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Biomass of Fast-Growing Weeds in a Tropical Lake: An Assessment of the Extent and the Impact with Remote Sensing and GIS

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1. Introduction

The Oussudu watershed is situated at 11°57' North and 77°45 ' East on either side of the border separating the Union Territory of Puducherry and the Indian state of Tamil Nadu (Figure 1). Apart from playing a crucial role in recharging the ground water aquifers, the Oussudu watershed also harbors rich flora and fauna (Chari and Abbasi, 2000; 2002; 2005). This watershed supports Puducherry's largest inland lake Oussudu which is also called - *Ousteri* (a Tamil language hybrid of *Oussudu* and *eri,* meaning Oussudu lake) with a surface area of 8.026 Km² and shore line length of 14.71 Km². Oussudu lake is such an important wintering ground for migratory birds that it has been identified as one of the heritage sites by IUCN (Interactional Union for Conservation of Nature) and has been ranked among the most important wetlands of Asia (Scott 1989).

In the recent past, Oussudu lake and its watershed have been subject to enormous pressures due to the increasing population, industrialization and urbanization. The resultant inputs of pollutants – rich in nitrogen and phosphorous – has provided aquatic weeds an opportunity to grow uncontrollably in the lake to the exclusion of other flora. This has led to a defacing of the lake by large patches of ipomoea (*Ipomoea carnia*) and other weeds.

2. Methodology

2.1 Biomass estimation

The biomass estimation was done using the total harvest method as per APHA (2005). Brass rings of 31 cm diameter and 0.5 m length were used as a sampling units. These rings were placed at 5 representative sites (Figure 2). All the macrophytes that were within the circumference of the rings were then harvested, segregated, identified, packed in polythene covers and labeled appropriately. Some of the samples included grossly decayed plant material which had become unidentifiable. Such biomass was recorded as 'mixed phytomass'.

The samples were washed under the running tap to remove the debris and silt and were placed in a cloth bag. To this bag a piece of strong thread was tied and the bag was swirled till all the excess water was removed by the centrifugal force due to the swirling action. At

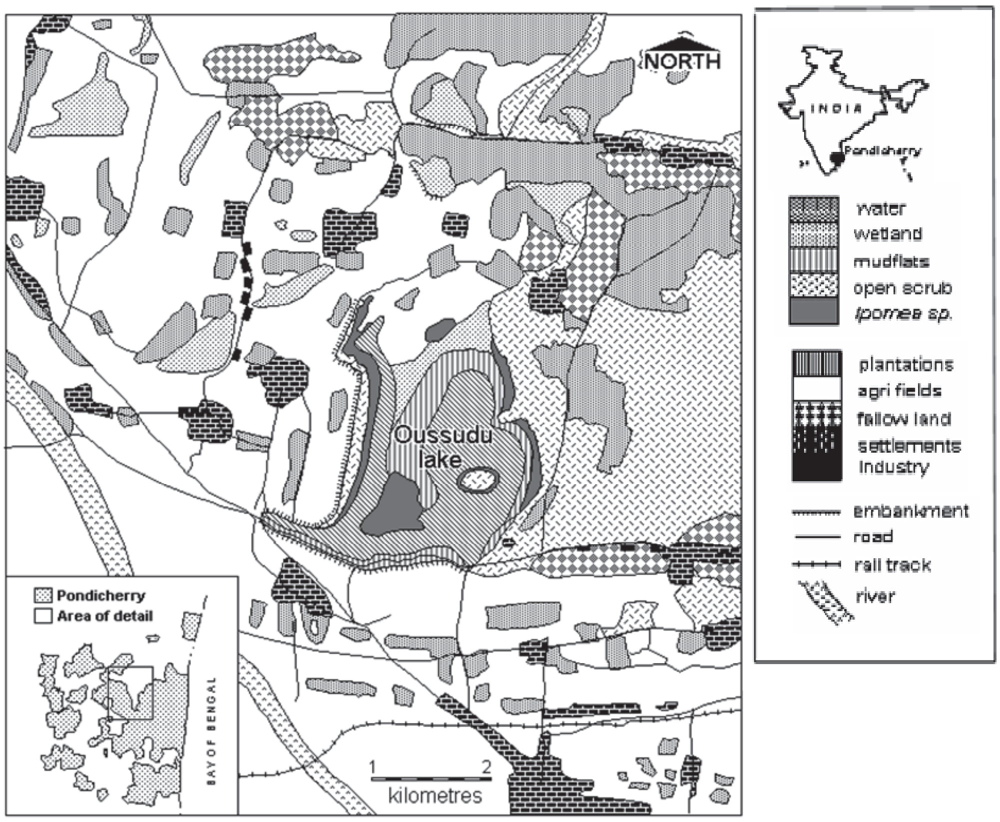

Fig. 1. Location and land use/land cover of the Oussudu catchment

Fig. 2. Location of the sampling stations (MI, M2, M3, M4, MS) for estimating biomass in Oussudu lake

this point the samples were weighted for their *fresh weight,* also called the *wet weight.* The samples were then oven dried at 105° C to a constant weight, and their *dry weight* was taken The moisture content was calculated as follows:

$$\text{Moisture, \%} = \frac{\text{(Fresh weight - dry weight) x 100}}{\text{Fresh weight}}$$

2.2 Remote sensing and GIS

The area covered by *Ipomoea* was estimated using remote sensing and GIS. A satellite imagery, IRS-ID L1SS Ill , was processed using the image processing software *Image Analyst* 8.2 and the GIS software *MapInfo Professional* 5.5 (Abbasi and Abbasi, 2010a). The image (Figure 1) was then classified for the land cover / land use categories as per the system adopted from Avery and Berline (1992).

The classified image was interpreted by means of visual observation (on-site verification). Five locations were chosen for biomass essay on the basis of achieving representativeness in terms of a) lake depth, b) extent of infestation, and c) proximity to population clusters.

3. Results and discussion

The dominant phytomass species at each of the five locations and the overall biomass density at each location are presented in Table 1. Lake-wise averages, computed on this basis, are presented in Table 2. This data, as well as visual observations indicate that Oussudu lake is heavily infested with *Ceratophyllum demersum* and *Hydrilla verticillata* — two of the world's most dominant submersed weeds. The weeds form such dense mats in some parts of the lake that it is impossible to cast dragnets for capturing fishes there (Chari and Abbasi, 2005).

Site	*Depth (m)*	*Seechi depth (m)*	*Dominant macrophyte*	*Fresh weight g m^{-2}*	*Dry weight g m^{-2}*	*Moisture content (%)*
			Ceratophyllum sp.	2576	3 17	87.7 %
M1	0.48	0.34	*Hydrilla sp.*	5	1	85.6%
			Ceratophyllum sp.	268	31	88.4%
M2	0.62	0.59	*Hydrilla sp.*	676	74	89. 1%
M3	0.29	--	*Ceratophyllurn sp.*	864	97	88.7%
			Mixed phytornass	555	6 1	89.1%
M4	0.45	0.39	*Ceratophyllum sp.*	439	47	89.4%
M5	0.06	--	*Cera tophyllum sp.*	849	11 7	86.2%

Table 1. Biomass density in Oussudu lake at five locations

The species, *Ceratophyllum,* is the most widespread and present at all the sites (Table 1, Figure 3). The fresh weight of this species varies between 268 g m^{-2} and 2576 g m^{-2}, with an average of 999 g m^{-2}. The dry weight varies between 31 g m^{-2} and 317 g m^{-2}, with an average of 122 g m^{-2} (Table 2, Figure 3). The moisture content, with respect to fresh weight, varies between 89.4% and 87.67%, with an average of 88.1% (Table 2, Figure 5).

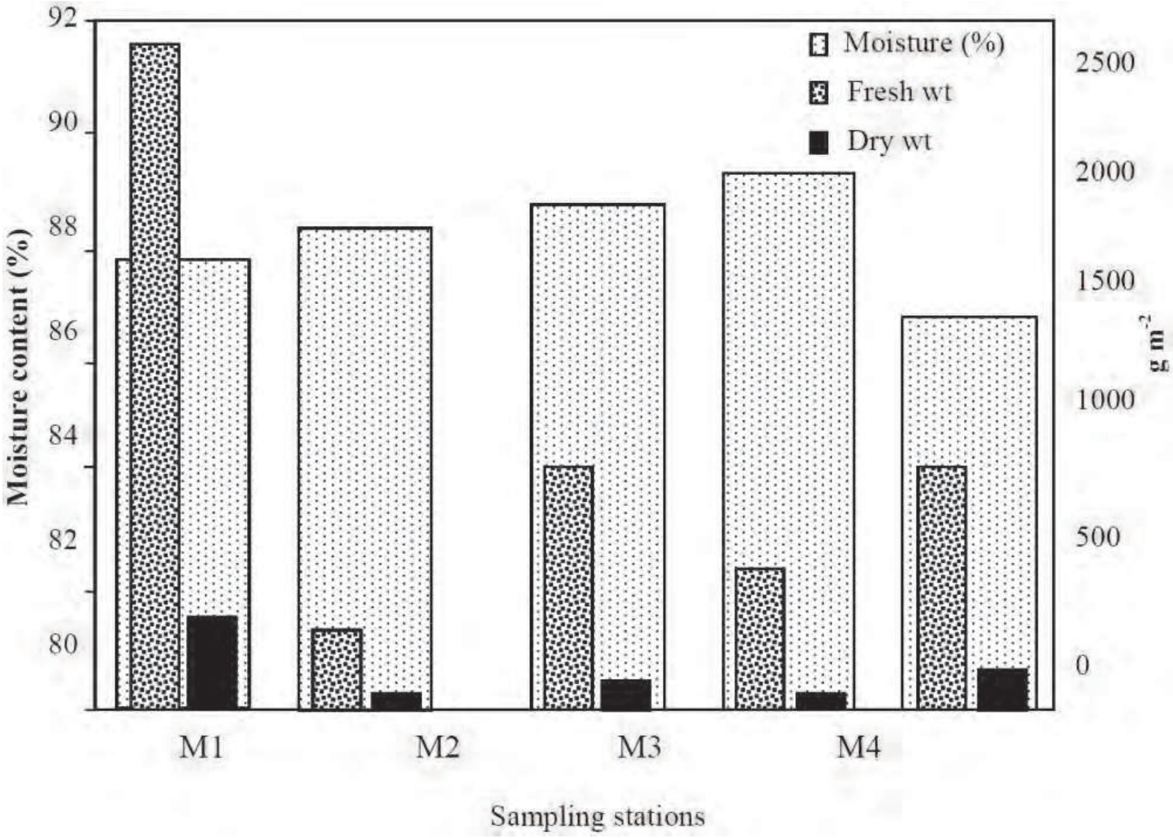

Fig. 3. Distribution of biomass of *Ceratophyllum demersum* at various locations in Oussudu lake

Phytomass species	*Average fresh weight (g m-2)*	*Average dry weight (g m-2)*	*Average moisture content (%)*
Ceratophyllum sp.	999	122	88.1
Hydrilla sp.	340	38	87.3
Mixed phytornass	555	61	89.1

Table 2. The average fresh weight, dry weight and moisture content of phytomass in Oussudu lake.

Like *Ranuncules, Nymphea,* and *Vallisneria, Ceratophyllum* is known to precipitate lime. Also, this species is capable of utilizing bicarbonate ions as a source of carbon (Gupta, 1987).
The other aquatic weed, *Hydrilla verticillata,* is found at the sites MI and M2 (Table I, Figure 4). The fresh weight of the species varies between 5 g m^{-2} and 676 g m^{-2}, with an average of 340 g m^{-2}. The dry weight varies between 0.75 g m^{-2} and 74 g m^{-2}, with an average of 37 g m^{-2} (Table 2, Figure 4) . The moisture content, with respect to fresh weight varies between 85.6% and 89.07%, with an average of 87.3% (Table 2, Figure 5).
Hydrilla, due to its low light compensation (10 - 12 Einsteins m^{-2} sec^{-1}), is known to grow even at depths where most other plants can't thrive in the aquatic habitats (Gupta, 1987). Indeed the spread of *Hydrilla* shows a positive correlation with the water depth of the lake (Figure 6).
The mixed phytomass sample collected at site M3, weighed 555 g m^{-2} when fresh, and 61 g m^{-2} when oven-dried. The moisture content measured 89% of the fresh weight (Table 2, Figure 4).

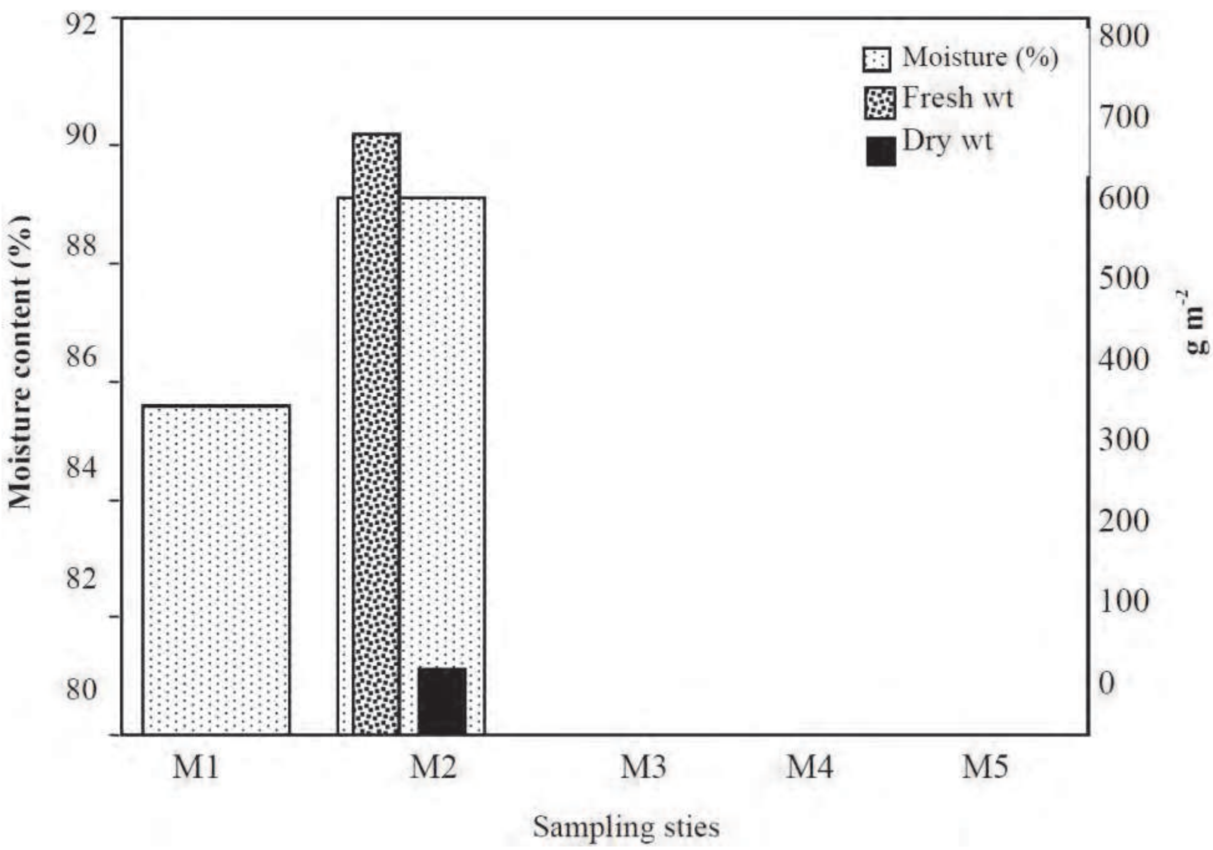

Fig. 4. Biomass of *Hydrilla verticillata* at the sampling sties

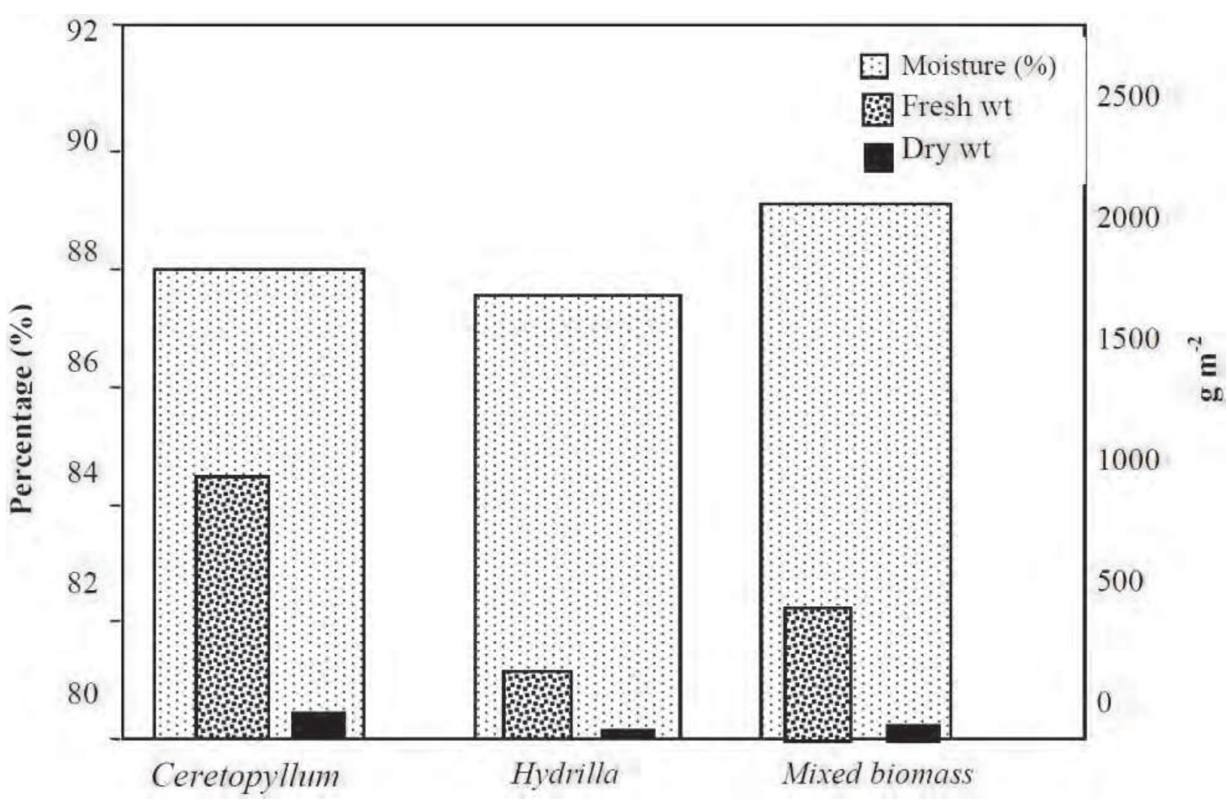

Fig. 5. The average fresh weight, dry weight and moisture content of the macrophytes

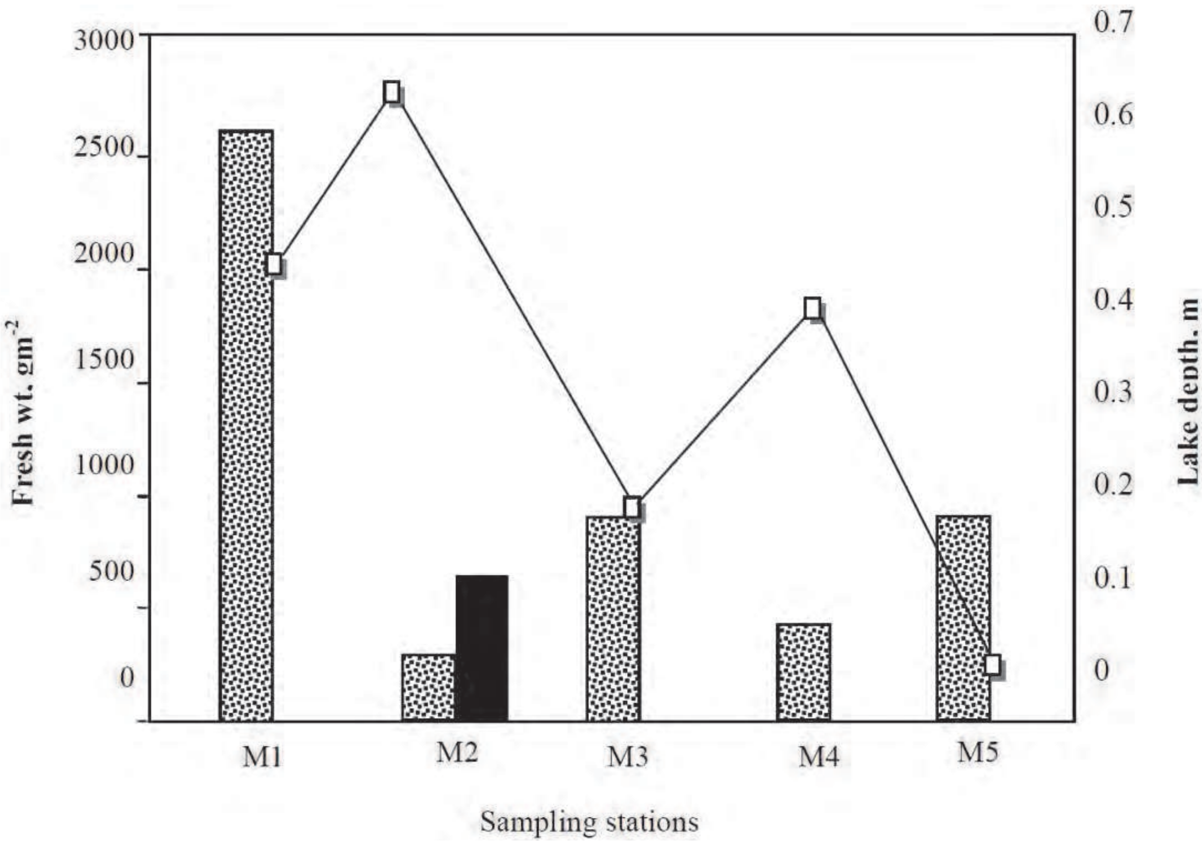

Fig. 6. The distribution of macrophytes at various sites as a function of lake water depth

3.1 Areal coverage

According to the remote sensing and GIS studies carried out by the authors, *Ipomoea* covered an area of 1.16 Km², which is as much as 14% of the water-spread of Oussudu lake. Huge islands of ipomoea can be seen at the shallower portions of the lake, presenting an unseemly sight and seriously jeopardizing the beauty and recreational value of the lake, besides exacerbating the environmental degradation of the lake as elaborated in the following section.

The presence of rampaging mats of terrestrial and aquatic weeds in Oussudu indicates that the lake is highly polluted and is, as a result, becoming eutrophic or 'obese' (Abbasi and Chari, 2008; Abbasi and Abbasi, 2010 b; Figure 7).

3.2 Impact on the lake ecosystem

Colonization of Oussudu by aquatic weeds threatens to upset the lake ecosystem in several ways. These include the following:

i. The thick mats of the weeds prevent sunlight from reaching the submerged flora and fauna, thereby cutting off their energy source. This situation would disfavor several species leading to dwindling of their populations and causing loss of diversity.
ii. Once weeds colonize a water body due to pollution, they deteriorate the water quality further (Abbasi and Nipaney, 1993; Abbasi and Abbasi 2000; Abbasi and Abbasi 2010c). The decaying of the weeds adds to the depletion of dissolved oxygen, and increases the BOD, COD, nitrogen and phosphorus. This also encourages growth of various pathogens which may be harmful to humans.

Fig. 7. Ipomoea in Oussudu lake (above) and a closer view of the weed (below)

iii. The spread of weeds in the lake reduces the area available to fishes and hinders their mobility. The depletion of dissolved oxygen may result in mass fish kills or may favor only certain kinds of fishes, (which can tolerate low oxygen levels), thereby eroding the piscian diversity.
iv. The profuse growth of weeds breaks natural water currents. Consequently the water becomes stagnant, favoring the breeding of mosquitoes and other disease causing vectors.
v. Ipomoea is known to give off exudates which are toxic to certain animals and plants. The extracts of decaying leaves and rhizomes of several aquatic weeds are known for their phytotoxicity (Sankar Ganesh et al., 2008).
vi. Weeds provide ideal habitat for the growth of molluscs, which in turn choke water supply systems (canals and pipes) and impart undesirable taste and odour to water. Mollusks such as snails, are primary hosts to blood and liver flukes the human disease causing pathogens. These mollusks seek shelter, multiply, and find sustenance among the roots of the weeds.

Many of the abovementioned impacts have been documented (Abbasi et al., 2008; 2009).

4. Remedial measures

The very high net biomass production in Oussudu lake may hasten the process of wetland-to-land succession, sounding the death-knell for the lake. Hence measures to control the weeds while at the same time blocking further ingress of pollutants in the lake are both very urgent requirements. Several methods of controlling the aquatic macrophytes have been suggested and field-tested for their effectiveness; these have been summarized in Table 3. Of these methods, the one based on weed foraging by the diploid grass carp *(Ctenopharyngdon idella,* white amur) is the most effective at controlling the growth of aquatic macrophytes and filamentous algae (Cooke et. al., 1996). Hence, using the grass carp would not only control the aquatic weeds but also the filamentous algae of Oussudu lake.

Treatment (one application)	*Short-term effectiveness*	*Long-term effectiveness*	*Cost*	*Chance of negative effects*
Sediment removal	E	E	P	F
Drawdown of water	G	F	E	F
Sediment covers	E	F	P	L
Grass Carp	P	E	E	F
Insects	P	G	E	L
Harvesting	E	F	F	F
Herbicides	E	P	F	H

E = Excellent; F= Fair; G= Good ; P= Poor; H= High; and L= Low

Table 3. Comparison of lake restoration and management techniques for the control of aquatic weeds (Olem and Flock, 1990)

The species - *C.idella* - was earlier introduced by Puducherry's Department of Fisheries in Oussudu lake, but is no longer present now. The triploid variant of this species, which is genetically derived from the diploid grass carp, would preclude any possibility of the spread of the species.

Apart from C. *idella, Tilapia zilli* and *T. aurea* also feed voraciously on the macrophytes and the filamentous algae. Introduction of those would help in the reduction of phytomass and speed up the recovery of the lake.

5. Acknowledgement

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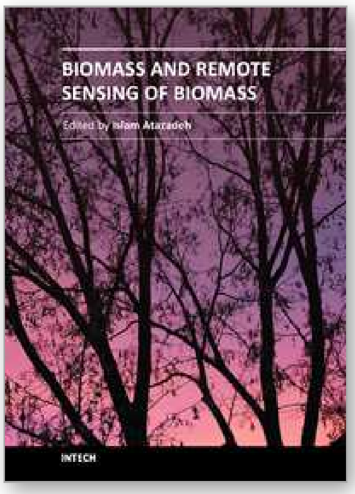

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Generally, the term biomass is used for all materials originating from photosynthesis. However, biomass can equally apply to animals. Conservation and management of biomass is very important. There are various ways and methods for biomass evaluation. One of these methods is remote sensing. Remote sensing provides information about biomass, but also about biodiversity and environmental factors estimation over a wide area. The great potential of remote sensing has received considerable attention over the last few decades in many different areas in biological sciences including nutrient status assessment, weed abundance, deforestation, glacial features in Arctic and Antarctic regions, depth sounding of coastal and ocean depths, and density mapping. The salient features of the book include:
Several aspects of biomass study and survey
Use of remote sensing for evaluation of biomass
Evaluation of carbon storage in ecosystems
Evaluation of primary productivity through case studies