# REMOTE SENSING APPLICATION ON EUTROPHICATION MONITORING IN KAVIRONDO GULF OF LAKE VICTORIA KENYA

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**Abstract**

*The water hyacinth now prevalent in the Kavirondo gulf of the Lake Victoria poses problems to both fishing and navigation. It thrives in environmental conditions favored by accelerated deposition of nutrients accompanied by high temperatures. Despite unsuccessful efforts to control the weed through chemical, biological and mechanical methods, control of nutrients that enhance the growth (eutrophication) may prove useful. In this study dependency of the hyacinth biomass production on the nutrients levels is investigated. Remotely sensed water normalized vegetation index (IDVI) and water quality parameters (nutrients) have been subjected to trend, correlation and regression analyses. Results have revealed that phosphorous is the major nutrient responsible for eutrophication of the lake and that agricultural zones in the vicinity of the lake are the major nutrient sources.*
*An empirical relationship has finally been established between the hyacinth biomass production and nutrients (phosphorous) released into the lake. It is hoped that this empirical relationship once applied in all the agricultural activity zones around the lake will regulate the phosphorous release into the lake thereby minimizing the blooming of the hyacinth.*

*Résumé*

*L'hyacinthe d'eau, actuellement très répandue dans le Golfe de Kavirondo du Lac Victoria pose des problèmes à la pêche et à la navigation. Elle pousse bien dans des conditions environnementales favorisées par une déposition accélérée de substances nutritives accompagnées de hautes températures. En dépit de vains efforts pour contrôler la mauvaise herbe par des méthodes chimique, biologique et mécanique, le contrôle des éléments nutritifs qui améliorent la croissance (eutrophisation) peut être utile. Dans cette étude, on a examiné la dépendance de la production de biomasse de l'hyacinthe sur les niveaux de substances nutritives. L'index de végétation normalisée d'eau (IDVI) et les paramètres de la qualité d'eau (substances nutritives), mesurés par télédétection, ont été soumis aux analyses de tendance, de corrélation et de régression. Les résultats révèlent que le phosphore est la substance principale responsable de l'eutrophisation du lac et que les zones agricoles environnantes sont les sources principales des substances nutritives.*

*On a enfin établi une relation empirique entre la production de la biomasse de l'hyacinthe et les substances versées (phosphore) dans le lac. Il est à espérer que cette relation empirique, une fois mise en application dans toutes les zones d'activités agricoles autour du lac, contrôlera le versement du phosphore dans le lac et ainsi minimisera l'éclosion de l'hyacinthe.*

## 1.0: INTRODUCTION

### 1.1: Background Information

Lake Victoria is the second largest freshwater Lake in the world with an area of about 68000 square kilometers. The three East African countries of Kenya, Uganda and Tanzania share the lake. The lake is a great economic resource to these countries in terms of food, water and transportation. It is located within latitude $05^0$ N and $03^0$S and longitude $32^0$E and $34^0$E. The narrow strip on the Kenya side known as the

Kavirondo gulf, bounded by latitude 01⁰S and 03⁰S and longitude 33⁰E and 34⁰E was chosen for the study (***fig1 and 2***). The basin of the Kavirondo gulf section of the Lake has several rivers originating from agriculturally productive areas of highlands West of the Rift Valley. These rivers are the source of nutrients and sediments supply or eutrophication to the lake, a condition favorable for the blooming of algae and water hyacinth growth. According to *Witzig and Whitehust* (1981) phosphorous and nitrogen are the known nutrients controlling the growth of algae in fresh water bodies. The main sources are fertilizers and industrial wastes, which are carried into the surface and ground waters through sewage, industrial wastes and storm runoff. Pote *et al.,* (1996) suggested that intensive animal manure production may accelerate eutrophication through enhanced nutrients from pastoral and agricultural lands.

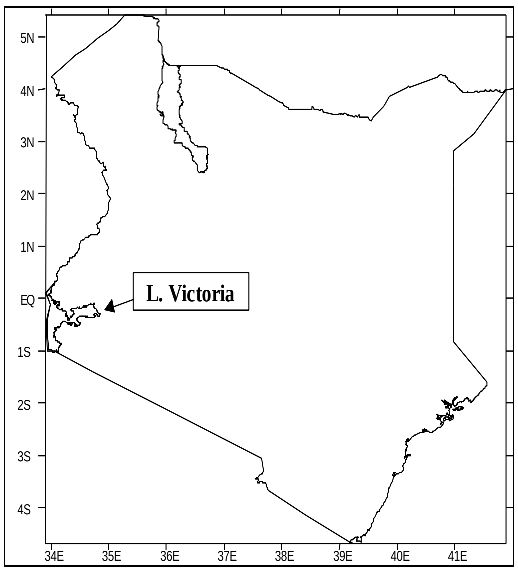



***Fig1*: The location of L.Victoria in Kenya**

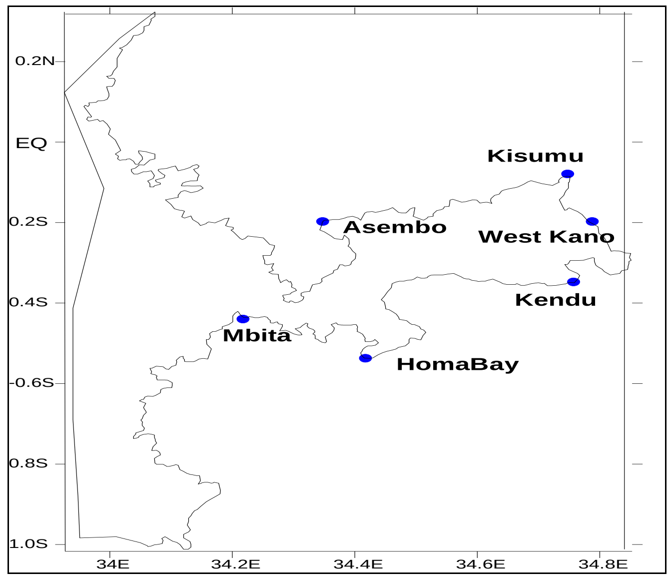



***Fig2*: Kavirondo Gulf and Stations for study**

From the early 1990's, there has been an invasion of the Lake, especially the Kavirondo Gulf by water hyacinth (***photo 2***). The weed growth has rendered the operations within the Lake, especially transportation and fishing, almost impossible. Water hyacinth, scientifically known, as *Eichhornia Crassipes* is a free floating plant that is native of South America (Brazil) and grows in all types of fresh waters. It has blue-green leaves, thick stalk and showery purple flowers (see ***Photo1***). It thrives in tropical regions where the temperatures are relatively warm and in waters that have high nutrient levels. Satellite images of Lake Victoria in 1996 show that the hyacinth covered about 1% of the lake but the figure is now estimated at 3% with the port of Kisumu particularly hardest hit by the menacing weed.

In a bid to minimize the effect of the hyacinth, mechanical harvesting of the weed was attempted. However, this method only provided a short-term solution. While the harvesting method might have been effective, the *El Nino* event of 1997 to 1998 might have played a role in changing the nutrients levels of the lake by creating ideal conditions for the growth of hyacinth. Biological method (introducing special weevils to feed on the weed) also failed due to high multiplication and mobility of the weed and the fact that birds and some reptiles feed on the weevils. Research on river Niger indicated that chemical methods using herbicides pose a serious environmental health threat to animals depending on water, thereby making the method unsuitable as a measure of control.

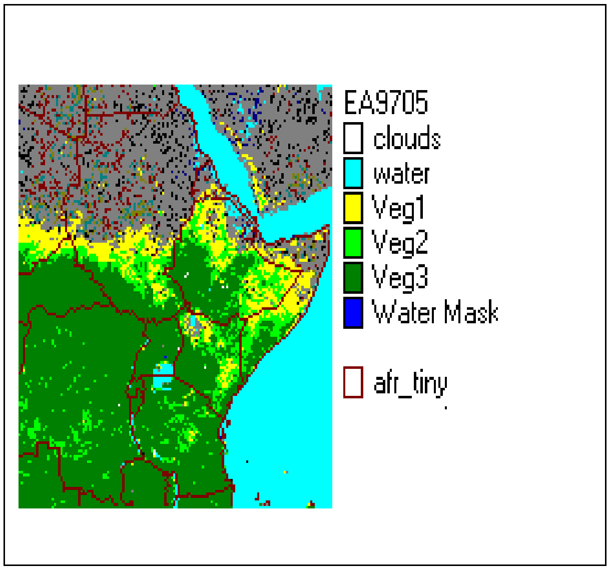



***Image1*: NDVI** for Great Horn of Africa

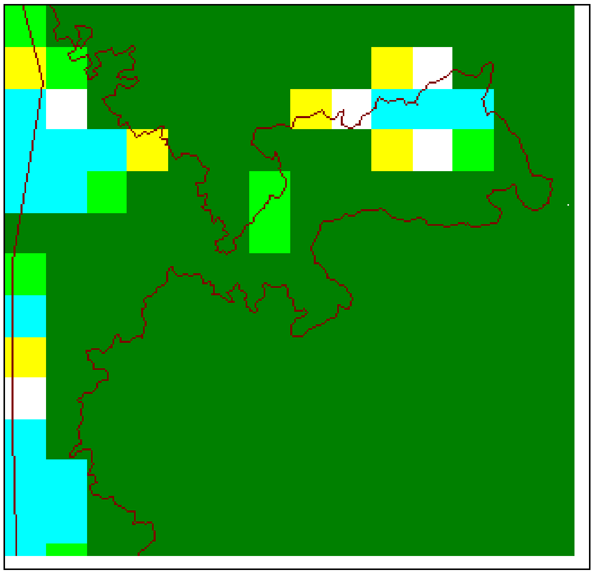


***Image 2*:** Window of Kavirondo Gulf with visible pixels

***Photo1:*** *Fully-grown water hyacinth*

***Photo2:*** *Carpet of floating water hyacinth in L.Victoria*

Controlling the nutrients that enhance growth rate of water hyacinth may provide long-term solution. Remote sensing of water bodies may provide useful information on the presence of water hyacinth in water. This study therefore attempts to investigate the utility of remote sensing in the monitoring of the growth of water hyacinth in the Lake and the link that may exist between growth rate and nutrient levels. Therefore, the main objective of this study is to investigate the utility of remote sensing in monitoring the growth of water hyacinth in Kavirondo Gulf of LakeVictoria.

## 2.0: DATA AND METHODS OF ANALYSIS

### 2.1: Data

Normalized Difference Vegetation Index (***NDVI***) data for the period 1982 to 1998, obtained through IGAD Remote Sensing Office, Nairobi was used as a measure of vegetation greenness. A window for the Lake Victoria was cut and enlarged for the various pixels to be visible (***see image2***). The dekadal vegetation indices were extracted and processed into mean monthly *NDVI* using *WINDISP* package for trend and time series analyses.

Water quality data was obtained from the ministry of Water, Environment and Natural Resources headquarters-Nairobi. Nitrogen, phosphorous and potassium were chosen as the nutrients responsible for eutrophication while turbidity was chosen as a measure of clarity of water.

### 2.2: **Methodology**

The methods used in the study include trend, time series, correlation and regression analyses. By performing the image subtraction operations between successive images for different years, for example May 1983 minus May 1982, a trend in the vegetation cover was obtained. Time series and trend analyses were also performed using the extracted mean monthly vegetation indices for the years 1982 to 1998.

Correlation analysis determines the degree of relationship between two independent variables and can be represented mathematically as

$$r=Cov\ (X, Y)/\ (Sd_x Sd_y)\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Regression analysis gives the functional relationship between variables. This may be mathematically represented as;

$$Y=a+bX_1+cX_2+\ldots\ldots\ldots\ldots+nX_n\ \ldots\ldots\ldots(2)$$

Where Y is the dependent variable, $X_1$, $X_2$………..$X_n$ are the independent variables and a, b, and c are constants while r, $Sd_x$ Sd and cov(X,Y), are correlation coefficient, standard deviations for X and Y variables and covariance for X and Y respectively.

## 3.0: RESULTS AND DISCUSSIONS

### 3.1: Results from the trend and time series analyses

Results from the trend series analysis show that there has been an increase in the vegetation cover of the Kavirondo gulf (***Images3 to 6***; ***Fig3***). West Kano, Kisumu and Kendu Bay show the highest increase in vegetation cover while the other stations show the least increase. These stations are close to the inlets (mouths) of Nyando and Sondu-Miriu rivers. The rivers carry nutrients responsible for aquatic plant growth (water hyacinth and algae) from the agricultural zones into the lake basin, thereby attributing agricultural zones to the nutrient source into the Lake Victoria. Results from time analysis show seasonal variation in *NDVI* with peak values in the months of May to July and December to January (***fig4***), a time lag of one to two months after the seasonal rainfall peaks in the Lake Victoria catchment areas. This indicates that the blooming of water hyacinth or algae may depend on nutrients carried into the lake through the rivers and surface run-off from the seasonal rains. This further indicates that agricultural practices may be the major source of nutrient enrichment of the lake. A noticeable time series result is the increase in *NDVI* values in 1997. The rise may be attributed to the *El-Nino* event of 1997-98 that released nutrients into the lake accelerating the growth rate of hyacinth in he lake.

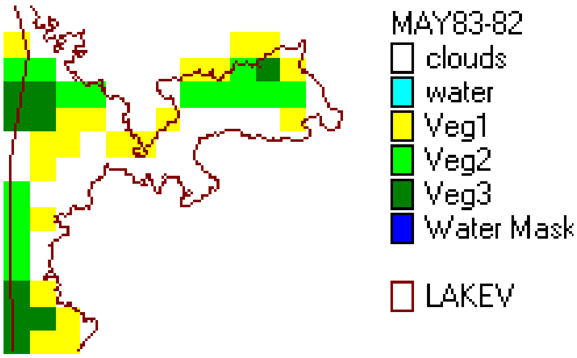



***Image3*:** Subtraction result (May 1982 and 1983)

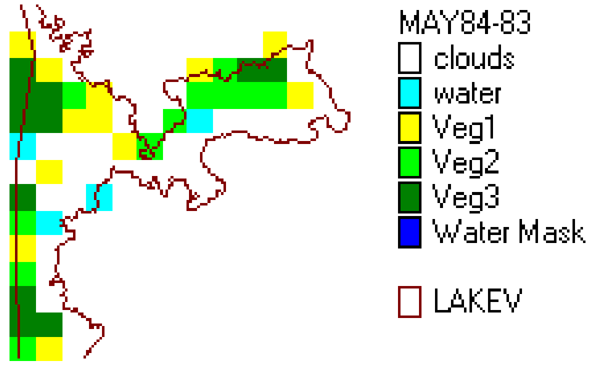



***Image4***: Subtraction result (May 1983 and 1984)

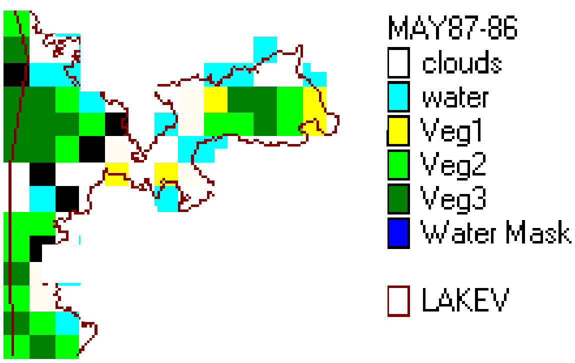



***Image5***: Subtraction result(May 1986 and 1987)

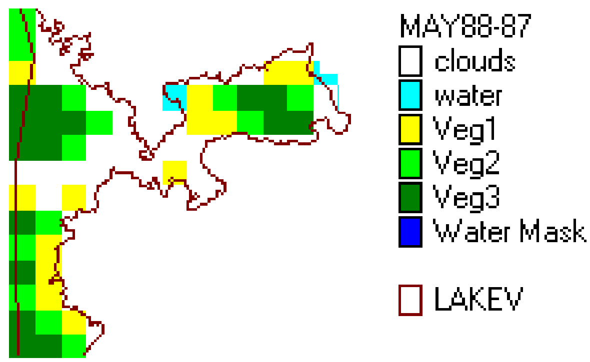



***Image6***: Subtraction result (May 1987 and 1988)

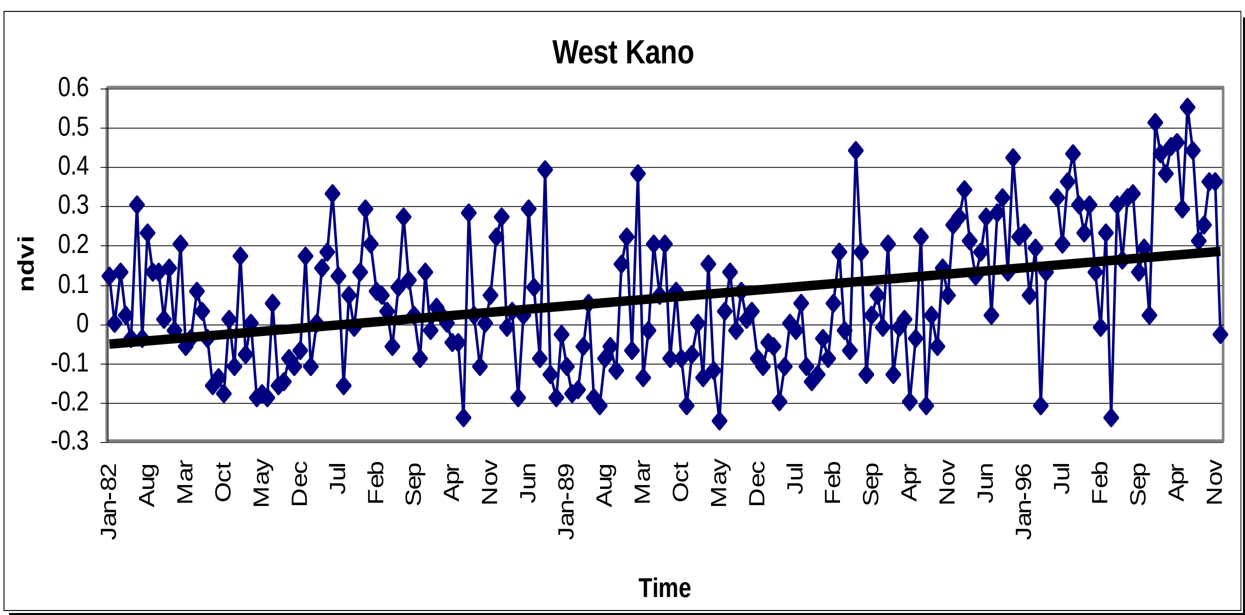



***Figure3**:* Monthly variations in ndvi ***(Time series)*** and trend line

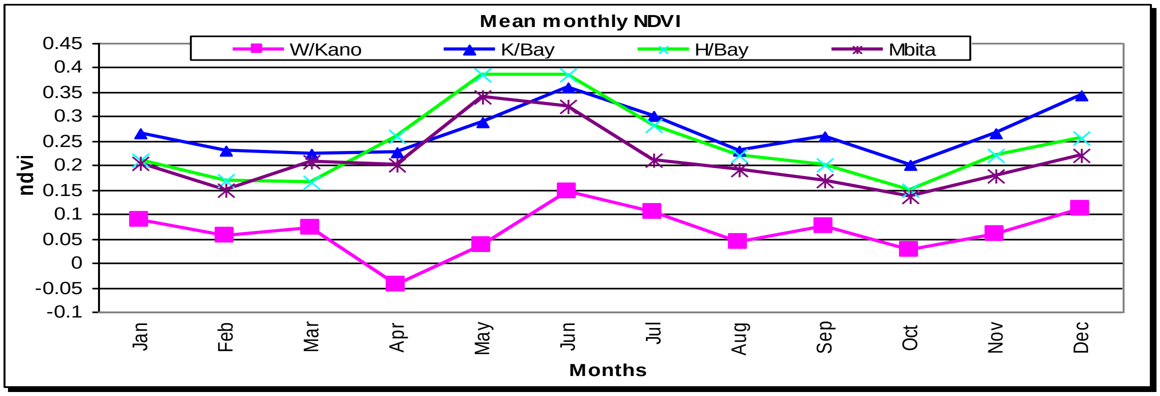
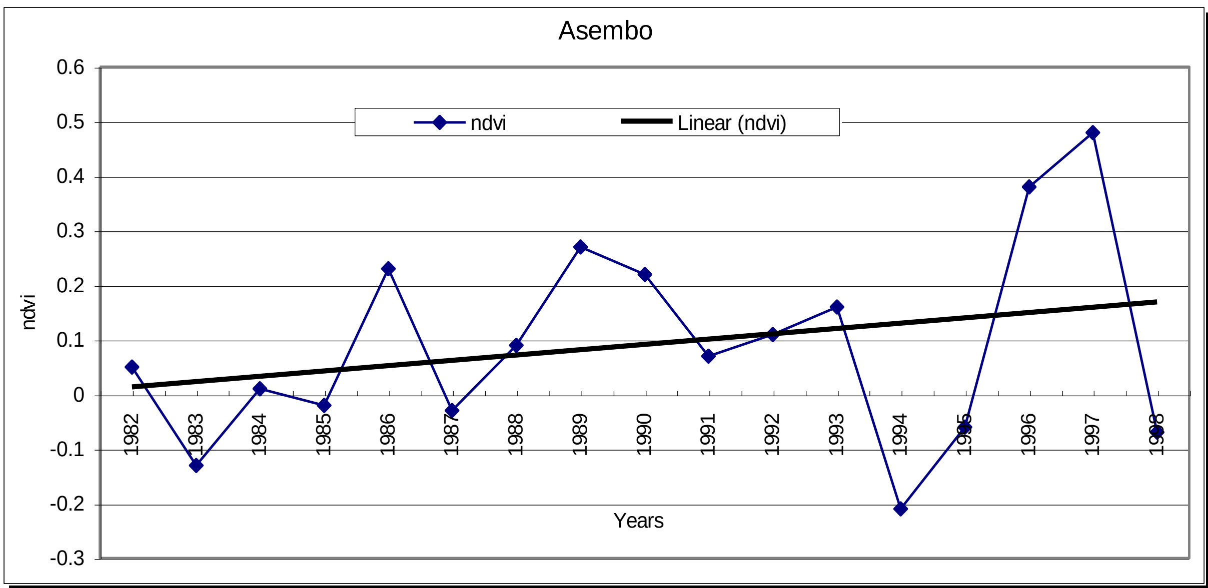



***Figure4:*** Seasonal variation in ndvi (time series)




***Fifure5:*** Annual variation in ndvi (time series) and trend line

### 3.2: Results from correlation and regression analyses

Results indicate high correlation of 0.81, 0.65 and 0.67 between NDVI and phosphorous, turbidity and Potassium ions respectively (***Table1***). These results show that phosphorous and potassium are the major nutrients responsible for eutrophication of Kavirondo gulf. Stepwise regression analyses also show that phosphorous and potassium are the major nutrients contributing to eutrophication of the gulf. Therefore the following regression equation obtained;

NDVI = 1.16P+0.14K-0.63……………………………(3)

Where P and K are the chemical symbols for phosphorous and potassium respectively.

| | **Turbidity** | **Phosphate** | **Potassium** | **NDVI** |
|---|---|---|---|---|
| NDVI | 0.65 | 0.81 | 0.67 | 1.00 |

***Table1*:** Results of correlation between ndvi and water quality parameters

## 4.0: CONCLUSIONS

This study reveals that phosphorous and potassium are the major nutrients responsible for eutrophication of the gulf. They originate from the rich agricultural areas of highland west of Rift Valley and the lake basin. These nutrients are carried into the lake through surface and river (*channel*) run-off. The study also reveals that the vegetation cover (*NDVI*) of the lake can be viewed or observed through remote sensing techniques. Thus, making remote sensing techniques a useful method in detecting the presence and monitoring the trend in growth of water hyacinth and hence eutrophication levels in water bodies.

The regression results indicate that the eutrophication process can be inferred from the changes in the chlorophyll (*NDVI*) concentration of water bodies.

## RECOMMENDATIONS

The results were based on remotely sensed data obtained from *NOAA* satellite with a spatial resolution of 8 Km by 8Km. This resolution may be too coarse to give accurate results. The use of data from a satellite (*SPOT4* or *LANDSAT*) with finer resolutions should be investigated.

The study was based on a few stations that had water quality data available. The use of many stations is recommended for further studies, for more accurate and logical results.

The use of phosphorous and potassium related compounds in agriculture and industries should be minimized through strict legislative measures as a strategy in controlling eutrophication and the corresponding aquatic plant growth in water bodies. This calls for use of alternative fertilizers and a joint effort between the countries sharing Lake Victoria as a resource in controlling eutrophication.

Remote-sensing methods should be applied in monitoring eutrophication levels in water bodies. For instance incorporating remote-sensing methods with other methods already mentioned in controlling the growth of water hyacinth in water bodies would be more effective.

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