INTRODUCTION

1.1 Background

Wetlands are the most productive ecosystem on the world. They are described as "biological supermarket" because of their extensive food webs and rich biodiversity they support (Barbier *et al.*, 1997). Wetland are called Simsar in Nepali.

Wetlands are widely scattered throughout the country occupying approximately 5 percent of total land of Nepal (DOAD, 1992). In particular, lakes are classified into glacial, tectonic and ox-bow lakes (Sharma, 1973). Highland lakes are of glacial origin, while lakes in low-lying flat lands are of oxbow types. The lakes in the midlands are tectonic and are formed due to land subsidence. Some lakes have marshes and swamps at the outskirts. Swamps are waterlogged around lake-margins and in part of floodplains while marshes are more or less permanently covered by shallow water in area where groundwater, surface spring, stream runoff are common.

Present study aims to study two smaller lakes namely Gunde and Maidi lake, located in Lekhnath Municipality of Pokhara valley. The sorry state affair is that both lakes have been receding rapidly due to siltation and lake area encroachment. Hence documentation of plant species can help to the municipality's concept to develop town as "Garden city of seven lakes" through highlighting ecological status of Gunde and Maidi lake systems. Further, most of the studies have been concentrated only in the relationship between species richness and biomass of terrestrial grassland. A few studies have been done in alpine region (Bhattarai *et al.*, 2004). Yet to my knowledge, plant species richness and biomass relationship of marshlands of Nepal has not been investigated till now. Therefore, this study is aimed to test the relationship between species richness and biomass of wetlands, situated in Pokhara valley.

1.2 Classification of Wetlands

There are several classification of wetlands developed by Odum *et al.* (1974), Miller (1976) and Cowardin *et al.* (1979). Later, Scott (1989) classified wetlands into 23 categories for describing the Asian wetlands. Dugan (1990) recognized 30 categories of natural wetlands and a artificial (man made) one. Wetlands in Nepal have been classified into following types: (1) lakes, (2) ponds (3) reservoirs (4) river flood plain (5) swamp (6) marsh and (7) rice paddies for the sake of convenience (Shrestha and Bhandari, 1992). But later, Sah (1993) in his work in Koshi Tappu, Nepal described 8 categories of Nepalese wetlands including rivers in the above classification.

HMG/N (1995), classified Nepalese wetlands into following categories: viz.

Lacustrine systems, Palustrine system, Riverine system, Man made system.

1.3 Importance of wetlands

Wetlands comprises approximately 6.2% of world's total land area and are lands transitional between terrestrial and aquatic systems where water table is usually at or near the surface or land is covered by shallow water. Any land to be wetlands most have one or more of following attributes.

– At least periodically, the land supports predominantly hydrophytes.

– The substrate should be undrained hydric soil (wet soil).

– The substrate is non soil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Most of the wetlands are home to dense and diverse populations of plants and animals. Hence, it possess ecological, economic, cultural and recreational value. Wetlands are considered to be one of the world's most productive environment, as some along eusturies are extremely fertile due to constant replenishment of nutrients being washed in by costal tides. The net primary productivity of wetland may be as high as 4000gm/m^2/year, which equals that of tropical rain forest (Richardson, 1994).

Wetlands play a vital role in maintaining ecosystem and environmental quality, such as filtration and purification of water, removal of sediment and regulation of microclimate. Hence, wetlands are sometimes described as the "kidneys of the planet" James (1995), because they cleanse the water from sediments, chemicals and other pollutants that passes through them. Many countries are using wetlands as a site for sewage treatment. They are sometimes referred as "Nature's civil engineer" for providing effective systems of flood control and protecting from soil erosion.

Wetlands are considered to be an invaluable key to reconstruction of regional biogeography. Wetlands specially bogs are considered to be a good palynological reserves. So, due to their potentiality if they are destroyed or altered, there may be a closure of door for scientific knowledge (Greenson *et al.*, 1978).

1.4 Status of wetlands

A fundamental feature of the earth is an abundance of water, which cover 71% of its surface (Wetzel, 1983). Among them, 97% remains in the seas as salt water and remaining 3% exists as fresh water, in river, streams, reservoirs, lakes, underground water, and permanent glaciers. Shiklomanov (1993) estimated that the freshwater lakes in the world have a total area of about $1.5\times10^{12}m^2$ and further including saline inland seas, the total area added another $1\times10^{12}m^2$ to it.

Encyclopedia Wikipedia (2008) estimated the total area of water bodies to be $148{,}939{,}063km^2$ (29.2% of total land coverage of earth's surface) in countries among which, Nepal lies at 93 position with a share of 0.10 percent area. Nepal is the second richest countries in the world in terms of water resources; about 2.27% of the world water is found in Nepal. The total area occupied by freshwater in Nepal has been estimated approximately 743,183ha. Out of which, lotic ecosystem covers an area of about 395,000ha and lentic ecosystem covers about 350,000ha, paddy field (325000ha), marshy land (12000ha), reservoir (1380ha) and village ponds (5183ha) comprising approximately 5.05% of total land area of Nepal (Rajbanshi and Gurung, 1994).

Lakes that occur above 3500 m asl are mostly of glacial origin. Altogether, 2,223 glacial lakes covering a total area of 750ha have been recorded in areas above 3,500 m asl in Nepal (IUCN, 2004).

Bhandari (1992), compiled several data and listed 295 wetland sites in Nepal. Altogether 126 wetlands have been reported from Terai region. Among which, 50% are found in far-western development region followed by 24% in western development region. The eastern Nepal harbours only a few number of wetlands.

After acceding to Ramsar convention on December 17, Nepal designated Koshi Tappu Wild life Reserve (KTWR) for inclusion on the List of Wetland of International Importance (LWII), which comes under the mandate of convention. Further, Beeshazaree Tal, Chitwan; Jagdishpur Reservoir, Kapilvastu; and Ghodaghodi Tal, Kailali are included in Ramsar list on Oct. 13, 2003 (Lekhak and Lekhak, 2005). Recently, high altitude lakes like : Gokyo and associates lakes, Sagarmatha National Park; Gosainkunda and associates lakes, Langtang National Park; Phoksundo lake, Dolpa; and Rara lake, Rara National Park were designated in Ramsar site of Nepal on 21 Dec. 2007 (Encyclopedia Wikipidia, 2008).

1.5 Species richness and productivity

The relationship between species richness and above ground biomass is emerging as a central theme in diversity studies and is fundamental to the management and preservation of biodiversity (Mittelbach *et al.*, 2001). Hence it always has been a central focus in community ecology and has undergone intensive empirical and theoretical studies in recent years. This relationship has been investigated since mid 1960s. Despite years of study and intense theoretical interest, this relationship remain controversial (Bhattari *et al.*, 2004) with disagreement over whether productivity controls or is controlled by species richness. This relationship appears to be hump-shaped (unimodel) in many system, with species richness peaking at intermediate level of biomass (Palmer and Mumtaz, 1997). However, it is now clear that the generality of hump-shaped model should not be overstated (Waide *et al.*, 1999). At very low productivity or high disturbance, few species can survive; hence richness is low. Alternatively, at low biomass, there tend to be few individuals, and hence, as a sampling artifact, few species exist (Oksanen, 1996). At high productivity or low disturbance, one or a few species can monopolize the available resources and thereby competitively exclude other species. It is only at intermediate levels of productivity or disturbance that richness is capable of reaching a peak (Palmer and Mumtaz, 1997) Rosenzweig (1999) called the pattern of decline in diversity at high productivity the "paradox of enrichment."

Productivity can affect community structure in a variety of ways. Changes in productivity can also result in changes in number and diversity of species in a community. The nature and causes of relationship between productivity and species diversity have been disputed by ecologists for many years. The nature and shape of relationship between productivity and diversity in plant communities depends on spatial scale. However, various analyses showed that even for a single set of sites, there is no unique relationship between productivity and diversity. It depends upon the scale of analyses, with different components of scale having different effects (Gurevitch *et al.*, 2002).

1.6 Objectives

The present study was done in Gunde and Maidi lakes system with following specific objectives:

1. To document plant species found in Gunde and Maidi lake system.
2. To understand the pattern of change in species richness, biomass and soil attributes from shoreline towards the center of lake.
3. To understand the relationship between plant species richness and biomass in wetland system.

1.7 Justification and limitation of the study

The proposed study areas, i.e. Gunde and Maidi lakes has not been explored ecologically. Since no remarkable work is carried out and is almost untouched and unexplored, are best example of the wounds of neglects. The research gap has implored this young researcher to document the floristic composition and biomass estimation of both lake. They have been receding rapidly due to siltation and encroachment. The output of present research will provide novel insight into relationship between species richness and biomass, a first land in Nepalese wetland system in Nepal.

1.8 Limitation

As the study area is marshland it was difficult to carryout field work in different seasons taking one's life in stake. Thus, single field visit was made during May and June and data were collected.

LITERATURE REVIEW

2.1 Plants diversity in wetlands

Wetlands are lands transitional between terrestrial and aquatic system where soil is frequently waterlogged, the water table is usually at or near the surface or land covered by shallow water (Poddar *et al.* 2001). Nepal is rich in wetland resources such as permanent fast flowing rivers to seasonal streams, high altitude glacial lake to low land ox-bow lakes, ghols to swamp and marshlands, river flood plains, paddy field, manmade reservoirs and ponds. Most of the wetlands are located in the low land of the country which is most densely populated and developed zone of Nepal (Sah and Sah, 1999).

According to DOAD (1992), lakes and marshlands share 0.7 and 1.6% of the total area of wetlands of Nepal and lakes alone are estimated to hold 3 percent of all available water (Sharma, 1997). Based on their origin, Nepal's permanent lakes are broadly categorized into glacial, tectonic and ox-bow lakes. Among them, the most famous lakes of tectonic origin in mid-hill are eight subtropical lakes of Pokhara valley. They are Phewa, Begnas, Rupa, Khaste, Dipang, Gunde, Kamalpokhari and Maidi which together covers some 3.68 square mile in area (Gurung, 2002). Among eight lakes, lake Phewa, lake Begnas and lake Rupa belong to larger lakes in descending order with relatively larger open waterscape and remaining Maidi, Gunde, Dipang, Khaste belong to smaller lake with small open water body. Due to dam construction lake Phewa and lake Begnas are in better shaped with increment in their water volume and depth (Rai *et al.* 1995) whereas other small lakes are under the verge of extinction (Gurung, 1970, Hickel, 1973, IUCN, 1996, Shrestha, 1998).

All lakes particularly the smaller ones are on the verge of extinction primarily due to overgrowth of aquatic weeds (Hickel, 1973, Oli 1996, Shrestha, 1998) and converting into ponds due to sedimenation and nutrient inflow. There exist drastic reduction in size of Maidi Tal in aerial photos of 1990 as compared to Toposheet map of 1958. According to IUCN (1993), water bodies with 8 hectare area and less than 2 meter depth belongs to ponds. In this respect, the so called Maidi Tal, Dipang Tal and Gunde Tal (Tal - a lake, in Nepali) which have been reduced into size and depth due to accelerated succession, lately fall under the category of ponds.

Vegetation may be varied based on habitat. Broadly, habitat of Nepal can be divided into forestland, fallowland, grassland, cropland, wetland, and snowland. The estimated wetlands based on land use pattern is 5 percent (NBS, 2002) and about 25 percent of the total vascular plants are wetland dependent (Bhandari, 1992). On the basis of their general habitat, they may be categorized as: (i) free floating and rooted floating hydrophytes (ii) suspended and rooted-submerged hydrophytes (iii) amphibious/emergent hydrophytes. Many of the wetland species are of alien origin because they are highly productive and are the most susceptible to IAS (Alien Invasive Species).

The wetland habitats together with floodplain mainly consists of aquatic macrophytes, seasonally flooded grassland and riverine forest (Sah, 1997). The common species found in swampy wetland in Nepal are *Eulaliopsis binnata, Phragmites karka, Saccharum spontaneum*. In other hand, marshes are particularly extensive near the stream and river and commonly dominated by germinoid plants such as cattails, reeds, sedges and rushes (Sah, 1997), Paddy field, which are considered as managed wetland, house a number of aquatic weeds. These are *Aponogeton ratans, Azolla pinnata, Hemoturbid compresa, Leersia hexandra, Eriocaulon cinernum, Echinochloa colona, Sagittaria trifolia, Lemna minor* and many others. (Regmi and Ranjet, 1985, Dangol *et al.* 1986).

Shrestha (1998) reported altogether 65 species of aquatic macrophytes from seven lakes of Pokhara valley with different morphometry and limnological features, out of total, 10 species were troublesome aquatic weeds of Indian subcontinent. Among these, lake Rupa recorded higher number of species (48) followed by lake Phewa (39), Dipang (25), Khaste (16), Begnas (15), Maidi (13) and Gunde (12). On the basis of area of coverage and plant biomass. *Hydrilla verticillata* and *Trapa bispinosa* were found dominant in lake Phewa and lake Rupa respectively and wild relative of rice *Oryza rufipogan* and *Leersia hexandra* were reported from both lakes. However, 65 species of aquatic macrophytes were recorded by Adhikari (2002). Of them, 59 species from Khaste and 52 species from lake Dipang representing *Hydrilla verticillata* being frequent and dominant in both lake in all seasons.

Aquatic macrophyte in reasonable quantities have several important values and function in wetland ecosystem. However, their excessive growth and resultant nuisance potential in absence of adequate management represent them as aquatic weed (Shrestha, 1998). Almost all aquatic and marshy plants known to occur in Asia have been considered weeds in one or other situation (Gopal, 1993). The menace of aquatic weed is a global problem particularly severe in warm tropical water; where increasing number of dams and irrigation project with increase in cultural eutrophication have enhanced aquatic growth (NAS, 1976). This can be relating with abundant growth of aquatic macrophyte in most eutrophic lakes of Pokhara valley, Nepal. Oli (2000) recorded highest number of invasive aquatic weeds (6 species) in Rupa lake followed by Begnas (5 species), Dipang (4 species), Khaste (3 species) Tal Khola (3 species), Gunde (2 species). Notable aquatic weeds includes *Hydrilla verticillata, Potamogeton crispus, Potamogeton pectinatus, Echinochloa colona* and *Pancium repens*.

2.2 Biomass and species richness

The rate at which the green plants produce biomass or store is referred to as primary productivity and the primary productivity of aquatic ecosystem gives the quantitative details regarding energy fixation and its availability to support bioactivity of total system (Goldman, 1968). The balance between the biomass of aquatic macrophytes and consumer is essential to maintain the stability of aquatic ecosystem. Macrophytes generally confine themselves to the shallow zone of aquatic ecosystem and contribute significantly to total primary production and acclerate eutrophication (Adani and Yadav, 1985).

Nepal's wetland habitat is created through varied water bodies ranging from permanent flowing rivers to seasonal streams, lowland ox-bow lake, high altitude glacial lake, swamp, marshes, paddy field, reservoir and ponds. But, whatever their condition, the species composition follows the same patterns from emergent, free floating and submerged species. Regarding productivity emergent species of shallower region always have maximum share. Vandervalk and Davis (1976) observed the same pattern in Big Kettle, USA with standing crop biomass (541-729g/m^2) followed by submerged zone (156-225g/m^2). Kaul *et al.* (1978) from Kashmir lakes such as Dal lake, Anchar lake, India also opined the same and reported the maximum contribution to productivity were by emergent species (3161.94t) followed by submerged (802.78t) and rested floating species (247.35t).

Temporal change in nutrients and seasonal variation are related to the biological process in water system and influence the primary productivity (Carrillo *et al.* 2006). Biomass generally increases from early rainy season to winter and decreases with the advent of summer (Acharya, 1996). Same phenomenon had also been reported by Sharma (1995) from Kawar lake, Bhagalpur, India. Sankhala and Vyas (1982) from moist bank community of Banghela tank in Udaipur, India with biomass peaked (266.2g/m^2) per month in rainy season and was a minimum (149.5g/m^2) per month in summer season.

The fluctuation in water level has significant effect on biomass of free floating plants. Nohara and Tsuchya (1990) showed two seasonal peaks of biomass of *Nelumbo nucifera* in Japan and maximum biomass they obtained was 294g/m^2 in July and minimum 75g/m^2 (dry wt.) in August. Similarly, Paillison *et al.* 2006 investigated aboveground biomass and morphological response to *Nymphaea alba*, to small spring water level (0.1 - 0.5m) and manipulated in large shallow lakes over 9 years in 1995-2003. They found that the amplitude and duration of exposure to level water affected the spring and biomass of *N. alba* and plant respond to high spring water level by producing longer and thinner petiole to preserve leaves from flooding with no significant change in leaf area and leaf petiole biomass and concluded that smaller deviation of spring water can be driving force in large system to control the aboveground biomass of this plant. Same phenomenon was also observed by Ali *et al.* (2006) while quantitatively documenting the invasion of *Mariophyllum spicatum* into lake Nasser and its impact on submerged species.

The relationship between species richness and biomass or productivity has been a central focus in community ecology (eg.: Grime, 1973, 1979, 1997, Rosengweig, 1992, 1995, Huston, 1994, Abraham, 1995, Johnson *et al.* 1996, Grace, 1999, Waide *et al.* 1999, Mithelbach *et al.* 2000, Fox, 2003 etc.). This relationship has been investigated since the Mid-1960s, but the causal mechanism have been remains in dispute. However, the relationship between herbaceous species and biomass often has a hump-shaped with a peak in species richness at a low to intermediate level of biomass (Grime, 1997, 1997).

Most of the studies, where biomass has been related to species richness, have been done on grasslands and wetlands (Bhattarai *et al.* 2004) and regarding the productivity and botanical composition, Flipek (1969) worked in meadow in condition of different frequency of mowing. He recorded reduced tall grass after mowing and noted that mowing four time promoted the development of rye-grass of white clovar supporting the result of Gurevitch and Unnasch (1989) on *Dactylis* species and they hypothesize that the decline in diversity is due to increased composition from dominant species.

Grime's model on relationship between standing crops plus litter and species density whether it fits well or not was tested by Oh and Yoon Soon (1983) and the result agree with model for grassland and salt marshes. The number of species was 11 for grassland and 7 for salt marshes within the range of 300-700g/m^2 for maximum standing crop. The Grime's result does not seems to fit with the result of forest stands on this study.

Mittelbach *et al.* (2003) thoroughly discussed the relationship between species richness and biomass during nutrient limitation. Later Venterink *et al.* (2003) evaluated whether this kind of nutrient limitation (N, P, or K) may affect species richness-productivity patterns. They found that role of nutrient not only reveals mechanism that may explain in species richness- productivity but it also way be important for nature management practices.

A hump-shaped pattern is common among herbs species and Espiner (2006) while working in Mediterranean wetlands detected hump-shaped relationship between species richness and biomass. He further tested the effect of number plots on ability to detect this relationship by using bootstrap procedure and concluded that number of plots affect to detect the hump shaped pattern. However, a conceptual model that taking into account underlying relationship connecting productivity with species richness produces a heterogenous distribution of relationship. Ziv and Tasiri (2004) suggested stopping search for a single pattern of species richness-productivity relationship (SRPRs) and direct future researches to explore the mechanism responsible for various SRPRs.

Wetland are known for their great diversity and important carbon sink or sink for different greenhouse gases depending on their condition. However, human off shores activities are increasing threatening to conservation interest. Liv *et al.* (2002). The threats are both natural and manmade. Siltation and vegetation succession are natural threats whereas overfishing, grazing, land encroachments, plant harvesting are man-made threats (Bhandari, 1998).

THE STUDY AREA

Pokhara is famous for its unique physiographic features which includes lakes, rivers, streams, caves, terraces, deep gorges, steep slopes and panoramic Himalayas. It has been called as "lake valley of Nepal" covering an area of about 200sq. km. (Tripathi, 1984/1985).

The study area is situated in Lekhnath Municipality, Kaski district, western Nepal. It is located in southeastern part of Pokhara valley, at a distance of 10 km east of regional/district headquarter. Among eight major lakes lying within Pokhara valley, the present study has covered two lakes namely, Gunde lake and Maidi lake which are shallower, densely vegetated, and more exploited than other.

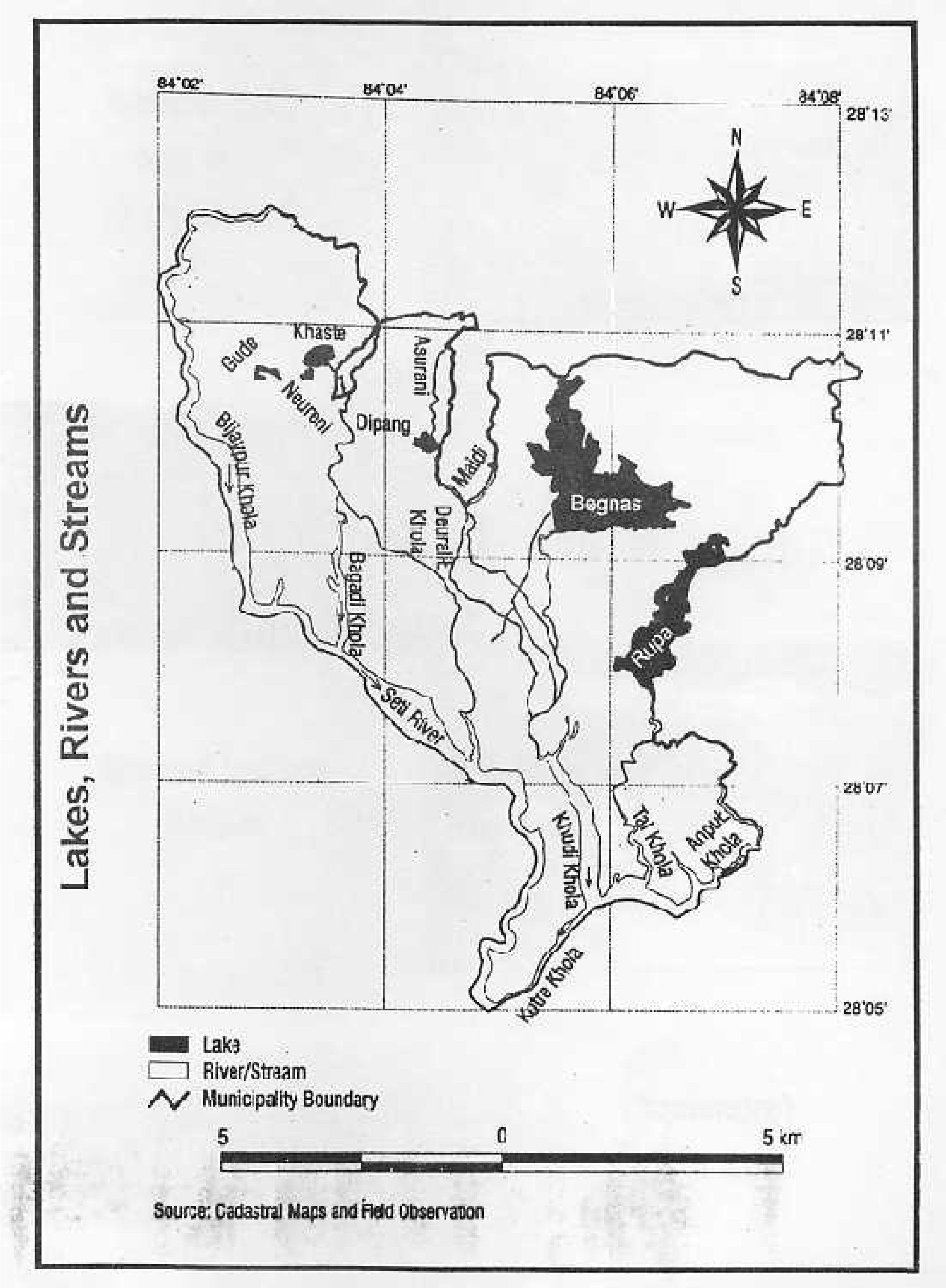
3.1 Location and topography

The Gunde lake lies at 84°03'E longitude and 28°11'N latitude in the Pokhara valley of western Nepal. The lake is situated in ward no. 4 of Lekhnath Municipality. Begnas, Rupa and Khaste (Kamal Pokhari) lakes lie on western and Neurini, Dipang on eastern side from this lake.

This lake lies at 635 m altitude with an area of 4.98 ha. It has an average depth of 0.5 to 1m. Several springs feeds this lake and small canal arises as outlet from the lake. It is eutrophic and tectonic lake with overgrown aquatic macro-vegetation and swampy shore. It's northern and southern parts are agricultural land where as eastern is agricultural and wasteland and the western side with *Schima-Castanopsis* forest.

The Maidi lake lies at 84°05'E longitude and 28°10'N latitude and is situated in ward no. 8 (Sisuwa) of Lekhnath Municipality. Begnas, Rupa and Khaste lakes lies on western and Neurini, Dipang lakes on eastern side from this lake.

This lake lies at 630 m altitude with an area of 1.17 ha. It has an average depth of 1.5-2m. A small perennial creek the Kadam khola feeds the Maidi lake having a single outlet, the Deurali khola, which joins Khundi khola downwards. Maidi lake is entirely overgrown by aquatic macro vegetation having larger swampy shores. It's northern side is agricultural land and widely cultivated banana farmland. The southern part is agricultural land. It's eastern and southern sides are forest and wasteland with *Schima-Castanopsis* and *Shorea robusta* mixed forest.



Cited source: Souvenir, Pokhara Darpan

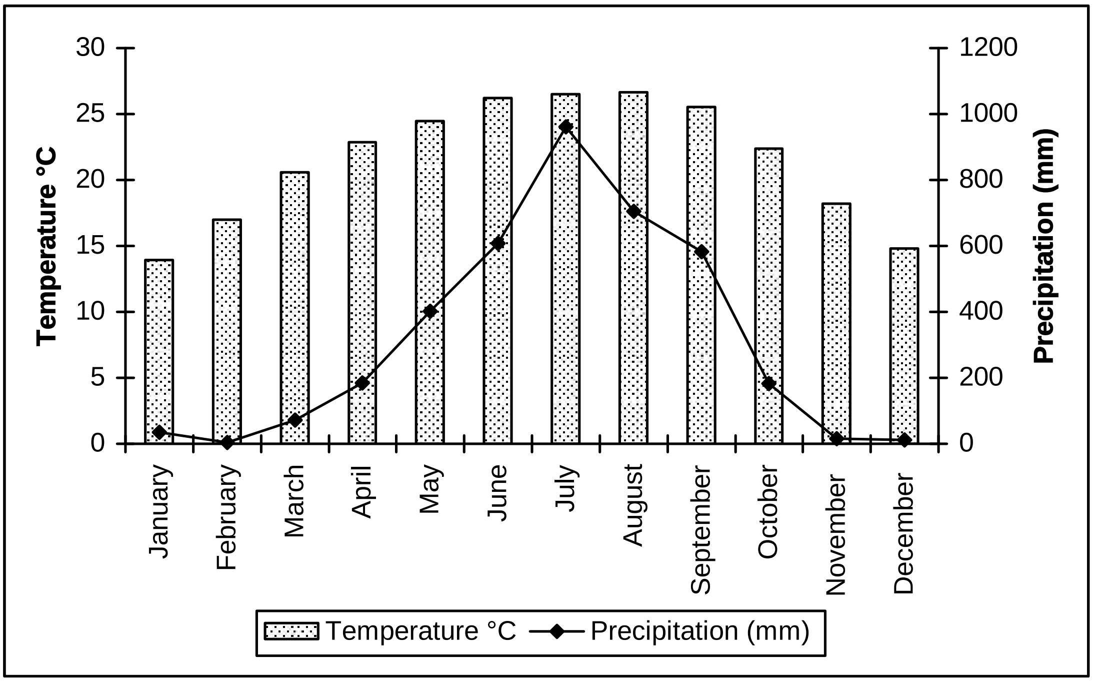
Fig. 1: Map of Lekhnath municipality showing location of various lake system including the present study lakes (Maidi and Gunde).

3.2 Climate

The study area has the humid and sub-tropical climate with monsoon rainfall pattern. It is characterized by a moderate temperature, heavy rainfall and distinct seasonal variation.

The average maximum temperature for Pokhara Airport during the last five year period (2002-2006) was seen in the month of August i.e. 26.67°C (Fig. 2). Similarly, the average minimum temperature was in the month of January i.e. 13.95°C. The average of last five year (2002 - 2006) showed that the highest and lowest precipitation occurred in the month of July (961.22 mm) and December (11.84 mm) respectively, with the average total precipitation of 3793.27 mm per annum.

The average summarized climatic data revealed that, the present site falls under *Shorea robusta* zone with a warmth index (wi) value of 199.12. Similarly with annual precipitation of 3793.27 mm, PER (Potential Evapotranspiration rate) of 0.033 and bio temperature of 21.59, the study site falls within a wet forest life zone in Holdrige's lower montane altitudinal belt.



(Source: Department of Hydrology and Metrology, Babar Mahal, Kathmandu)

Fig. 2: Average climatic data recorded at Pokhara Airport (28° 13'N, 84° 00'E and elevation 827 m) during 2002 - 2006. The study area is about 10 km west of Pokhara Airport.

3.3 Major Flora

The lakes are endowed with a wide variety of aquatic macrophytes. Plant species are distributed according to their adaptability to the depth of the lake. Due to shallowness, the lakes are inhabitated by emergents, mostly by members of Poaceae and cyperaceae..The dominant species include *Eleocharis palustris, Leersia hexandra, phragmites* sp and *Rotala rotundifolia*. Wild variety of rice *Oryza rufipogon* has been reported from the Maidi lake (Shrestha, 1998).

3.4 Major Fauna

The lake provides an ideal place for aquatic fauna due to its strategic location and luxuriant growth of aquatic macrophytes. The species of fish found in lakes include Silver carp (*Hypophthalmichthys molitrix*) and Bighead carp (*Arostocytyus nobilis*). Other stocked species include grass carp (C*tenopharyngodon idella*), common carp (*Cyprinus carpiol*, Rohu (*Labeo rohita*, Naini (*Cirhina mrigala*), Bhakur (*Catla catla*), Mahaseer (*Tor puttitara*) and others. Likewise, over a number of species of local and migratory birds viz. hawks, teal, goose, egret, king fisher, cranes etc. were seen from the lakes.

MATERIALS AND METHODS

The reconnaissance survey of study site was undertaken in one season only, that is, in summer season (May, June, 2007). The overall study was focused on Marsh land, of Gunde and Maidi lake system for analyzing the relationship between species richness and productivity.

4.1 Methods

4.1.1 Experimental design

In each lake, the marshland is divided into eight equal parts, corresponding to eight imaginary line transect. To know the composition, distribution and dominance, of plant species, systematic random sampling method was applied with the help of 1m×1m quadrat. Altogether, 10 quadrats were sampled along each line transect at a distance of 10 m interval starting from flooded shoreline to the center of lake. All quatrats were sampled in the same side of each transect. In total, 80 quadrat were sampled in each lake system.

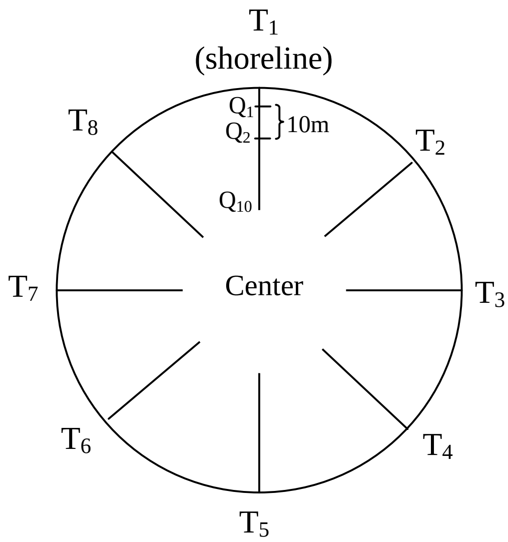


Fig. 3: Graphical representation of layout of sampling plots.
T : Transect
Q : Quadrat

4.1.2 Species richness

The species richness is defined as the total number of species occurring within one square meter, which is a common plot size in vegetation analysis of grassland (Bhattarai *et al.*, 2004). All plant species rooted within the $1×1m^2$ plots were recorded.

4.1.3 Herbarium preparation and plant identification

Plant species encountered in quadrat were collected and then pressed, dried and prepared herbaria. Herbarium specimens were identified by relevant literatures such as Flora of Bhutan, Flora of Kathmandu valley and crosschecking the herbarium of CDB (TUCH) and National herbarium (KATH), Godawari and consulting plant taxonomists .

4.1.4 Biomass estimation

Biomass of each quadrat was estimated by harvest method. Each quadrat was divided into four equal parts (quarters) and one part was selected randomly for biomass harvest. Above ground biomass was collected from the selected quarter (0.5m × 0.5m) and separated into individual species. They were sun dried in the field, air dried in room and then oven dried at approx. 75°C for 48 hours in ecology lab of Central Department of Botany (CDB). Oven dry mass was measured using electric balance (0.001g).

4.2 Soil analysis

4.2.1 Soil sampling and analysis

. From the each quadrat sampled, about 200gm soil was collected from about 10cm depth (after removal of litter and debris). It was then air dried in shade for a couple of weeks and slightly grinded in mortar with pestle and then packed in air tight plastic bag until laboratory analysis. Soil was analyzed for its texture, pH, total nitrogen (%) and total organic matter (OM%) at laboratory of Central Department of Botany, Tribhuvan University, Kirtipur.

Soil texture: Soil texture means the relative proportions of various size groups of individual soil particles. Soil particle size can be grouped as follows(Zobel *et.al.*1987):

Coarse gravel	more than 5cm
fine gravel	2mm to 5cm
coarse sand	0.2mm to 2mm
fine sand	0.02mm to 0.002mm
silt	0.002mm to 0.02mm
clay	less than 0.002mm

First of all, soil sample oven dried at 100°C for 24 hours were passed through a series of sieves with different mesh sizes. Then, mass of soil in each sieve was measured by electric balance (0.001g). Based on the mesh size of the sieves, three texture classes were identified.

Table 1. Various mesh sizes of sieve and soil texture classes

Mesh number	Mesh size (mm)	Soil texture
1	2.36	fine gravel
2	1.18	coarse sand
3.	0.6	
4.	0.425	
5.	0.15	fine sand + slit + clay
6.	0.075	

In present study, coarse sand was termed as coarse soil and the fine sand-silt-clay was termed as fine soil. The percentage of coarse and fine soil was calculated as follows.

$$\text{Coarse soil (\%)} = \frac{\text{mass of coarse soil}}{\text{total mass}} \times 100$$

$$\text{Fine soil (\%)} = \frac{\text{mass of fine sand + slit + clay}}{\text{total mass}} \times 100$$

4.2.2 Organic Matter (Walkey Method)

Soil OM (%) was determined by Walkely and Black rapid titration method as described in Gupta (2000). In this method, 0.5g air dried soil was taken in a dry 500ml conical flask. For samples having higher OM, 0.25g of soil was taken instead of 0.5g to ensure complete digestion of OM. Then 5ml of 1N $K_2Cr_2O_7$ was pipetted in and swirled gently. 10ml of conc. H_2SO_4 was added and swirled again two to three times. The flask was then allowed to cool down for 30 minutes and then 100ml distilled water was added on it. After that 5 ml of orthophosphoric acid (pure) was added and then 0.5ml of diphenylamine indicator was added in the conical flask containing the mixture of soil and reagents. The colour of the solution of the flask was obtained blue violet. Now the content was titrated with 0.5N ferrous ammonium sulphate till the colour changed from blue violet to green. A blank was also run simultaneously for each batch of soil samples tested for OM. The soil organic carbon (%) of the sample was determined by using following formula.

$$\text{Soil organic carbon estimated (\%)} = \frac{0.003 \times 10\ (\textit{Blank reading} - \textit{Titration reading})}{\textit{Blank reading} \times \textit{Mass of soil (g)}} \times 100$$

The organic carbon (%) obtained by above formula was multiplied by a factor 1.3 (based on the assumption that there is incomplete oxidation of the organic matter in this procedure and only 77% recovery occurs through this method).

Hence, organic carbon (%) = organic carbon estimated (%) x 1.3

Now, to determine organic matter content (%) of soil, this value of organic carbon (%) was multiplied by Van Bemmelen factor of 1.724 (because organic matter is assumed to contain 58% organic carbon).

Hence, organic matter content (%) = organic carbon (%) x 1.724

4.2.3 Total Nitrogen (%)

The total nitrogen (%) of soil was determined by microjeldahl method with techniques described by Gupta (2000). This method includes following 3 steps:

Digestion

One gram of air dry and fine soil (passed through 0.425mm sieve) was taken in a dry kjeldahl digestion flask of 300ml. Then 3.5g potassium sulphate and 0.4g copper sulphate (i.e. catalysts) were added to the flask containing soil. Now, 6ml of conc. H_2SO_4 was added to the mixture of soil and catalyst in flask and shaken gently.

The flask was then placed on the preheated (30°C) heating mantle for digestion. Temperature was raised to about 310°C after the bubbles disappeared. The end of digestion process was known as the colour changed from black to brownish and ultimately greenish. Then the flask was removed immediately from the mantle and allowed to cool down for 30 minutes. To the digest, 50ml of distilled water was added and the mixture was shaken well. A blank without soil sample was also run for each batch of soil samples digested through this process.

Distillation

The diluted digest of kjeldahl digestion flask was now transferred to kjeldahl distillation flask. A beaker of 100ml capacity with 10ml of boric acid indicator was placed below the nozzle of the condenser in such a way that the end of the nozzle dipped into the indicator. After the digest become warm, 30ml of 40 percent NaOH solution was added and mouth of distillation flask was closed with cork making the system air tight. The temperature of the mantle was now raised just to boil the content. The distillate eveporated through distillation flask began to condense and the colour of boric acid indicator changed from pink to green. The distillation was continued until the volume of distillate in beaker reached to about 40 ml.

Titration

The distillate removed out from distillation plant was titrated with 0.1N HCl. The volume of HCl consumed in titrating distillate was recorded. The volume of acid consumed by both blank and soil samples were noted and on the basis of which the total nitrogen content (N%) of the soil sample was calculated by using following formula.

$$\text{Soil N (\%)} = \frac{14 \times N \times (S - B) \times 100}{M}$$

Where, N = normality of HCl

S = Volume of HCl consumed with soil sample (ml)

B = Volume of HCl consumed with blank (ml)

M = Mass of soil taken (mg)

4.2.4 pH

Soil pH was determined by the potentiometric method, using a pH meter (Digital pH meter, 802, systronics (89-92) Naroda Industrial Area, Ahmeda Bad, India). Before pH measurement, the electrode of the pH meter was dipped for 24 hours in tap water. Then, buffer solutions of pH tablet 7.0 and 4.0 were prepared freshly. The pH meter was warmed up for 15 minutes before starting pH measurement. 10g of air dried fine soil was mixed in 100ml of distilled water and stirred well by the help of glass rod. Then, the mixture of soil and water was left for decantation about half an hour and hence solution of soil sample was made ready for pH measurement. Now, the pH meter was callibrated through buffer solution of pH 4.0 and 7.0 and pH measurement was taken for each solution of soil sample. Electrode of pH meter was flushed by distilled water and wiped by cotton each and every time before dipping it from anyone solution either buffer or of soil sample to next.

4.3 Statistical Analysis

Correlation coefficient (r) between different parameters were obtained by using statistical package for social science (SPSS, 2001 version 11.5). Mean values of species richness biomass and various soil attributes of two lake systems were compared by non-parametric Kserskal-Wallis-U test. Regression analysis was done between biomass and species richness, and soil pH and species richness. In both analysis, species richness was considered as response variable.

4.3.1 Index of Similarly (IS)

The simplest similarity indexes compare samples of vegetation only in terms of which species are present. It gives the degree of similarity between any two stands which depends on the quantitative phytosociological characters of species common to both stands. This index equals to one in case of complete similarity and zero if the set is completely dissimilar. Index of similarity between two lakes was calculated as Sorenson's index modified by Gregsmith (1964).

$$\text{Index of similarity (IS)} = \frac{2C}{A+B}$$

Where, A = Total no. of species in one lake system

B = Total number of species in other lake system

C = Total number of species in both the lake systems.

4.3.2 Resource utilization and threats

Respondents of different age group (15-75 years) were randomly selected at watershed area of both lakes. Besides, information pertaining to resource utilization, and natural as well as anthropogenic threats of both lakes were also gathered through informal talks with municipality office's staffs and concerned authorities (LIBRD, SORUP- Nepal, FRC-Pokhara).

A semi structured questionnaire (Appendix VI) was used to interview respondents of watershed area. Altogether 40 respondents were interviewed.

RESULT

5.1 Soil Attributes

5.1.1 Soil texture

Both the lake reveals their silt loam and loamy type of soil texture. Gunde lake had sandy loam, silt loam and again sandy loam type of soil texture as we went from shoreline to the way to center where as Maidi lake had sandy loam at shoreline and then slit loam towards the way to center of the lake.

5.1.2 Soil pH

The soil pH of marshland of Gunde lake was 6.26 to 7.49 with mean 7.01±0.33. Similarly, the soil pH of marshland of Maidi lake was 6.28 to 7.82 with mean 7.07± 0.28. The pH ranges from 6.26 to 7.82 when data of both lake were combined with mean 7.03±0.31 (Appendix IV).

Gunde lake had comparatively lower pH at shoreline (Fig. 9). It started increasing at middle and then went on decreasing towards center of the lake. The Maidi lake had higher pH at shoreline and it started declining towards center of the lake (Appendix III).

5.1.3 Organic matter (OM%)

The soil organic matter of marshland of Gunde lake was 8.55 to 32.22% with mean 25.17±4.79. Similarly, Maidi lake had 15.88 to 32.03% of organic matter with mean 25.78± 4.16.

The organic matter (OM%) of soil ranges from 8.5 to 32.22% when all data combined with mean 25.47± 4.49. In Gunde lake, OM was found lower at shoreline and it started increasing to the way to centre (Fig. 9).

Maidi lake system had lower soil OM at shoreline and it started increasing towards the way to center of the lake (Appendix III).

5.1.4 Nitrogen (N %)

The soil nitrogen of marshland of Gunde lake was 0.532 to 2.754% with mean 1.66± 0.52. Similarly, soil nitrogen in Maidi lake was 1.036 to 2.884% with mean 2.22± 0.37. The soil nitrogen ranged from 0.532 to 2.884% when data of both lake system were combined, with mean of 1.94 ± 0.53.

In Gunde lake, nitrogen was found lower at shoreline (Fig. 9). It then started increasing at middle and declined to the way to center of the lake.

In marshland of Maidi lake, the soil nitrogen was almost double than Gunde lake system (Fig. 9). Besides, higher percentage of nitrogen at shoreline were observed in all the cases. It was then started declining towards the center following same pattern (Appendix III).

Table. 4: Pearson's correlation coefficient between different ecological attributes of marshland of Gunde lake.

Ecological attributes	Biomass	Soil pH	Soil OC%	Soil OM%	Soil N %	Coarse soil %	Fine soil %
Species richness	0.144	0.120	0.013	0.036	0.077	– 0.085	.085
Biomass	–	0.09	0.132	0.131	– 0.052	– 0.041	0.048
Soil pH	–	–	0.061	0.076	– 0.115	– 0.007	– 0.005
Soil Organic Carbon	–	–	–	0.99**	0.00	– 0.053	0.022
Soil Organic matter	–	–	–	–	0.005	– 0.049	0.018
Soil Nitrogen	–	–	–	–	–	0.001	– 0.014
Coarse soil	–	–	–	–	–	–	–0.979**

** Correlation is significant at the 0.01 level (2-tailed)

A significant positive correlation was observed between species richness and plant biomass in lake Gunde. But highly negative correlation was obtained between coarse soil and fire soil (Table 4).

Table. 5 : Pearson's correlation coefficient between different ecological attributes of marshland of Maidi lake.

Ecological attributes	Biomass	Soil pH	Soil OC%	Soil OM%	Soil N %	Coarse soil %	Fine soil %
Species richness	0.69	0.130	0.871	0.657	0.334	0.295	0.297
Biomass	–	0.259	0.099	0.102	0.513	0.617	0.558
Soil pH	–	–	0.452	0.344	0.149	0.932	0.950
Soil Organic Carbon	–	–	–	0.00	0.997	0.513	0.788
Soil Organic matter	–	–	–	–	0.949	0.551	0.831
Soil Nitrogen					–	0.987	0.863
Coarse soil						–	0.00

** Correlation is significant at the 0.01 level (2-tailed)

A significant positive correlation was observed between species richness and plant biomass. Similarly, positive correlation was also obtained for species richness and soil OC and species richness and soil OM.

5.2 Species composition

A total of 27 plant species were recorded from Gunde and Maidi lakes. Among them 15 species were recorded from Gunde and 23 species in Maidi lake with 12 species common to both lakes.

Beside these 27 species encountered in sampling plots of the marshland, other submerged and terrestrial species were also recorded from lake boundaries and inaccessible areas of aquatic system. These species were recorded as associated species (Appendix I).

Table. 2: Plant species recorded in marshland of Gunde lake

S.N.	Plant species	Family	Local name	Frequency of occurrence (%)
1	*Ageratum conyzoides* L.	Compositae	Gandhe	30
2	*Arundinella* sp.	Gramineae		30
3	*Cyperus palustris* R. Br.	Cyperaceae		90
4	*Eleocharis palustris* (L.) R. Br.	Cyperaceae	Suirey	100
5	*Leersia hexandra* (Swartz)	Gramineae	Karaute	100
6	*Mimosa pudica* L.	Leguminosae	Lajjawati	20
7	*Nymphaea nouchali* Burn. F.	Nymphaeaceae	Patkauli	90
8	*Nymphoides indica* (L.) Kuntze	Gentianaceae	Pyakute	70
9	*Oenanthe javanica* (Blume) DC	Umbelliferae	Simghans	30
10	*Oryza sativa* L.	Gramineae	Dhan	70
11	*Persicaria barbata* (L.) Hara	Polygonaceae	Kande pire	60
12	*Persicaria hydropiper* (L.) Spach	Polygonaceae	Priryе jhar	80
13	*Phragmites* sp.	Gramineae		100
14	*Rotala rotundifolia* (Buch-Ham ex. Roxb) Koechne	Lythraceae		90
15	Unknown species			100

Table. 3: Plant species recorded in marshland of Maidi Lake

S.N.	Plant species	Family	Local Name	Frequency of occurrence (%)
1	*Adenostomma lavenia* Kuntze	Compositae		20
2	*Arundinella* sp.	Gramineae		20
3	*Cyperus palustris* R. Br.	Cyperaceae		100
4	*Dryopteris* sp.	Pteridaceae		50
5	*Eleocharis palustris* (L.) R. Br.	Cyperaceae	Swiney	100
6	*Elsolzhia eriostachya* Bentham	Labiatae		30
7	*Fimbristylis dichotoma* (Retz) Linki	Cyperaceae	Mothey	90
8	*Hedyotis diffusa* Willd	Rubiaceae		100
9	*Isachne globosa* (Thumb) Kuntze, Rev Gren	Gramineae	Banso	10
10	*Leersia hexandra* (Swartz)	Gramineae	Karaute	90
11	*Nymphaea nouchali* Burn. F.	Nymphaeaceae	Patkauli	60
12	*Nymphoides indica* (L.) Kuntze	Gentianaceae	Pyakute	20
13	*Oenenthe javanica* (Blume) DC	Umbelliferae	Simghas	100
14	*Oryza rufipogan* Griff, Notul	Gramineae	Dhan	90
15	*Osbekia melastoma* L.	Melastomataceae		40
16	*Paspalum scrobiculatum* L. Mant.	Gramineae		70
17	*Persicaria barbata* (L.) Hara	Polygonaceae	Kandepirye	100
18	*Persicaria hydropiper* (L.) Spach	Polygonaceae	Pirya Jhar	40
19	*Phragmites* sp.	Gramineae		100
20	*Rotala rotundifolia* (Buch-Ham ex. Roxb) Koechne	Lytharaceae		100
21	*Sacciolepsis indica* (L) Chase, proc.	Gramineae		90
22	*Typha anguistifolia* L.	Typhaceae	Gund	40
23	Unknown species			100

5.3 Species richness

The species of Gunde lake ranged from 3 to 9 species with the mean value of 5.38 ± 1.33 species/m^2. Similarly, the species richness of Maidi lake ranged from 2 to 10 species/m^2 with mean 6.54 ± 1.99 species/m^2. The species richness ranges from 2 to 10 species 1m2 when all data combined with mean 5.97 ± 1.78.

Mean values of species richness-biomass and different soil attributes in lake Gunde and lake Maidi

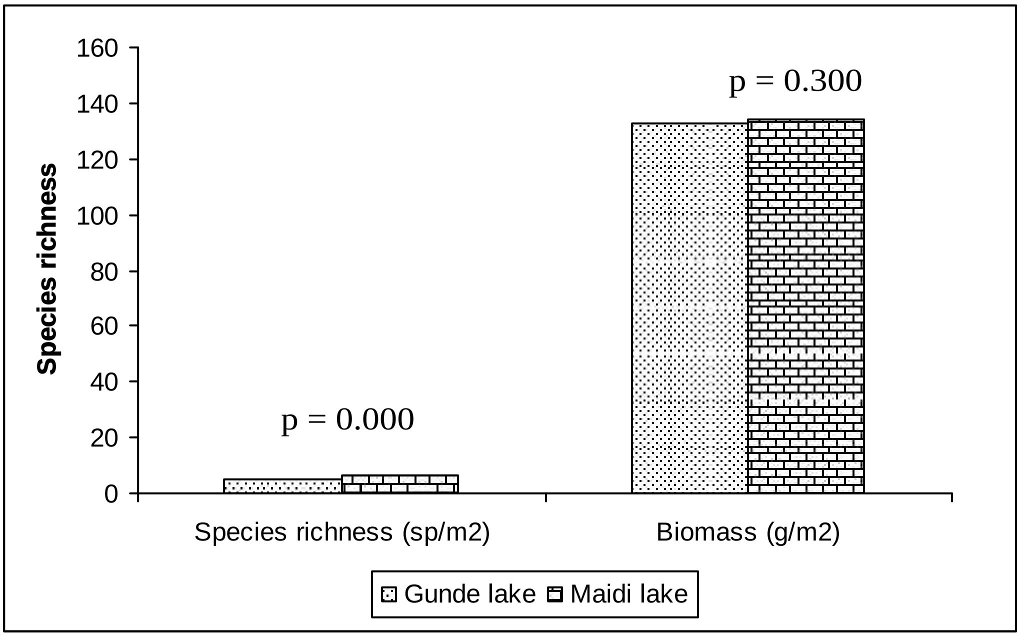


Fig. 4: Average value of species richness and biomass and Gunde and Maidi lake.

p- values indicate significance level obtained by Kruskall-Wallis-U-test. Mean values of the attributes of two lakes differed significantly if $p < 0.05$.

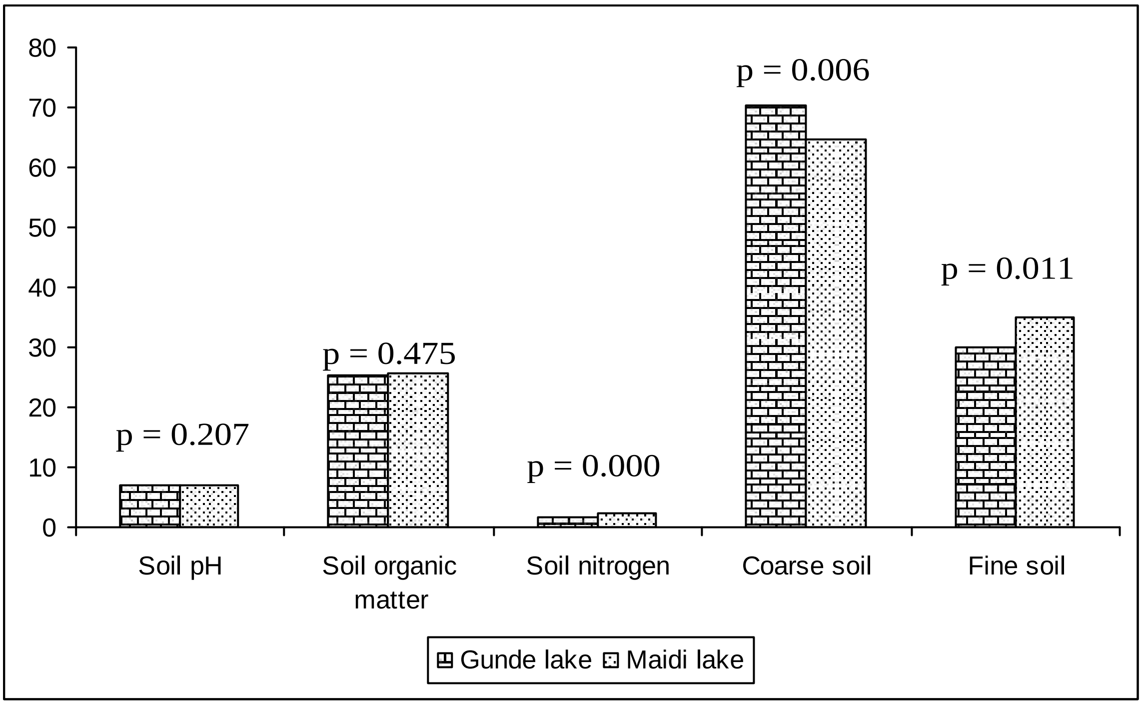


Fig. 5: Average value of soil parameter of Gunde and Maidi lake

p- values indicate significance level obtained by Kruskall-Wallis-U-test. Mean values of the attributes of two lakes differed significantly if $p < 0.05$.

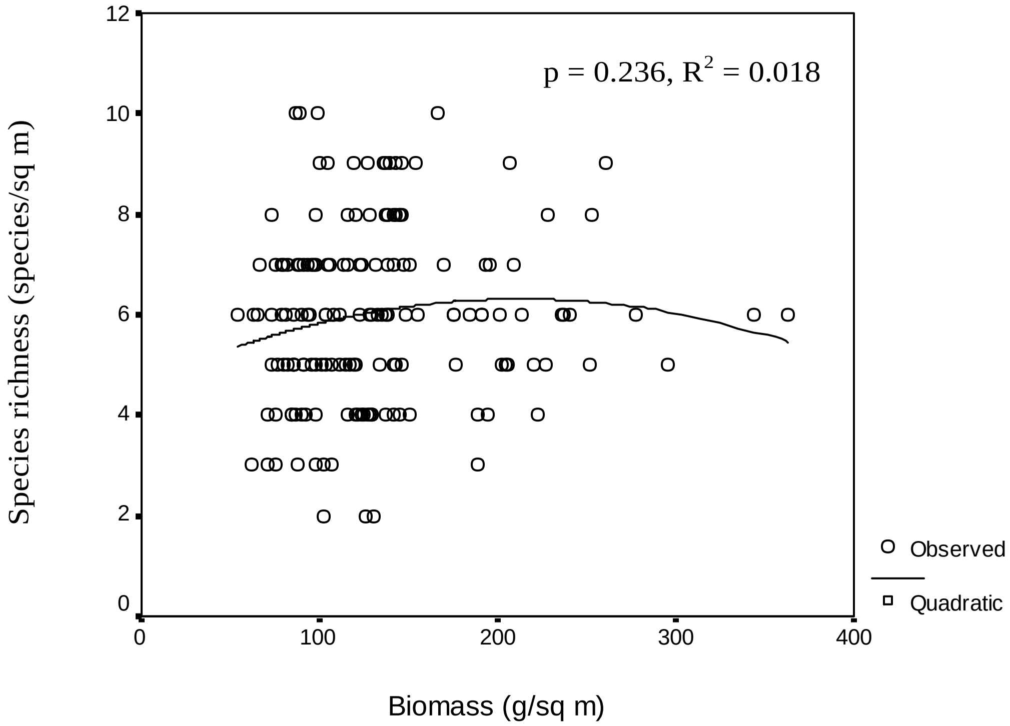


Fig. 6: The relationship between species richness and aboveground biomass in Gunde & Maidi lakes: when all data combined. The fitted line was obtained by quadratic regression.

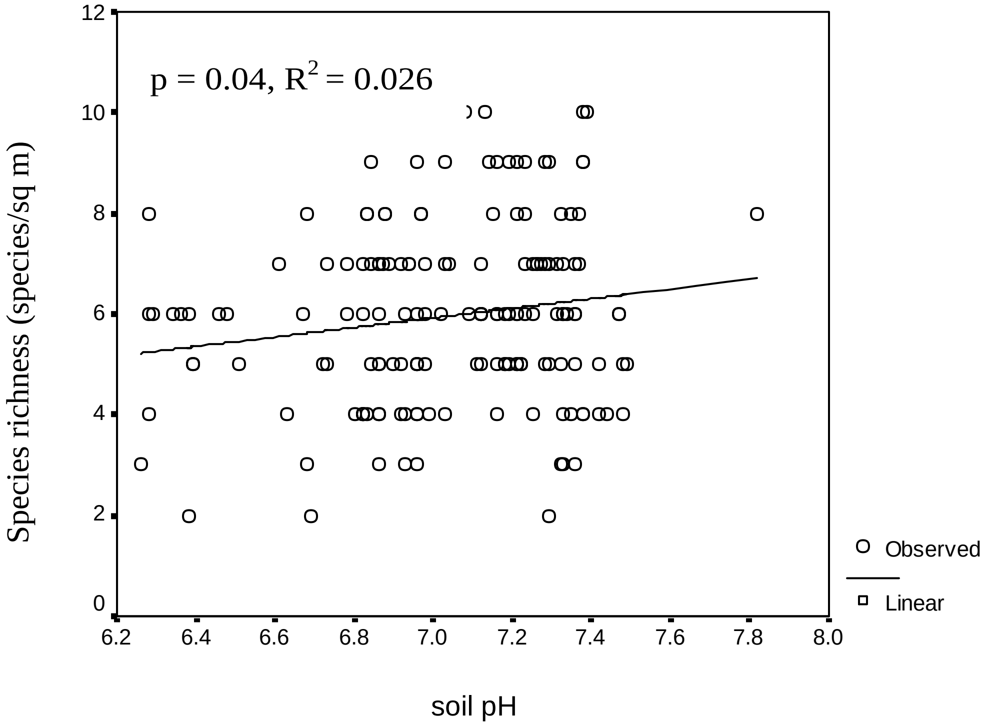


Fig. 7: The relationship between species richness and soil pH when all data of Gunde & Maidi lakes were combined. The fitted line was obtained by linear regression analysis.

5.4 Biomass

The biomass of Gunde lake was 54.09 to 259.5g/m^2 with mean value 132.58±58.11. Similarly, biomass of Maidi lake was 71.10 to 363.34g/m^2 with mean 133.82 ± 58.58. The biomass ranges from 54.09 to 363.34g/m^2 when all data of both lakes were combined with mean 133.33± 54.77.

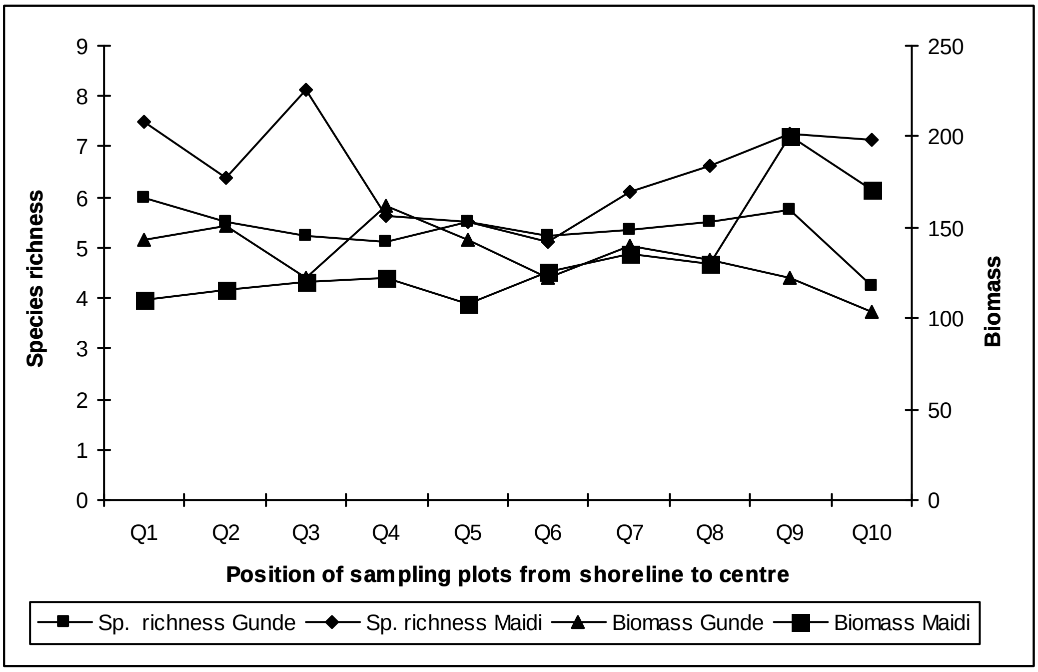


Fig. 8: Variation of species richness and biomass from, shoreline to centre in Gunde and Maidi lake.

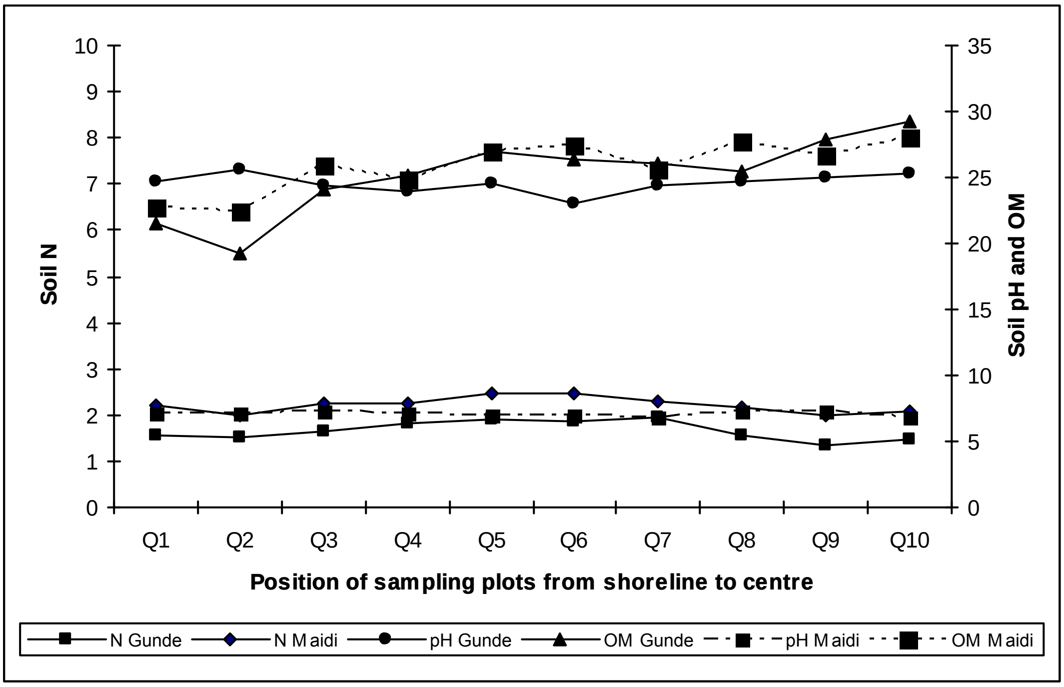


Fig. 9: Variation of pH, OM and Nitrogen from shoreline (Q1) to centre (Q10) in Gunde and Maidi lake.

5.5 Indices

The similarity index between Gunde and Maidi lakes was 6.15 i.e. 61.54%.

5.6 People's dependency and resource utilization of both lakes

Although, most people ware not directly dependent upon wetland resources for livelihood. Most weeds posses several economic and ecological benefits and a few have nuisance potential too. Majority of respondents confess that collection of fodder was the most benefit they achieved from the lake. Households who reared livestock, take them to graze either in the grassland or forest around the lakes or in marshes along the side of lake. The density of livestock grazing in the area at peak hours of late afternoon, was found 5-10 livestock unit per hectares.

Lake water was utilized for irrigating agricultural land in northern and western part of settlements. Majority of respondents were well aware about the deteriorating condition of lakes. They argued that if the lakes were not managed properly they will disappear in the immediate/near future turning into a agricultural field.

It was envisaged that *Typha anguistifolia* (locally called as **Gund**) were heavily exploited from the lakes for making mats. (locally called **Gundris**) rope and other household materials. Intensity of Gund harvesting was higher in Maidi and the people collect it mostly during summer and winter season. According to the local people lake Gunde, which was named after the plant as it was found luxuriantly in the past, was devoid of gund today as it was indiscriminately exploited.

From the field study, it was observed that higher number of aquatic plants constitute food values to fishes, water birds, fauna and humans. The rhizome petiole and seeds of *Nelumbo nucifera* and fruits of Trapa are used as food and possess medicinal value. Leaves of *Hydrilla verticillata* and *Leersia hexandra* (cut grass) are applied as fish food item. *Azolla imbricata*, *Ceratophyllum demersum* and *Lemna minor* were used as bio-fertilizer by some farmers of the northern and western settlement areas.

Only 32.5% of respondent perceived that the wildlife could be the source of income through tourism and about 84% of respondent expressed that the aquatic animals were decreasing in lakes. It was because of fluctuation in water level and the decrease in frequency and number of migratory birds visiting the lake area was noticed by most of the respondents (95%).

Now, with burgeoning number of conservation oriented community groups, wetland specific interested groups, people have become more conscious and responsive towards wetland values and issues. The awareness campaign and conservation education and its management disseminated by local NGOs like, LI-BIRD, SORUP-Nepal, Seed foundation and IUCN have tremendously contributed in boosting of existing knowledge on wetland values, capacity and incentives.

5.7 Economic values of aquatic macrophytes

With regard to valuation of aquatic macrophytes in terms of economic uses and ecological functions, most weeds posses beneficial aspects and a few have nuisance potential (Appendix V). From the study it was envisaged that higher number of aquatic plants constitute food values to fishes, water birds, fauna and humans. The rhizome, petiole and seeds of *Nelumbo nucifera* and fruits of *Trapa* are used as food and medicine. Species like *Eichornia crassipes*, and *Artemisia vulgaris* also possess medicinal potential. Many emergent grass and sedges are used as fodder to animal. Leaves of *Hydrilla verticillata* and *Leersia hexandra* (cut grass) are applied as fish food item. Some species used as bio-fertilizer are: *Azolla imbricata*, *Eichornia crassipes*, *Ceratophyllum demersum* and *Lemna minor*.

DISCUSSION

6.1 Soil attributes

6.1.1 pH

The mean value of pH obtained from Gunde and Maidi lakes were 7 and 7.07 respectively. Hence, the pH was almost neutral when data of both lakes were combined with pH ranging from 6.26 to 7.28 and standard deviation 0.31. From the fig. 7, it is evident that the biomass obtained were maximum when pH is at neutral point which is also a general trend. There was a significant linear relationship between soil pH and species richness and the result agrees with the result of Xu *et al.* (2007) while investigating the effect of fertilization on species richness in wetland ecosystem in northeast China as these marshy plant species responded to soil nutrient and pH differently because species have different nutrient requirement and exploit nutrients in varying efficiency thereby inducing change in its pH value.

6.1.2 Organic matter (%)

The field study was carried out during May and June and hence relatively higher percentage of organic matter had been observed. It may be due to the effect of temperature and rainfall which mineralizes the accumulated litter before the advent of winter season (Sharma, 2004).

The mean value of organic matter when all data combined was 25.47±4.49%. This value perfectly agrees with idea of Hanson *et al.* (2007) regarding median sizes (168-they surveyed) lakes of about 1.1 hectar in northern highland lake district (NHLD) of Wisconsis, USA. They found that the hydric soil of smaller lake tended to have higher acid neutralizing capacity (ANC) with dissolved organic carbon (DOC) $10.1 mgL^{-1}$ about 50% higher than it would have been without smaller lakes. Therefore excluding smaller lakes introduces bias in the estimate of organic and inorganic carbon value.

The species richness show positive correlation with organic matter (r =0.657). Thus it shows species richness depends upon organic carbon and organic matter of hydric soil.

6.1.3 Nitrogen (%)

Nitrogen occurs in aquatic system both as a result of bacterial oxidation of atmospheric nitrogen and from the decomposition of organic matter in the watershed (Lind, 1974).

The nitrogen content of soil from marshland of Gunde and Maidi lakes were 1.66 and 2.21% respectively. The higher value of nitrogen in Maidi lake system might be due to deposition of soil nitrogen by nodulus bacteria and higher microbial activity. Further, high concentration of nitrogen were generally associated with proportion of cultivated land (Hakala *et al.* 2003). They found positive correlation with concentration of inorganic nitrogen to proportion of agricultural field in 21 small drainage area of lake Paajarvi (Southern Finland) and the maximum load of total nitrogen they found was 10 times higher than minimal value they observed in forested drainage area.

Regarding sampled sites, almost double the total nitrogen obtained in lake Maidi might be due to higher microbial activity accompanied by greater accumulation of in marshland, higher moisture content due to close canopy in forestland with aeration.

Lower nitrogen in Gunde lake might be due to low microbial activity, less litter and direct exposure to sunlight that triggers oxidation of nitrogenous compound.

6.2 Species composition

In the present study, an attempt has been made to analyze the floristic composition and aboveground biomass of marshland associated with Gunde and Maidi lake.

In Marshland of both Gunde and Maidi lakes, altogether 27 plant species comprising mainly grasses, herbs and few shrub species were recorded. The species recorded in Gunde is 15 and that of Maidi lake is 23 which is higher than species recorded by Shrestha (1998) i.e. 12 species in Gunde lake and 13 species in Maidi lake.

A remarkable higher number of species in Maidi lake as compared to Gunde can be attributed to higher portion of shallow depth area with fine sediment, advancing eutrophic condition (Nichols, 1992). The fringe of Maidi lake has turned into a quaking bog and that of Gunde is into marshy merging into paddy fields. Some studies showed changes in structures of wetland communities due to increase in nutrients input i.e. nutrients loads (Miller, 1973, and Simpson *et al.*, 1983).

Studies also showed that there is often an increased in diversity in transition zone, i.e. shoreline, area of contact between communities. This increase in diversity occurs because the transition zone contains species from the area on either side (Gurevitch *et al.*, 2002).

Further, the growth of emergent form in greater depth requires extra energy for reaching surface and if this added energy demand is great enough, plant would be weakened to the point where other environmental factors could be detrimental. Probably, this may be the cause of low species richness in deep water (Miller, 1973). Handoo and Kaul (1982) also found the gradual increase in species richness with decrease in water depth.

As far as species is concerned, *Phragmites* sp. *Leersia hexandra* and *Eleocharis palustris, Rotala rotundifolia* were found to be more dominated emergent species. As they were uniformly distributed in area of both lakes and recorded all the times in every quadrat sampled with significant biomass. It may be due to their nature of vegetative propagation and capability to compete with its neighbours for the nutrient. These species were able to tolerate the grazing pressure (Tsuyuzaki and Tsujii, 1990).

Oryza rufipogon was recorded frequently from Maidi lake (Table 3) and it was absent in Gunde lake (Table 2). This may be due to extensive marshy area of lake Maidi which is the best suited habitat for this species (Shrestha, 1998).

Nymphoides indica has been found almost in all site of Gunde lake but in Maidi lake it was concentrated only in the middle open water body, surrounded by dense emergent. As Gunde is very shallow (0.5 to 2m) *N.*

indica get suitable substrate to fix their root & rhizome. Acharya (1997) found similar type of result in wetland vegetation of Ghodaghodi and Nakrodi lake of Kailali district Nepal.

The shallower water condition support a luxuriant growth of *Trapa quadrispinosa* in Gunde lake and was not found in Maidi lake where as *Trapa bispinosa* found only on Maidi lake at the inner part with deeper water condition. This result is supported by the findings of Handoo and Kaul (1982). They found *Trapa bispinosa* dominant in high water level than in low water level. From the lake shoreline to the center of the lake and corresponding increase in depth contour, colonization of species generally followed a same pattern from emergent, floating leaved species to submerged species. A similar pattern was observed by Wassen *et al.* (2003) while comparing the vegetation composition and inundation depth in undisturbed floodplain of Biebrza river (NE-Poland) with *Glycerietan maximae* close to river, followed by *Carietum gracelous* and *C. elatae* and finally *Calamgrastietum sfricate* on the margin of river plain.

6.3 Biomass estimation of aquatic macrophytes

Present study recorded the mean biomass of Gunde and Maidi lake almost equal, i.e. 132.85 gm/m^2 and 138.82gm/m^2 respectively The mean biomass obtained was 133.68±54.77gm/m^2 when all data of both lake were combined. Similar results were demonstrated by Sankhola and Vyas (1982), in moist bank community of Bangela tank in Udaipur, India, in which they recorded biomass of 132.01g/m^2 in month of April. But, the present biomass recorded was lower than those of Acharya (1996) in Ghodaghodi tal, Nepal and Hando and Kaul (1978) in Kashmir lakes in India where they recorded average biomass of 389.25g/m^2 and 228.29g/m^2 respectively. The main reason behind it may be the time of study and difference in geomorphology of lakes. Present study was done during the month of May and June and wetland species attained maximum biomass during rainy season (Shankhala and Vyas, 1982).

Shallower area near the shoreline of Gunde lake system was found to be more productive than the inner zone of the lakes (Fig. 8). It might be due to higher nutrient concentration, that might have leached from surrounding agricultural land, shallower depth and higher proportion of fine sand and silt. This result agrees with the idea of Sharma (1995) in Kawar lake, India and Whittaker and Likens (1975) in the productivity biosphere stated that emergent macrophyte of littoral wetland in shore regions are among the most productive habitat of biosphere.

6.4 Relationship between species richness and biomass

In the study area, when the relationship between species richness and biomass for combined data was analyzed, a weak hump shaped pattern was obtained (Fig. 6). This humped-shaped relationship between species richness and biomass has been reported by Grime (1973, 1997), Gue and Berry (1998) Waide *et al.* (1999), Kassen *et al.* (2000) Mittelbach *et al.* (2001), David *et al.* (2004), Bhattarai *et al.* (2004) etc. The relation between species richness and biomass resembled hump-shape in present study, but the relations was not significant. Weak hump-shaped or no significant relations between species richness and biomass has also been reported in literature. (Chalcraft *et al.* 2004). According to Espinar (2006), in order to identify significant hump-shaped in the data set, it is necessary to have at least 78 plots and there is a high probability that the humped-shaped pattern will not be perceptible (within each year or within microhabitat) if the number of samples is less than 70. Altogether 160 quadrat were sampled and it is higher than the sampling plots mentioned above. Hence this might be because of disturbance in vegetation due to fodder collection.

From the fig. 6, it is evident that the majority of observed biomass were found to lie around 100g/m^2. While collecting fodder, the species number remained the same but its biomass get reduced. Had there been continuous increment in range of biomass to 300-400g/m^2, a significant hump-shaped pattern would have found and the relation between species richness and biomass would have been significant.

Regarding the mechanisms underlying the hump shaped pattern in species-biomass relationship have been much debated. Grime (1973) suggests that species richness in herbaceous vegetation is controlled by antagonistic force of inter specific competition and disturbance (stress). In stable, productive habitats, competitively dominant species are able to monopolize space excluding inferior competitors from community. Biomass is high but species richness is low in such environment and in the environment with high disturbance (low productivity), only few species persist, and biomass is also low. The highest species-richness occurs at the intermediate levels of biomass with moderate disturbance or productivity (Grime 1973, 1979).

The nature of the cause and effect relationship between species richness and biomass was not addressed in this study, but the result that the primary effect of increased productivity was in the generation of dissimilarity in species composition.

In the present study, maximum species richness were found at lower biomass range (around 100g/m^2). This value is slightly lower than the result of Bhattarai *et al.* (2004) which predicts maximum species richness in between 120 ± 40g/m^2 biomass. It may be due to difference in climatic zone, ie, sub alpine (semi-arid) zone and sub-tropical region. The grassland was completely undisturbed when Bhattarai *et al.* (2004) sampled. But present study site was frequently disturbed. This could be reason for lower biomass in plots with maximum species richness. When the fitted line is considered, maximum species richness was around 200g/m^2 biomass. This value is higher than that reported by Bhattarai *et al.* (2004). This could be due to warm and moist climate.

6.5 Economic and ecological values of lakes

Aquatic weeds encountered in the lake have different economic and ecological values. Most of them are beneficial while some impart adverse impacts too. This indicates the prospect of conservation of aquatic plants through utilization by local communities residing in lake periphery. The fruits of *Trapa* rhizome, petiole and fruits of *Nelumbo nucifera* are used as human food as well as medicine (Sculthorpe, 1967 and Chatterjee *et al.* 1999). Aquatic plants like; *Eichornia crassipes, Lemna minor, Potamogeton* spp. *Trapa quadrispinosa, Ceratophyllum demersum* are used as fish food (Singh 1967). *Azolla imbricata, Lemna minor*, *Eichornia crassipes* are good fertilizer. (Basak, 1948). Fruits of *Potamogetun* spp. are a good source of food for water bird and the members of *Poaceae* and *Cyperaceae* family like, *Cyperus* sp., *Lerrisa hexandra. Oenathe javaninca* are used as fodder (Chatterjee *et al.* 1999 and Pirie, 1970)

Despite their huge economic and ecological services, dense mats of *Nelumbo nucifera*, *Nymphodies indica* and *Trapa* spp. are not only impending to boating but also loss in recreational value of lake.

CONCLUSION

Present study was carried out in Gunde and Maidi lake, located in Lekhnath municipality of Pokhara valley, Nepal..

- The diversity-productivity (D-P) relationship was examined in 160 plots (1m×1m) when both lake are combined. It was done by harvest method.
- Altogether, 27 plant species were recorded. Of them, 23 species were found in Maidi and 15 species were found in Gunde lake. But this number is not comparable to the total plant species of lake in all year round.
- The average above ground biomass was 133.34g/m^2 and the biomass was found highest in intermediate species richness position.
- The species richness in Gunde and Maidi lakes were 5.38sp/m^2 and 6.54species/m^2 for one season. But this number may be higher if temporal scale increased to cover all seasons.
- The soil nutrients has significant effect on biomass and less to species richness.
- The relation between species richness and aboveground biomass resembled hump-shaped for combined (160 plots) data of both lake system but the relation was not significant. This number of samples are large enough to allow detection of the hump-shaped pattern across microhabitants but it was too small to confirm the hump-shaped pattern within each individual microhabitat.
- The socio-economic survey of watershed communities reflects their dependency on wetland resources, conservation attitude and awareness. Based on study, high in-migration from upland hills of watershed and lack of grazing land in comparison to livestock unit are major threat to lake environment where as eutrophication, sedimentation, undefined lake boundary, land encroachment and luxurious growth of aquatic weeds are major problems of both the lakes.

RECOMMENDATION

Based on the study, some recommendations are proposed for the environmental management of lake:

- The lake area should be permanently demarcated in order to protect the lakes from further encroachment.
- A long term systematic research should be conducted in all major seasons in order to know the relationship between species diversity-productivity (D-P) relationship of wetland ecosystem.
- Furthermore, the mechanisms, driving the relationship between species richness and biomass remain unclear in many ways, and the extrapolation of much of this theory to wetland system is to be worked out.

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APPENDIX I

Associated species

S.N.	Botanical name of the plant species	Family	Lake
1	*Fimbristylis dichotoma* (Retz) Linki	Cyperaceae	G
2	*Lindernia* sp.	Scrophulariaceae	M
3	*Lamium complexicule* L.	Labiatae	G
4	*Ottelia alixmeiodes* (L)	Hydrocharitaceae	M
5	*Eriocaulon nepalense* Prescot	Eriocaulaceae	M
6	*Oenothera rosea* Aiton	Onagraceae	M
7	*Potamogeton polygonifolius* Pourr	Potamogetonaceae	M
8	*Brachiaria ramosa*	Gramineae	G/M
9	*Nelumbo nucifera* Gaerth	Nymphaceae	M
10	*Conyza bonariensis* (L) Conquist	Compositae	M
11	*Hydrocotyle asiatical* (L)	Umbelliferae	G/M
12	*Centella ariatica* (L).	Umbelliferae	G/M
13	*Trapa quadrispinosa*	Trapaceae	M
14	*Chara* sp.	Characeae	G/M
15	*Cynoglossum* sp.	Boraginaceae	G/M
16	*Elecoharis cengesta* D. Don	Cyperaceae	M
17	*Bidens pilosa* Var minor (Blume) sherff	Compositae	G/M
18	*Commelina paludosa*	Commelinaceae	G/M
19	*Floscarpa scandens* Lour	Commelinaceae	G/M
20	*Azoola imbricata (Roxb) Nakai*	Salvinaceae	G/M
21	*Trapa bispinosa* Roxb	Trapaceae	M
22	*Lemna minor* Linn.	Lemnaceae	G/M
23	*Gleichenia dichotoma*	Gleichnicaeae	G/M
24	*Cheilanthes bicolor*	Adiantaceae	G
25	*Artimissia vulgaris* L.	Compositae	G (Titipate)
26	*Ceratophyllum demersum*	Certatophyllaceae	G/M
27	*Ludwigia adscendens* (L.) Hara	Onagraceae	M
28	*Ipomoea carnea Jacq.*	Convolvusaceae	G. (Sanai phul)

APPENDIX IV

Average mean values of the ecological attribute from shoreline to centre

Gunde Lake

NO. OF SPECIES	BIOMASS	PH	OC (%)	OM (%)	N (%)	F.SOIL	C.SOIL
Q1= 6	143.272	7.06	12.544	21.51	1.568	18.037	81.952
Q2=5.5	150.548	7.31	11.133	19.193	1.531	38.448	61.552
Q3=5.25	121.916	6.95	14.05	24.14	1.644	29.981	70.019
Q4=5.12	162.284	6.82	14.62	25.21	1.819	31.313	68.877
Q5=5.5	143.188	7.01	15.666	27.01	1.901	25.189	74.811
Q6=5.25	122.632	6.59	15.275	26.33	1.842	35.315	64.685
Q7=5.37	139.826	6.95	15.095	26.04	1.932	30.541	69.459
Q8=5.5	131.876	7.07	14.808	25.53	1.541	34.085	65.915
Q9=5.75	121.984	7.15	16.201	27.93	1.361	23.017	76.983
Q10=4.25	103.932	7.23	14.466	29.23	1.493	30.249	69.751

Maidi Lake

NO. OF SPECIES SPP	PH	BIO MASS	OC (%)	OM (%)	N (%)	F. SOIL	SEA SOIL
Q1=7.5	7.13	110.5	13.165	22.696	2.205	42.022	57.978
Q2=6.4	7.17	115.148	13.049	22.498	1.985	36.339	63.661
Q3=8.12	7.22	119.7	14.426	25.836	2.24	31.841	68.159
Q4=5.62	7.11	122.404	14.414	24.916	2.254	35.592	64.408
Q5=5.5	6.94	108.108	15.605	26.969	2.485	36.665	63.335
Q6=5.12	6.97	126.072	15.946	27.455	2.45	35.675	64.325
Q7=6.12	6.81	135.988	14.833	25.572	2.306	30.224	69.776
Q8=6.62	7.24	129.86	16.102	27.76	2.17	39.911	60.089
Q9=7.25	7.25	199.988	15.469	26.67	1.988	31.242	68.758
Q10=7.12	6.89	170.628	16.279	28.058	2.064	32.206	67.794

APPENDIX V

Mean values (ï S.D., standard deviation) of ecological parameters

Gunde lake

Ecological attributes	No. of samples	Mean ± SD	Range
Species richness (sp/m^2)	80	5.38±1.33	3.00-9.00
Biomass (g/m^2)	80	132.85±58.11	54.09-295.04
Soil pH	80	7.003±0.326	6.26-7.49
Soil organic carbon (%)	79	14.61±2.79	4.96-18.69
Soil organic matter (%)	79	25.17±4.79	8.55-32.22
Soil nitrogen (%)	80	1.66±0.52	0.532-2.75
Coarse soil (%)	80	70.21±12.76	43.93-95.40
Fine soil (%)	80	29.93±12.92	4.61-56.07

Maidi Lake

Ecological attributes	No. of samples	Mean ± SD	Range
Species richness (sp/m^2)	80	6.54±1.99	2.00-10.00
Biomass (g/m^2)	80	133.82±51.58	71.10-363.34
Soil pH	80	7.07±0.28	6.28-7.82
Soil organic carbon (%)	78	14.89±2.39	9.21-18.58
Soil organic matter (%)	78	25.78±4.16	15.88-32.03
Soil nitrogen (%)	79	2.22±0.37	1.03-2.88
Coarse soil (%)	75	64.82±8.78	41.77-86.37
Fine soil (%)	75	34.88±9.41	2.70-58.24

APPENDIX VI

A SURVEY OF SEMI-STRUCTURE QUESTIONNAIRE

(General Model of Questionnaire)

i) Name of Respondent:

ii) Date :

iii) Locality : Ward No. Tole : VDC:

iv) Occupation:

v) Family type: Joint: Nuclear family:

vi) Age-group in family (child/teen/adult/old)

Species Model of Questionnaires:

a) How many members in your family are involved in collection and use of wetland resources ?

....

b) What amount of resource are collected by one individual in a day, during a season from study site ?

....

c) How much time do you contribute for collection and trade of the resources (If any ?)

....

d) Do you collect equal amount today and 10 years back ?

....

e) What do you use from wetlands ?

Grass/fodder .... Fishes.......... Recreations .... Others ....

f) What are your views on the wetland resources ?

....

g) What do you think about the status of lake ?

....

h) Do you have any difficulties facing, what you need ?

....

i) What are the importance of wetland ecosystem ?

....

j) Is this lake hosts any econ important plants. If yes, what are they ?

....

k) Do you have any comments and suggestions regarding improvement and management of lakes ?

....

l) Should this lake be conserved/managed ?

If yes/no then why ?

....

m) Have you implemented any management practices to improve the condition of lakes ?

If yes, what are they ?

....

n) Do you know the value of lakes of Pokhara valley as an international important site for wetlands.

....

PHOTO 1

Maidi Lake

Research in Maidi lake

PHOTO 2

Gunde Lake

Women collecting fodder in Maidi lake system