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Assessment of Spatio-Temporal Pattern of Water Hyacinth (*Eichhornia crassipes*) Dynamics and its Nitrogen and Phosphorus Content of Lake Koka, South East of Addis Ababa, Ethiopia

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Abstract

Background: The water hyacinth (*Eichhornia crassipes*) is often regarded as the world's most notorious invasive species. In Southern Eastern Ethiopia, lake Koka has serious problems related to the alien water hyacinth invasive weed. This study aimed to examine the spatial-temporal pattern of water hyacinth and it's dynamic with seasonal variability and the nutrient (nitrogen and phosphorus) content of lake Koka. The area of water hyacinth and surface area of the lake were mapped using Landsat 7 ETM+ and Landsat 8O LI image data from the years 2013, 2017 and 2021 and Sentinel-2 MS I image data of 2017-2021. The amount total nitrogen was determined by TNT persulfate digestion method and total phosphorus by molybdovanadate method.

Result: The annual coverage areas of water hyacinth increased by 328.89% from 45.74 ha in 2013 to 21.23 ha in 2021 over the last nine years. The annual maximum lake surface area was 164.63 km^2 occurred in 2017 and the minimum was 77.38 in 2021 km^2. Seasonal spatial-temporal dynamics of water hyacinth in lake Koka exhibit a periodic cyclical pattern, the mean percentage seasonal land uses of water hyacinth are the maximum on spring 2.99%, followed by summer 2.10%, then 1.25 % in winter and the list is on the autumn 0.57%. Total Nitrogen was average ranging from 5.6 mg/L-16.5 mg/L However, the concentration varied from site to site with the highest concentration site of draining the wet season average value of 13 mg/L-19 mg/L. Total phosphorus was average ranged from <.001 mg/L-0.85 mg/L. However, the concentration varied from site to site with the highest concentration site of draining the wet season with average value of 1 mg/L-1.3 mg/L.

Conclusion: In general, the significantly increasing spatial coverage of water hyacinth on lake Koka in the last 9 years and impearled with water quality degradation, however, the management and control almost nil wards to the weed infestation. Therefore, a holistic approach, effective and sustainable management strategy and action must be implemented to stop the spread of water hyacinth on Lake Koka.

Keywords: Water hyacinth; Lake Koka; Remote sensing; GIS; Image classification

Introduction

Water hyacinth has substantial negative impacts on hydrology, socioeconomics and the aquatic ecosystem. Because of this, It is known as "Blue devil" or Bengal terror" in India, "Florida devil" in South Africa, "German weed" in Bangladesh and "water terror" in South-Western Nigeria. Once established, water hyacinth is extremely difficult, if not impossible, to eliminate and attempts to do so often adversely impact remnant native vegetation [1]. More achievable, however, is the control of the weed, but the elimination or even control of waterweeds is a costly process both in fiscal and temporal terms. Three basic methods exist to remove water hyacinth: Physical, chemical and biological controls. High levels of salinity in wastewater can limit the growth of water hyacinth and other aquatic macrophytes. The plant has very prominent black, stringy roots, and when it occasionally becomes stranded in mud, it may appear rooted. Its growth rate is among the highest of any plant known and populations can double in as little as 12 days. Habitats for the water hyacinth have ranged from shallow temporary ponds, marshes and sluggish flowing waters to large lakes, rivers and reservoirs [2]. A broad spectrum of physico chemical environments characterizes these habitats. In temporary water bodies, the plants often have to survive on moist mud for prolonged periods or perennate in the form of seeds.

The nutrient bases provided by the various habitats differ widely. They range from clean waters that are poor in major nutrients such as rivers and reservoirs to highly polluted waters with large amounts of nutrients and organic matter, as is the case in sewage lagoons. In addition such waters may receive a variety of organic and inorganic industrial effluents containing heavy metals. The water hyacinth plants can stand both highly acidic and highly alkalinic conditions, but more vibrant growth is supported by neutral water bodies [3].

In Ethiopia introduction of water hyacinth firstly officially reported in the 1950's in Aba Samuel reservoir and then infestation it spread into lake Koka, lake Ellen, Koka dam and the Wonji site through the

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Awash river and the spied of the expand theist infestation on Gambella area (Sobate, Baro,Gillo and Pibor rivers) identified in 1980. Recently on Abay basin 2011, it was officially known as that one of the tops environmentally dangerous and worst invasive weeds infested lake Tana. Currently water hyacinth has reached the overall Ethiopian rift valley system and is linked with a decrease of macrophyte biodiversity. Moreover, to the ecological problem, it is distressing individual health, lake water quantity and quality, fishing, irrigation, navigation, livestock and aquatic biodiversity in Ethiopia [4].

Materials and Methods

Description of the study area

Lake Koka administrational located in the South-Eastern part of Ethiopia, Oromia regional state, East Shoa zone (between Lome, Boraand Adamaweredas) and Arsi zone (Dodotawereda). Geographically, located in the range located between 8°20'N to 8°28'N latitude and 39°00'E to 39°10'E longitude and an altitude elevation of 1590 meters above the level sea. It is an artificial lake formed by the construction of a concrete dam in the Awash river for the production of hydroelectricity [5]. Climate is characterized by a bimodal rainfall pattern, with a short minor rainy period from March to May and a major rainy period from June to September. The mean maximum monthly air temperature varies between 29.5°C (November and December) and 38.5°C (Airily), while the mean minimum monthly air temperature ranges from 10.4°C (December) to 15.5°C (May). Lake Koka is found in upper Awash river basin. The first part Awash basin and a river basin that crosses the Ethiopian plateau to the central rift and it covers 11,402 km^2. Major tributaries upstream of the Koka reservoir include Kebena, great and little Akaki and Mojo (Figure 1) [6].

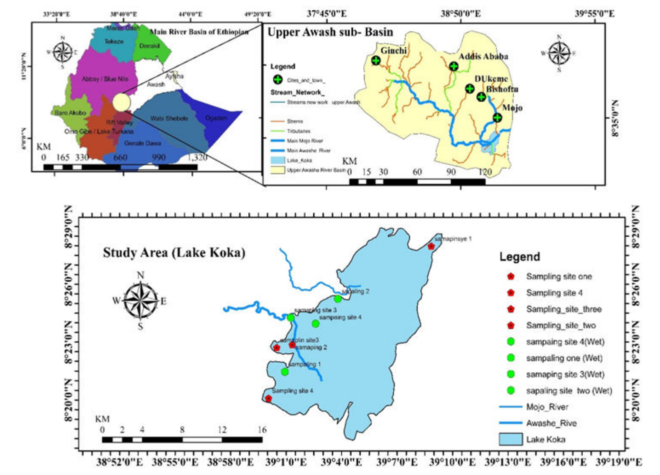

Figure 1: Map of the study area.

Data source

Remote sensing data: To sense and map the annual, monthly and seasonal spatio-temporal distribution pattern of water hyacinth and the surface area of Lake Koka, the study has been utilized Landsat 7 ETM + and Landsat 8O LI from the United States Geological Survey (USGS) website. Landsat Enhanced Thematic Mapper plus sensor (ETM+) was carried on Landsat 7 since July 1999 with a 16 days revisit period of the ETM+ sensor. Landsat 7 ETM+ images consist of eight spectral bands with a spatial resolution of 30 meters for bands 1 to 7. The panchromatic band 8 has a resolution of 15 meters. Bands 1-5 and 7 are Multi Spectral (MS) images. While band 8 is panchromatic with 15 m resolution and band 6 is thermal with a resolution of 60 m. Landsat 7 ETM+ data is capable of mapping and monitoring water hyacinth [7].

Ground truth points and google earth data: "Ground truth'' refers to information collected on location. Ground truth allows image data to be related to real features and materials on the ground. The collection of ground truth data enables calibration of remote sensing data and aids in the interpretation and analysis of what is being sensed. Examples include cartography, meteorology, analysis of aerial photographs, satellite imagery and providing trustworthy data to guide the analytical process, such as creating samples to support supervised classification; verifying, evaluate and assessing the results of remote sensing investigations and providing information to model the spectral behavior of specific landscape features. In this study, field data collection had been conducted from the two dry and wet seasons, on the wet are September 14 and November 14, 2021 the dry seasons on February 1, 2022 to record the location of water hyacinth and other land cover classes using a GPS free android app named 'AndroiTS GPS Test' which is installed on my adorned phone. Three infested Woredas such as Lome Bora Weredas and Dodatana Sire [8]. Check has also been done on the shore of the lake using a local Boat and Bajaj taxes. A total of 20 ground GPS points and more than 50 reference points from google earth were randomly identified. These data were used for assessing the accuracy of the final classified map, creating training samples and image interpretation during the image classification process. High resolution Google earth imagines was used as a complementary reference to distinguish confusing water hyacinth class from other aquatic vegetation. During the fieldwork, the farmers have to clear the weed during the dry season for land preparation shore of lake Koka. In the study, field data collection had been conducted from the two dry and wet seasons; on the wet are September 14 and November 14, 2021 the dry seasons on February 1, 2022 to record the location of water hyacinth and other land cover classes using a GPS free android app named 'AndroiTS GPS Test'. The water samples were collected from four different points of lake Koka sites (A) The highly water hyacinth infested area sites (B) The medium water hyacinth infested area located sites (C) The poorly water hyacinth infested area site (D) Free from water hyacinth invasion site [9]. All sites were selected purposely to analyze the physicochemical properties, especially the nutrient constant of lake Koka and analyze the impact of physicochemical parameters on the growth of water hyacinth and compute the chemical parameters (nutrient content) that can exist on the lake.

Results

The whole classification accuracy assessment and identification of the infested area in the lake from 50 google earth points and 20 ground truth points were shown on Figure 2.

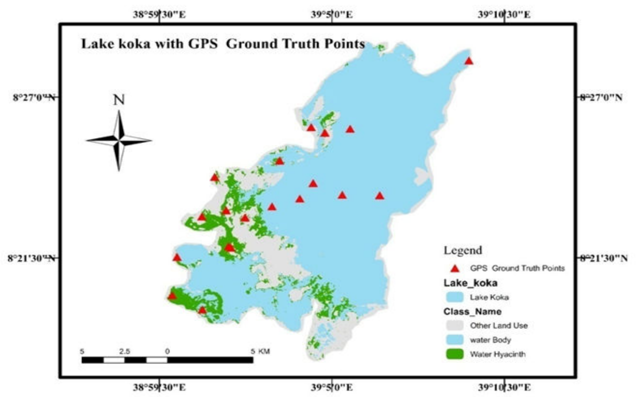

Figure 2: Map of water hyacinth in the lake.

The results have shown that the spatial distribution and configuration of water hyacinth, water and other land use can be accurately detected and mapped with an overall classification accuracy ranging from 95.88% to 97.54% with a corresponding kappa statistics varied 0.91 to 0.96 of Landsat 8 and Sentinel 2 images respectively, which implies that the classification process is avoiding from 95.58% to 97.58% percent (Table 1).

Years	Class name	Producer's accuracy (%)	User's accuracy (%)	Overall accuracy	Kappa static	Omission error	Commission error
2013	Water	98.04%	97.07%	95.88%	0.91	2.06%	3.04%
	Water hyacinth	96.73%	97.70%			3.27%	2.30%
	Berland	97.18%	95.04%			1.82%	4.96%
	Croup land	97.62%	100%			2.38%	0.00%
2017	water	97.91%	98.40%	97.54%	0.96	2.09%	1.86%
	Water hyacinth	98.48%	97.85%			1.52%	2.15%
	Berland	97.79%	97.22%			2.21%	2.78%
	Croup land	100%	95.89%			0.00%	4.11%
2021	Water	97.09%	97.94%	96.96%	0.95	2.91%	2.06%
	Water hyacinth	94.85%	97.64%			5.15%	2.36%
	Berland	98.42%	95.75%			1.48%	4.25%
	Croup land	100%	97.06%			0.00%	2.93%

Table 1: Assessment of water hyacinth and another land use of Landsat 7 and Landsat 8 (2013-2021).

Water hyacinth areal coverage

The annual maximum areal overages of the water hyacinth were 495.00 ha, 1021.00 ha and 2123.00 ha in October 2013, December 2017 and October 2021, respectively. The annual minimum areal coverage of the water hyacinth was 45.74 ha, 143.66 ha and 102 ha April 2013, June 2017 and March 2021, respectively (Table 2).

In the years between 2013 and 2021, as shown on the Table 2 the coverage of the water hyacinth has increased from 45.74 ha to 2123.00 ha. This is a fast invasion of the weed over the lake in 9 years [10].

Year	Lake surface area (Km^2)		Area covered by water hyacinth (ha)		
	Min	Max	Min	Max	Rate of expansion (%)
2013	112.09	165.09	45.74	495.00	-
2017	117.45	164.63	143.66	1021.00	106.26
2021	77.38	163.44	102.00	2123.00	107.93

Table 2: Water hyacinth expansion rate from 2013-2021.

Moreover the annual maximum and minimum spatial configuration of water hyacinth and other land use practice the lake reached maximum in the end of wet seasons map (Figure 3).

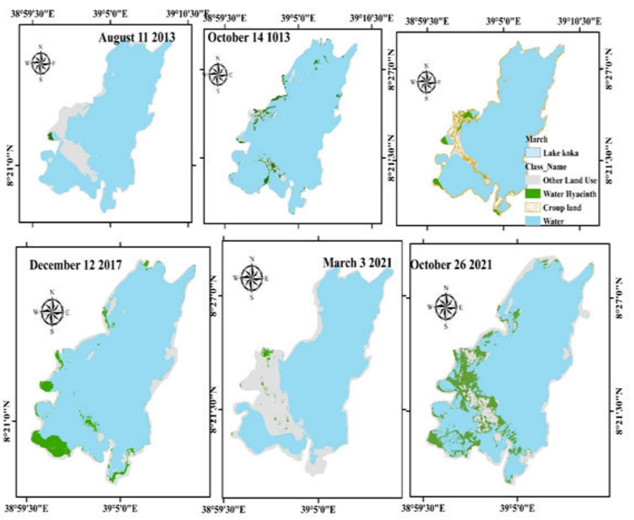

Figure 3: Map maximum and minimum spatial disruption of water hyacinth the lake.

The laboratory water analysis result showed that the average of total nitrogen and total prosperous in the wet season wear was 16.5 mg/L and 0.85 mg/L respectively (Table 3).

Season	Parameter	Result
Wet season (6/9/2021)	Total Nitrogen (as N)	16.5 mg/L
	Total Phosphorus (as P)	0.85 mg/L
	Total Nitrogen (as N)	6.25 mg/L
Dry season (28/01/2021)	Total Phosphorus (as P)	<0.001 mg/L

Table 3: Total nitrogen and total phosphorus in the lake.

Discussion

The result indicates that there has been a significant increment in annual spatial coverage of water hyacinth in the lake from 2013 to 2021. By now it almost cover most area of the lake (Figure 4).

Figure 4: Infestation water hyacinth area on lake.

Study conducted Firehun showed that there has been an increasing trend of water hyacinth invasion observed in the upstream water bodies including the study lake [11]. This indicates such rapid infestation of water hyacinth over time had adverse consequences on the normal pattern of land use a land cover over lake Koka and close areas. Water hyacinth can take up large quantities of nitrogen, resulting in rapid growth and multiplication [12]. Influence of nutrient supply on growth and nutrient storage by WH plants has been widely reported. Increases in water nitrogen increases water hyacinth growth rate. Reddy and Tucker reported that water hyacinth invasions reduce available light for submerged plants hence depleting oxygen, alters the composition of invertebrate communities, impacts fisheries, displaces native plants and wildlife and increases sediment loading. Water hyacinth infestations also threaten human health by intensifying mosquito problems by increasing habitat for species that attach to plants [13].

Conclusion

A well thought and designed water hyacinth management plan is a vital tool in the control of the aquatic plant. This weed have an impact on water flow, blocks sunlight from reaching native aquatic plants and starves the water of oxygen, often killing fish or other life in the water. The plants also create a prime habitat for mosquitoes, the classic vectors of disease and a species of snail known to host a parasitic flatwarm which causes schistosomiasis (snail fever). Hydroelectric power, transportation and irrigation schemes will be definitely victims by the invasive weed. Generally water hyacinth remains a major problem in the area unless effective control programs are in place. As chemical and mechanical removal is often too expensive and ineffective, researchers have turned to biological control agents to deal with water hyacinth, but this has also a limited success and time taking properties there has to be exhausted studies on ecosystem interactions prior to the introduction of weevils.

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Author's Contribution

KN involved in data collection, write up and TK did data analysis and editing.

Consent for Publication

Not applicable.

Funding

None.

Competing Interest

Authors declare as no computing interest.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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