# CHAPTER I

# Introduction

## 1.1 Background

Wetlands are broadly classified into two categories: natural and man-made. The natural wetlands comprise lakes and ponds, riverine floodplains, swamps and marshes, while man-made wetlands include water storage areas and deep-water agricultural lands (IUCN-Nepal, 1996). DOFD (2001/2002) has estimated that wetlands occupy 816954 ha or roughly five percent of the total area of Nepal. Irrigated paddy fields occupy 48.72 % of the total wetland area of Nepal, followed by rivers (48.35 %), marginal/swamps/gholes (1.41 %), village ponds (0.73 %), lakes (0.61 %) and reservoir (0.18 %). IUCN (1998) inventory of 19 Terai districts alone estimated that wetlands cover some 7, 24,257 ha in these districts alone. The table below shows the wetland types of Nepal.

**Table 1: Wetland Types in Nepal**

| S.N. | Wetland type | Estimated area (ha) | Percent |
|---|---|---|---|
| A. | Natural Resources | | |
| i. | Rivers | 395000 | 48.35 |
| ii. | Lakes | 5000 | 0.61 |
| iii. | Reservoirs | 1500 | 0.18 |
| B | Village Ponds | 5954 | 0.73 |
| C | Marginal/Swamps/Gholes | 11500 | 1.41 |
| D | Irrigated Paddy Fields | 398000 | 48.72 |
| | **Total** | **816954** | **100.00** |

Source: DOFD (2001/2002)

IUCN-Nepal (1996) has identified 242 wetland sites in Nepal of which 163 sites lie in the Terai Region and 79 sites in Hill and Mountain Region. According to the Development Region, 64 wetland sites lie in far-western region, 52 sites in central region, 50 in western region, 42 in eastern region and 34 in mid-western region. The table below shows the number of wetland sites in Nepal recorded by IUCN-Nepal (1996).

**Table 2: Wetland Sites in Nepal**

| Development Region | Terai | | Hill & Mountain | | Total | |
|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % |
| Eastern | 18 | 7.4 | 24 | 9.9 | 42 | 17.4 |
| Central | 37 | 15.3 | 15 | 6.2 | 52 | 21.5 |
| Western | 34 | 14.4 | 16 | 6.6 | 50 | 20.7 |
| Mid-western | 12 | 5.0 | 22 | 9.1 | 34 | 14.0 |
| Far-western | 62 | 25.6 | 2 | 0.8 | 64 | 26.4 |
| Total | 163 | 67.4 | 79 | 32.6 | 242 | 100.0 |

Source: IUCN- Nepal (1996)

Global aquatic ecosystems fall into two broad classes defined by salinity-the freshwater ecosystem and the saltwater ecosystem. Freshwater is a small part of the global stage and volume but a key one. This is because of the role of water in defining the biosphere and of fresh water in supporting that part of it, a third of the planet including the terrestrial systems, which doesn't live in the ocean (Moss, 1998). Freshwater ecosystems, the study of which is known as limnology, are conveniently divided into two groups i.e. *lentic* or standing water habitats and *lotic* or running water habitats. The lotic follows a gradient from springs to mountains brooks to streams and rivers, while the lentic follows a gradient from lakes to ponds to bogs, swamps, and marshes.

Wetlands are the sites which are distinguished by the presence of water, often have unique soils that differ from adjacent uplands and support vegetation adapted to the wet conditions that may be *lentic* or *lotic*. Wetlands comprise ecotones which lead to high biological diversity. Wetlands are the cradle of aquatic biodiversity upon which countless species of plants and animals depend for the survival (Burlakoti, 2003; Dugan, 1990). Wetlands also store excess water in the rainy season acting as sponges for food abatement and provide irrigation water for agriculture production (GoN/MoFSC/NBS, 2002; Hussain, 1994). They are also one of the most threatened habitats because of their vulnerability and attractiveness for the development (GoN/MoFSC/NBS, 2002; Hollis et al., 1988).

The Nepali term for wetlands is "*Simsa*r", which means land under water not suitable for cultivation lands. The informal group in Nepal at the first informal meeting on wetlands management in Nepal attempted to define wetlands as " Wetlands represent landmass saturated with water due to high water table through ground water, atmospheric precipitation or inundation and it may be natural or artificial, permanent or temporary, static or flowing and freshwater or brackish" (Shrestha & Bhandari, 1992). Wetlands in Nepal are rich in biological diversity and known to regularly support more than 2000 waterfowl during the peak period between December-February.

About 172 species of the major wetland plants are listed in Nepal by IUCN, which provide food, forage and cover for both domestic and wild animals (IUCN-Nepal, 1996). Out of 833 birds found in Nepal, 193 are known to be dependent on wetlands (Baral et al., 1996; Choudhary, 1996; Halliday, 1982; Scott, 1989; Inskipp & Inskipp, 1991; Suwal & Shrestha, 1990; Perennou et al., 1994). Of these wetland-dependent species, about 187 are known to be dependent on the wetlands of Terai. Wetlands in Nepal are suffering and very little data is available about wetland degradation and conservation. Since the formation of DNPWC, some valuable wetlands have been given protection within protected areas. In additional, ten wetland sites in the Terai have been identified for urgent conservation action by the Biodiversity Profile Project which are Beeshazar Tal, Gaindahawa Tal, Jagdishpur Reservoir, Badahiya, Ghodaghodi Tal, Narcrodi Tal, Rampur Tal, Deukhuria, Patriyani and Betkot (BPP, 1995).

Ramsar Convention 1971 defines wetland as "The areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine waters, the depth of which low tide doesn't exceed six meters" and may include "riparian and coastal zones adjacent to wetlands, or islands or water bodies of marine water deeper than six meter at low tide lying within the wetlands" (Ramsar Convention Bureau, 1992). The Convention on Wetlands of International Importance especially as Waterfowl Habitat, also known as Ramsar Convention after the city in Iran where it was originally signed in 1971 and came into force in December 1975, sets forth a process for identifying important wetlands analogous to that of UNESCO's program for Biosphere Reserves. Its mission is “the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development through out the world”. The 138 countries that have signed the convention pledge to designate at least one wetland within their borders for inclusion of the convention’s “Lists of Wetlands of International Importance”, as well as to include wetland protections in their national land use planning. Again, national and local laws provide the exclusive management standards for wetlands include on the list, which now includes over 1300 wetland areas covering over 100 million hectares (Groom et al., 2006).

Nepal became a signatory of the Ramsar Convention in 1987. Even though, Nepal is a mountainous country, it has many different types of wetlands that ranges from areas of permanently flowing rivers to areas of seasonal rivers, lowland oxbow lakes, high altitude glacial lakes, swamps and marshes, paddy fields, reservoirs and ponds (GoN/MoFSC/NBS, 2002; Scott, 1989). Only four wetland sites are enlisted in Ramsar Site of “Lists of Wetlands of International Importance”. They are Koshi Tappu Wetland (1987 December 17) in Saptari & Sunsari District, Beeshazar Lake & its Associated Lakes (2003 August 13) in Chitwan District, Ghodaghodi Lake (2003 August 13) in Kailali District and Jagadishpur Reservoir (2003 August 13) in Kapilvastu District (Ramsar Conservation Bureau, 2003).

The floristic and faunal diversity of wetland is influenced by several physico-chemical parameters of water such as water transparency, velocity, depth, hydrogen ion concentration, nutrients, etc (Burlakoti 2003; CBIP, 1979). To assess the water quality whether suitable for the survival of aquatic flora and fauna, the analysis of physico-chemical characteristics of water is very much necessary. Water quality can undergo significant changes through the seasons (Gibson et al., 1996). Catchment vegetation and soils modify hydrological regimes, sediment loadings, dissolved ions, and dissolved organic matter (Hill & Dimick, 2002; Engstrom et al., 2000; Likens & Bormann, 1974), but the most significant effects of terrestrial vegetation may be those that occur at the aquatic–terrestrial interface. Riparian plants contribute large amounts of particulate organic matter to benthic food webs (Hill & Dimick, 2002; Cummins et al., 1989).

## 1.2 Literature Review

According to Ranjitkar (2006), Kirkpatrick can be considered as the pioneer scholar in the field of freshwater environment of Nepal. He described some fishes (*Tot* spp., *Schizothorax* spp., *Barilus* spp. and *Anguilla* spp.) of Trisuli River in 1773. Berhm (1953) and Ueno (1966) are also the earlier researchers to study on freshwater environment in Nepal.

Loffler (1969) is considered as the pioneer scholar in the field of limnological studies of lentic environment in Nepal. He conducted the study on the high altitude lakes and found calcium dominated among cations, chloride was low and phosphorous less than 1 mg/L, which suggest that phosphorous was limiting.

Hickel (1973) investigated on lakes of Pokhara Valley (Phewa, Begnas, Rupa and Khaste) and that lakes were characterized as eutrophic (phosphorous ranges 10-15 µg/L and 50-110 µg/L, respectively) in pre-monsoon and mesotrophic (phosphorous ranges 4-9 µg/L) in post-monsoon indicating consistent with the international standard values of phosphorous given by UNEP (2000) and Forsberg and Ryding (1980).

Kaul et al. (1978) had shown hydrological factors in governing the occurrence and growth of wetlands species in Kashmir. They studied water chemistry of two lakes in Kashmir and showed the fresh water macrophytes had a more dominant influence upon the physicochemical characteristics of water. The dense growth of macrophytes in water bodies was mainly due to their high nutrient level. While sparse growth of non-attached macrophytes in such water bodies was mainly due to their nutrient poor conditions.

Sharma et al. (1979) noted physico-chemical characteristics of fresh water and found comparatively higher values of conductivity, chloride, ammonia, nitrate, nitrite and phosphorous in polluted water than non-polluted one. The maximum value of dissolved oxygen in summer and lowest value in winter were observed in unpolluted water bodies, whereas the reverse values were observed in the polluted water bodies.

Okino and Sato (1986) on their study on high altitude lake (Lake Rara) reported that it had low productivity based on chlorophyll-a (0.036-0.465 mg/m$^3$), total nitrogen (10-30 mg/L) and dissolved oxygen (4.84-8.06 mg/L) and suggested that the lake was oligotrophic. Nitrogen concentration was similar among Terai and mid hill lakes but the concentration decreased by 3-fold in high altitude lakes, it might be due to the greater nutrient export from unconsolidated sedimentary or alluvial geology compares to igneous and metamorphic geology.

Singh and Sahai (1986) studied the primary production of phytoplankton in relation to physico-chemical parameters of a tropical shallow water body. Primary productivity was found to be greatest during monsoon when the phytoplankton were dominated by blue green algae. The green algae and diatoms accounted for a small share of total production during winter and summer.

Lohman et al. (1988) carried out limnological work by indicating a major distinction in the deposition of ions in wetlands as Terai lakes has high value (average 2.188 mg/L) as compared with mid hill lakes (1.011 mg/L) and high altitude lakes (0.489 mg/L) attributed due to huge deposition of alluvium in Terai.

Jones et al. (1989) found Beeshazar Lake of Chitwan as oligotrophic based on total nitrogen (340 µgm/L) and eutrophic based on total phosphorous (53 µgm/L) and chlorophyll-a (15 µgm/L) as proposed by Forsberg and Ryding (1980). The pH value of the lake observed in the study was 8.4.

Yadav (1989) in his study on Kulekhani Reservoir reported that the transparency value was seasonally fluctuated and the surface water of the reservoir was always saturated with oxygen throughout the investigation period.

Maskey (1992) performed the study on socio-economic and bio-physical pressures on wetlands of Nepal and mentioned the finding of sixteen oxbow lakes in Chitwan National Park, which are shallow, permanent, eutrophic with luxuriant growth of aquatic vegetation.

McEachern (1993) investigated 3 lakes; Devi Tal, Lami Tal and Tamor Tal of Chitwan National Park and reported that the impact of water hyacinth mat on improving the trophic status from mesotrophic (Jones et al., 1989) to oligotrophhic level in the Devi Tal. He noted that the anoxic environment created by the hyacinth and high bacterial activity likely result in high losses of nitrogen as volatile ammonia and nitrogen gas. Phosphorous levels were probably depleted by the sheer demand from hyacinth propagation.

BPP (1995) investigated 51 wetlands throughout the Terai of Nepal. The study has recorded 235 species of plants in which 89 were aquatic species and 146 were terrestrial species in adjoining grass and forest. Among the total 235 species recorded includes 213 Angiosperms, 4 Bryophytes, 5 Pteridophytes, 6 Algae and 7 Fungi. It also recorded that the pH (8.1) and dissolved oxygen (10.1 ppm) of water at 20.4 $^{o}$C temperature in Beeshazar Lake, Chitwan.

McEachern (1996) ranked Beeshazar Lake as mesotrophic based on total nitrogen (445 µgm/L) and eutrophic based on total phosphorous (53 µgm/L). The conductivity value observed in the investigation was 185.8 µS/cm.

Acharya (1997) found productive nature of Ghodaghodi and Nakhrodi Tal based on physico-chemical parameters of water, which was also evident by a luxuriant growth of macrophytes. Water of lakes was acidic in nature with high free $CO_2$ content but medium dissolved oxygen. High values of hardness, total dissolved solids, total nitrogen and total phosphorous showed the eutrophic nature of lake as proposed by Forsberg and Ryding (1980).

Bhatta (1997) performed the study on the physico-chemical characteristics of water and phytoplankton analysis of Taudaha Lake and found that surface temperature varied from 14 $^{o}$C to 26.7 $^{o}$C with average transparency as 109.66 cm. Its surface water had high dissolved oxygen and pH remained alkaline throughout the investigation period. A wide range of total solids and high conductivity and a wide range of total hardness were found. He finally classified Taudaha Lake as Mesotrophic Lake and it was moderately polluted.

Jayana (1997) investigated on the physico-chemical parameters of Beeshazar Lake and observed the surface water temperature ($27.28 \pm 2.1$ $^{o}$C), transparency (119.90 cm), pH ($8.20 \pm 0.14$), free $CO_2$ ($2.45 \pm 0.93$ mg/L), total alkalinity ($119.17 \pm 20.8$ mg/L), total hardness ($183 \pm 19.44$ mg/L), D.O. ($7.1 \pm 1.0$ mg/L), nitrate ($0.304 \pm 20.67$ mg/L) and orthophosphate ($0.361 \pm 24.29$ mg/L). The lake was ranked as eutrophic state based on orthophosphate content.

Adhikari (2002) performed the study on the seasonal variation, composition and frequency distribution pattern of aquatic macrophytes and their status of Lake Khaste and Dipang. The distribution pattern of wetland was found to be influenced by limnological parameters. The limnological parameters showed eutrophic nature of both lakes whereas lake withnessed a luxuriant growth of macrophytes. Trophic status of both lakes were found to be eutrophic based on chlorophyll-a, total-P and secchi disk visibility.

IUCN (2002) carried out a single sample water analysis in Beeshazar Lake and found oligotrophic state of lake based on chlorophyll-a, eutrophic based on total nitrogen and hypereutrophic based on Secchi disc transparency and total phosphorus. Dissolved oxygen was found below the minimum international level (3-5 mg/L) of surface water. (http://www.wetlands.org).

Yadav (2002) investigated on the physico-chemical components and biological components of Bagmati River and reported that the pH value of the water was neutral to alkaline. He also reported the low values of D.O. and high values of BOD and total solid content of water at downstream of Bagmati River. He reported 7 tree species in the forest at the upstream of the river.

Burlakoti (2003) assessed the seasonal variation of water quality parameters of Beeshazar Lake. He found the highest values of temperature, conductivity and pH in the rainy season, followed by the summer season and the lowest in the winter season. He found the highest transparency value in the winter season followed by the summer season and the lowest value in the rainy season, while the highest value of total solids was observed in the rainy season followed by the summer and winter season. Similarly, free $Co_2$ value was found to be highest in the summer season followed by the rainy season and lowest in the winter season, while the dissolved oxygen was found maximum in the winter season followed by the rainy season and the lowest value in the summer season. He classified the lake as hypereutrophic according to the average value of total nitrogen ($7.29 \pm 1.61$ ppm) and orthophosphate ($0.113 \pm 0.03$ ppm).

## 1.3 Justification

In the previous studies on Beeshazar Lake System, the scholars used to focus separately on water quality (Jones et al., 1989; McEachern, 1996; Jayana, 1997; Burlakoti, 2003), forest soil (Shrestha, 2003) or forest vegetation (Shrestha, 2003), rather than the overall study on all these factors. The present overall investigation may help in evaluating whether the Beeshazar Lake System is improving or deteriorating compared with the previous investigations. As the previous scholar (Burlakoti, 2003) had reported that the growth of macrophytes (*Eichornia crassipes, Trapa bispinosa, Leersia hexandra, Ipomoea carnea, etc)* in the lake had threatened the wetland ecosystem, the present study could be an important platform for the authorized bodies to protect the wetland ecosystem.

## 1.4 Objectives

The broad objectives of the present investigation were to make the physico-chemical analysis on water parameters of Beeshazar Lake and surface soil parameters of the forest around the lake. The present study also aimed to make a quantitative analysis on the tree species of the forest around the lake. The specific objectives of the present investigation were as follows.

- to show the seasonal fluctuations on the physico-chemical parameters (Transparency, Temperature, pH, Conductivity, Total Solid, Dissolved Oxygen, Free $CO_2$, Total Alkalinity, Total Hardness, Chloride, Orthophosphate, Total Nitrogen and Nitrogen-$NO_3$) and GPP of Beeshazar Lake.
- to show the seasonal fluctuations on the surface soil parameters (pH, Conductivity, Organic Matter, Phosphorous, Potassium and Total Nitrogen) of the forest floor around Beeshazar Lake.
- to make a quantitative analysis (Density, Basal Area, Volume and Above Ground Biomass) of tree species of the forest around Beeshazar Lake.

## 1.5 Limitations

During the preliminary survey a boat was seen in the lake, therefore it was also aimed to analyze the certain water parameters at different depths of the lake. But during the main investigation periods, the boat was not seen. According to the local people, the boat was stolen that made it impossible to collect the water samples at different depths. It was also aimed to take the data of water and surface soil in summer season but the political instability of the country made it impossible to collect the water and surface soil samples in summer season.

## 1.6 Study Area

### 1.6.1 Location

Beeshazar Lake lies in ward no. 3 of Gitanagar VDC, Chitwan District; adjacent to Khageri Irrigation Canal within Barandabhar Forest of the buffer zone of Chitwan National Park. It is located at $27^{o}$ 36’ 54’’ to $27^{o}$ 37’ 44’’ N latitude and $84^{o}$ 26’ 14’’ to $84^{o}$ 26’ 44’’ E longitude, with an elevation of 170 to 200 m from the mean sea level. The lake covers an area of 100 ha of open water body; representing the second largest lake in the Terai Region (IUCN, 1998). It encompasses an area of 3200 ha including the mosaics of diverse habitats of open water bodies, marshes, swamps, grasslands, and forests (Ramsar Conservation Bureau, 2003). It has a maximum depth of 5 m and an average depth of 3 m. The lake is linked to all-weather graveled motorable road; 7.2 south-west of Mahendra Highway following Khageri Irrigation Canal and 15 km south-east of Narayanghat Bazaar. The Ramsar Site lying within the Barandabhar Forest is bordered by Rapti River in the south, Mahendra Highway in the north, Khageri River, Budhi Rapti River, Ratnanagar Municipality and Bachhauli VDC in the east and Bharatpur Municipality, Patihani and Gitanagar VDC in the west.

### 1.6.2 Genesis

Beeshazar Lake was a marshy or swampy area before 1966, with unique undulating features of forested landscape. The monsoon rains flooded and impounded over these areas converted into a huge water bodies. But due to lack of water retaining structures impounded water in depressed area lasts for few months in a year. After the construction of Khageri Irrigation

Canal in 1966, the canal not only served as an impoundment but also provided continual supply of water to the lake system, and produced a permanent water bodies by raising the water level of the lake. So, it can be said that the lake is an internal part of Khageri Irrigation Canal.

### 1.6.3 Climate

Beeshazar Lake falls in the Tropical Climatic Regime and dominated by summer monsoon climate. The monsoon begins from late June and continues until early October and brings nearly 80 % of the rainfall in the area; which play a key role in the maintenance of the seasonal wetlands, particularly in the depressed land areas of the old alluvial plain and grassland or wetland unit on either side of the active alluvial plain. The average annual rainfall (Figure 1 & Appendix 1) in Chitwan District (Rampur Station) was 2201.89 mm and the monthly average temperature (Figure 2 & Appendix 2) varied from 8.19 $^{0}$C in January to 35.82 $^{o}$C in May (GoN/MoEST/DHM, 1994-2005). Except scattered precipitation sometimes during the months of December and February, the weather is almost dry in the rest of the months. In December and February, a scattered rain under the influence of westerly disturbances occurs for a period of week.

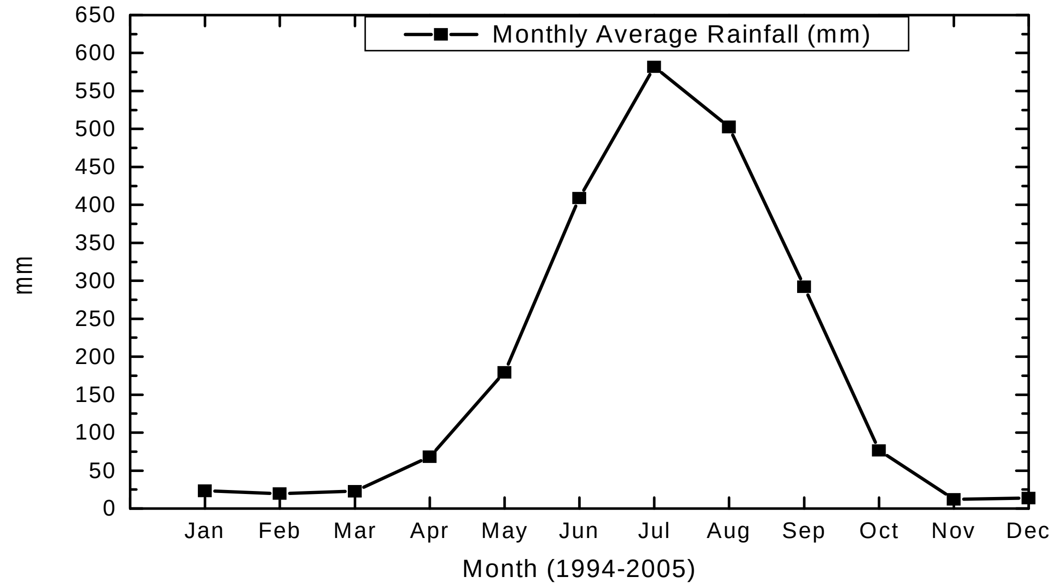


**Figure 1: Rainfall (mm)**

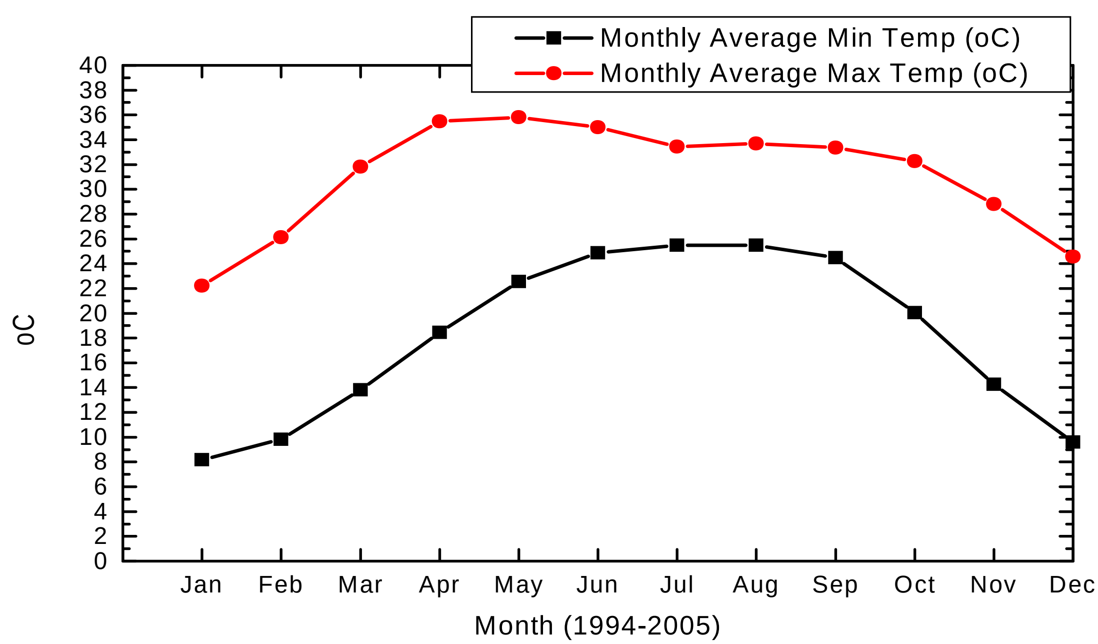


**Figure 2: Temperature ($^{o}$C)**

### 1.6.4 Hydrology

Khageri Irrigation Canal and precipitation are the main sources of water in Beeshazar Lake. Khageri River (source of Khageri Irrigation Canal) is fed by two perennial streams i.e. Thulo Syangdi Khola and Sano Syangdi Khola. The lake serves both an inlet and outlet for the canal. Beeshazar Lake is drained to the west through an outlet, which is fed to the Khageri Irrigation Canal passing across the Barandabhar forest in east-west direction. The water balance in the lake is determined by the outflow rate of the water from the lake to Khageri Irrigation Canal, inflow rate of water from the canal to the lake and changes in the water level of the lake by precipitation and evaporation.

### 1.6.5 Biodiversity

Beeshazar Lake lying within the Barandabhar Corridor Forest holds outstanding values due to its high ecological importance. The Beeshazar Lake Basin is rich in biodiversity represented by 131 species of plants comprises 32 trees, 64 shrubs and 99 aquatic species (IUCN, 1998). The aquatic vegetation include 99 species consisting of 72 genera and 36 families of which 79 species are emergent in nature (IUCN, 1998). The aquatic plants life forms inhabiting different zones of lake comprising 8 free floating plants, 7 submerged plants and 4 rooted floating broad-leaved plants (IUCN, 1998). Barandabhar forest which bears Beeshazar Lake system that adjoins the CNP in the south has over 22 mammals, 274 species of birds, 17 species of fishes and 13 species of reptiles (Yonzan, 2000).

### 1.6.6 Socio-Economic

Beeshazaar Lake system has influence over three VDCs (Gitanagar, Bachhuali and Patihani) and two municipalities (Ratnanagar and Bharatpur) of Chitwan District. However, except Bachhauli VDC, area of remaining VDCs and municipalities are partially influenced. The major ethic groups in these VDCs and municipalities are Brahmin, Chhetri, Damai, Kami, Newar, Tamang, Magar and Tharu (GoN/Park People Programme/UNDP, 2001). Farming and wage labor are the key livelihood activities of the people of these VDCs and municipalities. Beside, farming and wage labor, they also collect firewood, fodder, thatch, fish, snail and wild vegetable from the lake system in the leisure time. Crop damages by the wild animals especially by the rhino and wild pigs are frequently reported by the people living surrounding the lake system.

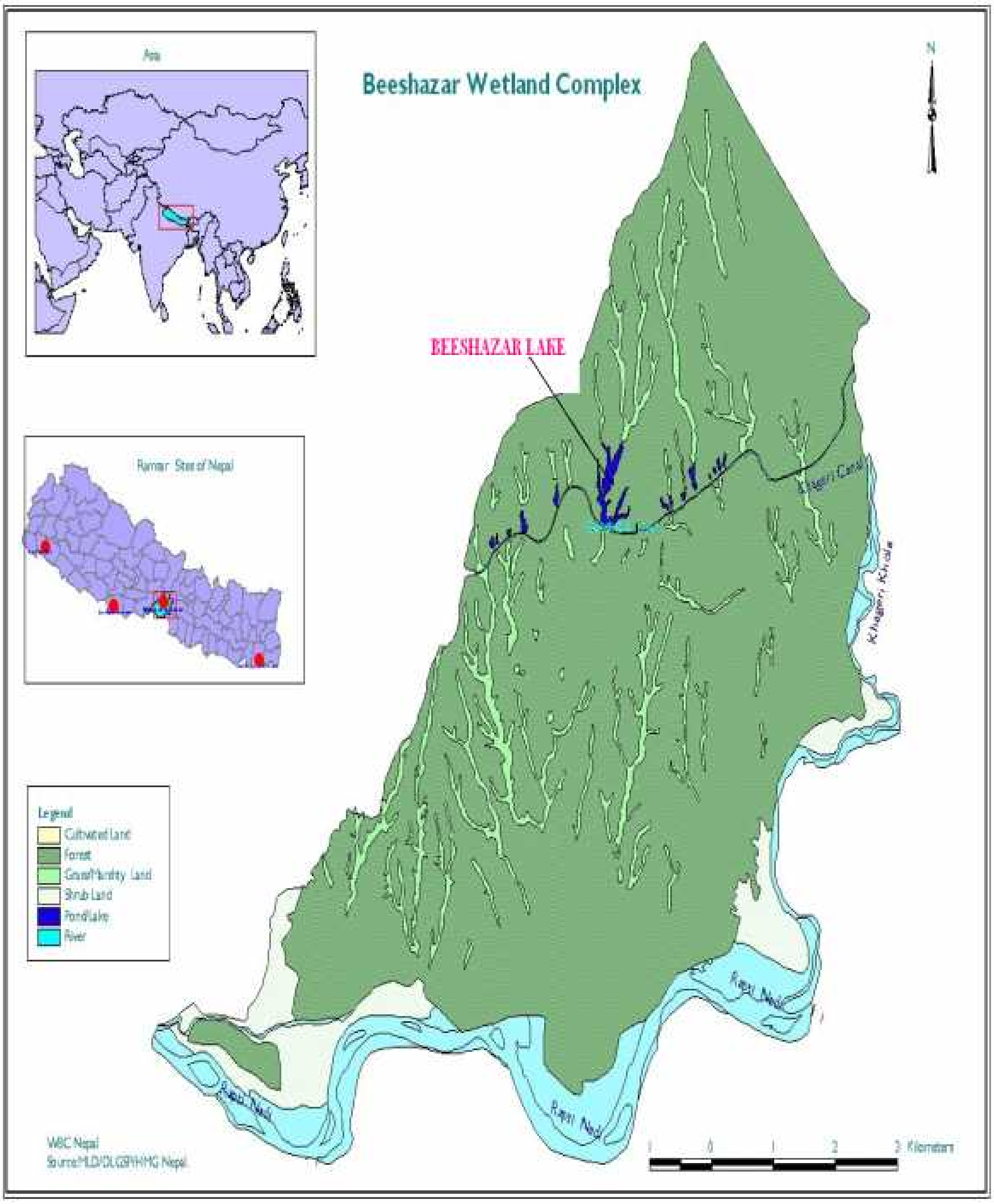


**Figure 3: Location Map of Beeshazar Lake**

# CHAPTER II

# Materials and Methods

## 2.1 Reconnaissance Survey

For the collection of the baseline information about the research area, it was visited from 13 to 15 January 2006 and more information were collected by consulting the related experts, local people, literatures and maps of the research area. For the detail research work, the research area was visited in the three different seasons of the year 2006 i.e. winter season, monsoon season and autumn season.

## 2.2 Physico-Chemical Analysis of Water Parameters

### 2.2.1 Water Sampling

Systematic sampling method has been applied in some regular manner because it is more advantageous when the interest centers variability within the area (Greigh-Smith, 1964). For the water sampling of Beeshazar Lake in each season, three different sites were selected systematically. The sites were selected on the basis of depth of the lake, macrophyte occurrence and human influence in the lake.

**Site 1:** It was located at 70 m north of the tourist centre of Beeshazar Lake, where there was an excessive growth of macrophytes (*Leersia hexendra*). The site was at the right of *Chautaha* (local name of the place) with average depth of 1.65 m. The site was not much influenced by human activities but it was one of the major fishing spots for the local people.

**Site 2:** It was located at 20 m east of the tourist centre where there was no growth of any macrophytes. It was the deepest zone of the lake with average depth of 3.2 m and not influenced by any human activities.

**Site 3:** It was located at the adjacent to Khageri canal, which was in between inlet of the lake and dam (between the lake and the canal) with average depth of 0.98 m. There was a little growth of macrophytes (*Leersia hexendra*) with maximum leaching of nutrients from the forest floor. It was also a highly human influenced area, which was aside of a famous picnic spot.

Plastic bottles of different sizes (500ml/1000ml) were used to collect the water samples. These sampling bottles were rinsed twice with respective water samples and filled air tight. The parameters like Temperature, pH, Transparency, Dissolved $O_2$, Free $CO_2$, Conductivity, Total Alkalinity, Total Hardness, GPP and Chloride were measured in the field. The tagged samples with respective sampling sites, date and time of sampling were kept in the iceboxes to analysis the parameters like orthophosphate, Total Nitrogen, Nitrogen-$NO_3$ and Total Solid in the laboratory of Central Department of Environmental Science. All the water parameters except Total Nitrogen was analyzed as prescribed by APHA, AWWA, WPCF (1995) and the analysis for Total Nitrogen was performed as prescribed by Trivedy and Goel (1986).

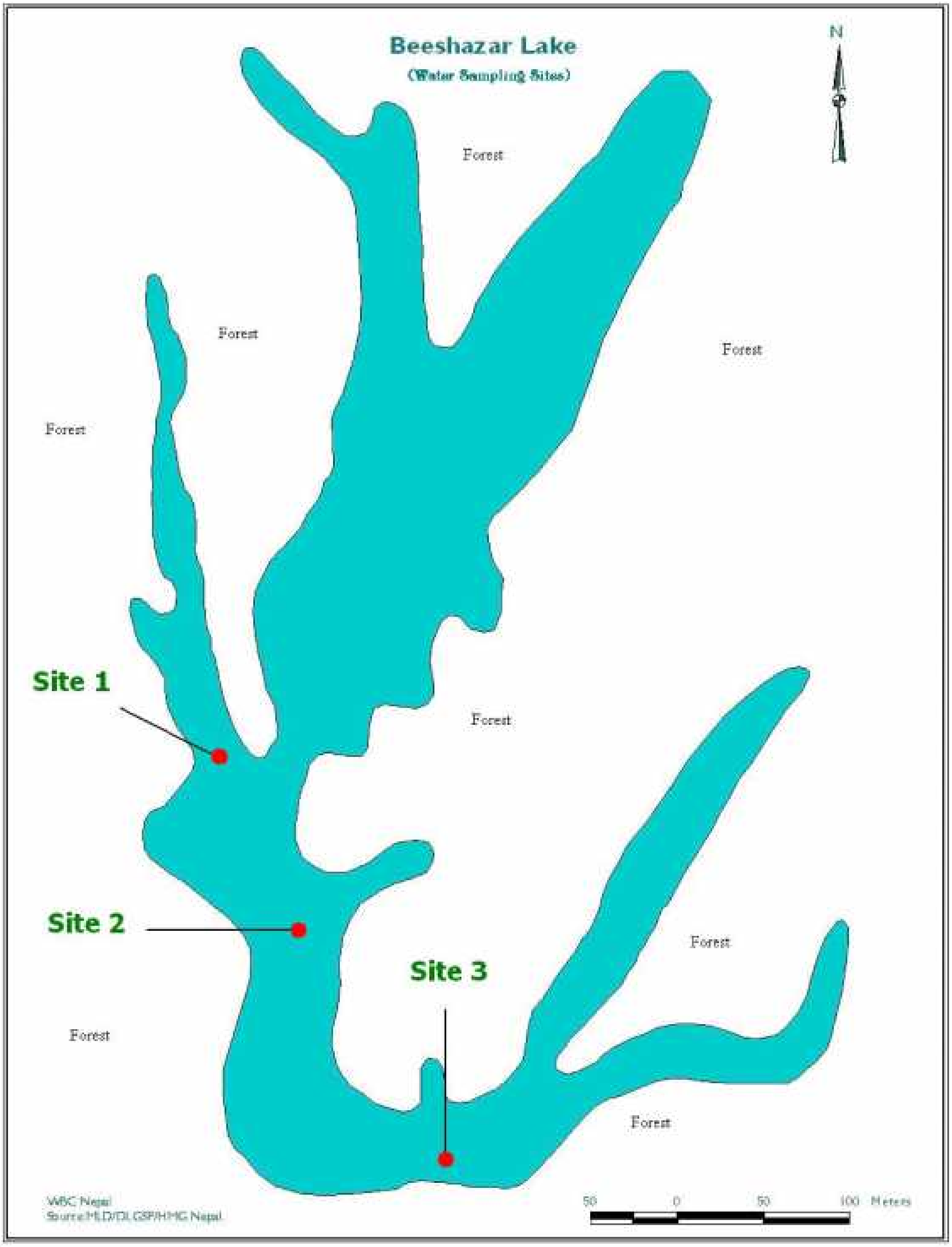


**Figure 4: Map of Beeshazar Lake Showing Water Sampling Sites**

### 2.2.2 Analysis of Water Parameters

**Transparency**

The transparency of water was measured by using a Secchi Disc of 20 cm diameter, divided into black and white quadrants. The disc was lowered in the water and the point where, it just disappeared was noted. The disc was further lowered and began to rise and the point where it just reappeared was again noted. The distance was calculated with the help of those marked points, using the following formula.

$$\text{Secchi disc transparency (cm)} = \frac{A + B}{2}$$

Where,

$A$ = depth at which Secchi disc disappears (cm)

$B$ = depth at which Secchi disc reappears (cm)

**Surface Water Temperature**

Temperature of the sampled water was determined by using a mercury thermometer. The sampled water was put in the beaker. The bulb of the mercury thermometer was dipped in the beaker containing sampled water. After 2 minutes the temperature of the sampled water was noted.

**pH**

An automatic digital pH meter (HI 8314 portable pH meter, HANNA instrument with an accuracy of $\pm$ 0.01 at 20 $^{o}$C/68 $^{o}$F) was calibrated by using the buffer of different pH values. The sample water was put in the beaker and the pH value of the sampled water was determined by dipping the pH meter on it.

**Conductivity**

The conductivity of the sampled water was determined by using a digital conductivity meter (Model 4150 by Wagtech with accuracy of ± 0.5 %). The conductivity meter was first calibrated with standard potassium chloride solution of 0.01 N and the temperature was adjusted at 25 $^{0}$C. The instrument was first brought into the conductivity mode. Then the electrode was washed and rinsed a few times with distilled water and then dipped in the beaker containing the sampled water and the reading was noted.

**Total Solids (TS)**

Total solids were determined as the residue left after evaporation of the unfiltered sample. First, a porcelain basin was dried, cooled and its weight was noted down. Then, 100 ml of sampled water was taken in the porcelain basin and it was evaporated. The residues resulting form the evaporated sample was heated at 103-105 $^{o}$C. The final weight of the basin was noted after cooling it on a desiccator. The total solid of the sampled water was calculated by using the following formula.

$$\text{Total Solid (mg/L)} = \frac{(\text{A - B})}{\text{V}} \times 1000 \times 1000$$

Where,

$\text{A} = \text{Final wt.of basin (gm)}$

$\text{B} = \text{Initial wt.of basin (gm)}$

$\text{V} = \text{Vol.of sampled water (ml)}$

**Dissolved oxygen (D.O.)**

The dissolved oxygen was determined by the Standard Wrinkle's method. The sampled water was filled in the BOD bottle (glass stopper bottle) of known volume (300 ml) avoiding any kind of bubbling and trapping of air bubbles in the bottle after placing the stopper on it. Then, 2 ml of each $MnSO_4$ and alkaline KI solutions were added in the bottle to form the precipitation. The bottle was kept for sometimes to settle down the precipitation and then about 2 ml of conc. $H_2SO_4$ was added. The content was dissolved by shaking the precipitate for a moment. Finally, 50 ml of the content in the BOD bottle was taken in a conical flask and it was titrated against standard sodium thiosulphate solution (0.025 N) using starch as an indicator. The end point was noticed after the initial dark blue color changed to colorless. The volume of standard sodium thiosulphate Solution consumed for titration was noted and the dissolved oxygen concentration of the sampled water was calculated by using the following formula.

$$DO\ (mg/L) = \frac{(ml \times N)\ of\ Titrant}{V2 \times \frac{V1 - V}{V1}} \times 8 \times 1000$$

Where,

N = Normality (strength of sodium thiosulphate) i.e 0.025 N

V2 = Volume of content titrated

V1 = Volume of sample bottle (BOD bottle)

V = Volume of $MnSO_4$ and KI added

**Free Carbon dioxide ($CO_2$)**

For the determination of free $CO_2$ concentration, 100 ml of sampled water was taken in a conical flask and 2-3 drops of phenolphthalein was added on it as an indicator. Then, it was titrated against carbonate free NaOH (0.05 N) and the end point was noticed when its color changed to pink. The volume of NaOH consumed for titration was noted and the free $CO_2$ concentration of the sampled water was calculated by using the following formula.

$$Free\ CO_2\ (mg/L) = \frac{(V \times N)\ of\ NaOH}{Volume\ of\ Sample\ (ml)} \times 44 \times 1000$$

Where,

V = Volume of NaOH consumed (ml)

N = Normality (strength of NaOH) i.e. 0.05 N

**Total Alkalinity**

For the determination of total alkalinity concentration, 100 ml of the sampled water was taken in a conical flask and 2-3 drops of methyl orange was added on it as an indicator. It was then titrated against Standard $H_2SO_4$ (0.02 N) and the end point was noticed after yellow color of the water sample was changed to pink color. The volume of $H_2SO_4$ consumed for titration was noted and the total alkalinity concentration of the sampled water was calculated by using the following formula.

$$Total\ Alkalinity\ (mg/L) = \frac{a \times N}{V} \times 1000 \times 50$$

Where,

a = Volume of consumed Standard $H_2SO_4$ (ml)

N = Normality of $H_2SO_4$ i.e. 0.1 N

V = Volume of sample (ml)

**Total Hardness**

For the determination of total hardness concentration, 50 ml of the sampled water was taken in a conical flask and 1ml of buffer solution with 100-200 mg of Erichrome Black-T indicator was added on it. It was then titrated against standard EDTA (Ethylene diamine tetra acetic acid).The end point was noticed after the color of solution changed from wine red to blue. The volume of EDTA consumed for titration was noted and the total hardness concentration of the sampled water was calculated by using the following formula.

$$\text{Total Hardness (mg/L)} = \frac{\text{Volume of EDTA Consumed (ml)}}{\text{Sample Volume (ml)}} \times 100$$

**Chloride**

For the determination of chloride concentration, 50 ml of the sampled water was taken in a conical flask and 2 ml of potassium chromate (5 %) was added on it as an indicator, which changed the color of sampled water to yellow. Finally, the content was titrated against silver nitrate (0.02 N) and the end point was noticed when its color changed from yellow to red tinge. The volume of Silver Nitrate consumed for titration was noted and the chloride concentration of the sampled water was calculated by using the following formula.

$$\text{Chloride (mg/L)} = \frac{(V \times N)\text{ of } AgNO_3}{\text{Volume of Sample (ml)}} \times 1000 \times 35.5$$

Where,

$V = \text{Volume of } AgNO_3 \text{ consumed (ml)}$

$N = \text{Normality (strength of } AgNO_3\text{) i.e. 0.02 N}$

**Orthophosphate**

For the determination of orthophosphate concentration, 50 ml of sampled water was taken in a clean conical flask. The colloidal impurities and color content of the water sample were removed by adding a spoonful of activated charcoal prior to filtration. Then, 2 ml of ammonium molybdate and 5 drops of stannous chloride was added to the filtrate. The absorbance reading was noted at 690 nm (Spectrophotometer) within 5 to 12 minutes after the addition of stannous chloride. Then the orthophosphate of the sampled water was calculated by using standard curve.

**Total nitrogen (TN)**

For the determination of total Kjeldahl nitrogen, 40 ml of sampled water was taken in a Kjeldahl flask of 100 ml capacity. Then, 4 ml of $H_2SO_4$, 0.3 ml of $CuSO_4$ solution, 6 gm of solid potassium sulphate and 1 ml of 10 % NaCl solution were added on the Kjeldahl flask containing sampled water. Then, the flask was heated to avoid loss through foaming. When the color of the content turned to pale green, the heating process was continued for additional 30 minutes. The digested material was cooled and transferred to a 100 ml measuring flask. Additional distilled water was added to make up the volume up to 100 ml. Then, 25 ml of the digested solution was taken in a distillation flask and 20 ml of 40 % sodium hydroxide (NaOH) was added on it and the mixture was distilled. The liberated ammonia was collected in 10 ml of 4 % boric acid solution containing 2 drops of mixed indicator of methyl red and brom-crasd green (1:6). The distillate was titrated against standard HCL (0.01 N) and the end point was noticed when its color changed from blue to brown or faint pink. The volume of HCL consumed for titration was noted and the total Kjeldahl nitrogen concentration of the sampled water was calculated by using the following formula.

$$\text{Total Kjeldahl Nitrogen (mg/L)} = \frac{(a - b) \times D}{V} \times 1000 \times 14 \times 0.01$$

Where,

$a$ = ml of HCl used with sample

$b$ = ml of HCl used with blank

$D$ = Dilution factor (2.5)

$V$ = Volume of sample distilled

**Nitrogen- Nitrate (N- $NO_3$)**

The concentration of N-$NO_3$ was determined by phenol disulphonic acid method. For the determination of N-$NO_3$ concentration, 50 ml of filtered sampled water was taken in a porcelain basin and an equivalent amount of silver sulphate solution was added to remove chlorides in the sampled water. Then, the content was heated to evaporate to dryness. It was cooled and the remained residue was dissolved by 2 ml of phenol disulphonic acid. It was then diluted to 50 ml and 6 ml of liquid ammonia was added to develop yellow color. The absorbance reading was taken at 410 nm (Spectrophotometer) and the concentration of N-$NO_3$ was calculated using the standard curve.

**Gross Primary Productivity (GPP)**

Two BOD bottles labeled as Light bottle and Dark bottle were taken. Both bottles were filled with sampled water. Then, the light and dark bottle were left in the water for four hours and after four hours, they were removed from the water and the dissolved oxygen content of these bottles was determined by Winkler's method as previously described in the measurement of dissolved oxygen.. The value of GPP of the sampled water was determined by using the following formula.

$$\text{Gross Primary Productivity (GPP)} \ (O_2 \ mg / L / hr) = \frac{Dl - Dd}{H}$$

Where,

Dl = DO in light bottle (mg /L)

Dd = DO in dark bottle (mg /L)

H = Duration of exposure (hr)

## 2.3 Physico-Chemical Analysis of Surface Soil Parameters

### 2.3.1 Surface Soil Sampling

For the soil sampling in the forest around the lake in each season, ten different sites were selected systematically. GPS locations were noted down in the first season and the same locations were found out for the soil sampling in other seasons. The trunks of the trees were also marked in each site, so that the sites could be easily located in the next season. In every season, soil samples from each site were collected from the forest floor at 0 to15 cm depth and kept in air tight labeled polythene bags. The soil samples were then brought to Central Department of Environmental Science for the analysis of pH, Conductivity, Texture, Organic matter, N, P and K. The soil samples were oven dried at 70 $^{o}$C for 48 hours before the analysis. All the analyses except soil texture were performed as prescribed by Trivedy and Goel (1986). The analysis of soil texture was performed as prescribed by Goldman et al. (1986).

### 2.3.2 Analysis of Surface Soil Parameters

**Soil Texture**

Soil Texture was determined by sieving method as the grain size and /or the composition of the materials are often used as criteria to distinguish different sediment type (Sly, 1978). For the determination of soil texture, the oven dried soil sample was grinded gently in a grinder. The powdered soil sample was weighted and sieved by using the sieves of 2 mm, at the top to remove gravels and then 0.053 mm, 0.02 mm and pan respectively towards the bottom to retain sand, silt and clay, respectively. The soil fractions retaining in each sieve were weighted and percentage of sand, silt and clay were calculated. The percentages of sand, silt and clay were plotted on texture triangle to obtain the texture of the soil. The percentages of sand silt and clay of the soil sample was calculated using the following formulas.

$$\% \text{ of Sand} = \frac{c}{a} \times 100$$

$$\% \text{ of Silt} = \frac{d}{a} \times 100$$

$$\% \text{ of Clay} = \frac{e}{a} \times 100$$

Where,
a = Weight of Soil
c = Weight of Sand
d = Weight of Silt
e = Weight of Clay

**Soil pH**

For the determination of pH, 50 gm of soil sample, which was passed through 2 mm sieve, was taken in a beaker. Then, 250 ml of distilled water was added on it and it was stirred for about an hour. An automatic digital pH meter (HI 8314 portable pH meter, HANNA instrument with an accuracy of $\pm$ 0.01 at 20 $^{o}$C/68 $^{o}$F) was calibrated with the buffer of different pH values. The pH value of the soil sample was determined by dipping the electrode of the pH meter in the beaker containing stirred soil sample.

**Conductivity**

For the determination of conductivity, 50 gm of soil sample, which was passed through 2 mm sieve, was taken in a beaker. Then, 250 ml of distilled water was added on it and it was stirred for about an hour. A digital conductivity meter (Model 4150 by Wagtech with accuracy of $\pm$ 0.5%) was calibrated with standard potassium chloride solution of 0.01 N and the temperature was adjusted at 25 $^{0}$C. The instrument was first brought into the conductivity mode. Then, the electrode was rinsed by the distilled water and dipped in the beaker containing the stirred soil sample and the reading was noted.

**Organic Matter (O.M.)**

The amount of Organic Matter (O.M.) of the soil sample was determined by Walkley and Black Method. For the determination of organic matter, 1 gm of soil sample passed through 0.2 mm sieve was taken in a conical flask (500 ml) and 10 ml of $K_2Cr_2O_7$ (1 N) was added on it. Then, 20 ml of conc. $H_2SO_4$ was added and the solution was mixed by gentle rotation for 1 minute, to insure complete contact of reagent with the soil. The mixture was then allowed to stand for 30 minutes. After 30 minutes, 200 ml of distilled water with 10 ml of ortho phosphoric acid and 1 ml of diphenylamine indicator was added on it. The content was titrated against ferrous ammonium sulphate (0.5 N) until the dull green color changed to turbid blue. A standardization blank (without soil) was also run in the same way. The volume of ferrous ammonium sulphate consumed for the titration was noted and the organic matter on the sampled soil was calculated by using the following formula.

$$\text{O.M.}\,(\%) = \frac{(B - S) \times N}{W} \times 0.67$$

Where,

B = Volume of ferrous ammonium sulphate consumed with blank titration (ml)

S = Volume of ferrous ammonium sulphate consumed with sample titration (ml)

N = Normality (strength of ferrous ammonium sulphate) i.e. 0.5 N

W = Weight of soil (gm)

**Total Nitrogen**

The total nitrogen content of the soil was determined by Modified Kjeldahl method. For the determination of total nitrogen, 10 gm of soil was taken in a Kjeldhal digestion flask (300 ml) and 25 ml of distilled water was added on it. It was leaved for 30 minutes and 20 gm of catalyst digestion was added on it. The content was heated in the low heat until frothing stops after addition of 35 ml of conc. $H_2SO_4$ and few pieces of broken porcelain. Gradually, heat was increased until the acid boiled. The flask was swirled at intervals and digested until the color of the mixture changes to grey color or green blue and continued for 1 to 1.5 hours. Care was taken during digestion not to allow the flame to touch the flask above the part occupied by the liquid. The digest was cooled and 100 ml of distilled water was added on it. Then, 100 ml of 40 % NaOH and few pieces of Zinc was added in the distillation flask and a conical flask of 500 ml containing 25 ml of boric acid and mix indicator of methyl red and brom-crasd green (1:6) was placed below the condenser. About 150 ml of condensed was collected and the flask was removed after the mixed indicator in the condensate turned blue. Then, it was titrated against HCL (0.1 N) until the color changed to light brown- pink. The volume of HCL consumed for the titration was noted and the total nitrogen on the sampled soil was calculated by using the following formula.

$$N\,(\%) = \frac{(a - b) \times N}{S} \times 1.4$$

Where,

$a$ = Volume of HCL consumed with sample titration (ml)

$b$ = Volume of HCL consumed with blank titration (ml)

$N$ = Normality (strength of HCL) i.e. 0.1 N

$S$ = Weight of soil sample taken (gm)

**Available Phosphorus**

For the determination of available phosphorous, 1 gm of oven dried soil sample was taken in 500 ml conical flask and 200 ml of $H_2SO_4$ (0.002 N) was added on it. The suspension was shaken for half an hour. The suspension was filtered to get a clear soil solution. The concentration of P-$PO_4$ in the soil solution was obtained by employing the same method as described for water above to determine orthophosphate.

$$\%\ \text{available P} = \frac{\text{mg P/L of Soil Solution}}{50}$$

$$\text{Phosphorus (ppm)} = \%\ P \times 10000$$

$$\text{Available Phosphorous } (P_2O_5 \text{ - kg/ha}) = \text{ppm (P) in soil} \times 2.24 \times 2.3$$

Where,

2.24 is conversion factor for ppm in soil to kg/ha in soil

2.3 is conversion factor for P in $P_2O_5$

**Potassium**

For the determination of potassium, 50 gm of air dried soil sample was taken in a beaker of 500 ml capacity and about 100 ml of 40 % alcohol was added on it. It was kept for 15 minutes after shaking well. The suspension was filtered through Whatman No. 50 filter paper using Buchner funnel and vacuum pump. The soil was then washed 4 to 5 times with 50 ml of 40 % alcohol and finally it was washed with 50 ml of absolute alcohol to dry the soil. The filter paper was removed and the soil was scraped in a beaker of 250 ml capacity. Then the Buchner funnel and the filter paper were washed with 100 ml ammonium acetate solution to remove any adhered portion of the soil. The solution was stirred and kept overnight. The soil was filtered after filtering supernatant through Whatman No. 42 filter paper, with additional of ammonium acetate. The soil was leached 4 to 5 times more with portions of ammonium acetate and the final volume of filtrate was made 500 ml in a volumetric flask. The concentration of potassium was measured using flame photometer.

$$\text{Potassium (\%)} = \frac{\text{K/L of Soil Solution}}{\text{S} \times 1000} \times \text{V}$$

Where,

$\text{V} = \text{Total volume of extract prepared}$

$\text{S} = \text{Weight of soil taken}$

$\text{ppm (K)} = \text{\% K} \times 10000$

$\text{Poatssium } (\text{K}_2\text{O - kg/ha}) = \text{ppm (K) in soil} \times 1.2 \times 2 \times 1.12$

Where,

$1.2 = \text{Conversion factor for K to K}_2\text{O}$

$2 \times 1.12 = \text{Conversion factor for ppm to kg/ha}$

## 2.4 Quantitative Analysis of Tree Species

### 2.4.1 Sampling of Tree Species

For the analysis of trees of the forest in the periphery and 100 m away of the bank of the lake, random sampling was preferred. Requisite size of the quadrate was determined by Species Area Curve Method. The proper quadrate size was determined as 20 m × 20 m for the trees. Altogether, 20 plots were selected and the analysis was also done in each season partially, which represented a single data as no such distinct change in trees' morphology in a single year can be noticed. The trees having dbh 10 cm or more were only accounted for the analysis. The location (Longitude, Latitude and Altitude) were noted for each plot. For the unidentified tree species, leaves of the trees were collected to make the herbarium and were identified by the experts of the Central Department of Environmental Science consulting the text of Stainton (1972) "Forest of Nepal" and GoN/MoFSC (2001) "Flowering Plants of Nepal-Phanerogams".

### 2.4.2 Analysis of Tree Species

**Density**

The density of a species is the total number of individual per unit area. It was calculated using the following formula (Zobel et al., 1987).

$$\text{Density}\left(\text{Plants / ha}\right) = \frac{\text{Total number of individual species}}{\text{Total number of quadrates studied} \times \text{Area of quadrate(ha)}} \times 100 \times 100$$

**Relative Density**

The relative density (RD) is the proportion of a species to that of the stand as a whole. It was calculated using the following formula (Zobel et al., 1987).

$$\text{Relative Density}(\%) = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$$

**Basal Area**

BA refers to the ground actually covered by the stems penetrating the soil. It is expressed in $m^2$/ha of ground surface. It was calculated using the following formula (Zobel et al., 1987).

$$\text{Basal Area}\,(m^2) = \frac{(dbh)^2 \times \pi}{4}$$

Where,

$dbh = \text{Diameter at breast height}$

$$\text{Total BA}\,(m^2/ha) = \text{Average BA} \times \text{Density}$$

**Volume**

The volume may be used as an index of its biomass or of its worth as a commercial product. It was calculated using the following formula (Zobel et al., 1987).

$$\text{Volume}\,(m^3) = \frac{(\text{girth})^2}{16} \text{ x } H$$

Where,

$H = \text{Height of tree}$

$$\text{Total Volume}\,(m^3/ha) = \text{Average Volume} \times \text{Density}$$

**Biomass**

The total amount of living above ground biomass of tree is expressed on oven dry weight per unit area. Generally, destructive methods are used by many workers but it was inapplicable in the present study. Biomass of the tree was calculated by using double formula of moist forest (Brown and Inverson, 1992).

$$y = 1.276 + 0.034\,(D^2H)$$

Where, $y = \text{Biomass (Kg/tree)}$

$D = \text{Diameter of trees at breast height (cm)}$

$H = \text{Height of tree (m)}$

$\text{Total Biomass (kg/ha)} = \text{Average Biomass} \times \text{Density}$

# CHAPTER III

# Results

## 3.1 Physico-Chemical Analysis of Water Parameters

### 3.1.1 Transparency

The average values of Secchi disc transparency in the water of Beeshazar Lake ranged from 77.33±25.54 cm (monsoon season) to 114±53.92 cm (winter season). The average Secchi disc transparency value was 98.33±45.74 cm in autumn season. Throughout the three seasons Secchi disc transparency value was found highest at site 2 followed by site 1 and site 3.

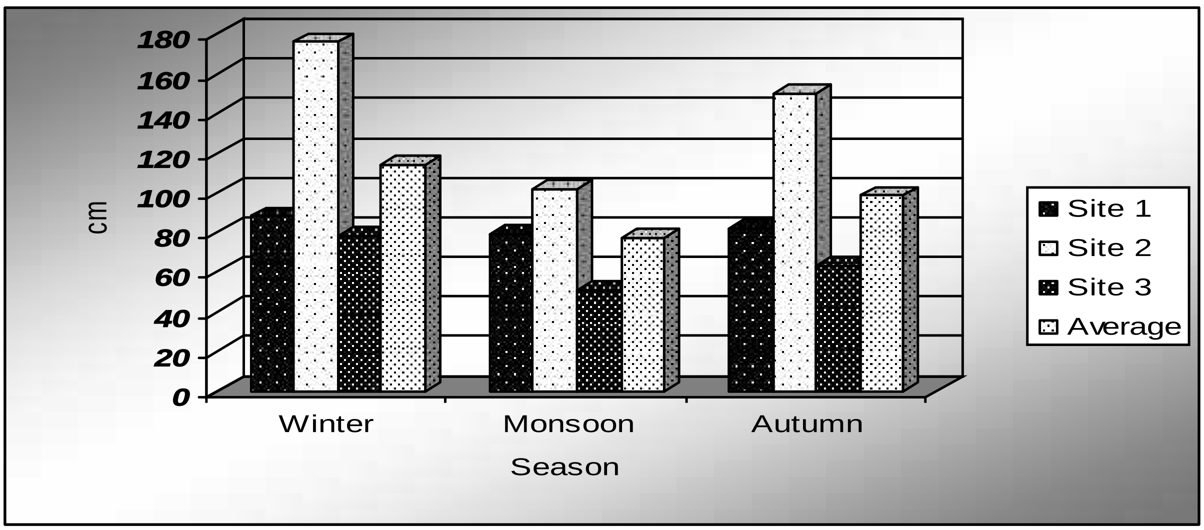


**Figure 5: Transparency (cm) at three Sites in three Seasons**

In winter season, the Secchi disc transparency value was 176 cm at site 2, followed by 88 cm at site 1 and 78 cm at site 3. In monsoon season, the Secchi disc transparency value was 102 cm at site 2, followed by 79 cm at site 1 and 51 cm at site 3. In autumn season, the Secchi disc transparency value was 150 cm at site 2, followed by 82 cm at site 1 and 63 cm at site 3 (Figure 5). The average value of the Secchi disc transparency observed in all seasons was 96.55±40.82 cm.

### 3.1.2 Surface Water Temperature

The average surface water temperature of Beeshazar Lake ranged from 15.5±1.32 $^{o}$C (winter season) to 30±1.0 $^{o}$C (monsoon season). The average surface water temperature was 24±0.5 $^{o}$C in autumn season. In winter season, the surface water temperature was 16.5 $^{o}$C at site 3 followed by 16 $^{o}$C at site 2 and 14 $^{o}$C at site 1.

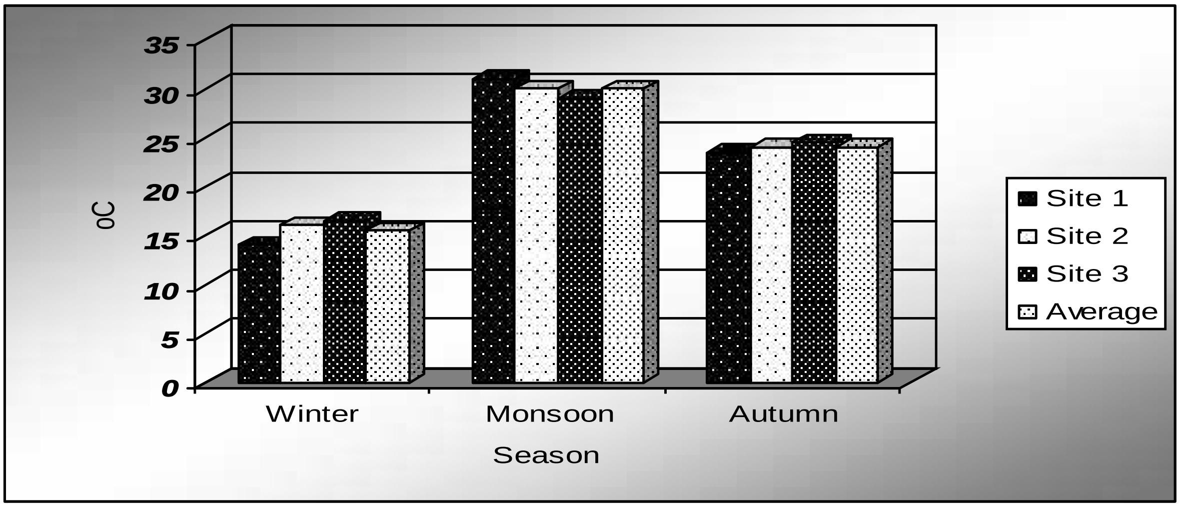


**Figure 6: Surface Water Temperature ($^{o}$C) at three Sites in three Seasons**

In monsoon season, the surface water temperature was 31 $^{o}$C at site 1, followed by 30 $^{o}$C at site 2 and 29 $^{o}$C at site 3. Similarly, in autumn season the surface water temperature was 24.5 $^{o}$C at site 3, 24.0 $^{o}$C at site 2 and 23.5 $^{o}$C at site 1 (Figure 6). The average surface water temperature observed in all seasons was 23.16±6.36 $^{o}$C.

### 3.1.3 pH

The average values of pH in the water of Beeshazar Lake ranged from 6.6±0.1 (winter season) to 7.3±0.1 (monsoon season). The average pH value was 6.86±0.05 in autumn season. Throughout the three seasons the pH value was found highest at site 1 than site 3 and site 2. In winter season, the pH value was 6.7 at site 1, followed by 6.6 at site 3 and 6.5 at site 2. In monsoon season, the pH value was 7.4 at site 1, followed by 7.3 at site 3 and 7.2 at site 2. Similarly, in autumn season, the pH value was 6.9 at both site 1 and site 3 and 6.8 at site 2 (Figure 7). The average pH value observed in all seasons was 6.92±0.31.

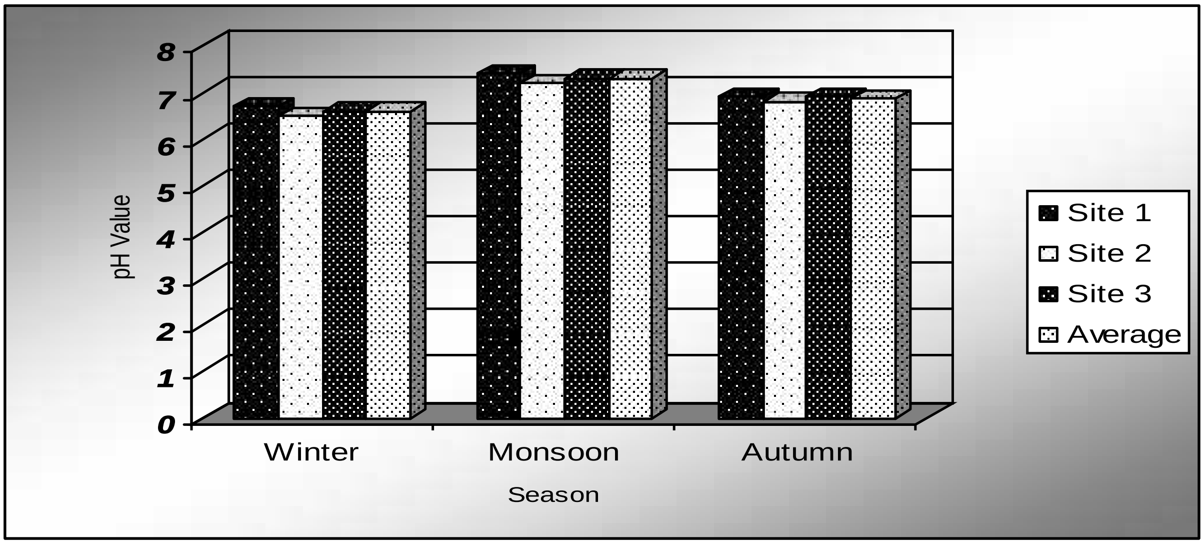


**Figure 7: pH of Water at three Sites in three Seasons**

### 3.1.4 Conductivity

The average values of conductivity in the water of Beeshazar Lake ranged from 140.33±1.15 µS/cm (winter season) to 175.66±3.05 µS/cm (monsoon season). The average conductivity value was 162.33±2.081 µS/cm in autumn season.

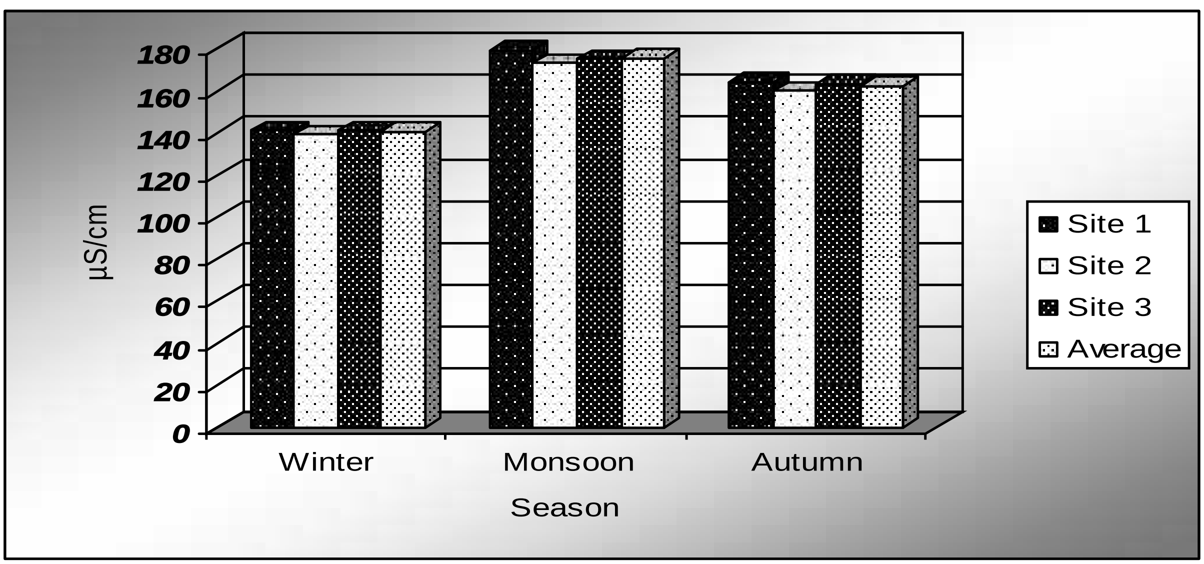


**Figure 8: Conductivity (µS/cm) of Water at three Sites in three Seasons**

Throughout the three seasons the conductivity value was found highest at site 1 than site 3 and site 2. In winter season, conductivity value was 141 µS/cm at both site 1 and site 3 and 139 µS/cm at site 2. In monsoon season, the conductivity value was 179 µS/cm at site 1, followed by 175 μS/cm at site 3 and 173 μS/cm at site 2. Similarly, in autumn season, the conductivity value was 164 μS/cm at site 1, followed by 163 μS/cm at site 3 and 160 μS/cm at site 2 (Figure 8). The average value of conductivity observed in all seasons was 159.44±15.57 μS/cm.

### 3.1.5 Total Solids

The average total solids content in the water of Beeshazar Lake ranged from 246.66±30.55 mg/L (winter season) to 556.66±66.98 mg/L (monsoon season). The average total solids content was 332±26 mg/L in autumn season. Throughout the three seasons the total solids content was found highest at site 3 followed by site 1 and site 2. In winter season, the total solids content was 280 mg/L at site 3, followed by 240 mg/L at site 1 and 220 mg/L at site 2. In monsoon season, the total solids content was 631 mg/L at site 3, followed by 538 mg/L at site 1 and 501 mg/L at site 2. In autumn season, the total solids content was 358 mg/L at site 3, followed by 332 mg/L at site 1 and 306 mg/L at site 2 (Figure 9). The average value of total solids observed in all seasons was 378.44±144.06 mg/L.

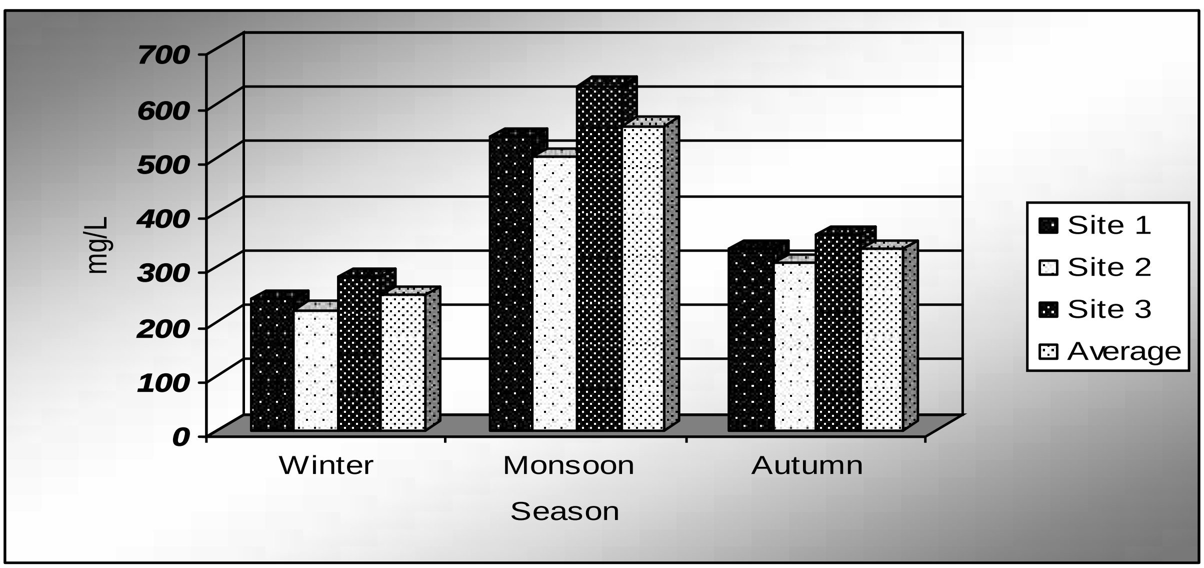


**Figure 9: Total Solids Content (mg/L) in Water at three Sites in three Seasons**

### 3.1.6 Dissolved Oxygen (D.O.)

The average dissolved oxygen concentration in the water of Beeshazar Lake ranged from 3.72±0.11 mg/L (monsoon season) to 4.52±0.27 mg/L (winter season). The average dissolved oxygen concentration was 3.99±0.03 mg/L in autumn season. Throughout the three seasons the dissolved oxygen concentration was found highest at site 2 followed by site 1 and site 3. In winter season, the dissolved oxygen concentration was 4.83 mg/L at site 2, followed by 4.43 mg/L at site 1 and 4.3 mg/L at site 3.

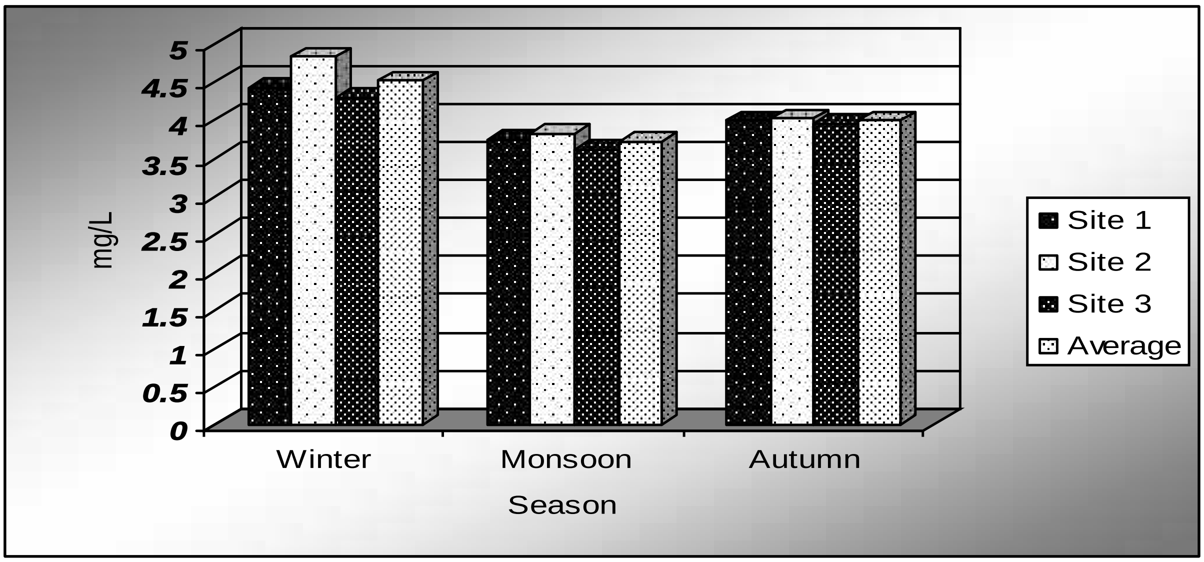


**Figure 10: D.O. (mg/L) Concentration of Water at three Sites in three Seasons**

In monsoon season the dissolved oxygen concentration was 3.83 mg/L at site 2, followed by 3.74 mg/L at site 1 and 3.61 mg/L at site 3. Similarly, in autumn season, the dissolved oxygen concentration was 4.02 mg/L at site 2, followed by 4.0 mg/L at site 1 and 3.96 mg/L at site 3 (Figure 10). The average dissolved oxygen concentration observed in all seasons was 4.08±0.38 mg/L.

### 3.1.7 Free $CO_2$

The average free $CO_2$ concentration in the water of Beeshazar Lake ranged from 16.96±0.25 mg/L (winter season) to 21.2±0.45 mg/L (monsoon season). The average free $CO_2$ concentration was 18.9±0.3 mg/L in autumn season. Throughout the three seasons the free $CO_2$ concentration was found highest at site 3 followed by site 1 and site 2. In winter season, the free $CO_2$ concentration was 17.2 mg/L at site 3, followed by 17.0 mg/L at site 1 and 16.7

mg/L at site 2. In monsoon season the free $CO_2$ concentration was 21.7 mg/L at site 3, followed by 21.1 mg/L at site 1 and 20.8 mg/L at site 2. Similarly, in autumn season, the free $CO_2$ concentration was 19.2 mg/L at site 3, followed by 18.9 mg/L at site 1 and 18.6 mg/L at site 2 (Figure 11). The average free $CO_2$ concentration observed in all seasons was 19.02±1.85 mg/L.

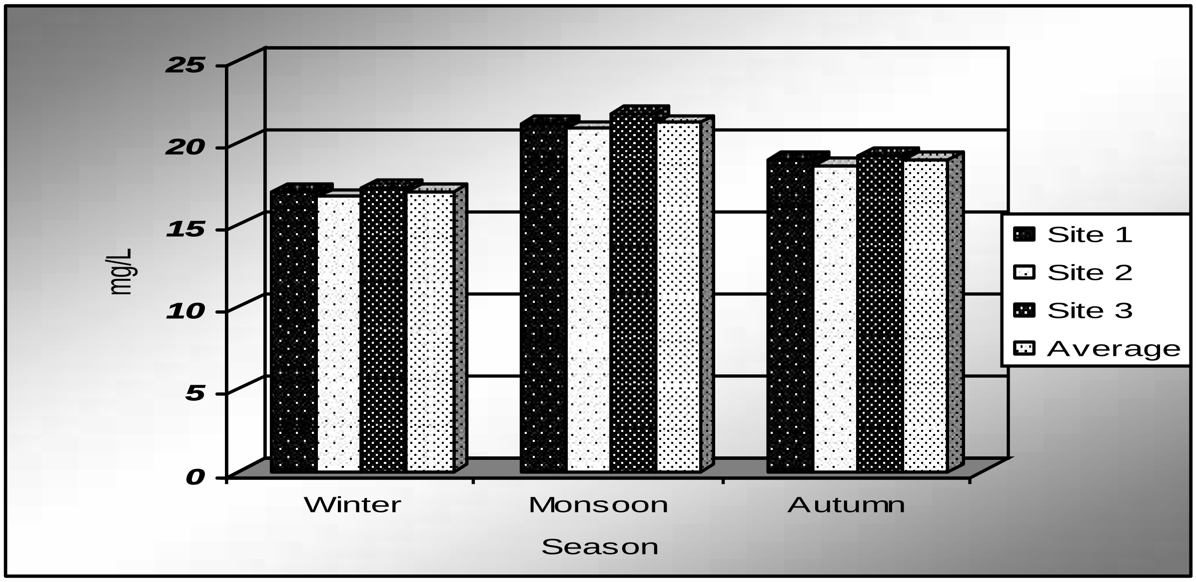


**Figure 11: Free $CO_2$ (mg/L) Concentration of Water at three Sites in three Seasons**

### 3.1.8 Total Alkalinity

The average total alkalinity value in the water of Beeshazar Lake ranged from 93.33±3.78 mg/L (monsoon season) to 122.33±3.71 mg/L (winter season). The average total alkalinity value was 110.66±1.15 mg/L in autumn season. Throughout the three seasons the total alkalinity value was found highest at site 1 followed by site 3 and site 2. In autumn season the total alkalinity value was 112 mg/L at site 1 followed by 110 mg/L at site 3 and 110 mg/L at site 2. In winter season, site 1 had the highest total alkalinity value (126 mg/L), followed by site 3 (121 mg/L) and site 2 (120 mg/L). Similar variations on the total alkalinity value according to the sites were observed in monsoon season i.e. site 1 (96 mg/L), site 3 (95 mg/L) and site 2 (89 mg/L) (Figure 12). The average total alkalinity value observed in all seasons was 108.78±12.89 mg/L.

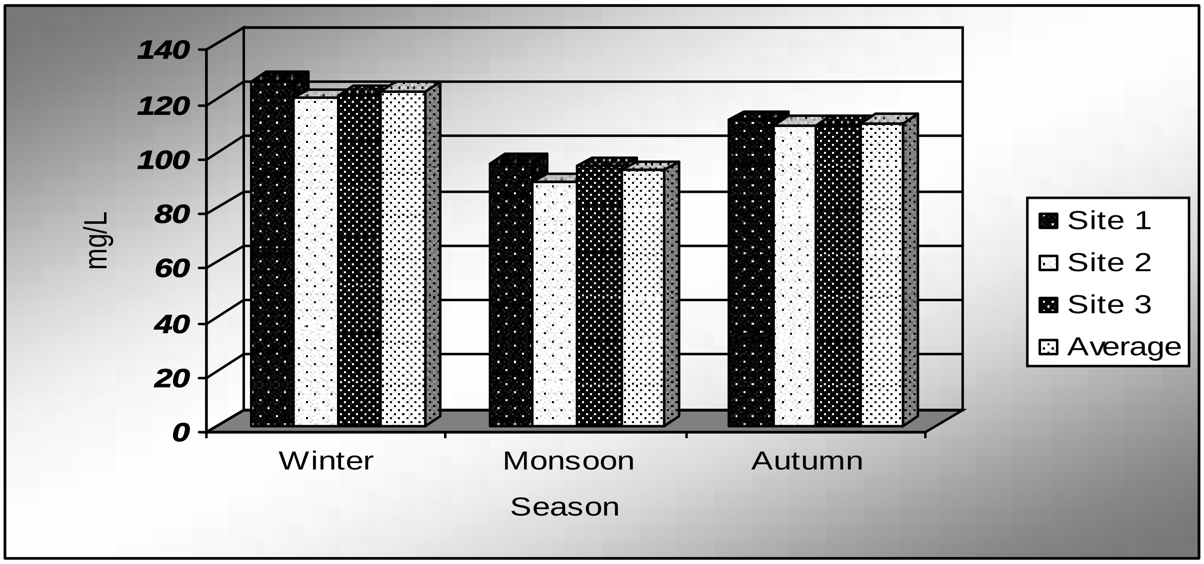


**Figure 12: Total Alkalinity (mg/L) Concentration of Water at three Sites in three Seasons**

### 3.1.9 Total Hardness

The average total hardness concentration in the water of Beeshazar Lake ranged from 31.73$\pm$3.71mg/L (winter season) to 75$\pm$1.0 mg/L (autumn season). The average total hardness value was 72$\pm$1.0 mg/L in monsoon season. Throughout the three seasons the total hardness value was found highest at site 2 followed by site 1 and site 3.

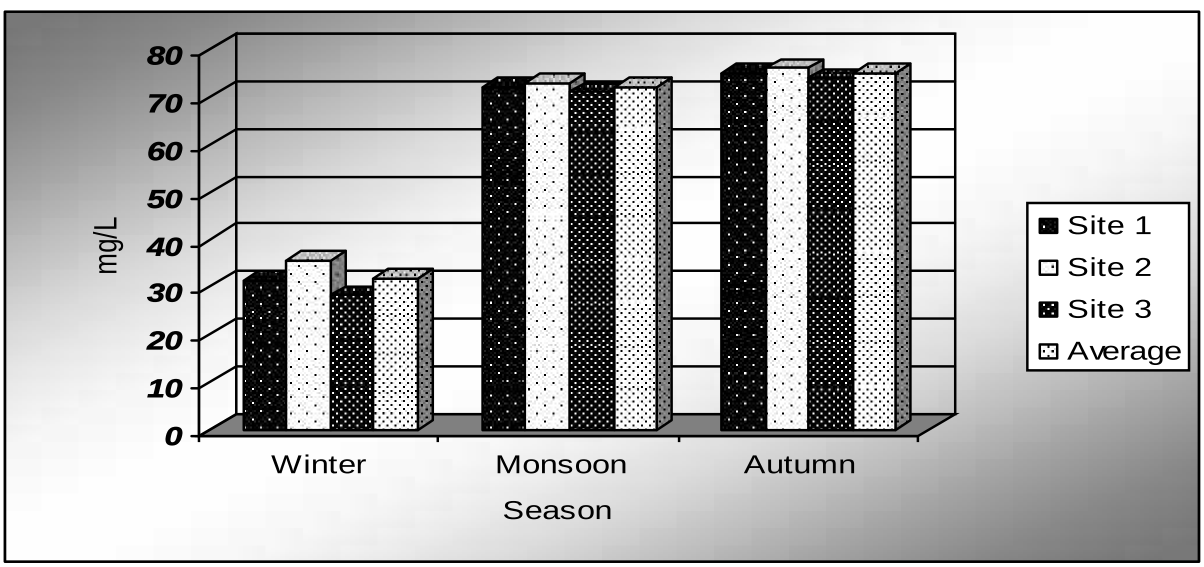


**Figure 13: Total Hardness (mg/L) Concentration of Water at three Sites in three Seasons**

In monsoon season, the total hardness value was 73 mg/L at site 2, followed by 72 mg/L at site 1 and 71 mg/L at site 3. Similarly, in autumn season the total hardness value was 76 mg/L at site 2, followed by 75 mg/L at site 1 and 74 mg/L at site 3. In winter season, site 2 had the highest total hardness value i.e. 35.6 mg/L, followed by site 1 (31.4 mg/L) and site 3 (28.2 mg/L) (Figure 13). The average total hardness concentration observed in all seasons was 59.57$\pm$21.01 mg/L.

### 3.1.10 Chloride

The average chloride concentration in the water of Beeshazar Lake ranged from 9.81$\pm$1.49 mg/L (winter season) to 11.87$\pm$1.54 mg/L (monsoon season). The average chloride concentration was 10.68$\pm$0.77 mg/L in autumn season. Throughout the three seasons the chloride concentration was found highest at site 3 followed by site 1 and site 2. In winter season, chloride concentration was 10.75 mg/L at site 3, followed by 10.61 mg/L at site 1 and 8.09 mg/L at site 2. In monsoon season the chloride concentration was 12.78 mg/L at site 3, followed by 12.76 mg/L at site 1 and 10.09 mg/L at site 2. Similarly, in autumn season, the chloride concentration was 11.20 mg/L at site 3, followed by 11.07 mg/L at site 1 and 9.79 mg/L at site 2 (Figure 14). The average chloride concentration observed in all seasons was 10.79$\pm$1.45 mg/L.

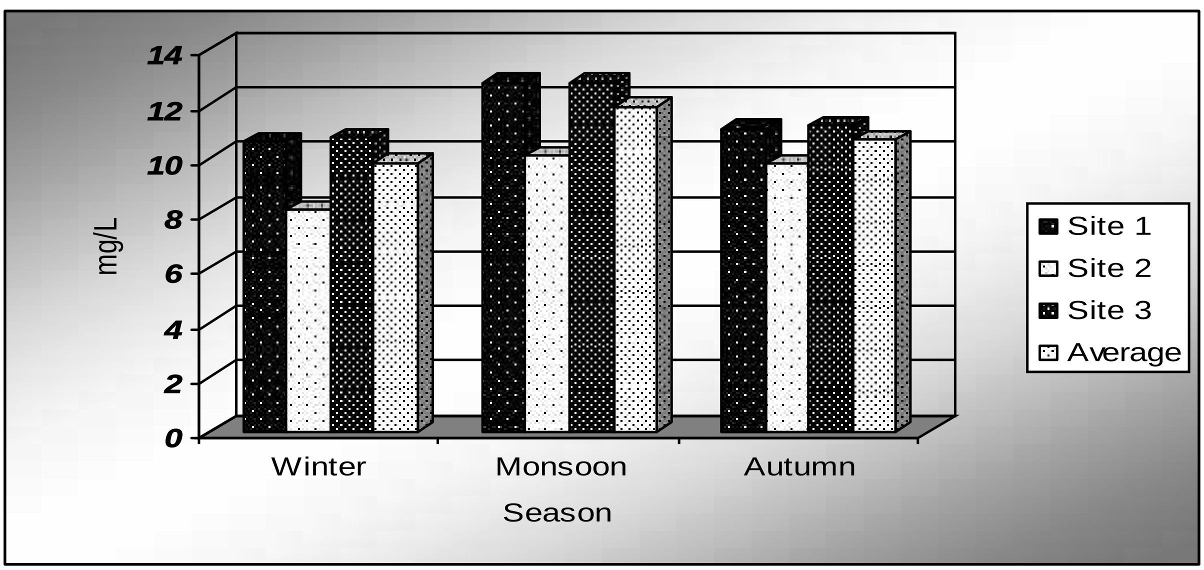


**Figure 14: Chloride Concentration (mg/L) of Water at three Sites in three Seasons**

### 3.1.11 Orthophosphate

The average orthophosphate concentration in the water of Beeshazar Lake ranged from 0.049667±0.015695 mg/L (winter season) to 0.094667±0.034443 mg/L (monsoon season). The average orthophosphate concentration was 0.065667±0.020033 mg/L in autumn season. Throughout the three seasons the orthophosphate concentration was found highest at site 3 followed by site 1 and site 2. In winter season, orthophosphate concentration was 0.062 mg/L at site 3, followed by 0.055 mg/L at site 1 and 0.032 mg/L at site 2. In monsoon season the orthophosphate concentration was 0.177 mg/L at site 3, followed by 0.112 mg/L at site 1 and 0.055 mg/L at site 2.

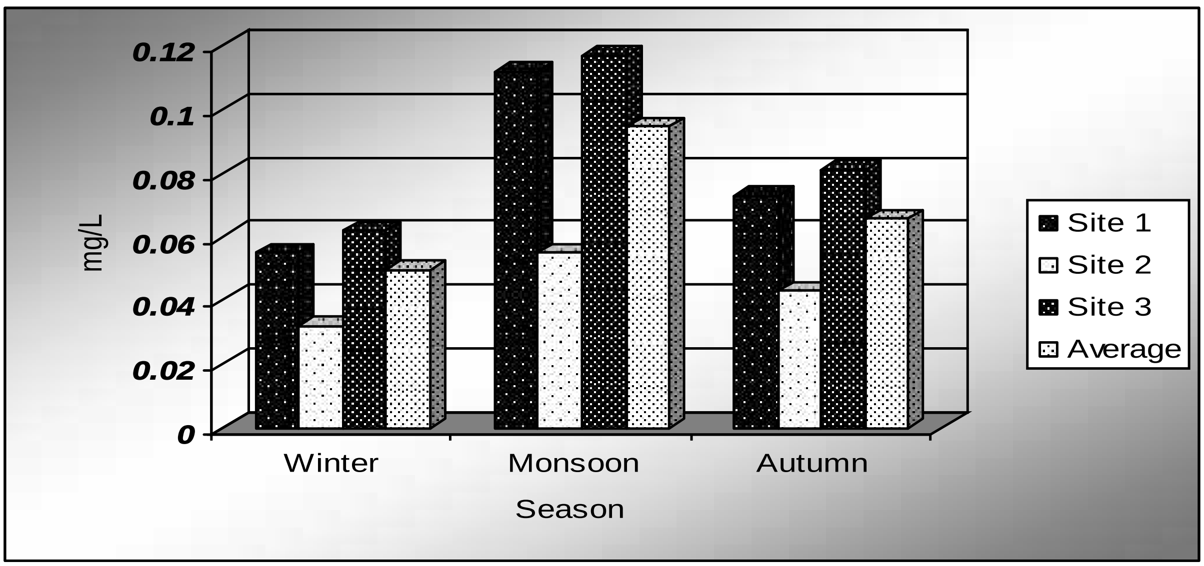


**Figure 15: Orthophosphate (mg/L) Concentration of Water at three Sites in three Seasons**

Similarly, in autumn season, the orthophosphate concentration was 0.081 mg/L at site 3, followed by 0.073 mg/L at site 1 and 0.043 mg/L at site 2 (Figure 15). The average orthophosphate concentration observed in all seasons was 0.07±0.029133 mg/L.

### 3.1.12 Total Nitrogen (TN)

The average total nitrogen concentration in the water of Beeshazar Lake ranged from 0.8721±0.05153 mg/L (winter season) to 2.026733±0.044049 mg/L (monsoon season). The average total nitrogen concentration value was 1.455±0.06896 mg/L in autumn season. Throughout the three seasons the total nitrogen concentration was found highest at site 3 followed by site 1 and site 2. In winter season, the total nitrogen concentration was 0.9275 mg/L at site 3, followed by 0.8632 mg/L at site 1 and 0.8256 mg/L at site 2. In monsoon season the total nitrogen concentration was 2.0764 mg/L at site 3, followed by 2.0114 mg/L at site 1 and 1.9924 mg/L at site 2. Similarly, in autumn season, the total nitrogen concentration was 1.5324 mg/L at site 3, followed by 1.4325 mg/L at site 1 and 1.4001 mg/L at site 2 (Figure 16). The average TN concentration observed in all seasons was 1.4513$\pm$0.502311 mg/L.

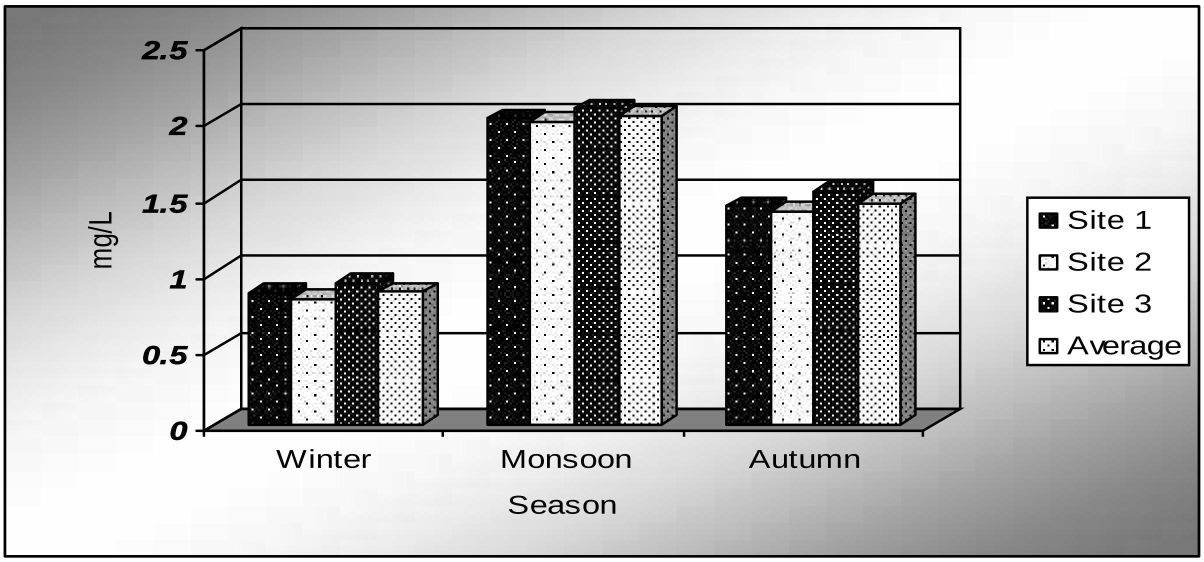


**Figure 16: Total Nitrogen (mg/L) Concentration of Water at three Sites in three Seasons**

### 3.1.13 Nitrogen-$NO_3$

The average nitrogen-$NO_3$ concentration in the water of Beeshazar Lake ranged from 0.016333$\pm$0.002517 mg/L (winter season) to 0.021667$\pm$0.003512 mg/L (monsoon season). The average nitrogen-$NO_3$ concentration value was 0.017333$\pm$0.002517 mg/L in autumn season. Throughout the three seasons the nitrogen-$NO_3$ concentration was found highest at site 3 followed by site 1 and site 2. In winter season, N-$NO_3$ concentration was 0.019 mg/L at site 3, followed by 0.016 mg/L at site 1 and 0.014 mg/L at site 2. In monsoon season the nitrogen-$NO_3$ concentration was 0.025 mg/L at site 3, followed by 0.022 mg/L at site 1 and 0.018 mg/L at site 2. Similarly, in autumn season, the nitrogen-$NO_3$ concentration was 0.02 mg/L at site 3, followed by 0.017 mg/L at site 1 and 0.015 mg/L at site 2 (Figure 17). The average N-$NO_3$ concentration observed in all seasons was 0.0184$\pm$0.003504 mg/L.

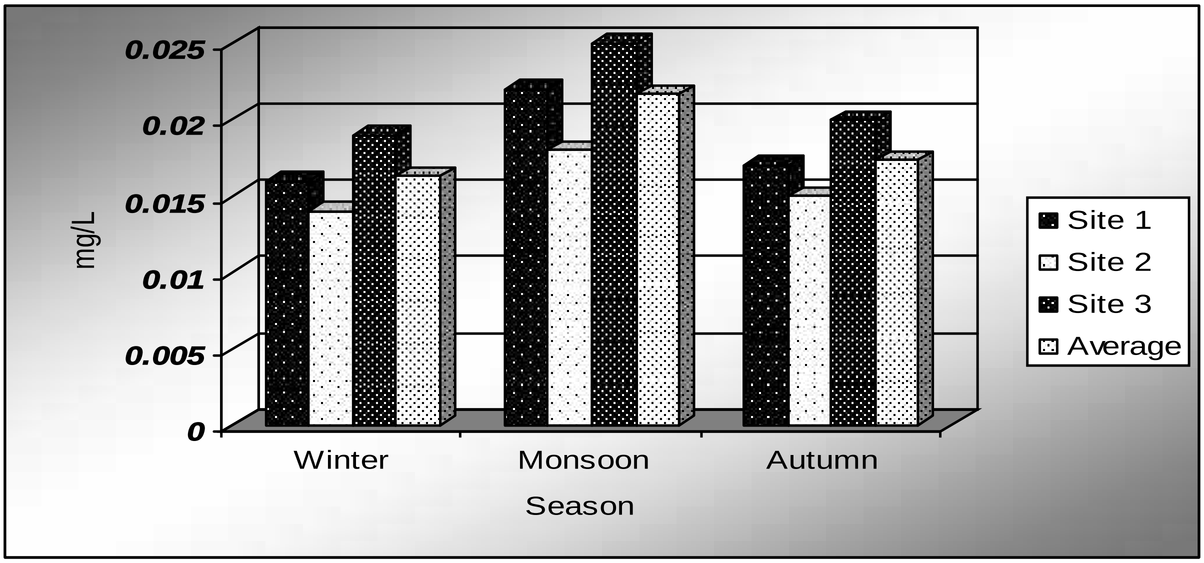


**Figure 17: N-$NO_3$ (mg/L) Concentration of Water at three Sites in three Seasons**

### 3.1.14 Gross Primary Productivity (GPP)

The average values of Gross Primary Productivity (GPP) in the water of Beeshazar Lake ranged from $0.041333 \pm 0.002517$ $O_2$ mg/L/hr (winter season) to $0.063 \pm 0.011$ $O_2$ mg/L/hr (monsoon season). The average GPP value was $0.047667 \pm 0.001528$ $O_2$ mg/L/hr in autumn season. Throughout the three seasons the GPP value was found highest at site 3 followed by site 1 and site 2.

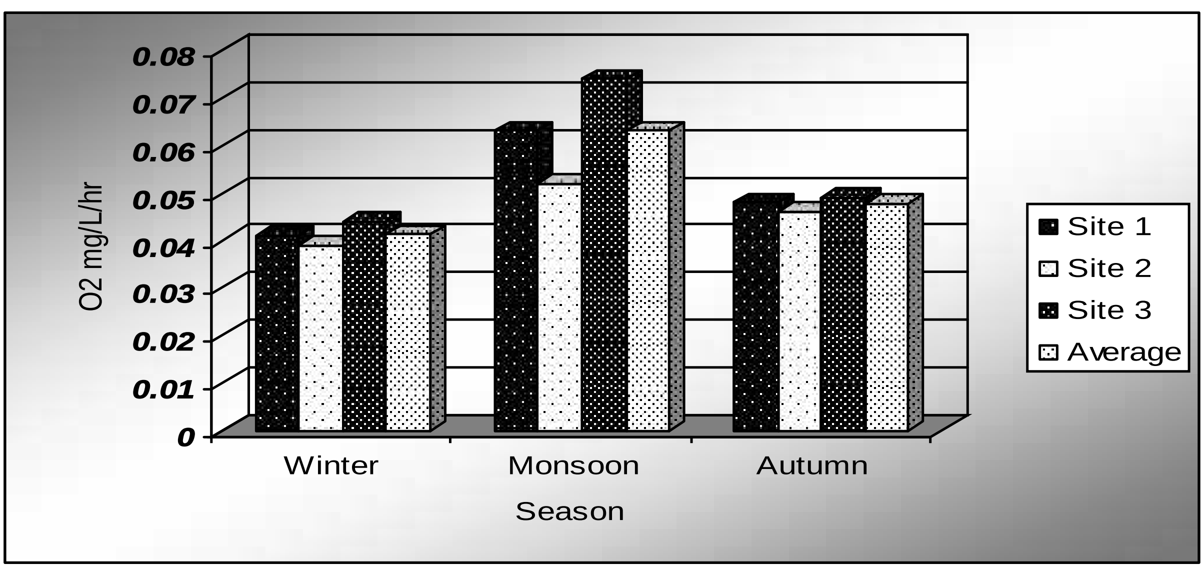


**Figure 18: GPP ($O_2$ mg/L/hr)** of **Water at three Sites in three Seasons**

In winter season, GPP value was 0.044 $O_2$ mg/L/hr at site 3, followed by 0.041 $O_2$ mg/L/hr at site 1 and 0.039 $O_2$ mg/L/hr at site 2. In monsoon season the GPP value was 0.074 $O_2$ mg/L/hr at site 3, followed by 0.063 $O_2$ mg/L/hr at site 1 and 0.052 $O_2$ mg/L/hr at site 2. Similarly, in autumn season, the GPP value was 0.049 $O_2$ mg/L/hr at site 3, followed by 0.048 $O_2$ mg/L/hr at site 1 and 0.046 $O_2$ mg/L/hr at site 2 (Figure 18). The average GPP value observed in all seasons was 0.0507±0.011203 $O_2$ mg/L/hr.

## 3.2 Physico-Chemical Analysis of Surface Soil Parameters

### 3.2.1 Soil Texture

The soil texture of the study area was found to be sandy loam, with 57.11±1.538 % sand, 28.08±1.665 % silt and 14.81±1.401 % clay content (Figure 19 & Appendix 3).

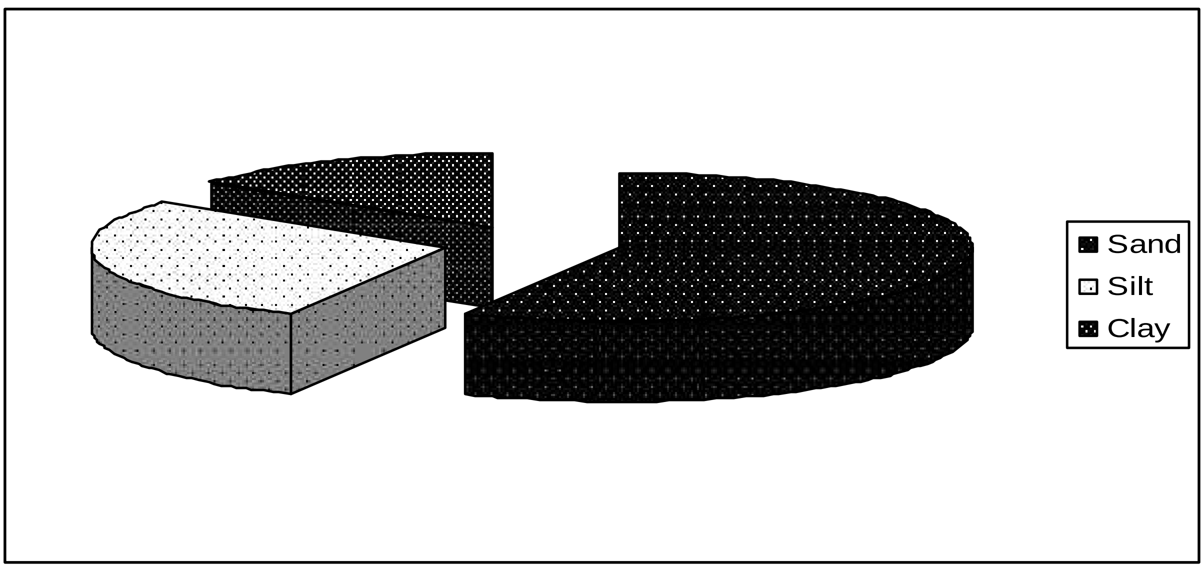


**Figure 19: Surface Soil Texture (%)**

### 3.2.2 pH

The soils of the study area were acidic in nature and its average value ranged from 5.27± 0.397 in monsoon season to 5.92± 0.468 in winter season. The pH value of the surface soil was 5.69 ±0.460 in autumn season. The average pH value observed in all seasons was 5.62±0.507 (Figure 20 & Appendix 3).

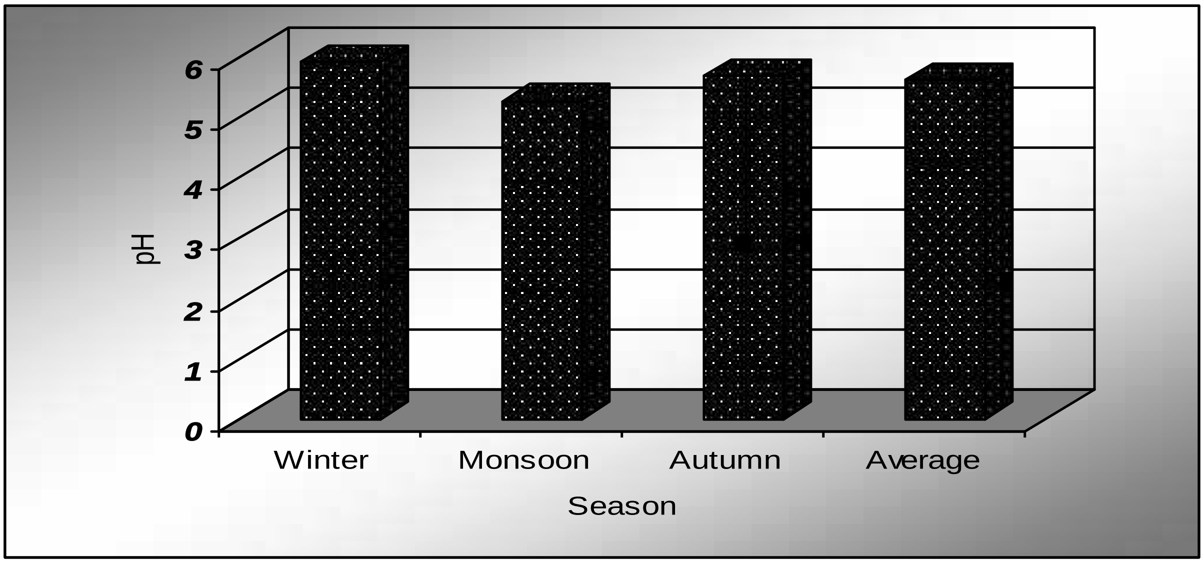


**Figure 20: pH of Surface Soil in three Seasons**

### 3.2.3 Conductivity

The highest average value of soil conductivity was observed in autumn season (54.4±14.576 µS/cm) and lowest in monsoon season (47.3±14.312 µS/cm). The average conductivity value of the surface soil was 50.9± 14.70 µS/cm in winter season. The average conductivity value of the surface soil observed in all seasons was 50.86±14.296 µS/cm (Figure 21 & Appendix 3).

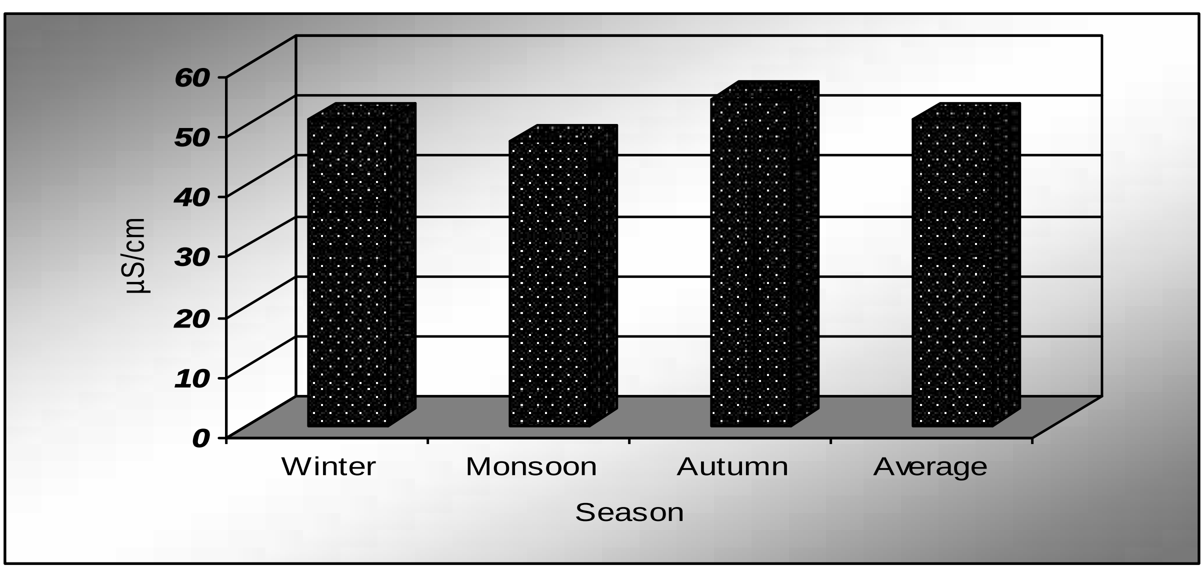


**Figure 21: Conductivity (µS/cm) of Surface Soil in three Seasons**

### 3.2.4 Organic Matters (O.M.)

The lowest average organic matter content in the soil of study area was observed in winter season (1.346±0.056 %) and highest in monsoon season (2.173±0.628 %). The average organic matter content of the surface soil was 2.122±0.561 % in autumn season. The average organic matter content of the surface soil observed in all seasons was 1.88±0.607 % (Figure 22 & Appendix 3).

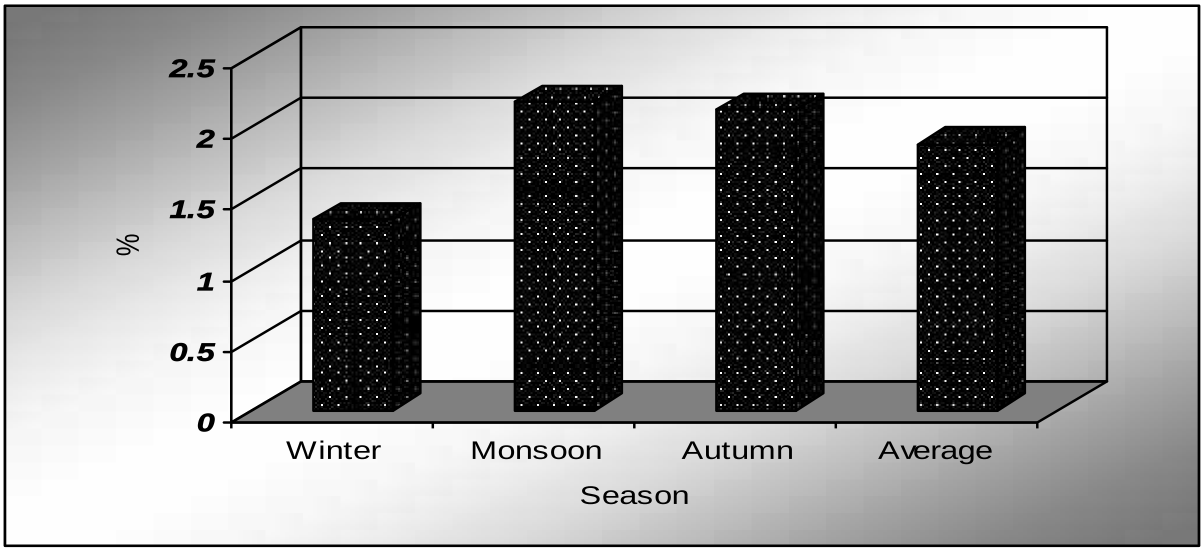


**Figure 22: O.M. (%) Content in Surface Soil in three Seasons**

### 3.2.5 Total Nitrogen

The lowest average total nitrogen content in the soil of study area was observed in monsoon season (0.078±0.0362 %) and highest in autumn season (0.120±0.021 %). The average total nitrogen content of the surface soil was 0.105±0.006 % in winter season. The average total nitrogen content of the surface soil in all seasons was 0.10±0.029 % (Figure 23 & Appendix 3).

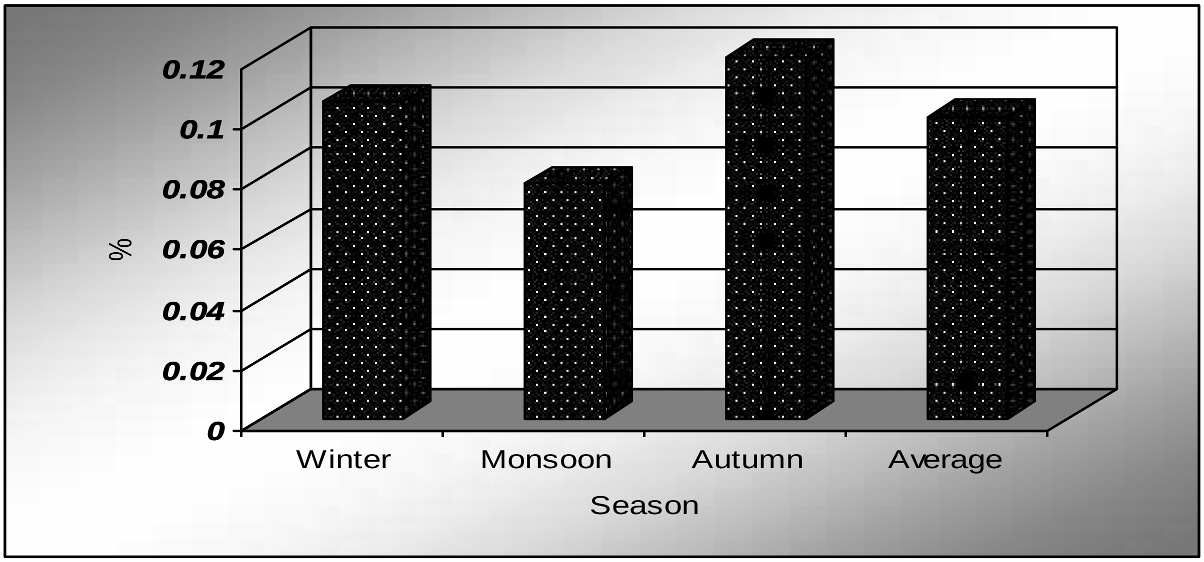


**Figure 23: TN (%) Content in Surface Soil in three Seasons**

### 3.2.6 Phosphorous

The average phosphorous content of the soil of the forest around Beeshazar Lake was observed maximum in monsoon season (112.09±13.796 $P_2O_5$ kg/ha) and minimum in winter season (34.14±3.636 $P_2O_5$ kg/ha). The average phosphorous content of the surface soil was 80.4±7.275 $P_2O_5$ kg/ha in autumn season. The average phosphorous content of the surface soil observed in all seasons was 75.543±33.755 $P_2O_5$ kg/ha (Figure 24 & Appendix 3).

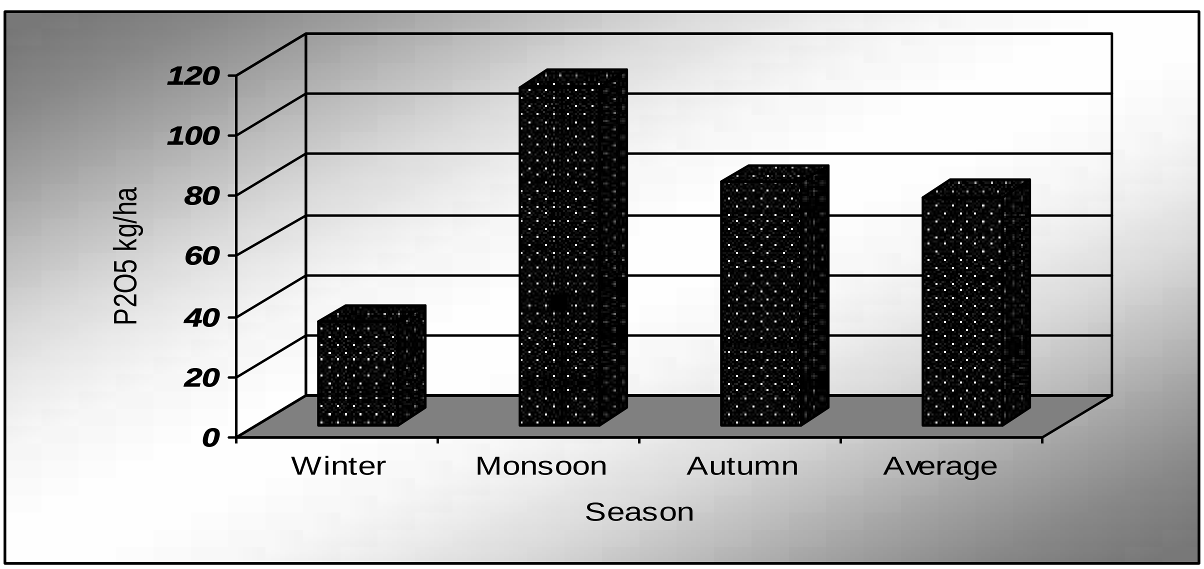


**Figure 24: Phosphorous ($P_2O_5$ kg/ha) Content in Surface Soil in three Seasons**

### 3.2.7 Potassium

The average potassium content of the surface soil of the forest around Beeshazar Lake was observed maximum in monsoon season (370.9±17.990 $K_2O$ kg/ha) and minimum in winter season (107.3±18.485 $K_2O$ kg/ha). The value of average potassium content of the surface soil was 291.12±18.387 $K_2O$ kg/ha in autumn season. The average value of potassium observed in all seasons was 256.466±113.646 $K_2O$ kg/ha (Figure 25 & Appendix 3).

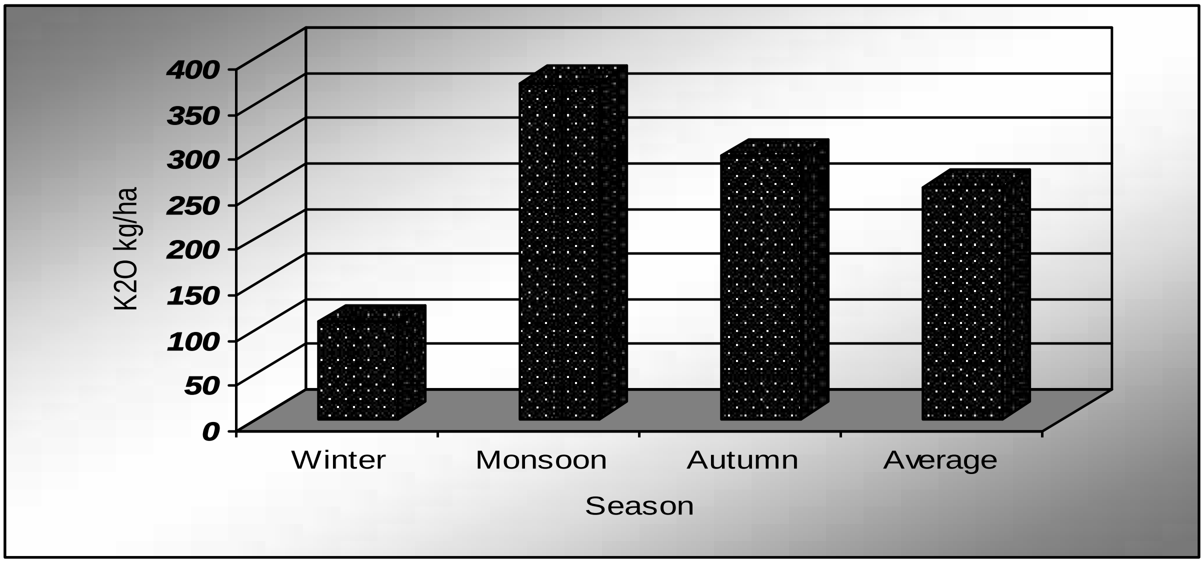


**Figure 25: Potassium ($K_2O$ kg/ha) Content in Surface Soil in three Seasons**

## 3.3 Analysis of Tree Species

### 3.3.1 Density

A total of 11 tree species were recorded in the forest around Beeshazar Lake, which belonged to 9 families (Table 3 & Appendix 4).The total density of all tree species recorded in the forest around Beeshazar Lake was 372.50 pl/ha. *Shorea robusta* had the highest density (268.75 pl/ha) and relative density (72.15 %) among the tree species recorded around the lake, followed by *Terminalia alata* with density 67.50 pl/ha and relative density 18.12 %, *Semecarpus anacardium* with density 8.75 pl/ha and relative density 2.35 %, *Cleistocalyx operculatus* with density 7.50 pl/ha and relative density 2.01 %. Similarly, *Trewia nudiflora* and *Dillenia pentagyna* both had density 5 pl/ha and relative density 1.34 %, *Syzygium cumini* had density 3.75 pl/ha and relative density 1.0 %, *Dalbergia latifolia* had density 2.50

pl/ha and relative density 0.67 %. *Careya arborea*, *Sapium insigne* and *Lagerstroemia parviflora* had the lowest density 1.25 pl/ha and relative 0.34 %. (Table 4 & Appendix 4)

### 3.3.2 Total Basal Area

The total basal area of all tree species recorded in the forest around Beeshazar Lake was 28.3246 $m^2$/ha. Among the tree species recorded in the forest around the lake, *Shorea robusta* had the highest total basal area (23.0587 $m^2$/ha), followed by *Terminalia alata* (3.942 $m^2$/ha), *Sapium insigne* (0.41375 $m^2$/ha), *Cleistocalyx operculatus* (0.252 $m^2$/ha), *Syzygium cumini* (0.2062 $m^2$/ha), *Trewia nudiflora* (0.1675 $m^2$/ha), *Semecarpus anacardium* (0.13825 $m^2$/ha), *Dillenia pentagyna* (0.0725 $m^2$/ha), *Dalbergia latifolia* (0.0325 $m^2$/ha), *Careya arborea* (0.025 $m^2$/ha) and *Lagerstroemia parviflora* (0.0162 $m^2$/ha). (Table 4& Appendix 4)

### 3.3.3 Total Volume

The total volume of all tree species recorded in the forest around Beeshazar Lake was 225.6159 $m^3$/ha. Among the tree species recorded in the forest around the lake, *Shorea robusta* had the highest total volume (188.125 $m^3$/ha), followed by *Terminalia alata* (31.93 $m^3$/ha), *Sapium insigne* (1.7998 $m^3$/ha), *Cleistocalyx operculatus* (1.2562 $m^3$/ha), *Syzygium cumini* (0.9573 $m^3$/ha), *Semecarpus anacardium* (0.56175 $m^3$/ha), *Trewia nudiflora* (0.41 $m^3$/ha), *Dillenia pentagyna* (0.3215 $m^3$/ha), *Dalbergia latifolia* (0.13775 $m^3$/ha), *Lagerstroemia parviflora* (0.0666 $m^3$/ha) and *Careya arborea* (0.05 $m^3$/ha). (Table 4 & Appendix 4)

### 3.3.4 Total Biomass

The total biomass of all tree species recorded in the forest around Beeshazar Lake was 196.6291 ton/ha. Among the tree species recorded in the forest around the lake, *Shorea robusta* had the highest total biomass (863 ton/ha), followed by *Terminalia alata* (27.852 ton/ha), *Sapium insigne* (1.563 ton/ha), *Cleistocalyx operculatus* (1.111 ton/ha), *Syzygium cumini* (0.841 ton/ha), *Semecarpus anacardium* (0.508 ton/ha), *Trewia nudiflora* (0.366 ton/ha), *Dillenia pentagyna* (0.2912 ton/ha), *Dalbergia latifolia* (0.1257 ton/ha), *Lagerstroemia parviflora* (0.060 ton/ha) and *Careya arborea* (0.045 ton/ha). (Table 4 & Appendix 4)

**Table 3: Tree Species Recorded**

| S.N. | Local Name | Scientific Name | Family |
|---|---|---|---|
| 1 | Bhalayo | *Semecarpus anacardium* | Anacardiaceae |
| 2 | Bhellar | *Trewia nudiflora* | Euphorbiaceae |
| 3 | Dhayaro | *Lagerstroemia parviflora* | Lythraceae |
| 4 | Jamun | *Syzygium cumini* | Myrtaceae |
| 5 | Khirro | *Sapium insigne* | Euphorbiaceae |
| 6 | Kumbhi | *Careya arborea* | Lecythidaceae |
| 7 | Kyamuna | *Cleistocalyx operculatus* | Myrtaceae |
| 8 | Saj | *Terminalia alata* | Combretaceae |
| 9 | Sal | *Shorea robusta* | Dipterocarpaceae |
| 10 | Satisal | *Dalbergia latifolia* | Leguminosae |
| 11 | Tantari | *Dillenia pentagyna* | Dilleniaceae |

**Table 4: Density/BA/Volume/Biomass**

| S.N. | Name of Tree Species | Density (pl/ha) | Rel. Den. (%) | Avg BA ($m^2$/tree) | Total BA ($m^2$/ha) | Avg Volume ($m^3$/tree) | Total Volume ($m^3$/ha) | Avg. Biomass (kg/tree) | Total Biomass (ton/ha) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | *Shorea robusta* | 268.75 | 72.15 | 0.0858 | 23.0587 | 0.7000 | 188.125 | 609.7233 | 163.8631 |
| 2 | *Terminalia alata* | 67.50 | 18.12 | 0.0584 | 3.942 | 0.4731 | 31.93 | 412.6294 | 27.8524 |
| 3 | *Semecarpus anacardium* | 8.75 | 2.35 | 0.0158 | 0.13825 | 0.0642 | 0.56175 | 58.0613 | 0.5080 |
| 4 | *Careya arborea* | 1.25 | 0.34 | 0.020 | 0.025 | 0.04 | 0.05 | 36.092 | 0.0451 |
| 5 | *Trewia nudiflora* | 5.00 | 1.34 | 0.0335 | 0.1675 | 0.0820 | 0.41 | 73.3696 | 0.3668 |
| 6 | *Sapium insigne* | 1.25 | 0.34 | 0.331 | 0.41375 | 1.43985 | 1.7998 | 1251.031 | 1.5637 |
| 7 | *Cleistocalyx operculatus* | 7.50 | 2.01 | 0.0336 | 0.252 | 0.1675 | 1.2562 | 148.1662 | 1.1112 |
| 8 | *Lagerstroemia parviflora* | 1.25 | 0.34 | 0.013 | 0.0162 | 0.0533 | 0.0666 | 48.3932 | 0.0604 |
| 9 | *Syzygium cumini* | 3.75 | 1.00 | 0.055 | 0.2062 | 0.2553 | 0.9573 | 224.4021 | 0.8415 |
| 10 | *Dalbergia latifolia* | 2.50 | 0.67 | 0.013 | 0.0325 | 0.0551 | 0.13775 | 0.3108 | 0.1257 |
| 11 | *Dillenia pentagyna* | 5.00 | 1.34 | 0.0145 | 0.0725 | 0.0643 | 0.3215 | 58.2447 | 0.2912 |
| | **Total** | **372.50** | **100.00** | | **28.3246** | | **225.6159** | | **196.6291** |

# CHAPTER IV

## Discussion

There was a distinct variation in the Secchi disc transparency value of the lake at three different sites in winter, monsoon and autumn seasons. Site 2 had the highest Secchi disc transparency value, which was followed by site 1 and site 3 in all the seasons. The highest Secchi disc transparency value at site 2 might be because the site was at the middle of the lake with comparatively less occurrence of plankton and was the deepest among the selected sites. The lowest value of Secchi disc transparency of the lake at site 3 might be due to the maximum discharge of sediment from the adjacent shoreline. The highest average value of Secchi disc transparency of water of Beeshazar Lake was observed in winter season (114±53.92 cm) and lowest in monsoon season (77.33±25.54 cm). The seasonal variations on the transparency value might be the result of various factors like growth of planktons, material derived from the shore of the wave action, erosion, the amount of wind induced turbulence keeping materials in suspension, the settling rate of suspended matter, etc (Yadav, 1989). The highest value of Secchi disc transparency in winter season might be related to the settling rate of the mineral, gradual decrease in growth of planktons due to low water temperature and lower total solids present in the water of the lake. Similarly, the lowest value of Secchi disc transparency in monsoon season might be due to maximum total solids in water discharged from the catchments and Khageri Irrigation Canal and increased growth of planktons. The average value of Secchi disc transparency observed in all seasons was 96.55±40.82 cm, which was quite consistent with observation made in previous studies by Jayana (1997); 119.9 cm and its value was observed higher than that observed by Burlakoti (2003); 62.97±34 cm in the same lake. The increase in Secchi disc transparency value than observed by Burlakoti (2003) might be because of the partial removal of macrophytes from the lake. The average value of Secchi disc transparency observed in the present study categorized the lake in eutrophic state (Forsberg & Ryding, 1980).

There was no such distinct variation in the surface water temperature of the lake at three different sites in winter, monsoon and autumn seasons. The highest average value of surface water temperature of Beeshazar Lake was recorded in monsoon season (30±1.0 $^{o}$C) and lowest in winter season (15.5±1.32 $^{o}$C), which was related with corresponding change in atmospheric temperature (Kundargar et al., 1996) as, the atmospheric temperature of the catchments area is the major controlling factor for the seasonal variation in the surface water temperature (Yadav, 1989). The average surface water temperature observed in all seasons was 23.16±6.36 $^{o}$C, which was more or less consistent with observation made by Jayana (1997); 27.28±2.1 $^{o}$C and Burlakoti (2003); 26.00±4.64 $^{o}$C in the same lake. As temperature is one of the most important factors for determining the lake productivity, the productivity of the lake should be higher in the rainy season as it had higher temperature within the optimum range. Changes in water temperature influences oxygen and calcium carbonate solubility (e.g. dissolved oxygen level); toxicant absorption; toxicity of some chemicals (natural or man made); viral persistence; density; conductivity; pH, partial pressure of $CO_2$; and saturation states of minerals (ANZECC/ARMCANZ, 2000). The increase of surface water temperature was followed by the increase of pH, which was also observed by Hussainy (1967) in Vihar Lake and Jayana (1997) in Beeshazar Lake.

There was no such distinct variation in the pH of the water of the lake at three different sites in winter, monsoon and autumn seasons. The highest average value of pH in the water of Beeshazar Lake was recorded in monsoon season (7.3±0.1) and lowest value in winter season (6.6±0.1). The decrease in pH values in cold season is mainly related to the high bicarbonate content, while the uptake of $CO_2$ by phytoplankton decreasing as a result of increasing in the concentration of bicarbonate (Abdel-Satar, 2005; El-Wakell & Wabby, 1970). Similar seasonal variation in pH value was also observed by Burlakoti (2003) in the same lake. Similarly, the lowest value of pH was found in winter season in Lake Rupa and Begnas of Pokhara Valley (Fisheries Research Center, 1994). Parajuli & Pradhanga (2002) also reported the highest pH value in the water of Nagdaha in monsoon season and lowest in winter season. The average pH value observed in all seasons was 6.92±0.31. The decrease in average pH value in the water of the lake i.e. 8.4 (Jones et al., 1989); 8.20±0.14 (Jayana, 1977); 7.04± 0.34 (Burlakoti, 2003) to 6.92±0.31 (Present Study) can indicate the increasing trend of free $CO_2$ concentration in the lake. The average pH value in the water of the lake indicates that the water is optimal for most organisms, as pH range of 6.5 to 8.2 is considered optimal (Field Ecology Lab, 2000) and when it drops to 4.5 or increase to 10.0, it supports low species diversity (Boyd, 1976; Anonymous, 1973). Also, Swingle (1967) stated that the pH level from 6.0 to 9.5 have been favorable for the aquatic animals living in an aquatic environment and below 5 or above 11 have been described as toxic and unsuitable for aquatic fauna. If pH declines below 6.5, few eggs hatch and aquatic insects level drops (UNESCO-IUCN, 2005). The close relation between surface water temperature and pH had been observed by Hussainy (1967) which supported the findings of the present study.

There was no such distinct variation on the conductivity of the water of the lake at three different sites in winter, monsoon and autumn seasons. The highest average value of conductivity in the water of Beeshazar Lake was recorded in monsoon season ($175.66 \pm 3.05$ μS/cm) and lowest in winter season ($140.33 \pm 1.15$ μS/cm). Similar seasonal variations were also observed by Burlakoti (2003) and Mishra & Saksena (1993). The high value of conductivity in monsoon season might be due to the liberation of ions from the decomposed plant debris and the low value in winter season might be due to the low rate of decomposition of organic matter and less input of various ions from catchment's area and Khageri Irrigation Canal. The average value of conductivity observed in all seasons was $159.44 \pm 15.57$ μS/cm, which was found lower than observed in previous studies by Burlakoti (2003); $182.89 \pm 33.47$ μS/cm and McEachern (1996); 185.8 μS/cm in the same lake. The close relation between surface water temperature and conductivity had been observed by Bhatt et al. (1999) which coincided the findings of the present study.

There was a distinct variation on the total solids content in the water of the lake at three different sites in winter, monsoon and autumn seasons. Site 3 had the highest total solids content value, which was followed by site 1 and site 2 in all the seasons. The fluctuations in the total solids content according to the sites were related to the Secchi disc transparency; as higher the value of Secchi disc transparency, lower would be the total solids content or vice versa. The highest average value of total solids in the water of Beeshazar Lake was observed in monsoon season ($556.66 \pm 66.98$ mg/L) and lowest in winter season ($246.66 \pm 30.55$ mg/L). The highest average value of total solids in the water of the lake in monsoon season might be because of the maximum discharge of various ions from the catchments and Khageri Irrigation Canal and high organic matter decomposition rate due to the favorable temperature. The average value of total solids observed in all seasons was 378.44±144.06 mg/L, which was more or less close to 350.22±254.07 mg/L observed by Burlakoti (2003) in the same lake.

There was no such distinct variation on dissolved oxygen concentration of the water of the lake at three different sites in winter, monsoon and autumn seasons. The highest average value of dissolved oxygen concentration in the water of Beeshazar Lake was observed in winter season (4.52±0.27 mg/L) and lowest in monsoon season (3.72±0.11 mg/L). Highest concentration of dissolved oxygen in winter season might be due to the low temperature with high aeration rate as; dissolution of oxygen from the atmosphere is the major source of oxygen in any water body. Similarly, lowest concentration of dissolved oxygen in monsoon season might be because of the high rate of decomposition of organic matter due to high temperature (Burlakoti, 2003; Badge & Verma, 1985). The average dissolved oxygen concentration observed in all seasons was 4.08±0.38 mg/L, which was found less than that observed by Jayana (1997); 7.10±1.0 mg/L and Burlakoti (2003); 6.26±1.43 mg/L in the same lake. The decrease in dissolved oxygen of the water of Beeshazar Lake than that reported in the previous studies might be due to the increase in organic pollution. The observed dissolved oxygen value in the present study was less than the tolerance limit of 6 mg/L (Kudesia, 1985). According to Yadav (2002), several researchers (e.g. Anonymous, 1973 & Boyd, 1976) have described that a minimum level of 2.5 mg/L dissolved oxygen is required for the existence of aquatic organisms but for the growth of most aquatic organisms about 5 mg/L dissolved oxygen may be necessary.

There was no such distinct variation on the free $CO_2$ concentration of the water of the lake at three different sites in winter, monsoon and autumn seasons. The highest average value of dissolved oxygen concentration in the water of Beeshazar Lake was observed in monsoon season (21.2±0.45 mg/L) and lowest in winter season (16.96±0.25 mg/L). The highest concentration of free $CO_2$ in monsoon season might be due to the increase in temperature, decomposition rate, respiration rate of living organisms (Verma & Agrawal, 1988; Rutterner,

1953) and atmospheric diffusion rate. The low value in winter season might be because of low temperature that decreased decomposition rate. The average free $CO_2$ concentration observed in all seasons was 19.02 $\pm$ 1.85 mg/L, which was found higher than that observed in previous studies in the same lake by Jayana (1997); 2.45 $\pm$ 0.93 mg/L and Burlakoti (2003); 11.70 $\pm$ 2.71 mg/L. It might be because of the increase in organic pollution in the lake. The high $CO_2$ may act indirectly to 'pump' mineral nutrients from the sediment into the water column as it stimulates macrophyte growth, nutrient uptake by macrophyte roots and nutrient translocation into shoots (Titus & Pagano, 2002). The sources of free $CO_2$ in an aquatic ecosystem are microbial decomposition, atmospheric diffusion and respiration by aquatic organisms. The aquatic organisms are greatly affected when free $CO_2$ concentration in water exceeds 25 mg/L (Yadav, 2002; Anonymous, 1973). The concentration of free $CO_2$ in water is inversely related with the dissolved oxygen content of water, thus the optimal level of dissolved oxygen in water cannot be maintained at higher level of free $CO_2$ (Yadav, 2002).

There was no such distinct variation on the total alkalinity concentration at three different sites in autumn season. The highest average value of total alkalinity concentration in the water of Beeshazar Lake was observed in winter season (122.33 $\pm$ 3.71 mg/L) and lowest in monsoon season (93.33 $\pm$ 3.78 mg/L). The seasonal fluctuations of total alkalinity value might be due to photosynthesis activity of macrophytes and algae (Mandal, 1979). The highest value of alkalinity in winter might be due to the low water level and dissolution of calcium carbonate from sediment, which increased the bicarbonate ions concentration in water. The average total alkalinity concentration observed in all seasons was 108.78 $\pm$ 12.89 mg/L, which was found lower than observed in previous studies in the same lake by Jones et al. (1989); 153 mg/L, Jayana (1997); 119 $\pm$ 17.21 mg/L and Burlakoti (2003); 164.44 $\pm$ 25.60 mg/L, which revealed some improvement of the water quality of the lake. The total alkalinity in the lake was only due to the functions of bicarbonates, as pH value ranged from 4.5 to 8.3 has practically no carbonates (Burlakoti, 2003; Jhingran, 1975). Higher ratio of bicarbonates over carbonates can be used as an index of higher productivity (Burlakoti, 2003; Khan & Quajjum, 1996). The total alkalinity value observed in the present study in three seasons categorized the lake as not acid sensitive lake as total alkalinity value less than 5 ppm is considered as very acid sensitive, 5 to 10 ppm is considered as acid sensitive, 10 to 20 ppm is considered as moderately acid sensitive and greater than 20 ppm is considered as not acid sensitive (www.skidmore.edu). Also the average total alkalinity value observed in the present study during three seasons showed that the water of the lake had fairly high total alkalinity, as Philipose (1959) categorized the static water on the basis of total alkalinity as low (4 to 50 ppm), moderately high (50 to 100 ppm) and fairly high (100 to 200 ppm). According to Spence (1964), the water bodies are divided into three categorizes according to total alkalinity value i.e. poor nutrient (1 to 15 ppm), moderately rich nutrient (16 to 60 ppm) and rich nutrient (>60 ppm). Hence, the total alkalinity value observed in the present study categorized the lake as nutrient rich lake according to the categorization of Spence (1964).

There was no such distinct variation on the total hardness concentration of the water of the lake at three different sites in monsoon and autumn season. The highest average value of total hardness concentration in the water of Beeshazar Lake was observed in autumn season ($75\pm1.0$ mg/L) and lowest in winter season ($31.73\pm3.71$mg/L). Highest concentration of total hardness in autumn season might be due to the decrease of water level by evaporation which increased the salt concentration and release of calcium and magnesium ions from the dead moluscan shell and bottom sediments. Low concentration of hardness in winter season might be because of the unfavorable temperature i.e. low temperature for calcium and magnesium release from moluscan shell and bottom sediments. The average total hardness concentration observed in all seasons was $59.57\pm21.01$ mg/L, which was found less than that observed in previous studies as reported by Jayana (1997); $183\pm19.44$ and Burlakoti (2003); $126.78\pm22.32$ in the same lake. The total hardness of the water of the lake in the present study showed that it was suitable for the growth of aquatic organisms as Swingle (1967) stated that the water having hardness of 15 mg/L or above may be considered suitable for the growth of aquatic animals and plants.

There was no such distinct variation on the chloride concentration of the water of the lake at three different sites in winter, monsoon and autumn seasons. The highest average value of chloride concentration of the water of Beeshazar Lake was observed in monsoon season ($11.87\pm1.54$ mg/L) and lowest in winter season ($9.81\pm1.49$ mg/L). The highest concentration of chloride in monsoon season might be due the maximum nutrient released from bottom sediment and high discharge rate from catchments and Khageri Irrigation Canal. Chloride serves as a useful marker for water movement and dilution (Brock, 1985). The average chloride concentration observed in all seasons was 10.79±1.45 mg/L, which was higher than that reported by Jayana (1997) in the same lake (7.10-8.5 mg/L). The chloride concentration is generally higher in waste water than in raw water because NaCl is common salt and passed unchanged through the digestive system. It enters surface waters naturally from sedimentary rocks.

There was no such distinct variation on the orthophosphate concentration of the water of the lake at three different sites in winter, monsoon and autumn seasons. The highest average value of orthophosphate concentration of the water of Beeshazar Lake was observed in monsoon season (0.094667±0.034443 mg/L) and lowest in winter season (0.049667±0.015695 mg/L). The seasonal variation of orthophosphate of the lake might be due to the fluctuation on surface runoff, weathering of rocks and soil decay and mineralization of plants and animals remains (Kennan and Job, 1980). The highest value of orthophosphate concentration in monsoon season might be due to the accumulation of ash and detritus from the catchments area and the rise in water temperature, which accelerated the return of orthophosphate from organic phosphate through the bacterial activity. The lowest value of orthophosphate level in winter season might be due to the use of nutrients by phytoplanktons (Gachter et al., 1974). Similar seasonal variation on the orthophosphate concentration in the water of Beeshazar Lake was also observed by Jayana (1997) in the same lake. The average orthophosphate concentration observed in all seasons was 0.07±0.029133 mg/L which was higher than the observed in previous studies by Jones et al. (1989) and McEachern (1996); 0.053 mg/L in the same lake. But its value observed in the present study was lower than that observed by Burlakoti (2003); 0.113±0.03 mg/L in the same lake which might be because of the partial clearance of macrophytes in the lake that decreased the deposition of organic matters in the bottom of the lake which released several nutrients. As, 0.025-0.1 mg/L of total phosphorous induce the onset of the eutrophic state of lake (Forsberg & Ryding, 1980), the lake according to the present study fell under eutrophic nature according to phosphorous concentration. Phosphorous availability often regulates the growth of algae in freshwater system (Golterman, 1977; Schindler, 1977) and consequently, high phosphorous concentrations are often associated with algal blooms, cyanotoxin accumulation, and reduce recreational use of fresh water lakes.

There was no such distinct variation on $N\text{-}NO_3$ and total nitrogen concentration of the water of the lake at three different sites in winter, monsoon and autumn seasons. The highest average value of $N\text{-}NO_3$ and total nitrogen concentration of the water of Beeshazar Lake was observed in monsoon season ($0.021667 \pm 0.003512$ mg/L & $2.026733 \pm 0.044049$ mg/L, respectively) and lowest in winter season ($0.016333 \pm 0.002517$ mg/L & $0.8721 \pm 0.05153$ mg/L, respectively). The highest value of $N\text{-}NO_3$ and total nitrogen in monsoon season might be due to the higher rate of organic matter accumulation from catchments and higher microbial decomposition of organic matter. The high inflow rate of water from Khageri Irrigation Canal to the lake might also increased $N\text{-}NO_3$ and total nitrogen in monsoon season. Similarly, the lowest value of $N\text{-}NO_3$ and total nitrogen in winter season might be due to the low microbial decomposition rate of organic matters due to the unfavorable water temperature and heavy utilization of nutrients by phytoplanktons (Ruttener, 1953). The average $N\text{-}NO_3$ and total nitrogen concentration observed in all seasons was $0.0184 \pm 0.003504$ mg/L and $1.4513 \pm 0.502311$ mg/L, respectively. Total nitrogen concentration observed in the present study was higher than the observed in previous studies i.e. 0.340 mg/L; Jones et al. (1989) and 0.445 mg/L; McEachern (1996) in the same lake. But its value observed in the present study was lower than that observed by Burlakoti (2003); $7.29 \pm 1.61$ mg/L in the same lake which might be because of the partial clearance of macrophytes in the lake that decreased the deposition of organic matters in the bottom of the lake which released several nutrients. But, still the lake was ranked as hypereutrophic in monsoon season and eutrophic in other two seasons, according to total nitrogen content of the water of the lake (Forsberg & Ryding, 1980).

There was no such distinct variation on the gross primary productivity (GPP) value of the water of the lake at three different sites in winter, monsoon and autumn seasons. The highest average value of gross primary productivity (GPP) of the water of Beeshazar Lake was observed in monsoon season ($0.063 \pm 0.011$ $O_2$ mg/L/hr) and lowest in winter season

(0.041333±0.002517 $O_2$ mg/L/hr). The highest GPP value in monsoon season might be because of the higher rate of organic matter decomposition due to the favorable temperature. An increase production gives rise to oxygen depletion in hypolimnium resulting in release of nutrients from the sediments (Burlakoti, 2003; Overbeck, 1989). The GPP increased with increased in pH and temperature of the water of the lake, which coincided the results of Karki (1988), Nasar & Duttamunshi (1975) and Sumitra (1969). The average GPP value observed in all seasons was 0.0507±0.011203 $O_2$ mg/L/hr.

The surface soil texture of the forest around Beeshazar Lake was found to be sandy loam which is suitable for good Sal regeneration and high trees (Poudel & Sah, 2003; Gupta, 1951). Sandy loam texture soil is very common in the Terai, and in Siwalik and Dun Valleys, all of which support dense Sal forests and other valuable timber trees (Poudel & Sah, 2003; Shah, 1999). The present result is similar to the finding of Shrestha (1997) in Chitrepani (Makwanpur), Sigdel (1994) in Chitwan National Park, Poudel & Sah (2003) in Eastern Nepal, Shrestha (2003) in Barandabhar Forest, Marasini (2003) in Churiya Forest in Rupandehi, Rana et al. (1988) in Central Himalaya Sal Forest, Chhetri (1997) in Chitwan National Park, Singh (1998) in Chitwan National Park and Gupta and Sukla (1991) in Sal forest in India. The similarity in results might be due to the similar type of forest vegetation i.e. Sal dominated forest.

The surface soils of the forest around Beeshazar Lake were acidic in nature and its average value ranged from 5.27± 0.397 in monsoon season to 5.92± 0.468 in winter season. The lowest soil pH value in monsoon season might be due to the production of organic acid (humic and fulvic acids) by the continuous decomposition of surface litter and high monsoon rainfall enhancing to leach basic cations from the surface horizons of the soils. The highest soil pH value in winter season might be due to the low decomposition rate and low soil moisture content. Similar seasonal variation on soil pH value was also observed by Shrestha (2003) in Barandabhar Forest and Singh (1998) in Chitwan National Park. Generally, low soil pH favors growth of Sal compared with high pH (Poudel and Sah, 2003; Bhatnagar, 1965; Mooney, 1947 and Giri 1997; Troup, 1921). Very high pH value i.e. >8 or very low pH value i.e. <4 of soil affects the distribution of Sal but the medium acidity doesn't show any significance effect on regeneration and distribution of the species (Marasini, 2003; Rauntiainen, 1994). The average pH value observed in all seasons was 5.62±0.507, which was quite close to those reported by Marasini (2003) in Churiya Forest in Rupandehi (4.5-5.5), Pant (1997) in two hill Sal forest (4-5.4), Poudel (2000) in community and government managed forest in Udayapur District (4.33-5.53) and more than those reported by Poudel & Sah (2003) in Eastern Nepal (4.33±0.39). Similarly, the pH range in the present study was lower than those reported by Sigdel (1994) in Chitwan National Park (5.9-6.42), Karki (1999) in Koshi Tappu Wild Life Reserve (6.4-7.1), Chhetri (1997) in Chitwan National Park (6.4-7.0) and Singh and Singh (1985) in Sal dominated central Himalaya forest (6.7-6.8). The variation of pH might be due to the different micro-climate of the areas.

The surface soil conductivity value did not show such distinct variation in three different seasons. Also, a distinct seasonal variation of soil conductivity was not observed in Sal forest of Gazipur in Bangladesh by Yousuf et al. (2001). The average conductivity value observed in the soil of the forest around Beeshazar lake in all seasons was 50.86±14.296 µS/cm. The highest average value of soil conductivity was observed in autumn season (54.4±14.576 µS/cm) and minimum in monsoon season (47.3±14.312 µS/cm). The lowest soil conductivity in monsoon season might be due to the heavy monsoon rains that dilute the nutrients in the soil environment.

The lowest average organic matter content in the surface soil of the forest around Beeshazar lake was observed in winter season (1.346±0.056 %) and highest in monsoon season (2.173±0.628 %). Similar seasonal variation of organic matter as in the present study was also reported by Singh (1998) in Chitwan National Park. The highest organic matter observed in monsoon season might be due to more litter accumulation and decomposition as decomposing litter adds organic matter to the soils (Poudel & Sah, 2003; Tamhane et al., 1964). The organic matter observed in the present study indicated the low soil fertility as organic matter ranging 1.74-2.33 % indicates low soil fertility (Poudel & Sah, 2003; Souheimo, 1995). But, Seth and Bhatnagar (1959) stated that higher amount of organic matter in the soil is some extend toxic for Sal. However, O.M. supplies energy and cell building constituents for the microorganisms (Poudel & Sah, 2003; Allison, 1973) and is critical factor in soil fertility (Poudel & Sah, 2003; Brady, 1984). The average O.M. value observed in all seasons was 1.88$\pm$0.607 %, which was more or less similar to the value observed in Barandabhar Forest (0.93-2.14 %) by Shrestha (2003), Churiya Forest in Rupandehi (1.33-2.45 %) by Marasini (2003), government managed and community forest in Udayapur District (1.01-2.42 %) by Poudel (2000), deforested area in the Terai (2.5 %) by Shrestha (1992), Riyale (1.8-4 %) by Shrestha (1996), tropical forest in Eastern Nepal (1.74-2.42 %) by Poudel & Sah (2003) but more than 0.23-1.8 % and 0.23-1.28 % in Chitwan National Park reported by Sigdel (1994) and Singh (1998), respectively. But its value was quite lower in the present study than that reported by Chhetri (1997) in Chitwan National Park (8.61-10.92 %), which might be due to the lower tree density and high human encroachment.

The lowest average total nitrogen content in the surface soil of study area was observed in monsoon season (0.078$\pm$0.0362 %) and highest in autumn season (0.120$\pm$0.021 %). The lowest total nitrogen content in monsoon season might be due to the heavy monsoon rainfalls that easily exhaust nitrogen from soil by runoff and leaching (Allen, 1964) as nitrate being highly soluble in water. The highest content of total nitrogen in autumn season might be due to the accumulation of nitrogen by biological fixation, lower rate of leaching and enhanced activity of nitrogen-fixing bacteria (Shrestha, 2003; Babour et al., 1999). There is evidence that the peak period of nitrogen availability from soil is during spring and autumn (Yousuf et al., 2001; William, 1969). Similar seasonal variation of nitrogen content in soil was also observed in the present study as reported in Barandabhar Forest by Shrestha (2003). The average total nitrogen concentration observed in all seasons was 0.10$\pm$0.029 %. The soil of the forest around Beeshazar Lake had medium total nitrogen content, as soil having 0.075-0.150 % total nitrogen in Terai is considered as medium nitrogen content soil (Pradhan, 1996). The value of total nitrogen in the present study was more or less equal to the value observed in Chitwan National Park (0.13 %) by Sigdel (1994), Churiya Forest in Rupandehi (0.052-0.153 %) by Marasini (2003); higher than those observed by Shrestha (2003) in Barandabhar forest (0.022-0.085 %) and Shrestha (1997) in Chitrepani, Makwanpur (0.04-0.09 %) and lower than that observed by Chhetri (1997) in Chitwan National Park (0.17-0.22 %).

Phosphorous content of the surface soil of the forest around Beeshazar Lake was observed maximum in monsoon season (112.09±13.796 $P_2O_5$ kg/ha) and minimum in winter season (34.14±3.636 $P_2O_5$ kg/ha). The maximum phosphorous content in monsoon season might be because of the forest fire (Shrestha, 2003; Sharma, 2000) that occurred in dry season, as fire releases the minerals in the soils in the form of ashes (Sharjo & Makhrawie, 1998). Similar seasonal variation on the phosphorous content of soil in Barandabhar Forest was also observed by Shrestha (2003). The average value of phosphorous observed in all seasons was 75.543±33.755 $P_2O_5$ kg/ha, which was close to 76.64-126.81 kg/ha observed by Poudel (2000) in government managed and community forest in Udayapur, 70.05-94.4 kg/ha observed by Shrestha (1997) in Chitrepani (Makwanpur), 41.04-87.79 kg/ha observed by Pant (1997) in two hill Sal forest and 36.78-184 kg/ha observed by Shrestha (2003) in Barandabhar Forest; as all these studies were carried out in Sal dominated forest. The soil of the forest around Beeshazar Lake had high phosphorous content, as soil having >55 $P_2O_5$ kg/ha is considered as high phosphorous content soil (Pradhan, 1996).

Potassium content of the surface soil of the forest around Beeshazar Lake was observed maximum in monsoon season (370.9±17.990 $K_2O$ kg/ha) and minimum in winter season (107.3±18.485 $K_2O$ kg/ha). The soil of the forest around Beeshazar Lake had medium potassium content, as soil having 110-280 $K_2O$ kg/ha is considered as medium potassium content soil (Pradhan, 1996). The maximum potassium content of the soil in monsoon season might be because of the maximum accumulation of potassium in the form of biomass. Similar seasonal variation on the potassium content of soil of Barandabhar Forest was also observed by Shrestha (2003). Potassium content of the soil in present study was found quite higher as potassium in soil is higher in good Sal regeneration areas (Poudel and Sah, 2003; Bhatnagar, 1965). The average value of potassium observed in all seasons was 256.466±113.646 $P_2O_5$ kg/ha, which was very close to 233.86-267.73 kg/ha reported by Poudel & Sah (2003) in Eastern Nepal, 329.57-399 kg/ha reported by Karki (1999) in Koshi Tappu Wildlife Reserve, 123.6-397 kg/ha reported by Shrestha (2003) in Barandabhar Forest, 210-439 kg/ha reported by Sigdel (1994) in Chitwan National Park, 137-204 kg/ha reported by Shrestha (1996) in Riyale, 196-449 kg/ha reported by Marasini (2003) in Churiya Forest in Rupandehi, 196.83-267.73 kg/ha reported by Poudel (2000) in government managed and community forest in Udayapur and 221-265 kg/ha reported by Pant (1997) in two hill Sal forest.

A total of 11 tree species were recorded in the forest around Beeshazar Lake, which belonged to 9 families. *Shorea robusta* dominated among the tree species recorded in the present study. Shrestha (2003) recorded 18 tree species in Barandabhar Forest (Chitwan) including 5 tree species in the forest around Beeshazar Lake. The total density of all tree species recorded in the forest around Beeshazar Lake was 372.50 pl/ha, which was higher than the total density of trees recorded by Shrestha (2003); 85 pl/ha-250 pl/ha and Subedi (1994); 300 pl/ha in Barandabhar Forest (Chitwan). It might be because the sites in the present study were not only selected in the human influenced area (deforested area) but also in the dense forest areas around Beeshazar Lake. *Shorea robusta* had the highest density (268.75 pl/ha) and relative density (72.15 %) and *Careya arborea*, *Sapium insigne* and *Lagerstroemia parviflora* had lowest density (1.25 pl/ha) and relative density (0.34 %). The density of *Shorea robusta* recorded in the present study was more or less close to that recorded by Chhetri (1997); 300 pl/ha in Chitwan National Park. Shrestha (2003) also reported highest density (180 pl/ha) and relative density (72 %) of *Shorea robusta* in same forest around Beeshazar Lake. The density of *Shorea robusta* recorded by Shrestha (2003) in the same forest was quite lower than recorded in the present study. But the relative density of *Shorea robusta* was close to the relative density of *Shorea robusta* recorded in the present study. But the density of *Shorea robusta* recorded in the present study was very much higher than that recorded by Singh (1998); 28.44 pl/ha in Chitwan National Park (Northern Side).

The total basal area of all tree species recorded in the forest around Beeshazar Lake was 28.3246 $m^2$/ha. In the present study, *Shorea robusta* had the highest total basal area (23.0587 $m^2$/ha) but the average basal area of *Sapium insigne* (0.331 $m^2$/tree) was recorded highest even than that of *Shorea robusta* (0.085 $m^2$/tree). The average basal area of *Shorea robusta* recorded in the present study was found lower than that recorded by Sharma (2004); 0.297 $m^2$/tree in Barandabhar Forest (Chitwan). The lowest total basal area was recorded for

*Lagerstroemia parviflora* (0.0162 $m^2$/ha). As basal area in an indication of the natural fertility of the site (Brueving, 1968), the highest total basal area of *Shorea robusta* was mainly due to its greater number. *Sapium insigne* having lowest density in the present study had the highest average basal area because it had the highest average diameter at breast height (dbh) than that of other tree species. Shrestha (2003) also reported the higher average basal area of *Syzygium cumini* and *Terminalia alata* than that of *Shorea robusta* in Barandabhar Forest.

The total volume recorded of all tree species in the forest around Beeshazar Lake was 225.6159 $m^3$/ha. The highest volume was recorded for *Shorea robusta* (188.125 $m^3$/ha) and lowest for *Careya arborea* (0.05 $m^3$/ha). The highest volume obtained by *Shorea robusta* was mainly due to its greater number and fair height of trees. The average volume of *Sapium insigne* (1.43978 $m^3$/tree) was recorded highest even than that of *Shorea robusta* (0.700 $m^3$/tree) that might be because of the higher average basal area and higher height of *Sapium insigne*.

The total biomass of all tree species recorded in the forest around Beeshazar Lake was 196.6291 ton/ha. The total biomass of tree species recorded in the present study was lower than 1038.16 ton/ha reported by Sejuwal (1994) in Sal Forest of Chitwan National Park. The lower total biomass in the present study might be due to the lower density, lower dbh and lower height of the trees in the forest around Beeshazar Lake, as the trees were at an intermediate stage of growth and only small portions are matured. In the present study, *Shorea robusta* was recorded highest total biomass (163.86 ton/ha) and *Careya arborea* had the lowest total biomass (0.045 ton/ha). The total biomass of *Shorea robusta* reported in the present study was higher than 109.8 ton/ha reported by Sejuwal (1994) for *Shorea robusta* in Chitwan National Park. The average biomass of *Sapium insigne* (1251.031 kg/tree) was recorded highest even than that of *Shorea robusta* (609.7233 kg/tree) that might be because of the higher average volume of *Sapium insigne*.

From the results of density, total basal area, total volume and total biomass of trees in the forest around Beeshazar Lake, it can be concluded that the maximum portion of the forest was at intermediate stage of growth and only the small portion was at mature stage.

# CHAPTER V

# Conclusions and Recommendations

## 5.1 Conclusions

Physico-chemical analysis of the water of Beeshazar Lake showed that the certain water parameters i.e. pH, conductivity, temperature, free $CO_2$, total solids, GPP, chloride, orthophosphate, nitrate and total nitrogen reached at the peak level in monsoon season. Similarly, total alkalinity, D.O. and transparency value of the water of the lake reached at the peak level in winter season; while total hardness value reached at the peak level in autumn season. The observed value of physico-chemical parameters of the water of the lake in the present study suggested the threatened status of the lake. High nutrients (N & P) content and low transparency of the water of the lake ranked the lake as eutrophic to hypereutrophic in nature.

Analysis of surface soil parameters of the forest around Beeshazar Lake showed that certain parameters i.e. organic matter, phosphorous and potassium reached at the peak level in monsoon season. Similarly, soil conductivity and total nitrogen reached at the peak level in autumn season, while soil pH reached at the peak level in winter season. The soil of the study area was found acidic and of sandy loam texture. There was low organic matter content, medium total nitrogen and potassium contents and high phosphorous content in the soil of the forest around the lake.

A total of 11 tree species belonging to 9 families were recorded in the forest around Beeshazar Lake. Quantitative analysis of tree species of the forest showed that the forest was Sal (*Shorea robusta*) dominated forest. The associated tree species were Saj (*Terminalia alata*), Bhalayo (*Semecarpus anacardium*), Kumbhi (*Careya arborea*), Bhellar (*Trewia nudiflora*), Khirro (*Sapium insigne*), Kyamuna (*Cleistocalyx operculatus*), Dhayaro (*Lagerstroemia parviflora*), Jamun (*Syzygium cumini*), Tantari (*Dillenia pentagyna*) and Satisal (*Dalbergia latifolia*). *Shorea robusta* had the highest density and relative density among the tree species recorded in the forest around the lake, followed by *Terminalia alata*, *Semecarpus* *anacardium*, *Cleistocalyx operculatus*, *Trewia nudiflora*, *Dillenia pentagyna*, *Syzygium cumini*, *Dalbergia latifolia*, *Careya arborea*, *Sapium insigne* and *Lagerstroemia parviflora*. Among the tree species recorded in the forest around the lake, *Shorea robusta* had the highest total basal area followed by *Terminalia alata*, *Sapium insigne*, *Cleistocalyx operculatus*, *Syzygium cumini*, *Trewia nudiflora*, *Semecarpus anacardium*, *Dillenia pentagyna*, *Dalbergia latifolia*, *Careya arborea* and *Lagerstroemia parviflora*. Similarly, among the tree species recorded in the forest around the lake, *Shorea robusta* had the highest total volume and total biomass followed by *Terminalia alata*, *Sapium insigne*, *Cleistocalyx operculatus*, *Syzygium cumini*, *Semecarpus anacardium*, *Trewia nudiflora*, *Dillenia pentagyna*, *Dalbergia latifolia*, *Lagerstroemia parviflora* and *Careya arborea*.

## 5.2 Recommendations

- A detail study focusing the major issues of Beeshazar Lake System should be conducted to assess the root causes that threat the wetland ecosystem.

- An appropriate action with the participation of local communities should be applied from the government level to solve the major issues that threat the wetland ecosystem.

- The area should be developed as a model nature reserve for the wetland of national significance and major tourist spot of Chitwan National Park that might uplift the socio-economic status of local people.

- Illegal poaching of wild animals, illegal fishing and over utilization of forest resources should be strictly checked by the authorized body.

- Awareness programmes should be launched focusing the sustainable natural resource management, so that the local people could play significance role to conserve the natural resources of Beeshazar Lake System.

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