Current Trend of Water Hyacinth Expansion and Investigation of Possible Cause for Water Hyacinth Using Remote Sensing in the Case Study of Lake Tana, Ethiopia

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CURRENT TREND OF WATER HYACINTH EXPANATION AND INVESTIGATION OF POSSIBLE CAUSE FOR WATER HYACINTH USING REMOTE SENSING IN THE CASE STUDY OF LAKE TANA, ETHIOPIA

Abstract

Lake Tana is facing a big problem with water hyacinth invasion since September 2011 of which it is worst for lakes in the world that invades vast area of lakes with in limited period of time if it does not control properly. Water hyacinth is an invasive and free-floating water plant that grows into large dense vegetable mats blocks transportation of boats and sun energy transmission into Lake Bottom. Since its official recognition, GPS have been used in order to delineate the infestation on the lake, but using GPS for infestation mapping is not time and cost effective, and note safe for data collectors. Considering this reason, this study focuses on mapping of water hyacinth infestation coverage area and analyzing its possible cause on Lake Tana by applying satellite imagery and nutrient level of it. In this document, Landsat 7ETM+ and Landsat 8 images were used with the conversion of DN values to TOA reflectance, and TOA were used to evaluate different spectral indices like NDWI and NDVI. These indices with dynamic threshold increasing between class variance were used to map potential water hyacinth infestation area from 2011 to 2018, and NDWI used to discriminate Lake Tana from its surrounding background feature while NDVI was used to separate open water surface from aquatic vegetation coverage areas. In addition to these indices, thermal band of Landsat images were used to discriminate water hyacinth from other features. The accuracy of satellite image classification on this study was evaluated using error matrices and achieved with the best overall accuracy and Kappa coefficient (K). Total nitrogen concentration was increased from dry month to wet month and total phosphorus was increased from wet month to dry month and potential water hyacinth was greatly found where nutrient level was highly available. To reduce infestation rate of its special soil management practice applies to reduce nutrient has to implement. In addition, there has to be buffer zone for the lake and recessional agriculture has to be stopped.

Key Words: NDVI, NDWI, Dynamic Thresholding, Potential water hyacinth
Introduction

Water hyacinth, Eichhornia crassipes (Martius) Solms- Laubach, is fast growing aquatic free floating fresh water plant indigenous to Brazil, Amazon basin and Ecuador region (Gopal, 1987a). In addition to this Water hyacinth has emerged as a major weed in more than 50 countries in the tropical and subtropical regions of the world with profuse and permanent Impacts (Téllez et al., 2008). It has often been marked as one of the world’s worst invasive aquatic species. In the course of the last century, it has infested many tropical water bodies all over the globe. It was introduced as an ornamental species to adorn the water bodies in many countries more than a century ago for their attractive blue or purple flowers, oblong to oval glossy leaves with bulbous petioles.

Later, this supposed-to-be prized plant was discovered to be an invasive species and posed serious socioeconomic and environmental problems affecting millions of people in riparian communities (Patel, 2012). It grows from a few inches to about a meter in height. The stem and leaves contain air filled sacs, which help them to stay afloat in water. In the developing world, it is used in traditional medicine and even used to remove toxic elements from polluted water bodies. They reproduce both asexually through stolen and sexually through seeds, which remain viable for up to 20 years and therefore are difficult to control (Center et al., 1999). Thus, it is also considered as a noxious weed in many parts of the world as it grows very fast and depletes nutrient and oxygen rapidly from water bodies, adversely affecting flora and fauna. There have been instances of complete blockage of waterways by water hyacinth making fishing and recreation very difficult.

In Africa, where water hyacinth is listed by law as a noxious weed in several countries, it is the most widespread and damaging aquatic plant species. The first African country which is water hyacinth weed was officially recorded in Zimbabwe in 1937. In Ethiopia, water hyacinth was announced in 1956 in Koka Lake and Awash River (Samuel and Netsanet, 2014; UNEP, 2013). Since then, it has been found in different regions of Ethiopia. It also prevailed in most of rift valley lakes, canals, reservoirs and irrigation water supply within different manifestation magnitude (Firehun et al., 2014). Sadly, in September 2011, it was officially recognized that one of the top ten ecologically dangerous and worst invasive weed, water hyacinth (Eichhornia crassipes), infested Lake Tana (Wondie et al., 2012). The exact source of water hyacinth infestation of Lake Tana is not well known. Currently, water hyacinth infestation is highly occurred in this lake and increased from time to time rapidly. Water hyacinth has a negative ecological impact on fresh
water bodies, suppressing all other species growing in the vicinity. Large water hyacinth mats negatively affecting microbes, prevents the growth and abundance of phytoplankton, prevent the transfer of oxygen from the air to water bodies (Gichuki et al., 2012). When the plant dies and sinks to the bottom the decomposing biomass depletes oxygen content in the water body.

Death and decay of water hyacinth vegetation in large masses deteriorate water quality and the quantity of potable water and increases treatment costs for drinking water (Mironga et al., 2011, Ndimele et al., 2011). Though previous attempts estimate the infestation of the lake by weeds using survey data, filled observations and discussion with the surrounding community has not showed the exact estimation of coverage area by the weeds. In this study, accurate estimates of trend of water hyacinth infestation coverage area are useful to assess the effectiveness of control methods to manage this aquatic weed. While large water bodies like Lake Tana require significant labor inputs with respect to ground-truth surveys, available technology like remote sensing could be capable of providing temporal and spatial information from a target area at a much-reduced cost.

The main objective of this thesis is to (1) predict current trend of water hyacinth expansion and investigation of possible cause for water hyacinth in the case study of lake Tana, Ethiopia from 2011 to 2018 of its coverage annually (2) to assess spatial and temporal variability area of water hyacinth over Lake Tana from 2011 to 2018 of its coverage annually (3) to examine and understand the possible causes of water hyacinth infestation in Lake Tana using remote sensing. GIS and remote sensing have played an immense role to map the distribution and areal extent of invasive species. As a result, it uses as a decision support system tool for decision makers. Integrated GIS and remote sensing have been applied to map the distribution of several plant and animal species, their ecosystems, landscapes, bioclimatic conditions and factors facilitating invasion (Los et al., 2002).

The increased usage of remote sensing data and techniques has made geospatial analysis faster and more powerful, but the increased complexity also creates increased possibilities for error. In the past, accuracy assessment was not a priority in image classification studies. Because of the increased chances for error presented by digital imagery, however, accuracy assessment has become more important than ever (Congalton, 2001). A common tool to assess accuracy is the error matrix. Error matrices 12 compare pixels or polygons in a classified image against ground reference data (Jensen, 2009). These matrices can measure accuracy in several ways.
The overall accuracy of the classified image compares how each of the pixels is classified versus the actual land cover conditions obtained from their corresponding ground truth data. Producer’s accuracy measures errors of omission, which is a measure of how well real-world land cover types can be classified. User’s accuracy measures errors of commission, which represents the likelihood of a classified pixel matching the land cover type of its corresponding real-world location (Congalton, 2001).

**Materials And Methodology**

**Description of the study area**

Lake Tana is geographically located in the north-western part of Ethiopia, between latitude 10°58’ – 12°47’N and longitude 36°45’ - 38°14’E. It has a surface area of 3,200 sq km, a mean depth of 8 meters and maximum depth of 14 meters with fluctuations due to increasing siltation levels. It is the largest freshwater body in the country, contributing about 50% of the water resource of the nation (Anteneh et al., 2015b). The lake lies at higher altitude in the range of 1,840 meter above sea level compared to Lake Victoria at 1,134 meters above sea level and is considered the highest lake in Africa. Due its altitude it is characterized by cold waters with mean temperature of 21.7°C (Anteneh et al., 2015a). The Lake Tana watershed consists of 347 Kebeles (the lowest administrative units) and 21 Woredas (districts) in four administrative zones (IFAD 2007). The lake catchment covers an area of 16,500sqkm.
Methods of Data Collection

Data collection basically included satellite image data which was collected from USGS’, GPS data, and nutrient contents of water such as nitrogen and phosphorus were collected from the lake. For this study both quantitative (measurable) and qualitative data were collected from primary and secondary sources.

Primary data source; the primary data was collected direct from fields using the following ways,

1. GPS data, the control points were collected direct from the lake using GPS to take as control points when Landsat imagery classification was processed so as to check the potential water hyacinth distribution was occurred under control points.
2. Nutrient concentration, the nutrient concentration of the lake such as, nitrogen and phosphorus were measured by taken sample data from the lake and measured in the laboratory to know the distribution of the water hyacinth and its relation with the nutrient level of the lake.

**Secondary data source,** The Secondary data was collecting from satellite image by download from USGS earth explorer land sat image with high reflectance and high resolution. In addition to this, using the control points taken from the lake using GPs instrument, coordinates were extracted from Google earth on open water and water hyacinth area by observing historical imagery dates to make accuracy assessment of the classified image from 2011 to 2018.

The materials and tools that used to investigate water hyacinth infestation in the study areas are: GPS, boat, ice box, chemical laboratory equipment to measure the concentration of nitrogen and phosphorus.

**Method of Data Analysis**

For this study, the data that were downloaded from USGS earth explorer freely available Landsat images were analyzed using functional soft wares that were some commercial and some not commercial or freely available soft wares. To make the Landsat images clear and free of unnecessary sensor detected images, the data were processed through some preprocessed techniques before using for scientific analysis. After accomplished different techniques of preprocessing methods like, destriping, pan sharpening and atmospheric correction, the Landsat images were used to classify it using soft wares. Then, the potential water hyacinth coverage area and open water of Lake Tana were observed from the result of ArcGIS software.
Selection of Image Data Sets

The primary remote sensing task in this study was, to discriminate water hyacinth from other image constituents such as open water, land, waves, and other types of vegetation. Even though a variety of space borne and airborne sensors were employee to achieve this research, only freely available Land Sat 7ETM+ and Land sat 8 imagery data was used from (2010 to 2018G.c) to detect and inspect the water hyacinth coverage area on Lake Tana. To do this work Cloud-free land sat 7ETM+ and land sat 8 images were needed or otherwise unimpeded imagery of the lake would be required from the sensors at a variety of time periods and at a variety of resolutions. For the success of this particular work, we have already used cloud free imagery of the lake which is required from sensors on the time of periods (2010 to 2018) with specific spatial resolutions, optical bands,
panchromatic band and thermal band of Landsat 7 and LandSat 8 images with high resolution for good quality of investigation.

Table 1. Satellite sensor information

<table>
<thead>
<tr>
<th>Date of Acquisition</th>
<th>Sensor Type</th>
<th>Spatial Resolution (meter)</th>
<th>Temporal Resolution</th>
<th>Path</th>
<th>Row</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>06-04-11</td>
<td>Landsat 7ETM+</td>
<td>30 Optical, 15 Panchromatic, 60 Thermal</td>
<td>16 days</td>
<td>170</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>07-03-12</td>
<td>Landsat 7ETM+</td>
<td>30 Optical, 15 Panchromatic, 60 Thermal</td>
<td>16 days</td>
<td>170</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>22-02-13</td>
<td>Landsat 7ETM+</td>
<td>30 Optical, 15 Panchromatic, 60 Thermal</td>
<td>16 days</td>
<td>170</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>21-03-14</td>
<td>Landsat 8</td>
<td>30 Optical, 15 Panchromatic, 100 Thermal</td>
<td>16 days</td>
<td>170</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>29-09-14</td>
<td>Landsat 8</td>
<td>30 Optical, 15 Panchromatic, 100 Thermal</td>
<td>16 days</td>
<td>170</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>24-03-15</td>
<td>Landsat 8</td>
<td>30 Optical, 15 Panchromatic, 100 Thermal</td>
<td>16 days</td>
<td>170</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>11-04-16</td>
<td>Landsat 8</td>
<td>30 Optical, 15 Panchromatic, 100 Thermal</td>
<td>16 days</td>
<td>170</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>29-03-17</td>
<td>Landsat 8</td>
<td>30 Optical, 15 Panchromatic, 100 Thermal</td>
<td>16 days</td>
<td>170</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>01-04-18</td>
<td>Landsat 8</td>
<td>30 Optical, 15 Panchromatic, 100 Thermal</td>
<td>16 days</td>
<td>170</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>26-10-18</td>
<td>Landsat 8</td>
<td>30 Optical, 15 Panchromatic, 100 Thermal</td>
<td>16 days</td>
<td>170</td>
<td>52</td>
<td></td>
</tr>
</tbody>
</table>

Image Preprocessing

Preprocessing functions involve those operations that are normally required prior to the main data analysis and extraction of information, which were downloaded from USGS, and image correction was performed on the entire images. After acquiring raw Landsat image datasets from the online source, the next step is to prepare or pre-process these images to make them useable for extracting information especially in land cover map derivation. Image preprocessing is an essential and pre-requisite procedure in remote sensing image analysis. When an image is captured by the satellite sensors and other air and space-based sensors, it is always associated with geometric, radiometric and atmospheric errors.

Therefore, as Landsat-7 ETM+ was used, we likely to encounter striping caused by the failure of the scan line corrector (SLC) in 2003. The SLC failure introduced major striping in ETM+ imagery. The gap must be filled to use the image in scientific analysis (USGS, 2004). In this study one of GDAL/OGR algorithms, FILLNODATA analysis was used to fill the gap due to the failure of the scanner.


**Extraction of Potential Water Hyacinth Coverage**

Potential water hyacinth is defined as areas having a spectral signature or high backscatter characteristic of aquatic vegetation that could include water hyacinth, but also other vegetation, and, in the case of radar data, waves, islands, ships and their wakes, and occasionally image noise. This section describes the process of spectrally determining the areas covered by water hyacinth and the areas free from water hyacinth in the images. But before doing the discrimination of water hyacinth, I have used Map Algebra Tool from Spatial analysis toolbox in Model builder window and conditional evaluation function, the NDVI imagery was extracted so as to it fits to the extent of Lake Boundary. For this study, The Conditional function permits to control the output value for each cell based on whether the cell value evaluates to Lake Region NDVI or background feature NDVI in a specified conditional statement.

**Accuracy Assessment**

The accuracy of a remotely sensed data product is important just as the information presented in the product. Without known accuracy, the product cannot be used reliably, and therefore, has limited applicability. Accuracy assessment is a general term for comparing the classification to geographical data that are assumed to be true, in order to determine the accuracy of the classification process. In an accuracy assessment of map data, the map is compared with higher quality data that is the classified map is compared with the reference map. The higher quality data, called reference data, is collected through a sample-based approach, allowing for a more careful interpretation of specific areas of the map. The reference data is collected in a consistent manner and is harmonized with the map data, in order to compare the two classifications. The comparison results in accuracy measures and adjusted area estimates for each map category. An accuracy assessment must provide full documentation of the map and reference data.

**RESULTS AND DISCUSSION**

As the result of this analysis, table 2 below provides aspatio-temporal analysis of the periodicity of vegetation change in Lake Tana from 2010 up to 2018. From result of which written on the table describes the aquatic vegetation coverage in 2010 was about 6276.78 hectares and this figure is taken as baseline for other water hyacinth coverage area getting from Landsat image classification. When I classified the 2011 Landsat image of Lake Tana,
the aquatic plant coverage increased to 12462.53 hectares and the potential water hyacinth coverage for 2011 is the difference of the aquatic plant coverage area in 2011 that of 12462.53 hectares of coverage area and for 2010 that of 6276.78 hectares of coverage area which is 6185.75 hectares were covered by water hyacinth.

In this document the 2010 Landsat classified image was taken as the reference point or baseline for other years of which infestation area is known depending on it because of water hyacinth occurrence in Lake Tana was known officially in 2011 G.C. So, it was determined that the vegetation coverage as well as other aquatic plants of which planted on lake Tana in 2010 was taken as the reference point or baseline to know the only water hyacinth infestation which differs from other aquatic plants.

According to the same procedure on the above analysis using arc Gis software, the potential water hyacinth coverage on Lake Tana was observed in different amount of coverage area from year to year that of from 2011 up towards 2018 G.C. finally, as the result of this investigation of lake Tana using remote sensing in Landsat image classification, the potential water hyacinth coverage were 12462.53 hectares on 06-04-2011, 24986.65 hectares on 07-03-2012, 17835.44 hectares on 22-02-2013, 26230.25 hectares on 21-03-2014, 40567.976 hectares on 29-09-2014, 28757.6568 hectares on 24-03-2015, 19350.21 hectares on 11-04-2016, 24794.54 hectares on 29-03-2017, 21436.86 hectares on 01-04-2018 and 26352.15 hectares on 26-10-2018 G.C in all years.

When we see the potential water hyacinth coverage area mapping of Lake Tana, the invasion is fluctuating in the study years; from 2011 to 2012 the invasion was increasing, from 2012 to 2013 the coverage area decreased, from 2013 to September 2014 there was very rapid invasion rate of which quick invasion rate was occurred from the previous years of water hyacinth coverage area. From 2014 to 2015 the potential water hyacinth coverage area was decreased very much due to different reasons and from 2015 to 2016 there was decreasing of water hyacinth coverage. From 2016 to 2017, the potential water hyacinth coverage area of Lake Tana was increased and from 2017 to April 2018, it was rapidly decreased. When we observe the invasion of potential water hyacinth in 2018 compared to
different seasons in different months, but in the same year that of 2018, the potential water hyacinth coverage area was increased to some extent from April 2018 to October 2018.

Table 2: Potential water hyacinth coverage and its rate of change

<table>
<thead>
<tr>
<th>Date of image Acquisition</th>
<th>DOY</th>
<th>Cumulative day</th>
<th>Potential Water Hyacinth Coverage</th>
<th>Difference from 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>12462.53</td>
<td>6185.75</td>
</tr>
<tr>
<td>06-04-2011</td>
<td>97</td>
<td>462</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>17835.44</td>
<td>11558.66</td>
</tr>
<tr>
<td>22-02-2013</td>
<td>53</td>
<td>1148</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>40567.976</td>
<td>34291.196</td>
</tr>
<tr>
<td>29-09-2014</td>
<td>272</td>
<td>2097</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>19350.21</td>
<td>13073.43</td>
</tr>
<tr>
<td>11-04-2016</td>
<td>102</td>
<td>2657</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>21436.86</td>
<td>15160.08</td>
</tr>
<tr>
<td>01-04-2018</td>
<td>92</td>
<td>3377</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3: Area coverage of potential water hyacinth and total vegetation coverage over Lake-Tana.
The true water hyacinth vegetation occurrence and expansion of it on Lake Tana was officially recognized in 2011. As compared to the greenness of which grown and covered a certain area of lake Tana that was seen in 2010, there was relatively wide area of green vegetation coverage on lake Tana in 2011 when it was compared in terms of coverage area of vegetation growth. When it was seen the characteristics of its expansion, naturally, water hyacinth is characterized by its rapid reproduction, expansion and wide area of coverage on lakes and other water bodies. As the result of this, its characteristic enables any one to recognize that the high difference in coverage area of vegetation on Lake Tana between successive years is due to water hyacinth.

Figure 4: potential water hyacinth area, a) on March 2010, b) on April 2011

When the analysis and mapping of water hyacinth coverage area on the lake described in terms of figure of which resulted from arc GIs Software, the map which designates on figure 3 above, the green color represents vegetation coverage on Lake Tana which was unnatural by suddenly happened water hyacinth invasion and the blue color represents open water of the lake which was not affected by water hyacinth in 2012. In this year, water hyacinth was aggressively expanded and invading Lake Tana which was unusual from the previous years of water hyacinth coverage area of the lake. As compared to the previous years, in this year, there was relatively wide area of coverage and fast rate of invasion on the lake. The vegetation coverage area of Lake Tana in 2012 was 24986.65 ha out of which 18709.87 ha was expected to be potential water hyacinth infestation on the lake.
On Figure 6 below, the green color represents vegetation coverage on Lake Tana and the blue color represents open water of the lake in 2013. As it seen in this year, water hyacinth coverage area was highly decreased on Lake Tana when it compared to invasion of the lake in 2012. The vegetation coverage of Lake Tana in 2012 was 24986.65ha out of which 17835.44ha remained in 2013. From 17835.44ha of coverage area only about 11558.66ha was expected to be potential water hyacinth infestation on the lake in year 2013. The decrease in water hyacinth coverage area of Lake Tana is recognized in this year. According to the report by Wassie et al., (2014), and taking the information from the community and different concerned governmental organizations, this was because of the removal of water hyacinth from Lake Tana by physical control method using manual extraction, Labor-intensive methods.

Figure 5: potential water hyacinth coverage on March 2012

Figure 6:  potential water hyacinth coverage on March 2013
From the map of which resulted from arc Gis software after it processed in other software using quantum Gis and pancroma software that represented on figure 7, the green color represents vegetation coverage area on Lake Tana and the blue color represents open water of the lake of which was not invaded by water hyacinth in February, 2014. In this year on month February, water hyacinth expanation and rapid invasion of water hyacinth on Lake Tana was happened aggressively. As compared to the previous years of water hyacinth invasion on Lake Tana, there was relatively wide area coverage and fast rate of invasion on the lake. When it observed, the vegetation coverage in February, 2014 was 26230.25ha out of which the 19953.47ha expected to be potential water hyacinth infestation on the lake. In this year, there was certain green vegetation coverage area on Lake Tana where water hyacinth is not happened yet. Therefore, the Potential water hyacinth which seen on Lake Tana near to the border of lake do not seem reasonable and it might be due to the presence of wave/tied or turbidity at the time of image acquisition or turbidity of the lake water.

![Figure 7: potential water hyacinth coverage on February, 2014](image)

As it investigated mapping of water hyacinth in the same year but different month of which described on figure 8, the green color represents vegetation coverage on Lake Tana and the blue color represents open water of the lake in September, 2014. In September, 2014 water hyacinth was aggressively invading Lake Tana too. As compared to the previous times, there was relatively wide area coverage and fast rate of invasion on the lake. The vegetation coverage in September, 2014 was 40567.976ha of which the 34291.196ha expected to be potentially water hyacinth infestation on the lake.
In the same case to the previous year of analysis but with different result that showed on figure 9, the green color represents vegetation coverage on Lake Tana and the blue color represents open water of the lake in 2015. In this year, the decrement of water hyacinth coverage area as well as decline of invasion rate was happened on Lake Tana. When it compared to the previous years, in this year, there was relatively narrow coverage area of the lake and unhurried rate of invasion on Lake Tana. When the coverage area of water hyacinth and invasion rate of Lake Tana in 2015 was compared to preceding year of it, the vegetation coverage on September, 2014 was 40567.976ha out of which 28757.6568ha was remained in 2015. Therefore, it is true that from 28757.6568ha coverage area of vegetation only about 22480.8768ha was expected to be potential water hyacinth infestation on Lake Tana. In this year there was very low vegetation coverage on Lake Tana relative to the preceding year and it implies as there was campaign to remove water hyacinth before the image acquisition date.
When the analyses were observed of which the result of water hyacinth mapping which displayed on figure 10, the green color represents vegetation coverage on Lake Tana and the blue color represents open water of the lake in 2016. In this year, water hyacinth coverage area as well as invasion rate of it was highly decreased on Lake Tana. As compared to the previous year particularly with the preceding year of it, in this year, there was relatively narrow area of coverage and it happen the decrement of invasion rate on Lake Tana. When it seen the water hyacinth infestation in 2016, The vegetation coverage was 19350.21 ha out of which the 13073.43ha expected to be potentially water hyacinth infestation on the lake. In this year there was an indication of removing of the water hyacinth extremely on Lake Tana.
Figure 10: potential water hyacinth coverage on April 2016

In the same procedure to the other years, on figure 11, it showed that the result of water hyacinth mapping of which describes, the green color represents vegetation coverage on Lake Tana and the blue color also represents open water of the lake in 2017. In this year, the coverage area as well as the invasion rate of water hyacinth was slightly increased on Lake Tana. As compared to the preceding year of it, there was relatively wide area coverage and fast rate of invasion on the lake. The vegetation coverage in 2017 was 24794.54 ha of which the 18517.76 ha expected to be potentially water hyacinth infestation on the lake in this year. In this year there was an indication of reinvading of the water hyacinth on Lake Tana after being removed in the preceding year.

Figure 11: potential water hyacinth coverage on March 2017

As it shown on figure 12 below, the green color represents vegetation coverage on Lake Tana and the blue color represents open water of the lake on month April, 2018. In this year it is true that water hyacinth was decreased on Lake Tana relative to the preceding year as it shown on the result of which displayed on water hyacinth mapping on figure 11 which was getting from arc Gis software. As compared to the previous years, in this year, there was relatively narrow area of coverage and fast rate of invasion decrement on the lake. The vegetation coverage in this year was 6735.6 ha of which the 479.8 ha expected to be potentially water hyacinth infestation on the lake.
In this year there was an indication of removing of the water hyacinth on Lake Tana that extremely invaded in the preceding year of it that is from the invaded coverage area in 2017.

![Figure 12: potential water hyacinth coverage on April 2018](image)

When it compared in the same year but different season as well as different month that shown on figure 13, the green color represents vegetation coverage area on Lake Tana and the blue color represents open water of the lake on month October, 2018. In this year, water hyacinth was highly increased on Lake Tana. As it compared to the previous month and season of it, but in the same year, there was relatively wide-ranging coverage area of the lake and highly increased rate of invasion on the lake.

In this year, the vegetation coverage area was 26352.15 ha out of which 20075.37 ha was to be expected potentially water hyacinth coverage area on Lake Tana. When it compared to the previous months, in this year, there was an indication of reinvading of the water hyacinth on Lake Tana after being removed in the previous month but in the same year. So from this result of water hyacinth coverage area in 2018, it shows that water hyacinth infestation was different from season to season as well as from month to month but in the same year due to different limiting factors like nitrogen and phosphorus content of lake Tana.
Figure 13: potential water hyacinth coverage on October 2018

In this study, NDWI and NDVI based image classification process was applied to Landsat 7ETM+ and Landsat 8 imagery. In addition to this, Otsu's threshold image segmentation classification by increasing between class variance applied to Landsat7ETM+ and Landsat 8 imagery that allowed the classification of the image was being classified into lake water and background features based on NDWI and the associated threshold values and then it classified the lake surface into open water and potential water hyacinth coverage area. From the above maps which are displayed on figure 3 up to 11, provide the resulting potential water hyacinth coverage of which extracted from NDVI and thermal bands with the aid of statistically determined thresholding values.

In this work, the classification of water hyacinth on Lake Tana was done by process of consecutive steps on the aid of remote sensing. When discussing the results of this study, the aquatic vegetation coverage in the year 2010 was taken as a baseline or reference frame for all image classification of it, because the official recognition of existence of water hyacinth on Lake Tana was well-defined in the year 2011. Due to this reason, it is taken that Potential water hyacinth coverage is determined based on a principle that there was no water hyacinth in 2010 on Lake Tana; in other words, the vegetation cover of the lake in 2010 is expected to be other plant species rather than water hyacinth in 2010. Former studies conducted in different lakes at several parts of the world have applied different methodologies in order to map water hyacinth coverage.
Among those studies the one done on Lake Victoria by USGS/CLI (2001) is greatly related to this study; but the data used by USGS/CLI incorporate RADAR, spectrometer readings from the lake, MODIS, IKONOS, and SPOT imageries in addition to Landsat images. The method they followed was very complex and lying to confusion as compared with the method used in this study. In this study, somewhat easier technique was followed in relative to other studies with easily accessible image data set that is freely available Landsat images. The methodology of this study was focused on the property of reflectance of different objects for different wave lengths. The response of different objects during acquisition time to the sensor for different wave lengths enabled the researcher to calculate indexes such as; NDVI, NDWI and these indexes are gray scale (one band) images. In addition to this, threshold values were determined in order to segment various features which depend based on maximum between class variance for this study and the application on threshold is unique to this study which is not applied in other studies conducted to map aquatic plants coverage on lakes.

**Examine Nutrient Concentration of Lake Tana**

Water hyacinth spreads in water environments mostly depends on the concentration of availability of key mineral elements namely nitrogen and phosphorus in the nutrients. The levels of available nitrogen and phosphorus have been often cited as the most important factors in limiting water hyacinth growth (Carignan et al., 1994). Phosphorus (P) is one of the elements that serve as an essential nutrient to plants and animals.

In most fresh water systems, P is the limiting factor to biota, i.e., the nutrient that steer the biological production and the amount of biomass in the water. P in lakes occurs both as bound to larger particles, and as dissolved (Lakewatch, 2000). When quantifying the amounts of phosphorus in water the fractions measured are most often total phosphorus (TP), which includes all forms of phosphorus in a sample. So, in this study the researcher was tired to investigate the availability of phosphorus and nitrogen in the lake by taking sample of water at different control points and saw concentration of these in the laboratory to check why water hyacinth infestation is densely populated in certain area and sparsely populated in other area.
When it observed from figure 14, the total phosphorus concentration was highly observed on January and slightly decreased on April and October. The concentration of it was low during sample tests on August then increased on October. So, during sample tests the total phosphorus concentration was low on wet months (rain occurred) slightly increased on dry months. Whereas total nitrogen concentration was observed high at wet months and slightly decreased on dry months. On figure 15 it showed that the concentration of total nitrogen was slightly low on January and somewhat increased on April. So, it indicates that during sample test, total nitrogen concentration was increased from dry month to wet rainy month.
When the researcher viewed the relation of nitrite concentration of lake and potential water hyacinth distribution location area, potential water hyacinth highly distributed where the concentration of total nitrogen and total phosphorus were available relative to open water (pelagic area) nutrient concentration. Generally, the concentration of total phosphorus observation was increased from wet months to dry months and the concentration of total nitrogen was increased from dry months to wet month based on sample test result of the lake.

Figure 16: distribution of total nitrogen on sample stations

Figure 17: Distribution of total phosphorus on sample stations
On figure 17 above, total phosphorus concentration of the lake was somewhat high on wet months at station 15, but all most similar on all stations whereas at station 2, 5, 17, 19, the concentration was high on January dry month. On figure 16 above, the concentration of total nitrogen was low at station 1, 2, 3, 4, 6, 10, 13 that is at all pelagic area and station 20 outlet of Lake Tana relative to other stations but in the same months. At station 18 (at Gilgel Abbay inlet), station 19 (at shoreline near Gilgel Abbay), station 17, 11 (near Megech river inlet), station 16, 9 (near to rib river inlet), station 15, 8 (near to Gumara river inlet), and station 19 (shoreline of lake), station 12, 14 (near to shoreline), station 5 (near to island) the concentration of total nitrogen was highly available relative to pelagic areas. From this analysis, the researcher tried to conclude that the possible cause of potential water hyacinth distribution on lake depends on the nutrient concentration of the lake. So potential water hyacinth was densely populated where total nitrogen concentration and total phosphorus concentration were available and sparsely populated where the concentration of it was low.

Figure 18: stations of sample point’s overly on classified image in 2014
CONCLUSIONS

In this study it is conclude that Using Landsat 7ETM+ and Landsat 8 imagery as well as satellite image classification on the aid of necessary software with dynamic threshold value to map potential water hyacinth coverage on Lake Tana for management and monitoring purposes is possible with best overall accuracy and Kappa Coefficient. Using the methodology followed in this study, it is possible to map water hyacinth potential areas to get quick information about it rather than delineating with GPS. The resolution of Landsat images used in this study is not capable of distinguishing water hyacinth from other aquatic plant species. Therefore, it showed that only potential water hyacinth was mapped in the study and found high invasion area in 2014 with 34291.196ha and low invasion area with 6185.75ha in 2011 and 11558.66ha in 2013. The hyacinth has high effect on fishery, tourism and it has big severity for the lake. TP increased in dry months and TN was increased in wet months and potential water hyacinth was greatly found where the nutrient content of the lake was highly available.

The satellite image classification processes and quantification results of the spatial and temporal variation of Potential water hyacinth, obtained by analyzing time series of satellite images, has been checked with the data extracted from Google earth and it provided a favorable result. The presented unsupervised, periodic, remote sensing, thermal band, NDWI and NDVI-based satellite image classification and quantification processes proved the efficiency of using Landsat 7ETM+ and Landsat 8 imagery with dynamic thresholding, to locate and quantify the spatial distribution of aquatic vegetation especially potential water hyacinth on Lake Tana. The results presented showed that the tested image classification method is appropriate to detect potential water hyacinth coverage though; it is difficult to separate water hyacinth from other aquatic plant species.

Conflict of Interest

Conflict of interest for this research is none.
REFERENCES


