crassipes* ponds cages in this area has developed quite rapidly. In 2006 only growing *E. crassipes* on the lake shore area that

extends, but in 2011 the development of *E. crassipes* has been expanding to the middle of the lake. Proliferation of *E. crassipes* growth is not out of the river which carries nutrients that support the growth of *E.crassipes*, such as housing, waste disposal, farm ducks, pigs that carry sediment sedimentation.

Nutrients that cause the explosion of water hyacinth in the lake waters Tondano derived from the use of chemicals (herbicides, pesticides, fertilizers) from agriculture, aquaculture and food remains. Duck farming is also one of the sources of pollution of the lake water. In line with the growth of *E. crassipes* also followed farming communities in developing cages. In 2006 the farm cages developed by the public only in some particular point, but that point in 2011 has developed into an area. This shows the intensity of the development of farm cages in the lake Tondano. Development and distribution of *E. crassipes* floating net cages can be seen in Figure 3 is a map of changes in land use following:

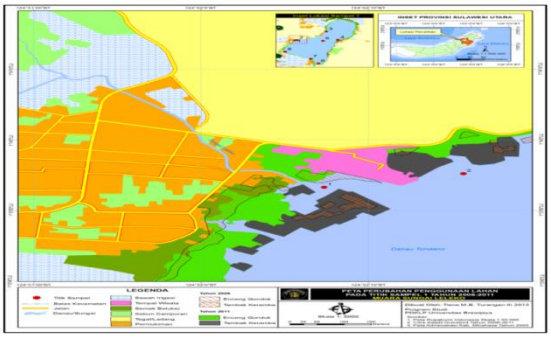

Figure 3: Map of land use changeTondano lake waters, stations 1, 2

3.2. Observation station 3, a floating dining area of the house / restaurant

Conditions and the development of *E. crassipes* ponds cages from 2006 to 2011 in this area is not as fast at stations 1 and 2. Developments in this area and the *E.crassipes* floating net cages are influenced by the development of land use in the form of a restaurant / eating floating home. *E. crassipes*, ponds cages existing in 2006 has been changed into a restaurant in 2011. Not growing *E. crassipes* ponds and cages are more influenced by the people who control the business open. But in the north leading to downstream ponds experiencing very rapid growth, in the northern part of the land use is dominated swamps and rice fields, so rich in phosphorus and nitrates that support the development of *E. crassipes*. Changes in land use in the 3 observation station can be seen in Figure 4 below.

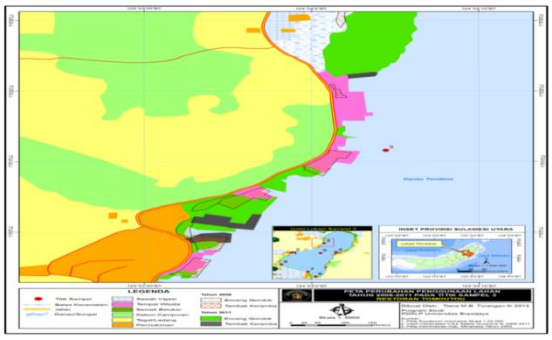

Figure 4: Land use change maps waters Lake Tondano, station 3

3.3. Observations stations 4, cages pond area

Observation station 4 more intensive cage farm development than the development of *E.crassipes*. Intensive development of *E. crassipes* in this area cannot be separated from the people who develop business activity cages. In 2006 only a cage that was developed waterfront areas, but in the year 2011 to the middle cage has grown considerably. Likewise with *E. crassipes* growing just on the edge in 2006 and growing to keep track of cage farms located on either side. This suggests that *E. crassipes* developed following contaminants that support for growth. The remains of the feed cage is one of the nutrients that support the growth of *E. crassipes* in this area. Changes in land use waters in station 4 can be seen in Figure 5 below.

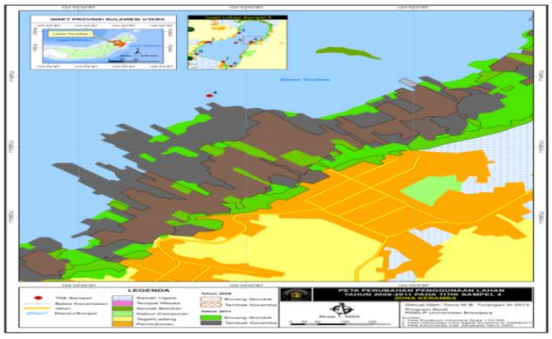

Figure 5: Land use change maps waters Tondano lake station 4

3.4. Observation Station 5, the center area of the lake

Observation station 5, which was taken in the middle of the lake waters showed no change. Similarly, an increase in the development of *E. crassipes* ponds and cages in the year 2011 does not appear. This condition illustrates that middle zone of the lake in general is still relatively clean, as seen in Figure 6 below

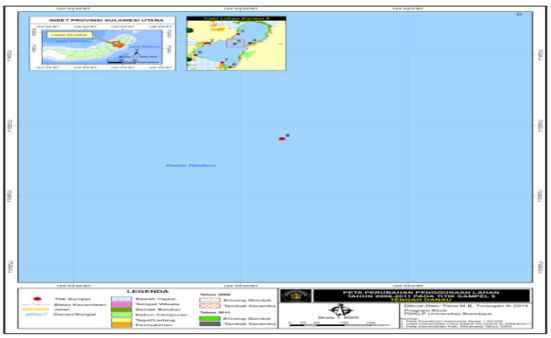

Figure 6: Map changes in land use lake waters Tondano station 5

3.5. Observation Station 6, residential areas

Observation station 6 is precisely the settlement region, changes in lake waters are dominated by *E. crassipes*, From 2006 to 2011 growth of *E. crassipes* in this area is quite high. The rapid spread of the *E. crassipes* invasion in this region cannot be separated from the influence of land use upstream areas such as rice fields, homes, and fields. The land use generally as a contributor of pollutants to waters of the lake in the form of pesticides, nitrate, phosphate, household waste and other activities where such elements as a source of nutrients for the growth of *E. crassipes*. Another fact of the high growth of *E. crassipes* in this area is also influenced by circulating water lake that is not good. Where the area is located on a corner of the lake that resembles a bay. Winds that move *E. crassipes* from other areas generally overlaid on the area. In 2006 from land-use change maps can be known stretch of *E. crassipes* are many and located around the region. In 2011, the development of *E. crassipes* showed wider distribution area. While the land use in the form of cages are not experiencing rapid development. This is due to the rapid growth of *E. crassipes* making it difficult to be penetrated by the community. Interpretation of results from the fact that many farms have been turned into a cage of *E. crassipes*. The following figure 7 map changes in land use observation station 6.

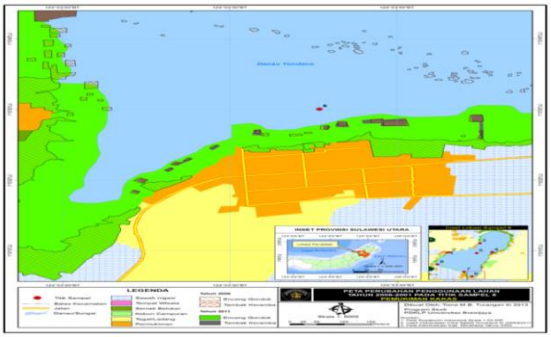

Figure 7: Map of land use change Tondano lake waters, station 6

3.6. Observation Station 7, estuaries region Panasen agricultural area

Observation station 7, the phenomenon of land-use change that occurs is the change in land use of *E. crassipes* which has now become a swamp. Land use changes that occur may indicate high sedimentation process, as a result of agricultural activity residual effluent, fertilizer, pesticides containing nutrients trigger the growth of *E. crassipes* as quickly. The growth of E. *crassipes* growing parallel to the edge of the lake, although this area is the mouth of the river, but the lake is relatively straight line, thus allowing good circulation of water flow. On the other hand the development of cage farms showed an increase, although not as fast as that found in the observation station 4. This means that there has been increased activity describe people who develop farm cages. Description more clearly seen in Figure 8, the map changes in land use in the area of the river mouth Panasen.

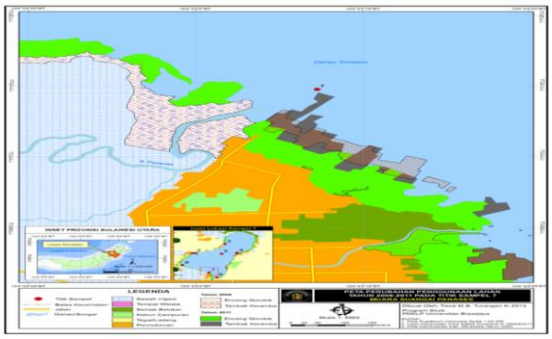

Figure 8: Map of land use change Tondano lake waters, station 7

3.7. Observation stations 8, regions hyacinth

The phenomenon of land-use change that occurred in this area is the development of *E. crassipes* quite rapidly. This is indicated by a change in activity cages into the *E. crassipes*. Such changes cannot be separated from the location of the observation 8 is located on the corner of the area / corner of the lake that resembles a bay, so the wind brought a lot of *E. crassipes* deposited in the area. The direct impact is felt by the people is the number of ponds and cages were damaged water hyacinth covered so it is difficult to penetrate. Phenomenon and the fact that symptoms can be seen in Figure 9, the map changes in land use observation station 8.

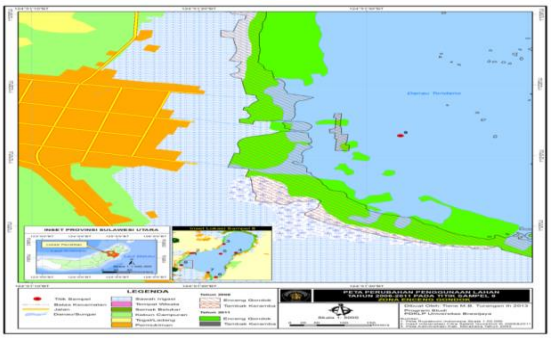

Figure 9: Land use change maps waters Lake Tondano, regional water hyacinth

Communities along the shores of lake activities, such as fishing using a net and trawl, pig and duck farms, dryland farming, wet, restaurant and residential wastes that contribute greatly to the acceleration of the growth of *E. crassipes*. Although *E. crassipes* can be exploited economically, but still regarded as aquatic weeds that damage the ecosystem of the lake Tondano once can interfere with the function of the lake to the various interests of the community. Therefore considering the rate of growth of *E. crassipes* is very fast so handling should be conducted simultaneously with the communities around the lake. Handling of *E. crassipes* cannot just rely on volunteers, but needs a systematic and programmatic handling. Controlling the influx of waste from domestic activities, agriculture, and fisheries needs to be done, among others, by the arrangement of ponds, restaurants and duck farms. To achieve this purpose the necessary local regulations regarding land use spatial lake waters.

Changes in land use in the coastal zone of the lake by the public as a place of settlement such as floating houses and restaurants, contributed a great influx of domestic waste that contains a lot of nutrients nitrogen and phosphate. Ignorance of the public about the value and potential of existing water resources such as lakes Tondano, then there was damage to the ecosystem of the lake. Include sedimentation or siltation that contains a lot of nutrients in the lake reached 135.75 tons / year. As a result of silting of the lake is continuously at speeds greater than 25 cm per year. Further explained that the detergent into the lake approximately 50 tons / year of residential solid waste, fertilizers and pesticides as much as 750 tons of urea / year and phosphate 250 tons / year (Mane *et al.*, 2011). Mane *et al.*, (2011) said that the lake Tondano currently logged in eutrophic category or status of eutrophication.

3.8. Invasion distribution on the surface of the water hyacinth

The dynamics of land use changes continue to change over space and time, as well as land use changes occur in waters of the lake Tondano Minahasa. Tondano Lake is one lake that is loaded with conflicts of land use by the public is for cage aquaculture. On the other side of the lake continues to shallowing and narrowing and reduced water availability. Siltation can also be caused by high erosion rates, can be seen in figure 10 distribution rate of coastal erosion in the lake Tondano, also due to the use of land by people who are Tondano seaboard lake, which is also followed by a rapid growth of *E. crassipes*, and will affect the amount of dissolved oxygen (DO) in water (Villamagna, 2009; Mironga *et al.*, 2012).

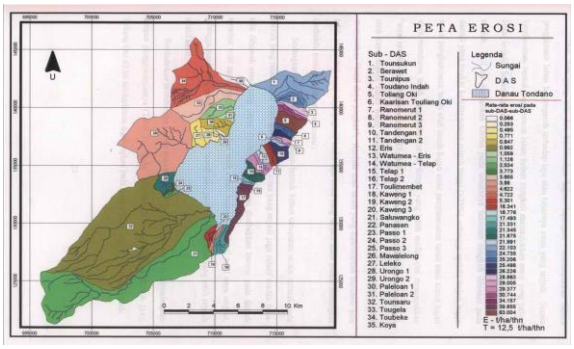

Figure 10: A map of the distribution of the rate of coastal erosion lake Tondano (Source: Moerdiyanto *et al.*, 2007).

Based on the results of the interpretation of satellite imagery data can be seen in 2006-2011 the trend changes Tondano lake waters are narrowed both by human activities such as cages or weeds (*E. crassipes*). In 2006 extensive *E. crassipes* is 130.77 hectares or 2.82% in 2011 and increased to 292.66 hectares or 6.32%. This means that during the period 2006-2011 *E. crassipes* increased by 161.89 Ha with an average annual growth of 32.38 Ha. With the growth rate can be assumed to be covered by the lake Tondano *E. crassipes* for a few years, if not affected by human intervention.

Changes in lake waters by human activity, namely the cages during the period 2006-2011 also increased widely, from 37.61 Ha (0.81%) increased to 72.75 Ha (1.57%). During the 5-year period increased by 35.14 Ha with an average annual increase of 7 hectares.

CONCLUSION

1. Water hyacinth (*E. crassipes*) is one of the aquatic plants are a threat to the sustainability of the lake Tondano, both the process and the silting up of the lake water quality or availability of water as a raw material source of drinking water for people and other activities.

2. Distribution of *E. cassipes* growth is quite high, nice views of the weight of plant biomass, number of leaves and number of stolons. The highest growth was found on the net location, the location near the rice fields and duck farms or farming population.
3. The rate of growth of *E. crassipes* is very fast so handling should be conducted simultaneously and comprehensively, from government agencies and stakeholders to engage communities around the lake. Handling *E. crassipes* cannot just rely on volunteers, but needs a systematic and programmatic handling.
4. Another solution is necessary to study the use of methods such as biological control, is to find an animal or insect that consumes herbivor *E. crassipes* leaves or stems. It is necessary for further research on the control of this plant.

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