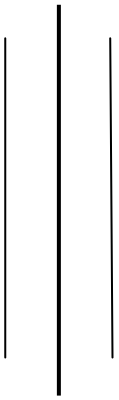
Assessment of Carbon Stock in Association with Nutrient Content in the Littoral Zone of Kalchuman Lake of Manaslu Conservation Area



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Letter of Recommendation

This is to certify that the dissertation entitled **"Assessment of Carbon Stock in Association with Nutrient Content in the Littoral Zone of Kalchuman Lake of Manaslu Conservation Area"** submitted by **Ms. Anju Rana** for the partial fulfillment of M.Sc. Degree in Environmental Science is based on the study carried out by her under our supervision. The dissertation or a part thereof has not been previously submitted for any other degree. Therefore I recommended this thesis.

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Letter of Approval

The dissertation presented by **Ms. Anju Rana** entitled **"Assessment of Carbon Stock in Association with Nutrient Content in the Littoral Zone of Kalchuman Lake of Manaslu Conservation Area"** has been accepted as a partial fulfillment of requirement for the completion of Master's degree in Environmental Science.

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Abstract

Carbon stock is the quantity of carbon contained in a "pool" and lakes are considered to be the potential sink of carbon dioxide. But, despite of the potentiality, their role as carbon sequester is not clearly known in case of Nepal yet. Additionally, variability of carbon sequestration with reference to nutrients in wetlands is also attracting more attention. Thus, the study was carried out to assess carbon stock and its association with nutrient content in the high altitude lake (3690 m) i.e. Kalchuman Lake of Manaslu Conservation Area. Along with it, the morphometric and catchment characteristics were also studied.

For the study of morphometric and catchment characteristics, georeferenced map of the study area was used with Arc GIS. And systematic random sampling method was used for sampling of 10 samples of water, 20 samples of sediments (10 from littoral zone and 10 from bank), 10 samples of macrophytes and 10 samples for litters. Then the carbon content and nutrient content were determined by the standard lab methods given by APHA (1995), Trivedy & Goel (1986), Jackson (1973) and Motasara & Roy (2008). Finally Pearson correlation and multiple regression analysis were done using SPSS to determine the relationship between carbon and nutrient content in water and sediment samples.

From the morphometric and catchment characteristic analysis it was found that the lake was not completely circular and its catchment area was found to be dominated by grasslands. The carbon stock in water, soil, macrophytes and litters of the lake were 15.57±5.9 mg/l, 23.56±8.29 ton/ha, 0.04 ton/ha and 0.18 ton/ha respectively which showed that among all components, soil was the highest storehouse of carbon. Though, carbon storing capacity of soil varied with the texture.

The concentration of nutrients in the lake was found to be lower in comparison to the lakes at lower altitude (Rara 2990m) and higher than that of higher altitude lakes (Tilitso 4690m and Gokyo 4750m). However, the correlation and regression analysis depicted the nitrogen as the factor with the highest predictive capacity for carbon.

Thus, the lake was found to be significant storehouse of carbon though its relationship was stronger with nitrogen content. Hence, conservation of lakes is necessary and lakes should also be enrolled in the CDM mechanism to mitigate the climate change.

Keywords: Carbon, Correlation, Climate change

Acronyms

AEC	Aquatic Ecology Center
ANOVA	Analysis of Variance
APHA	American Public Health Association
masl	Meter Above Sea Level
CDM	Clean Development Mechanism
CO_2	Carbon dioxide
DOAD	Department of Agriculture Development
DOC	Dissolved Organic Carbon
EC	Electrical Conductivity
FAO	Food and Agricultural Organization
FAS	Ferrous Ammonium Sulphate
GHG	Green House Gas
GIS	Geographic Information System
GoN	Government of Nepal
GPS	Global Positioning System
Gt	Giga tons
HMG/N	His Majesty's Government of Nepal
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
MoFSC	Ministry of Forest and Soil Conservation
MCA	Manaslu Conservation Area
NAST	Nepal Academy of Science and Technology
NCCKMC	Nepal Climate Change Knowledge Management Centre
NLCDC	National Lakes Conservation Development Committee

OC	Organic Carbon
OECD	Organization for Economic Co-operation and Development
OM	Organic Matter
PVC	Polyvinylchloride
POC	Particulate Organic Carbon
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total phosphorous
UNEP	United Nation Environment Programme
WBI	World Bank Institute
WECS	Water and Energy Commission Secretariat
WHO	World Health Organization
WMO	World Meteorological Organization

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Chapter 1: Introduction

1.1 Background

Carbon sequestration is the removal of carbon from the atmosphere by storing it in the biosphere (IPCC 2000). It encompasses all forms of carbon storage. Oceans, plants and underground geologic formations all function as significant reservoirs for CO_2. There are mainly three types of sequestration terrestrial, geologic and ocean. Among them ocean or the water body is considered to be the largest sink of the world as the world's oceans contain approximately 50 times the amount of carbon stored in the atmosphere and nearly 10 times the amount stored in plants and soils (Sabine *et al.* 2004). It act as a net sink for approximately 1.7 billion metric tons of CO_2 per year. About 45% of the CO_2 released from fossil fuel combustion and land use activities during the 1990s has remained in the atmosphere, while the remainder has been taken up by the oceans, vegetation, or soils on the land surface (IPCC 2007).

Without the ocean sink, atmospheric CO_2 concentration would be increasing more rapidly. Ultimately, the oceans could store more than 90% of all the carbon released to the atmosphere by human activities, but the process takes thousands of years (Archer *et al.* 1998). The Kyoto protocol has been promoting the carbon sequestration as a form of carbon offset. One of the important mechanisms is the Clean Development Mechanism (CDM) in which certain amount is paid for offsetting CO_2 from the atmosphere which is usually helpful for upgrading the livelihood of poor people. Similarly, some countries also seek to trade emission rights in carbon emission markets, purchasing the unused carbon emission allowances of other countries. But in the Clean Development Mechanism, only afforestation and reforestation are eligible to produce certified emission reductions (CERs) in the first commitment period of the Kyoto Protocol (2008–2012). Carbon sequestration by water body, or oceans or wetlands has not been mentioned yet.

1.1.1 Wetlands

Wetlands are areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters (Ramsar convention secretariat, 2006). Also known as "Simsar" in Nepal,

wetlands are the areas that lie between the land and deep water and remain submerged under water, seasonally or throughout the year. In most of the wetlands, water level fluctuates seasonally instead of being stable, a property that accounts for making wetlands highly productive environments. Productivity among wetlands varies depending on the type of the wetland, climatic condition and vegetation communities. In general, all kinds of biogeochemical processes as well as emission and removal of greenhouse gases in wetlands are controlled and governed by the degree of water saturation, physical environment and nutrient availability (IPCC 2006).

Nepal has several wetlands and almost all of them are freshwater wetlands. The Department of Agriculture Development (1992) has estimated that wetlands including water bodies of different size and characteristics occupy 743563 ha i.e. roughly 5% of Nepal's total land area (Table 1.1).

Table 1.1: Estimated area of various wetlands

Wetland types	**Estimated area (ha)**	**Percent**
Rivers	395000	48.35
Lakes	5000	0.61
Reservoirs	1500	0.18
Marginal/Swamp/Ghole	11500	1.4
Village ponds	5954	0.72

(DOAD 1992)

Acccording to Bhuju *et al.* (2010), there are 5358 lakes in Nepal, among them 42 % lies above 3000m asl. Nepal showed its conservation commitment by signing the Ramsar Convention on April 17, 1988 (HMGN/MoFSC 2003). Till 2009, nine wetland sites of Nepal have been included in Ramsar list covering total area of 34,455 hectares (Table 1.2).

Of the nine Ramsar sites in Nepal, four are high altitude lakes. These are the Gokyo and the associated wetlands (4700-5000m), Shey Phoksundo (3555m; DNPWC 2006), Lake Rara (2990m) and Lake Gosaikunda (4054-4620m). Maipokhari Lake (2150 m) in the eastern district of Ilam has been recently included in the Ramsar site. This shows not only a clear indication of importance of high altitude lakes and their ecological services but also the Government's commitment to strengthen conservational measures and wise use of these wetlands.

Table 1.2: A brief overview of Ramsar sites in Nepal

Ramsar sites	Area (ha)	Location (District)	Zone	Elevation (m)
Koshi Tappu	17500	Koshi	Tarai	90
Beeshazari and associated lakes	3200	Chitwan	Tarai	285
Ghodaghodi lake area	2563	Kailali	Tarai	205
Gokyo and associated lakes	7770	Solukhumbu	Himal	5000
Gosaikunda and associated lakes	1030	Rasuwa	Himal	4700
Jagdishpur Reservoir	225	Kapilbastu	Terai	195
Mai Pokhari	90	Illam	Mid Hill	2100
Phoksundo Lake	494	Solpa	Himal	3610
Rara Lake	1583	Mugu	Himal	2990
Total	34455			

(Kafle 2008)

1.1.2 Carbon sequestration and wetlands

Carbon sequestration is actually the process of capturing and securely storing carbon dioxide or other form of carbon emitted from the global energy system to mitigate or defer global warming and avoid climate change. The process is based on the capturing carbon dioxide from large point sources, such as fossil fuel, power plants and storing them in such a way that it does not enter the atmosphere. So far various form i.e. geo-sequestration, ocean sequestration, mineral sequestration, terrestrial-sequestration has been envisioned for permanent storage of CO_2. Among the different sequestration, the terrestrial-sequestration which involves the capture of atmospheric C through photosynthesis and storage in biota, soil and wetlands has been receiving

wide attention as they provide more economic and environmental friendly solutions to tackle climate change problem.

Recent studies show that lake and associated wetland, despite of their small fraction (3%) of the surface of the earth, play a significant role in the global C cycle (Dean & Gorham 1998) thereby providing more economic and environmental friendly solutions to tackle climate change problem. Studies carried out by different researches showed that tropical wetlands store more carbon than temperate (Bernal 2008). Similarly, peat land has been recognized worldwide as highly important for carbon storage since it accounts for nearly 50% of the terrestrial carbon storage with only 3% cover of world's land area (Table 1.3).

Table 1.3: Average carbon stocks of various biomes

Biomes	**Plant (ton/ha)**	**Soil(ton/ha)**	**Total(ton/ha)**
Tropical forest	54	55	109
Temperate forest	25	43	68
Boreal forest	29	153	182
Tundra	3	57	60
Cropland	1	36	37
Tropical Savannas	13	52	65
Temperate grassland	3	105	108
Semi desert/Desert	1	19	20
Wetland	19	287	306

(Source: Gorte 2009)

The carbon storage capacity of any lake largely depends upon the balance between carbon input and output. Recently, studies are focused on wetlands as they acts as an extremely active sites for carbon input (organic matter production), output (decomposition, methanogenesis etc.) and storage of considerable amounts of carbon received from the terrestrial environment (Schlesinger 1997). Inputs in the wetlands can occur in three states: as gas (photosynthesis, algae and macrophytes), solids (dust, water and soil erosion, and animal biomass), and dissolved substances (dissolved organic carbon, dissolved inorganic carbon). Similarly, outputs occur in three states: as gas through respiration (carbon dioxide); as solids (e.g., harvesting of vegetation such as hay cropping); and as dissolved substances in water through surface and

ground water flow (dissolved organic carbon and dissolved inorganic carbon). However, these processes are also largely determined by the several other factors such as lake size, topography and geological position of lake, hydrological regime; lake productivity and climatic condition (Schlesinger 1997) etc.

1.1.3 Nutrients in wetlands

Wetlands serve as sites for transformation of nutrients such as nitrogen (N) and phosphorus (P). Dissolved inorganic forms of N and P are assimilated by microorganisms and vegetation and incorporated into organic compounds. Phosphorus undergoes a variety of chemical reactions with iron (Fe), aluminum (Al), and calcium (Ca) that depend on the pH of the soil, availability of sorption sites, redox potential, and other factors. These biogeochemical reactions are important in evaluating the nutrient condition (oligotrophic, mesotrophic, eutrophic) of the wetland and its susceptibility to nutrient enrichment (EPA 2008).

Wetlands also serve as nutrient sinks, filtering out bioavailable nutrients from receiving waters, storing them in sediments and converting them to organic forms, which may be stored or exported in less available forms (Reddy *et al*. 1993). And the storage of the nutrients increases with nutrient loading into the wetlands (Wetzel 2001).

1.2 Research statement and justification

Carbon dioxide (CO_2) is the most important anthropogenic GHG. Its annual emissions have grown between 1970 and 2004 by about 80%, from 21 to 38 gigatonnes (Gt), and represented 77% of total anthropogenic GHG emissions in 2004 (IPCC 2007). This is accelerating the rate of increase in earth's surface temperature leading to the climate change. Although, Nepal's share in CC is negligibly small and is responsible for only about 0.025% of annual greenhouse gas emissions (NAPA\MOE 2010), Nepal is highly vulnerable to CC impacts. It is reported that all Nepal temperature has increased by about 1.8°C increase from 1975 – 2006 and 2006 was reported warmest year in record (Shrestha *et al*. 2012). And this has been creating several problems in the ecosystem as well as livelihood. Thus, one of the proposed mitigation strategies for the climate change is carbon (C) sequestration in terrestrial ecosystems like forest, rangeland or the grassland and in the aquatic ecosystems like lakes.

In Nepal, wetlands occupy approximately 5% of the total land area with 0.61% lakes, some of these being of international importance. To show the commitment in the conservation of the wetlands, Nepal had become signatory to the Ramsar Convention on Wetlands on 17th April 1988. But still, neither there is basic information like morphometry and catchment characteristic nor there quantification of carbon stored in them, despite of their significant role. The case is truer especially in case of high altitude lakes because of their remoteness (Bhat *et al*. 2011). Therefore, the focus needs to be stretched out and there is a need determine morphometry and catchment characteristic with the potential of the lake to sequester carbon thereby integrating scientific methods (Adhikari *et al*. 2009).

On the other hand, the interaction among the cycles of carbon (C), nitrogen (N) and phosphorous (P) in the wetlands is attracting more attention (Blodau 2002) because it can contribute information on the variability of carbon sequestration and its relation to climate change (Gorham 1991; Heathwaite 1993; Blodau 2002). But, the relationship between the carbon content and the nutrient are poorly understood. Thus this research was conducted in the high altitude lake (3690m) i.e. Kalchuman Lake to determine the carbon content and its relationship with nutrients. And since the littoral zone of a lake comprises a biogeochemically active, terrestrial-aquatic interface where carbon dioxide (CO_2) are exchanged with the atmosphere and organic carbon is transferred to the lake (Larmola 2005). The littoral zone of the lake was chosen for the study.

1.3 Objectives

The broad objective of the study was to determine the potential of the lake to store carbon and its link with nutrients, while the specific objectives are:

- To study the morphometric and catchment characteristics of the lake
- To determine carbon content in water, soil, macrophytes and litter of the lake
- To determine the nutrient content (NPK) in water, soil, macrophytes and litter of the lake
- To study the relationship between the carbon content and the nutrient content.

1.4 Limitations

- Since the area was remote and easily inaccessible, boat could not be used and limited samples were collected only from the littoral and accessible zones of the lake.

Chapter 2: Literature Review

2. Literature review

2.1 Global Climate change

Global climate change is a natural phenomenon; it is well known that the earth's average surface temperature has been increasing since the end of the Little Ice Age. The average temperature of the earth's surface did not vary much between 1940 and 1970 AD, but a continuous rise in temperature has been recorded since 1970. Over the past few decades, human activity has significantly altered the atmospheric composition, leading to climate change of an unprecedented character. The linear warming trend over the 50 years from 1956 to 2005 (0.13 [0.10 to 0.16]°C per decade) is nearly twice that for the 100 years from 1906 to 2005 (IPCC 2007).

The IPCC in its third assessment report revealed that the rate and duration of warming in the 20th century was larger than at any other time during the last thousand years. The average surface temperature of the earth has increased between 0.3ºC and 0.6ºC over the past hundred years and the increase in global temperature is predicted to continue rising during the 21st century. It is estimated that a 1ºC rise in temperature will cause alpine glaciers worldwide to shrink as much as 40 per cent in area and more than 50 per cent in volume as compared to 1850 (IPCC 2001b).

2.2 Climate change in Nepal

In context of Nepal, the global emission of greenhouse gases is negligible and is about 0.13 tonnes per capita CO_2 emission. Although the Per Capita CO_2 emission of Nepal is negligible, Nepal still faces the consequences of global warming including rise in air temperature. It is reported that all Nepal temperature is increasing steadily and 32 years temperature data analyzed showed about 1.8°C increase from 1975 – 2006 and in 2006 was reported warmest year in record (Shrestha *et al.* 2012). However, such minimal change in air temperature can result in rate of rapid melting of glaciers and Glacier Lake.

Evidence also shows that temperature changes are more pronounced at higher altitudes. Analysis of air temperature trends across 49 stations in Nepal between 1977 and 1994, for example, reveals a rising trend clearly and the change is much more pronounced in the higher altitude regions of the country (Shrestha *et al*. 1999). This has a twofold impact on the mass balance of glaciers. First, higher temperatures

contribute to accelerate melting. Second, higher temperatures can cause precipitation to occur in liquid instead of solid form, even at very high altitudes. The absence of a blanketing layer of snow on the ice lowers its albedo, making glaciers further prone to radiative melting (Mool *et al*. 2001a).

2.4 Wetlands and carbon sequestration

Carbon dioxide is by far the most important greenhouse gas influenced directly by human activities (Bruce *et al*. 1998). The entrance of CO_2 into a wetland system (mainly via photosynthesis), gives it the ability to moderate CO_2 concentrations in the atmosphere by sequestering this carbon and thus taking it out from the trophic exchange system (Bondavalli *et al*. 2000).

The balance between carbon input (organic matter production) and output (decomposition, methanogenesis, etc.), and the resulting storage of carbon in the wetland depends on several factors such as the topography and landscape position of the wetland, the hydrologic regime, the type of plants present, the temperature (and therefore climate) and moisture of the soil, the pH and salinity, and the morphology of the wetland (Collins & Kuehl 2001). This long list of factors indicates that carbon accumulation in wetlands is a delicate process influenced by many variables. However, wetlands represent a significant sink for carbon and are a key element to consider when managing and weighing earth's carbon pedological pool.

Wetland characteristics lead to the accumulation of organic matter in the soil and sediment serving as carbon (C) sinks and making them one of the most effective ecosystems for storing soil carbon (Schlensinger 1997). It has been estimated that different kinds of wetlands contain 350-535Gt C, corresponding to 20-25% of world's organic soil carbon (Gorham 1998).

The organic matter present in sediments derives from depositional processes and is both autochthonous and allochthonous in origin (Olesen *et al*. 1954).

According to Adhikari *et al*. (2009), the total soil organic carbon pool was estimated to be 1550 Pg in the world and wetlands are responsible for 450 Pg, one-third of this pool according to Mitsch & Gosselink (2007), despite the fact that they only cover 6-8% of the land and freshwater surface (Roulet 2000). Hence, wetlands represent one of the largest biological carbon pools and play a decisive role in the global carbon cycle (Chmura et al. 2003; Mitra *et al*. 2005).

Carbon is stored in wetland sediments over the long term. Short-term stores are in existing biomass (plants, animals, bacteria and fungi) and dissolved components in the surface and groundwater (Wylynko 1999).

Post *et al*. (1982) reported that wetlands cover a total land area of 280 million ha worldwide, and the average carbon density in wetland is 723t per ha. This amounts to a total of 202.44 billion tons of carbon in wetlands of the world. Of various wetland types, peat land has been recognized worldwide as highly important for carbon storage since it accounts for nearly 50% of the terrestrial carbon storage with only 3% cover of world's land area (Adhikari *et al*. 2009).

Tropical wetlands store 80% more carbon than temperate wetlands according to findings based on the studies conducted to compare ecosystems in Costa Rica and Ohio. Tropical wetland in Costa Rica accumulated around 1 ton of carbon per acre (2.63t/ha) per year, while the temperate wetland in Ohio accumulated 0.6 tons of carbon per acre (1.4t/ha) per year (Bernal 2008).

Bridgham *et al*. (2006) studied fresh water mineral soil wetlands and estuarine wetlands of North America and Concluded that North American wetlands contain about 220 Pg C, most of which is in Peat. Gorham (1991) calculated the pool in boreal and subarctic peatlands alone to be 460Gt. Whereas the carbon stored in peat could be 44-71% of the whole carbon held in the terrestrial biota (737 Gt), according to Matthews *et al*. (1987).

Wetland soils can be inorganic or organic in nature depending on the concentration of organic matter. Macrophyte dominated wetlands can produce a peat soil (Graham *et al*. 2005), a relatively un-decomposed organic soil that contains more than 20 to 35 percent burnable organic material (Mitsch & Gosselink 2000).

Carbon accumulation is largely due to un-decomposed plant material such as lignin and cellulose. Typically, 48% of biomass is organic carbon; therefore the largest storage component of biomass is the same as the largest storage of organic carbon. The largest storage of carbon in wetlands occurs in organic soil formation (Kayranli 2010).

The loss and degradation of carbon reservoirs (e.g., wetlands) can result in releases of large amounts of greenhouse gases into the atmosphere, negating gains made from emission reductions (Wylynko 1999).

2.3 Wetlands and nutrients

The lentic ecosystem or the lakes posses high nutrient content and this relatively high nutrient concentrations found in the sediments of the lentic environments may be associated with inputs of organic matter from the well-developed littoral zones, as well as from phytoplankton (Thomaz *et al*. 1997a).According to Mitsch & Bouchard (1998), additional nutrients, such as N and P also get accumulated in the wetlands as ORWRP wetland's open water zones was found to posses slightly greater accumulation of N and P, which may be associated with greater algal production in open water areas. In case of the sediments from the wetlands, the important source of them may be the detritus originating from aquatic macrophytes and phytoplankton (Odum & Cruz 1967). Additionally, nutrient accumulation of P is usually due to adsorption on organic particles and co-precipitation with $CaCO_3$. Along with the biomass accretion, the accumulation of nutrient is also dependent upon the type of biomass present in the aquatic ecosystem, and the pattern of inundation. Table 4 provides values for nutrient sequestration in the wetlands.

Table 2.1: Type of carbon accumulation in wetlands

Type of accumulation	**Value (kg/hectare/yr**	**Reference**
OC	830	Euliss 2007
C fixation	5000-11000	Bouchard & Mitsch 1998
C sequestration	8300-30500	Mitsch & Gosselink 2000
TC in peat	3300-20900	Graham *et al.* 2005
TN in peat	280-1730	Graham *et al.* 2005
TP in peat	12-75	Graham *et al.* 2005

Graham *et al.* (2005) also recorded relatively steady rate of nutrient accumulation in Klamath peat marshes for past 100 years. It was found that P accumulation in peat may be facilitated by the constant addition of organic material for P adsorption and that C and N are stored in the biomass material. Anderson & Mitsch (2006) also found that the rate of nutrient retention increased or stayed the same over a 10-year period. However total P was bound to sediment and was exported from the wetlands during periods of heavy inundation.

According to Burke (2011), high nutrient load was found in the constructed wetlands and when combined with low-cost operations, produce a system designed to offset greenhouse gas emissions. For shallow lakes, main reason for the increased level of nutrients are intense sediment–water contact, as well as increased mineralization rates resulting from relatively high sediment temperatures (Jeppesen *et al.* 1991).

2.4 Global Carbon Markets at a Glance

Global carbon market has expanded quickly over past two years (WBI 2007). Worldwide, carbon trading reached a total value of $59.2 billion in 2007, up 80% over 2006 (Chafe 2008). In 2006 about 23.7 million tons of CO_2 equivalent were exchanged on the voluntary market, including about 10.3 million tons exchanged through Chicago Climate Exchange. Although the carbon market is almost ad hoc in most developing countries with transactions at various levels, carbon trading systems are more sophisticated in industrialized nations especially in Organization for Economic Co-operation and Development (OECD) countries.

2.5 Association between carbon and nutrients

Dissolved organic matter or the carbon is a matter of great concern in aquatic environment since it is often associated with nutrients such as carbon, nitrogen, phosphorus, and sulfur (Michalzik *et al*. 2001). And the DOM is regarded as an important source of mineralizable C, N, and P; its production is also affected by N and P status in soils, such as their chemical forms and availability (Silveira 2005).DOC is also known as a strong complexing agent for many toxic metals such as iron, copper, aluminum, zinc and mercury. DOC increases the weathering rate of minerals and solubility and consequently affects the mobility and transport of many metals and organic contaminants (Niemirycz *et al*. 2006). Nitrogen retention in lakes does not only occur as incorporation in sedimenting organic matter, but also largely via denitrification, where nitrate is exploited for bacterial turnover of organic matter (Wetzel 2001). Thereby nitrate converts to ammonium or to free nitrogen (N_2) that may diffuse into the water phase and the atmosphere, and thus is lost from the system. According to Martinova (1993), N concentration in the sediments is controlled by the presence of organic matter, with 90% (or even more) of the N in sediment existing in organic forms. Higher the organic matter content in sediment, the lower is the alkaline phosphorus activity (Venkateswaran & Natarajan 1983, Jin *et al*. 2006).

Chapter 3: Materials and Methods

3.1 Study area

The study area is the Kalchuman Lake of Manaslu conservation area (MCA). It is located in Prok VDC, northern part of Gorkha district and lies between 28˚30'14"N to 28˚ 30' 25" N and 84˚ 47' 55"E to 84˚ 48' 57"E.

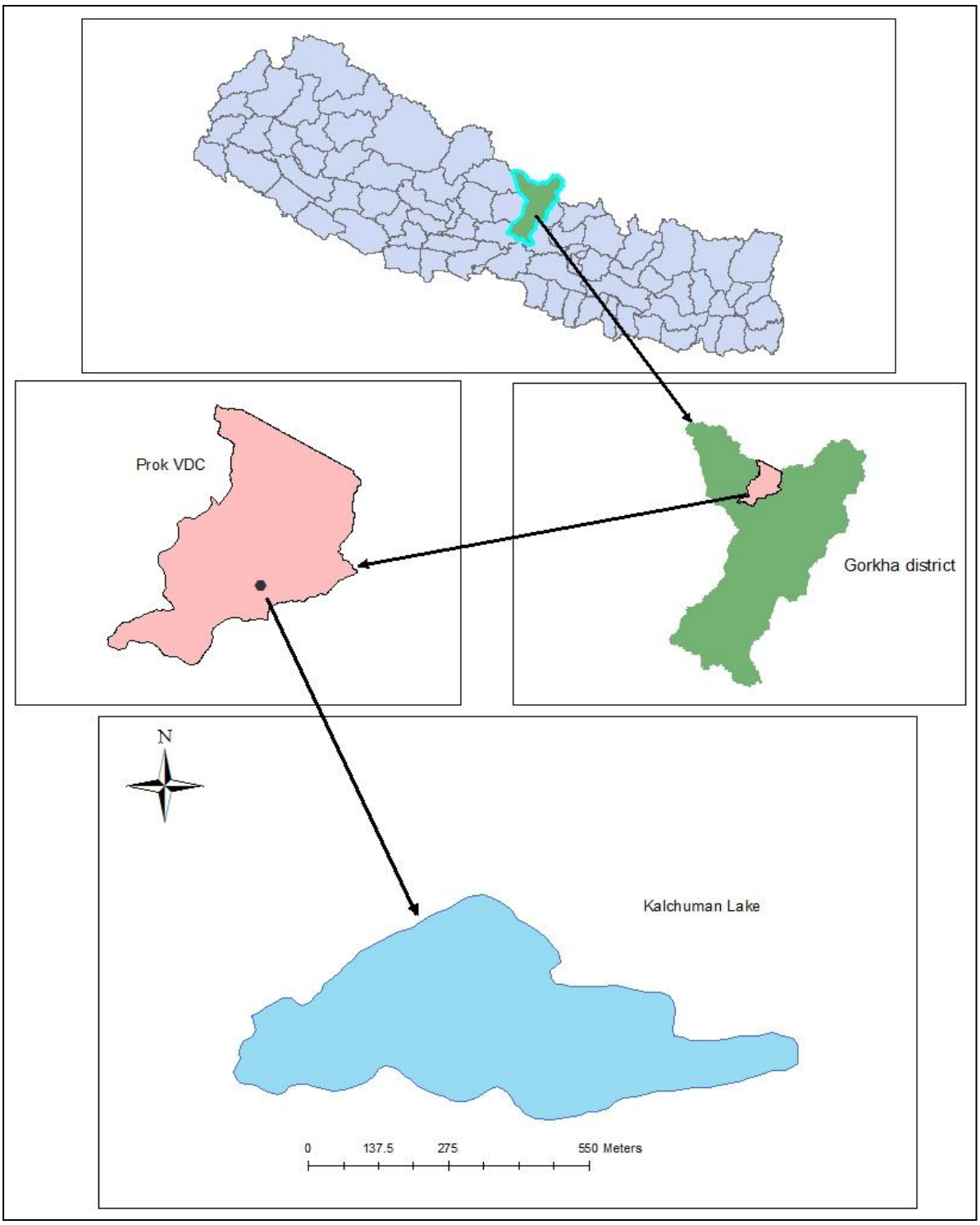


Figure 3.1: Study Area

It posses a fragile but highly diverse natural resource base and a rich cultural environment. It was declared as a conservation area in December 1998. It includes seven VDCs: Sirdibas, Chhekampar, Bihi, Prok, Lho and Samagaon. Traditionally, MCA is divided into three valleys: Tsum Valley, the eastern part consisting of two VDCs viz. Chumchet and Chhekampar Nubri Valley, the middle part consisting of four VDCs viz. Bihi, Prok, Lho and Samagaun VDCs; and Kutang Valley, the southern part consisting three VDC i.e. Sirdibas and small portions of Prok and Bihi VDCs (NTNC 2013). Each valley has distinct dialect, customs and traditions.

The area also shows a large altitudinal variation that ranges from 600 meters to 8,163 meters (Mt. Manaslu) and covers six climatic zones: the tropical and sub-tropical zone, (1,000–2,000 meters); the temperate zone (within elevation range of 2,000–3,000 meters); the sub-alpine zone (3,000–4,000 m); the alpine meadows (4,000–5,000 m) and the arctic zone (4,500 m). The region harbours a mosaic of habitats for 38 species of mammals, 201 species of birds, 13 species of butterflies and 5 species of reptiles (NTNC 2011).

3.1.1 Climate

The wet seasons in MCA starts from June to September whereas dry seasons from October to May and an average rainfall of the area is 1,900 millimeters (74 inches) per year (DNPWC 2010). A significant area of it is surrounded by a series of high mountains/ extension of the great Himalaya protecting it much from the southern monsoon cloud. Maximum and minimum temperature of the district is 33.5^{o}C and 2.3^{o}C respectively from 1982 to 2011 and the average yearly rainfall from 1981 to 2011 was 1256.55mm (DHM 2012).

3.1.2 Geology

The Manaslu mountain has rocks of Tibetan-Tethys zone (Dahal 2006). This zone is composed of sedimentary rocks, such as shale, limestone, and sandstone ranging in age from Cambrian to Eocene. This zone in some area is found as continuous deposits of higher Himalayan zone without normal fault (Dahal 2006).The topography of the region consists of steep rocky mountains. The land is poor and not suitable for agricultural crops. Local agriculture barley supplies sufficient food for three months in the MCA.

3.1.3 Vegetation

The vegetation of the area can be divided into three main categories, based mainly on the altitude. Eleven types of vegetation are recorded in this area. They are: upper alpine meadow, moist alpine scrub, trans Himalayan steppe, trans Himalayan high alpine vegetation, birch- rhododendron forest, fir forest, larch forest, upper temperate blue pine forest, temperate blue pine forest, temperate mountain oak forest, lower temperate oak forest and Chir pine and broad leaved forest.

Forest vegetation is mostly confined to the moist north facing slope of valley floor. However isolated stands of *Juniperus indica* are found at the lower elevation of southern slope. On the north facing slope, the lower belt (3500m) has *Larix himalaica, Abies spectabilis, Sorbus microphyll, Salix* sp., and Juniper forest while the upper belt (above 3800m) has *Betula utilis* and *Rhododendron campanulatum*.

Moist alpine scrub was dominated by *Rhododendron lepidotum, Rhododendron anthopogan, Astragalus* spp., *Cotoneaster, Juniperus indica, Juniperus recurva, Berberis* spp., *Caragana* spp. and *Ephedra***.** There are approximately 2000 species of plants and 13 types of forest.

3.2 Methodology

3.2.1 Sampling

Systematic random sampling method was used for the determination of sampling sites. Total ten sampling sites were selected among which the starting point was chosen randomly then other samples were taken in a set interval of 250m from that point.

Among these ten sites, site 1 (28º30'16"; 84º47'55") lied in east outlet region. Site 2 (28º30'16"; 84º48'05"), 3 (28º30'15"; 84º48'12") and 4 (28º30'14"; 84º48'16") lied in vegetation region. Site 5 (28º30'15"; 84º48'21") lied in west outlet region. Site 6 (28º 30'17"; 84º48'21") and 7 (28º30'21"; 84º48'18") lied in inlet region and site 8 (28º 30'24"; 84º48'12"), 928º 30'25"; 84º48'04") and 10 (28º30'20"; 84º48'57") lied in snow region.

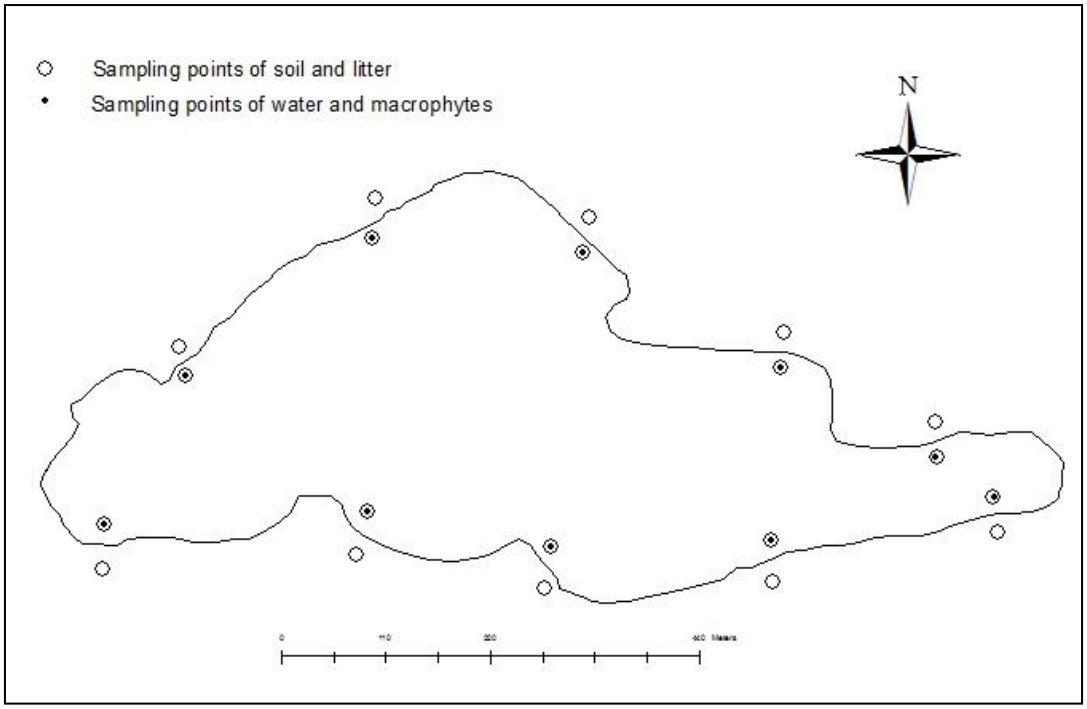


Figure 3.2: Sampling Sites

3.2.1.1 Water sampling

Water sampling was carried out for the determination of the total carbon content, and as well as the nutrient (NPK) present in the water with some parameters such as temperature, pH and the conductivity. For TOC, 100ml PVC bottle was used. First, the bottle was cleaned with distilled water and then with the lake water. After that the bottle was dipped about 20 cm below the surface of the water of the sampling plots to collect the water sample. After that 1M HCl was added to the water. Then, the bottled was sealed and labeled with the permanent marker. Similarly, another PVC bottle of 500 ml capacity was used for collecting the water sample to analyze the nutrient content that is Nitrogen (N), phosphorus (P) and Potassium (K). Then it was preserved by adding 2 ml concentrated Sulphuric acid.

3.2.1.2 Soil sampling

The soil sample from each sampling point of the lake was taken out by using the soil corer of definite volume (diameter of 7 cm and length of 8.5cm). Then they were weighted, stored in the polythene bags with the zipper and brought in the laboratory for the determination of carbon content, moisture content, bulk density, NPK, texture, pH etc.

3.2.1.3 Macrophytes sampling

For the sampling of the macrophytes, a quadrate of 0.25 m^2 was laid down in each sampling plots (Westlake 1965 and 1971) and the plants within the quadrate were carefully taken out and washed to remove adhered periphyton as well as organic and inorganic particulate matter. Then they were stored and put in the polythene bags and labeled. The fresh weight of the plants was taken in the field.

3.2.1.4 Litter sampling

For litter, 0.25 m^2 quadrant was laid down. The litters within the quadrates were collected and their fresh weight was taken at the site. The litter were then put in the polythene bags and brought in the laboratory for the determination of carbon content by loss on ignition methodology. A quadrate of the same size was also laid down in the adjacent area and the litter within the quadrate were collected, weighed, labeled and stored in the polythene bag for the further analysis.

3.2.2 Measurement

3.2.2.1 Morphometry of the lake

For the study of the morphometric features of the Lake, the geo-referenced map was used with Arc GIS 9.3 and then maximum, minimum and mean length, breadth were calculated. Similarly, the surface area, perimeter, diameter, shoreline length and development were also measured with the help of GIS.

Since the measurement of the mean depth and volume of the lake was not possible insitu due to the lack of boat, they were estimated using the equation-derived from the regression analysis of Area – mean depth and area – volume relationship between various glacier lakes (Budhathoki *et al*. 2010).

$\mathbf{D}=0.094\mathbf{A}^{0.452}$ ---------- (Eqn.1), where $r^2 = 0.939$

$\mathbf{V} = 0.094\mathbf{A}^{1.453}$---------- (Eqn.2), where $r^2 = 0.990$

Where, D= Mean depth of lake

A= Area of the lake

V= Volume of water

3.2.2.2 General water quality of the lake

a. pH

The pH of water was measured with the help of the standard pH meter (OAKTON^{R}). It was dipped into the water for about 2-3 minutes and the concurrent reading was noted down.

b. Temperature

The temperature of the water was measured with the help of the standard mercury thermometer. It was dipped into the water for around 2 minutes and the reading was noted down.

c. Conductivity

The conductivity was measured with the help of the conductivity meter (HI 8633) from HANNA Instruments. The electrodes of the conductivity meter was washed with the distilled water and then rinsed with the sample and it was immersed into the beaker containing sample and the stable conductivity value from the meter was noted down.

d. Turbidity

The turbidity of the sample was found out with the help of turbidometer (HI 8633 from HANNA Instruments). First of all the calibration of the instrument was done with the help of turbidity free distilled water. Then the turbidity tube was washed properly with the distilled water and then the tube was filled with the sample and the value was noted down from the meter.

3.2.2.3 General feature of the soil

a. Moisture

For the moisture content in the soil sample the oven drying method was used. The 1 gm sample was weighted and placed in the dry crucible into the hot air oven at 105˚C for 2 hours and the weight of the sample was again taken. The prior weight divided by the oven dry weight multiplied by 100 gave the moisture content in the sample.

b. pH

The pH of the soil sample was measured with the help of the pH meter. About 20 gram air dried sample was taken in the 50 ml dry beaker. And then 20 ml distilled

water was added and shaked for 10 minutes. Then it was left for 10 minutes and again stirred for 2 minutes and the pH was measured with the pH meter.

c. Texture

The texture was determined with the help of physical and mineralogical hygrometric method (Bouyoucos 1962). About 100 gram of the soil sample was taken in 250 ml beaker and sufficient amount of water was added to cover the soil sample. Then 10 ml of sodium hexametaphosphate solution was added and stirred with the help of the rod and left overnight. Then the next day all the materials were transferred into a liter measuring cylinder and the distilled water was added up to the mark and stirred for about 10 minutes. Then immediately the hygrometer was immersed into the cylinder and the reading was noted down at 40 seconds. At the same time the mixture temperature was noted down and the mixture was allowed to settle for 5 hours and the hygrometer reading and the temperature was noted down.

(Silt+ Clay)%= Hygrometer reading at 40 sec = 0.3 × (t-20)ºC
Clay% = Reading at 5 hrs + 0.3 × (t-20)ºC
% sand = 100 -% (Clay+ Silt)
% silt = % (Clay+ Silt) -% Clay

After this the texture was determined with the help of triangular chart.

3.2.2.4 Carbon Content

a. Water

For the determination of carbon content, the water samples were preserved by using concentrated sulphuric acid and TOC was measured with the TOC analyzer (Shimadzu TOC-VE Total Organic Carbon Analyzer) present in Aquatic Ecology center, (AEC) Dhulikhel, Kathmandu. TOC analyzer is based on 680 °C Combustion Catalytic Oxidation Method. Dissolved Organic Carbon (DOC) was calculated by multiplying TOC by 0.9 (Wetzel 2001) and POC was calculated by subtracting DOC from TOC.

b. Soil

The carbon content in soil was measured by Modified Walkley and Black Method (Jackson 1973). 0.25 gm of the sample was taken by sieving with 0.6 mm sieve into a conical flask. 10 ml of 1N Potassium dichromate and 20 ml of concentrated Sulphuric

acid was mixed with the sample. The mixture was let stand for 30 minutes at 150 degree. The blank was also run in the same way. After cooling, about 200 ml of distilled water was added with 0.2 gm NaF and 2 ml of diphenylamine indicator. The amount of potassium dichromate was then titrated against 0.5 N FAS (Ferrous Ammonium Sulphate) solution from burette. The volume of FAS consumed was noted for both the blank and the sample with the brilliant green end point. And the carbon content was calculated by using the following formula.

% of SOC= 3.951/g × (1-T/S)

Where,

g= weight of soil sample taken

S= ml (ferrous) solution with blank titration

T= ml (ferrous) solution with sample titration

Then, Organic carbon =% SOM/1.724

The bulk density was calculated by using the core sampling method given by Baruah & Barthakur 1999) of known volume. The soil samples were collected and they were oven dried at 105ºC for at least 48 hours and the oven dried weight was taken and divided by the volume of the core sampler used to get the bulk density.

Bulk density= Oven dry weight of the sample/Volume of the core

And the total organic carbon was calculated by using the following formula given by Pearson *et al*. (2007).

Total organic carbon= %SOC× Bulk density× soil horizon (m) expressed into tons per ha

c. Macrophytes

The fresh weight of the collected plant material was taken. Then the samples were oven dried at an average temperature of 40-45°C for approximately two weeks until it dried totally. The dry weight was measured with an electronic scale (OHAUS- GA 200). The dry weight values of the plant biomass are then multiplied by a factor of 0.5 to obtain the amount of carbon present (Motasara & Roy 2008). This factor is based on the principle that the plant matter of any ecosystem contains 50% carbon in its biomass once the water has been removed. (Vallejo *et al*. 2005).

d. Litter

The carbon content in the litter was calculated by using loss on ignition method (Kufel 2004). The fresh weights of the litter sample collected were taken. Then the samples were dried at 60 degree centigrade until it dries. Again the oven dried samples were taken and the samples were burnt in a muffle furnace at the temperature of about 450 to 550 degree centigrade for 2 hours. The weight of the ash was also taken. Then the organic matter present was calculated by the following formula.

Organic matter%= weight of ash at 550 degree centigrade/ weight of 60 degree centigrade sample X100

The carbon concentration corresponds to 47 % of the organic matter present. (Westlake 1963)

3.2.2.2 Nutrients

a. Water

i. Nitrogen

The nitrogen content in water was measured as per the Macro Kjeldahl digestion method APHA (1995). About 100 to 200 ml of the sample was taken and then 1 gram of digestion mixture was added. Again 10 ml of concentrated sulphuric acid was added and it was digested over heater until white fumes comes out. After that it was cooled and transferred to the distillation flask for the distillation. Again nearly 100ml of distilled water was added with about 50 ml of 40% sodium hydroxide solution and distilled. The distillate was collected in 25ml of boric acid solution. And it was titrated with standard 0.05N HCl solution using bromocresol green indicator. Then the Total kjeldal nitrogen was calculated by using the following formula.

$$\text{TKN}, \left({}^{\text{mg}}/_{\text{l}}\right) = \frac{14 \times \text{X} \times \text{Y} \times 1000}{\text{v}}$$

Where,

X= volume of acid consumed

Y= strength of acid

v =volume of sample taken

ii. Nitrate

Nitrate was measured by using spectrophotometer by the Brucine absorbtivity Method (APHA 1995). 2 ml of the sample, standard and distilled water for the blank was

taken in a 50 ml beaker separately. Then 1 ml brucine-4 aminobenzenesulphonilamide solution was added to each. And again 10 ml sulphuric acid solution was added into each beaker. All the beakers were shaked well and they were allowed to stand for 10 minutes in ice cold water in a dark place. Then 10 ml distilled water was added and mixed well and again allowed to stand in cool and dark place for 30 minutes and the absorbance was read at 410 nm. Then the concentration of NO_3-N was calculated from the standard curve.

NO_3-N = a X f

Where,

a= value from the graph

F = dilution factor

iii. Nitrite

Nitrite was calculated by NEDA spectrophotometer method given by APHA (1995). The sample was filtered through whatmann filter paper no. 42 and 10 ml of it was pipetted out in clean and dry conical flask. 10 ml of the distilled water was taken in another conical flask for the blank. Then, a series of nitrite standards was prepared. 1 ml of 4-aminobenzene sulphonilamide was added and it was left to stand for five minutes. Furthermore 1 ml of N-1 napthylene diamine dihydrochloride solution was added to each of the sample and they were let stand for 20 minutes for full color development. Finally the absorbance at 540 nm was measured and the concentration was calculated from the calibration curve.

$$\text{Nitrite-N (mg/l)} = \frac{a \times f}{10}$$

Where,

a =concentration from the calibration curve

f = dilution factor

iv. Ammonia

Ammonia was calculated by direct Nesslerization method given by APHA (1995). 50 ml of the sample was taken. Then 2 drops of Rochelle salt solution was added .Further 1 ml of nessler reagent was added and the mixture was mixed well. Then it was let stand for 10 minutes for the complete reaction after the addition of nessler reagent.

Then the absorbance of the samples and the standards was measured at 420 nm. And the final concentration was calculated by using the calibration curve.

Ammonia- N (mg/l) = $\frac{a \times f}{50}$

v. Orthophosphate-Phosphorous

Orthophosphate was determined spectrophotometrically by stannous chloride method proposed by Trivedi & Goel (1986). The standard calibration curve containing definite concentration and absorbance was prepared. For sample measurement, 50 ml of filtered water sample was taken in a volumetric flask. When the water sample contained colour and colloidal impurities, they were removed by adding a spoonful of activated charcoal and then filtering the water sample. 2 ml of ammonium molybdate was added to the water sample which was followed by 5 drops of stannous chloride solution. A blue colour appeared. Reading was taken at 690 nm in spectrophotometer (6715 UV- Jenway) using a distilled water blank with the same amount of chemicals. The readings were taken after 10 minutes but before 12 minutes of the addition of the latest reagent. Using the same specific interval for all determinations, the concentrations were found out with the help of the standard calibration curve.

Orthophosphate-phosphorous (mg/l) = a x f

vii. Pottassium

Pottassium was calculated by Flame Photometric method using the manual provided by Trivedi & Goel (1986) at the wavelength of 768nm. First of all the samples were filtered and the readings of flame photometer (Toshniwal) were noted down. Then concentration of flame photometer was calculated with the help of calibration curve using following formula.

K (mg/l)=(mg/l K) x dilution factor

b. Soil

i. Nitrogen

Nitrogen was calculated by using Kjeldal digestion method according to Jackson (1973). 1 gram of the sample was taken and transferred into the 100 ml kjeldal digestion flask. Then 1 gm of catalyst digestion mixture and 10 ml of sulphuric acid was added further with gentle swirling. Then the digestion was performed first at the

low heat and afterwards in high heat until breathing stops. The sample was heated until 2 hours to release all the residual nitrogen.

Then the flask was cooled and about 40 ml of the distilled water was added and transferred into the 100 ml volumetric flask and the volume was made. Further about 60ml of 40% sodium hydroxide solution was added and finally, the distillation was started with the conical flask of 500ml containing 25 ml of boric acid and indicator was placed below the condensers that the tip for the condenser should dip into the solution. About collecting about 150 ml of the condensate, 25 ml of it was titrated with 0.1 N HCl until the color changes to light brown pink. Then the nitrogen was calculated by the following formula:

$$\% \, N = 7 \times N \times \frac{(T-B)}{W}$$

Where,

N = strength of the acid

T= Volume of standard consumed by the distillate, ml

B= volume of standard acied consumed by the blank

W= weight of the sample taken for digestion,gm

ii. Nitrate

Nitrate from the soil was extracted with the copper sulphate and was determined by the phenoldisulphonic acid method. For this 50 gram of the soil sample was taken in a 500 ml conical flask. And the nitrate extraction solution was added and the flask was shaked for 10 minutes. Again 0.4 gram of calcium hydroxide was added and shaked for 5 minutes and 1 gram of magnesium carbonate was added for the precipitation of Cu and Ag and clarifies the suspension. Then, for the determination of nitrate phenoldisulphonic acid method was used. For this, 50 ml of the sample was taken and equivalent amount of silver sulphate solution was added to remove the chloride. Then it was heated slightly and the precipitate was filtered. The filtrate was evaporated in the porcelain basin to dryness and cooled and the residue was dissolved in 2 ml phenol sulphonic acid and was diluted to 50 ml. Again 6 ml of liquid ammonia was added and the reading was taken at 410 nm. And the concentration of nitrate was calculated by the standard curve.

iii. Nitrite

Nitrite from the soil was extracted with copper sulphate and then it was determined by using NEDA spectrophotometer method as described in water.

iv. Ammonia

Exchangeable ammonia from the soil was extracted by using sodium chloride solution in the acidic medium. For this 100 gram of the sample was taken and 200 ml of acidified NaCl solution was added. Then the flack was kept for about 30 minutes with intermittent thorough shaking.

The suspension was then filtered through Whatman No. 42 filter paper and the conical flask was rinsed with about 50 ml of NaCl solution to remove the residual soil and transfer the rinsing to the Buchner funnel. Then the soil was leached with 200 ml additional NaCl solution and the final volume was made to 500ml with NaCl solution in a volumetric flask. And finally, concentration was calculated by using the direct Nesslerization method given by Trivedi and Goel 1986.

Ammonia-N (mg/l) = (a x f) /50

v. Total phosphorous

For the determination of the total phosphorous, first of all the available phosphorous was calculated by the Olsen method given by Olsen (1954). For this 2.5 gm of the air dried sample was taken and 50 ml of the extracting reagent was added to the samples and the cap of the polythene bottle was closed tightly and they were kept over the mechanical shaker and were shaked for 30 minutes. After that the solution was filtered through whatman no 42. The blank was also run with 50 ml extracting reagent.

Then 5 ml of the sample and blank was pipette out in 25 ml volumetric flask. They were acidified with 5N sulphuric acid to pH 5 and distilled water was added to make the volume of 20 ml and then 4 ml of reagent B [mixture of reagent A (Ammonium molybdate and potassium antinomy tartarate) and ascorbic acid] was added and they were mixed well. At the same time the standards were also prepared by following the same procedure. And the absorbance was read at 785nm after 10 minutes. And the available phosphorous was calculated by the following formula:

Available phosphorous (mg/l) $=C\times\frac{50}{50\times W}$

Where,

C= Concentration of phosphorous from graph

W= Weight of the sample taken

After then the total phosphorous was calculated by the following method.

$$TP_{mg/l} = \frac{(mg/l)\ P_2\ O_5}{2.29}$$

vi. Total potassium

For the determination of the total potassium first of all the exchangeable potassium in soil was calculated by using Flame photometric method (Jackson 1973) after the extraction from ammonium acetate. For this 5 gram of the air dried soil sample was taken in 150 ml beaker and about 25 ml of Ammonia acetate solution was added and shaked well and kept for 15 minutes then the suspension was filtered through whatman No.1 filter paper. And the filtrate was aspirated into the atomizer of the calibrated flame photometer (Toshniwal) and the reading was noted. And the concentration of the potassium was calculated by locating the reading on the standard curve and the amount of K in the sediment was calculated using the dilution factor.

Available K (K_2O) = a × f

Where,

a= Concentration of potassium from graph

f= dilution factor

Then the total potassium was calculated as follows:

$$TK_{mg/l} = \frac{(mg/l)\ K_2O}{1.2}$$

b. Macrophytes and litter

The nutrients in the macrophytes and litter were determined according to Motasara & Roy (2008). The macrophytes and the litter samples were first of all cleaned of the soil particles with minimum amount of distilled water and they were dried in a forced draft oven at about 70℃.

The dried samples were then ground in grinding mill for the major nutrient determination.

i. Nitrogen

About 0.2 gram of the samples were taken and dropped into a 100 ml digestion tube. Then 2 gram of digestion mixture (mixture of $CuSO_4.5H_2O$ and Na_2SO_4) and 10 ml of concentrated H_2SO_4 was added and digested in low heat until the frothing has stopped. Then the temperature was raised to 400℃ and the digestion was continued until the carbaneous particle is present and the color changes to greenish blue. Then the flask was cooled and about 40 ml of distilled water was added and the volume was made. In another volumetric flask 20 ml of 4% boric acid and 4 drops of mixed indicator was taken and placed under the condenser. Then 20 ml of aliquot of the digested solution was taken in a distillation flask and about 100 ml of distilled water was added.

20 ml of the 40% NaOH solution was poured down the neck holding the flask at 45º and the flask was attached quickly to the distillation unit and swirl to mix. The distillation flask was heated till boiling and until it became about 75 ml. Then finally the nitrogen concentration was calculated by titrating the distillated with 0.05 M HCl. The color of the mixed indicator changed from blue to reddish at the end point. Similarly, the blank were also run with all the chemicals and process.

$$\mathrm{N}(\%) = \frac{(\mathrm{S} - \mathrm{B}) \times \mathrm{n} \times 7}{\mathrm{W}}$$

Where, S= Volume of standard acid (ml) used up by sample

B= Volume of standard acid (ml) used up by the blank

n= Normality of the standard acid

W= Oven dry weight of sample

ii. Total phosphorous

For the determination of total phosphorous in macrophytes and litter, first of all they were digested by acid –peroxide digestion method which was developed by Parkinson & Alien (1975). For this 0.5 gram of the sample sieved through 20 mesh was taken and 3.5 ml of concentrated H_2SO_4 was added and let that stand for 30 minutes.

Then 3.5 ml of 30% H_2O_2 was added in the digestion tube and it was placed into the hot plate at 350 C for 30 minutes and the digestion block was let stand for cooling and further 2 ml of aliquot of 30% H_2O_2 was added and digestion was repeated until the cool digest is clear. Then it was diluted with 25 ml distilled water.

Then 10 ml of the sample was taken in 100 ml beaker and evaporated to the dryness and the residue was dissolved in 5 ml of 2N HNO_3. Next it was transferred to 25 ml volumetric flask with distilled water and made the volume. Then 10 ml aliquot was taken in the volumetric flask and 10 ml of vanadomolybdate reagent was added and diluted to 50 ml with distilled water and mixed well. The yellow color was measured after 20 minutes at 420mu and compared with the phosphorous standards. And the phosphorous was calculated by the following formula.

ppm P in plant tissue= (ppm P in solution/W) × 10

$$\% \text{ p in plant tissue= ppm P in plant tissue} \times \frac{100}{10^6}$$

iii. Potassium

For the determination of potassium also the digested samples from acid peroxide digestion method were taken. They were diluted and 5 ml of the aliquot was taken in the beaker and was evaporated to dryness. Then the residue was dissolved in 5 ml of 2N HNO_3 and the volume was made up to 50 ml. And the concentration was determined by the flame photometer (Toshniwal) after calibration with the known standards and the standard curve.

$$\mathrm{K}(\%) = \frac{\mathrm{R} \times 100}{\mathrm{W} \times 10^6} \times \mathrm{DF}$$

Where,

R= ppm K in the solution

W=Oven dry weight of the sample

DF= dilution factor

3.3 Data analysis

For the data analysis, the software such as Microsoft Excel, SPSS 16.0 and Arc GIS 9.3 were used.

Chapter 4: Results

4.1 Morphometric and catchment characteristic of the lake

The lake was found to be spread within the area of 24.57 hectare at an altitude of 3690m. The perimeter and diameter was calculated to be 2755m and 356.85m respectively. Similarly, the shoreline development was 1.56 which depicted that the lake is not in the shape of perfect circle, because, if the shoreline development comes out to be 1, then the lake is a perfect circle.

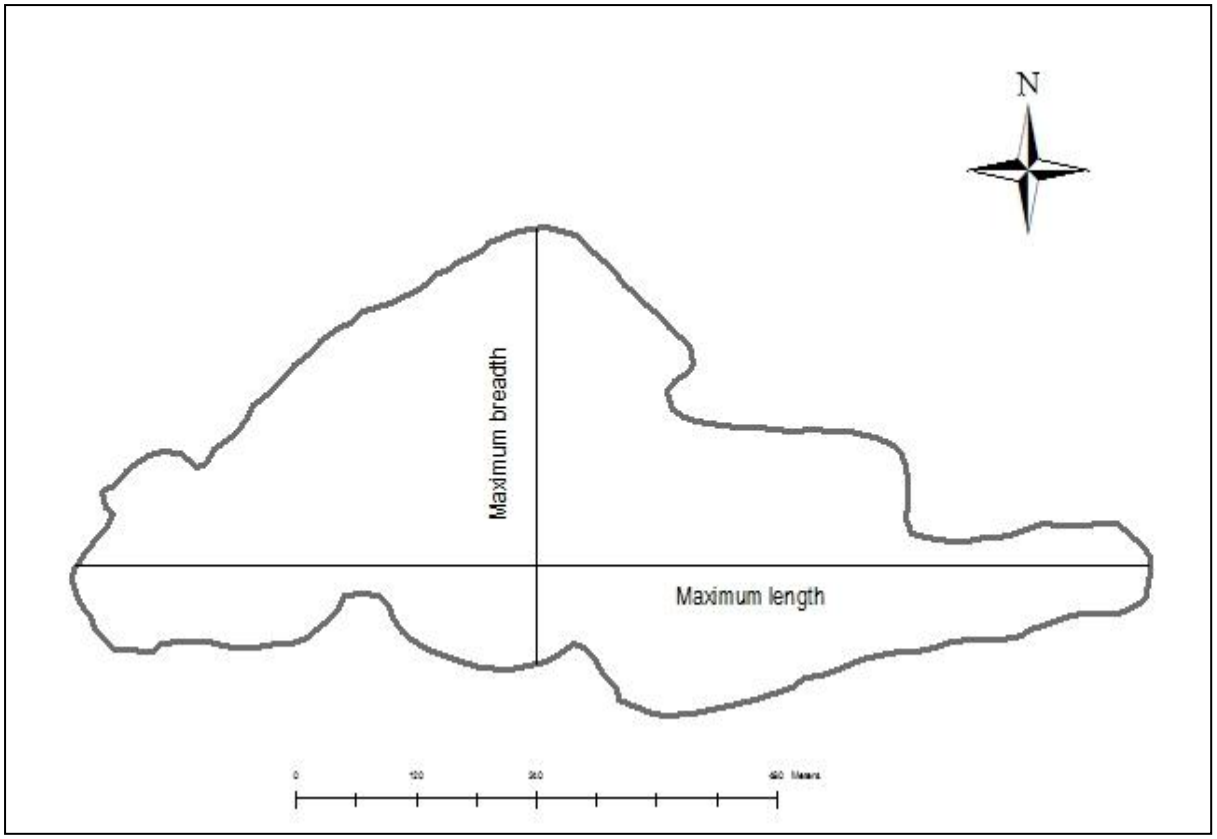


Figure 4.1: Morphometry of Kalchuman Lake

From Arc. GIS, it was found that the maximum length of the lake was 988.21m, maximum breadth was 470.1856m, mean length was 693.098m and the mean breadth was 343.32m. Similarly, the minimum length was 216.539m whereas the minimum breadth was 184.508m.The mean depth and the volume of the lake was also calculated by using the equation given by Budhathoki *et al*. (2010) and was calculated to be 25.6 m and 6.4 Mm^3 respectively.

The total catchment area of the lake was calculated to be 842.16 ha. The grassland was found to be dominant in the catchment area with 49.5% of the total. And the barren land

was about 16.9%, forest area was 30.65% and only 2.9% of the area was covered with the lake.

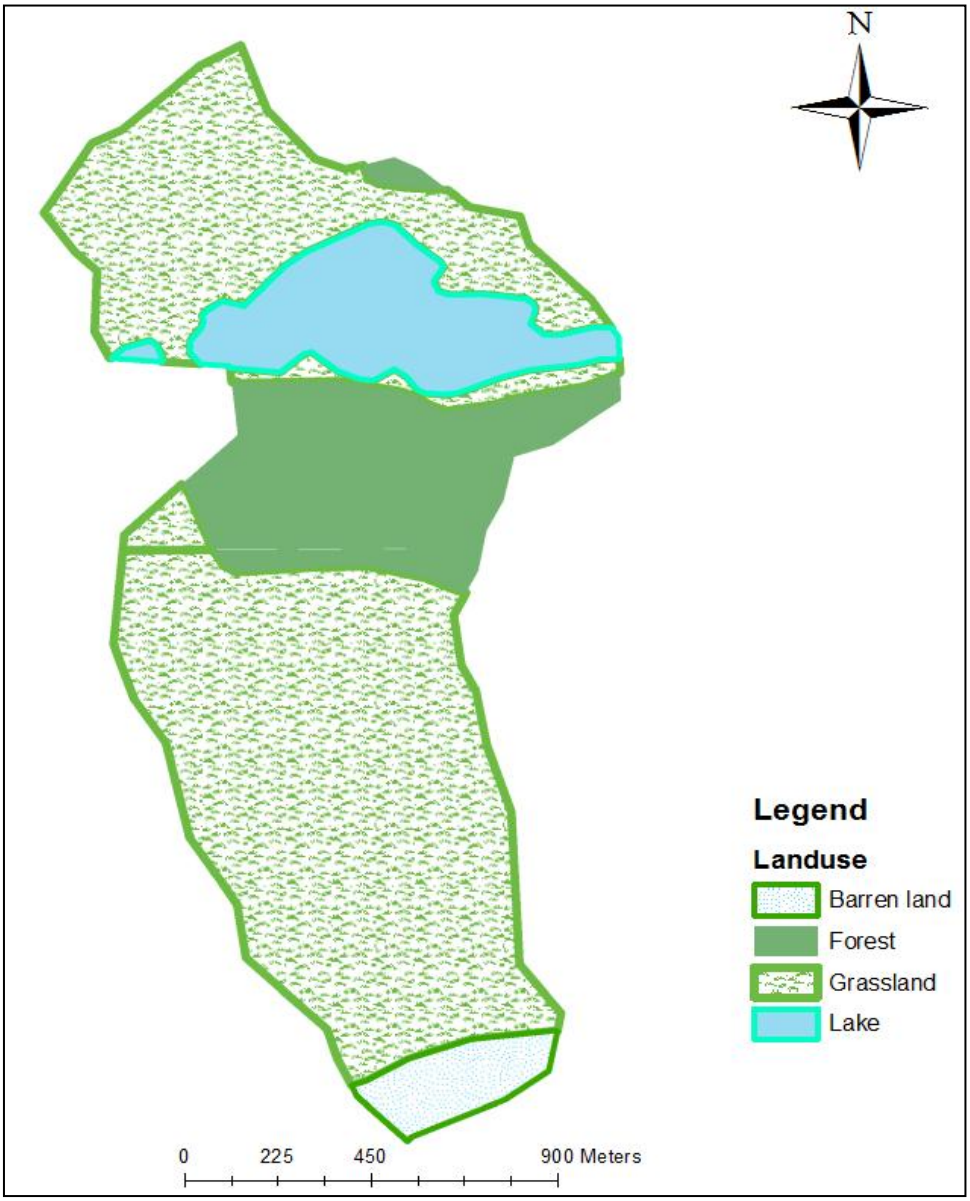


Figure 4.2: Catchment map of Kalchuman Lake

4.2 Carbon content in different components of lake

4.2.1 Water

The mean pH value of water was found to be 6.54±0.85 (Annex II). That means there was approximately neutral condition in the water ecosystem. The mean water temperature was 5.47ºC±0.54 ºC. Similarly the mean conductivity was 38.86±9.2µS/cm and turbidity was found to have the mean of 7.76±9.79 NTU.

The carbon content (TOC) in water varied from 8.63 mg/l to 26.03 mg/l. The value was found to be maximum in site 1 that is near the outlet and minimum in site 8 (figure 4.3) where there was snow at the adjacent bank. Similarly, the carbon in the dissolved form (DOC) was calculated to be 13.9±5.3 mg/l and 1.57±0.59 mg/l was found in the particulate form (POC).

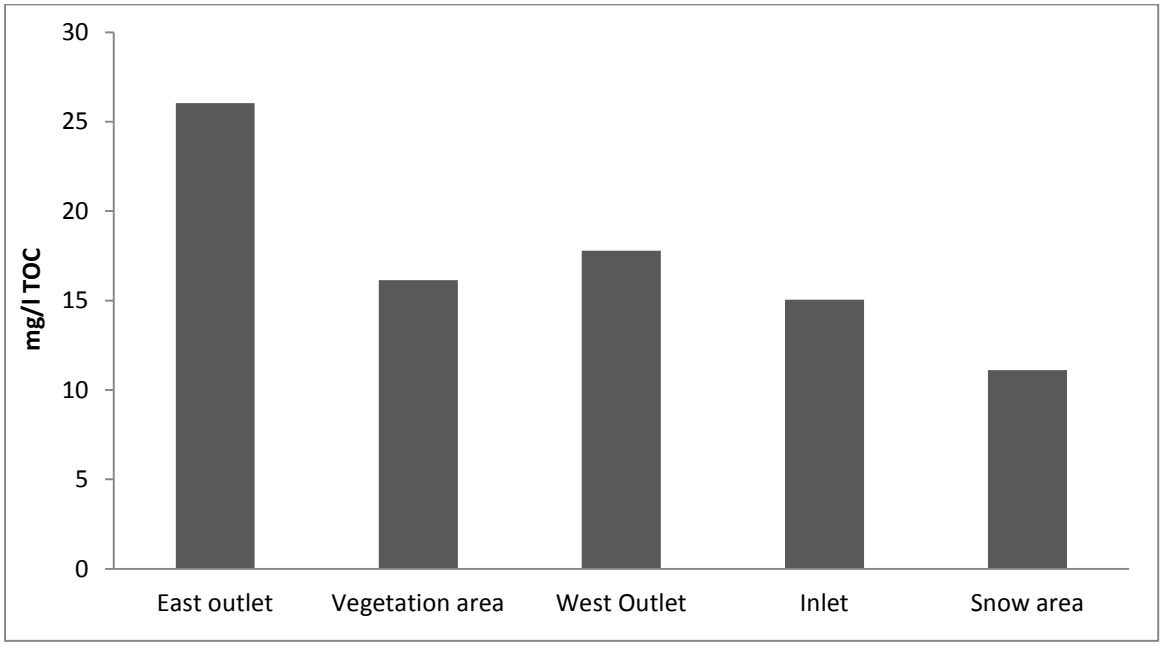


Figure 4.3: TOC in water of different sampling sites

As the volume of water in the lake was calculated to be 6.4 Mm^3 and since the littoral zone accounts for only 1% of the total volume of the lake (Geddes *et al*. 1997), total TOC content in the water of the lake was found to be 0.996 tons.

4.2.2 Soil

The mean pH of the soil from the littoral zone was 5.6 ±0.32 and for the soil from the bank, it was 5.52±0.89. Similarly, the mean moisture content of the soil was 50.01±18.42% and 27±17.55% respectively.

The mean carbon content of the soil collected from littoral zone was 6.33±2.81% with maximum carbon content in the site 2 near the outlet (13.8%) and minimum in the site 6 in the soil of inlet (2.38%). Where as in case of the soil collected from the bank of the lake, the mean carbon content was 5.79±2.51% with maximum carbon content in the site 2 (15.73%) and minimum in the site 10 with the snow adjacent (3.50%).

However, the difference was not significant (ANOVA TEST; P=0.657). The result indicates that the carbon content (SOC) was found to be decreasing going away from the land water interface. The carbon stock in soil from littoral zone of the lake was calculated to be 23.56±8.29 ton/ha and since most of the lake posses about 30% of their lake area designated as littoral zone (Heffman 2010), the total carbon stock in the littoral zone of lake is 173.66 ton.

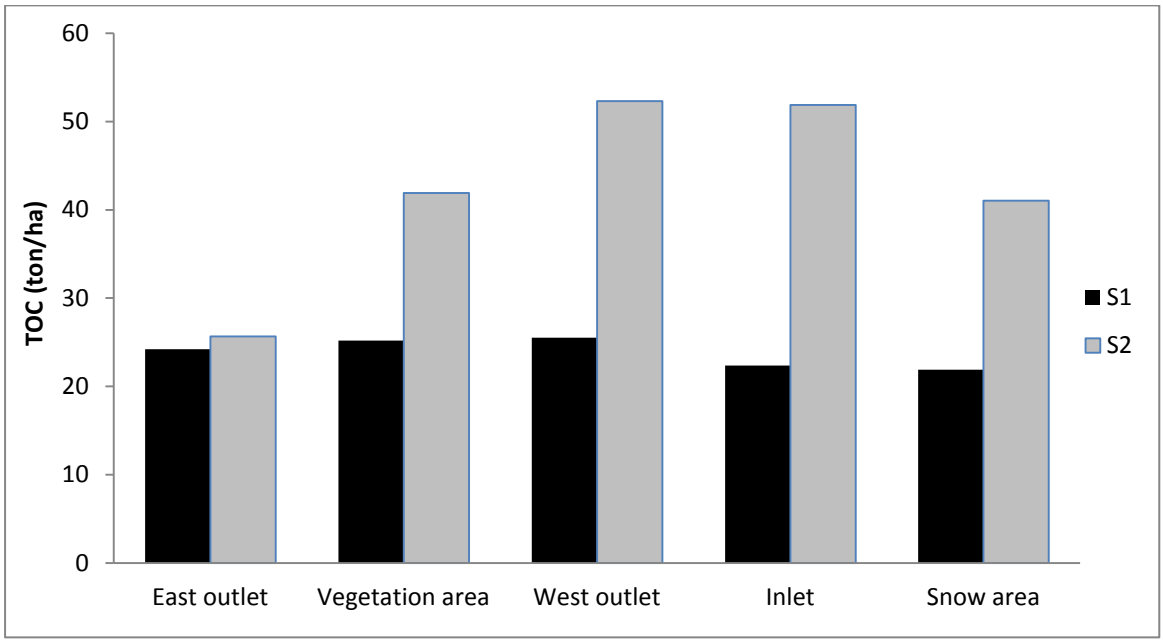


Figure 4.4: SOC in soil of littoral zone and bank of the lake

Similarly, among the sediment samples collected from inside the lake, three different types of soil textures i.e. silty loam, loamy sand and sandy soil were found. Similar types of texture i.e. silty loam, loamy sand and sandy loam were found from the bank of the lake as well.

In most of the sampling plots including outlet silty loam was found whereas sandy soil was found in the inlet. And among the different textured sediment samples, the maximum carbon content was found in silty loam while minimum was in the sandy soil (Figure 4.5).

The mean bulk densities of the soil were 459.157 kg/m^3 and 899.54 kg/m^3 for the littoral zone and bank of the lake respectively. The difference was significant among the two zones (ANOVA test, p=0.008).

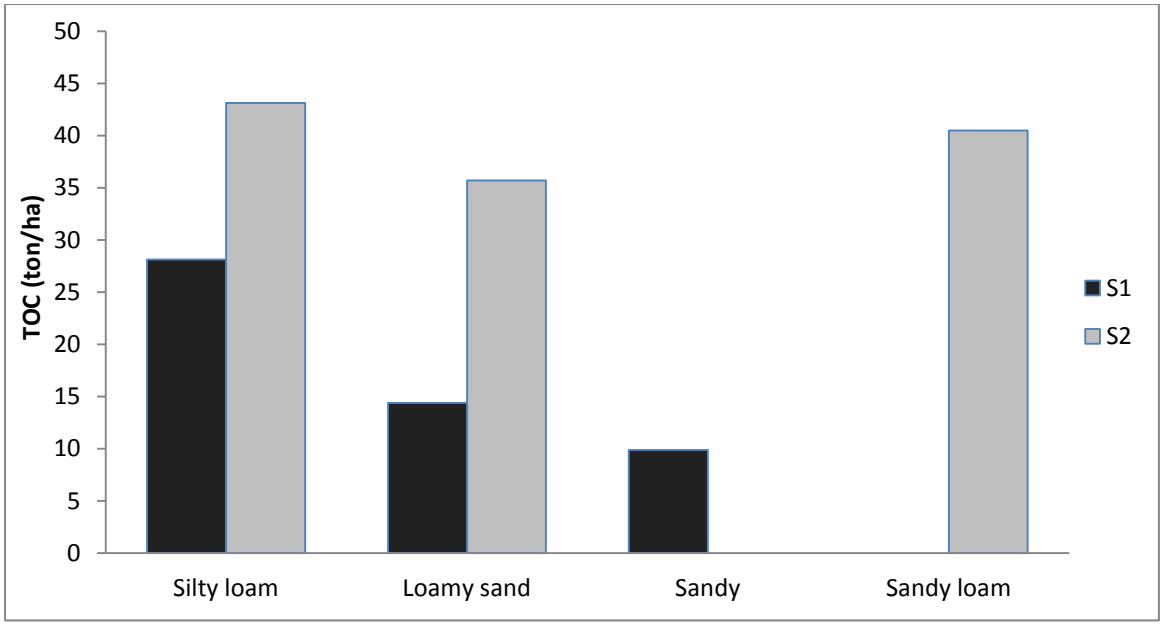


Figure 4.5: SOC in various textures of soil

4.2.3 Macrophytes

Only one species of the aquatic plant was found in the lake. Among the 10 sampling plots, macrophytes were found only in the four sites; site 2 &4 (vegetation area), 7 (inlet area) and 8 (snow area). Among the different component, the plant had the highest moisture content with the value ranging from 96% to 98.09% while the dry matter ranged from 1.91% to 3.83%. Similarly, the mean carbon content in the plant was 1.405 % ±0.435 or 0.04 ton/ha with maximum value and minimum value 1.8% to 0.85% respectively for site 8 and site 4.

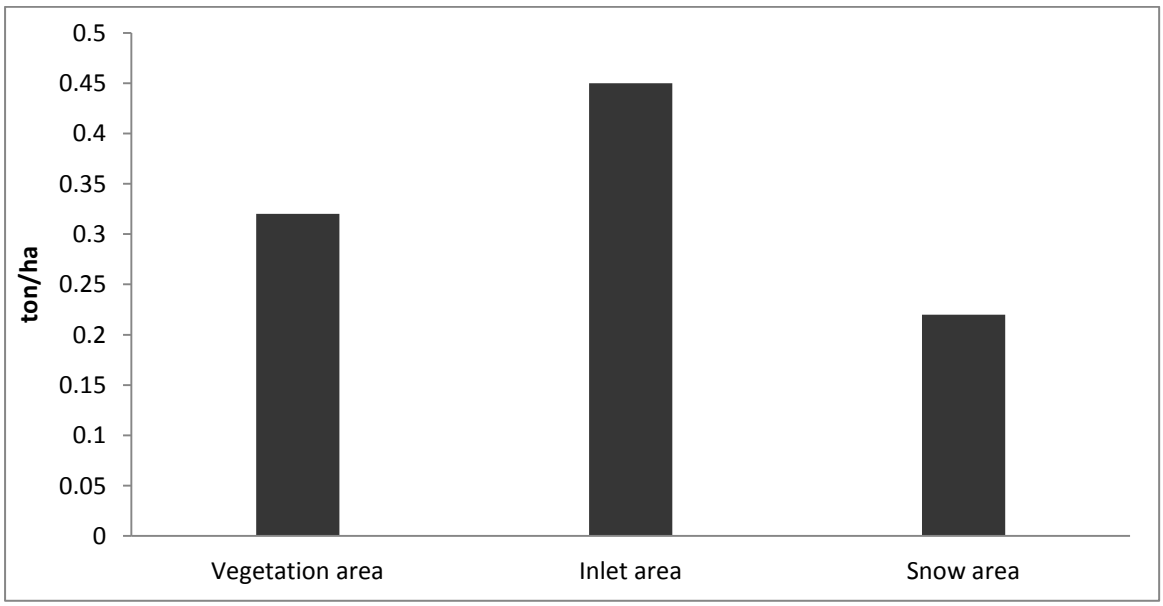


Figure 4.6: carbon content in macrophytes

In total, carbon content in the aquatic plants from littoral zone of the lake was 0.04 ton/ha which is equivalent to 0.29 tons carbon.

4.2.4 Litter

Among all sampling plots, litters were found only at sites 1 (east outlet), 2 & 4 (vegetation area), 5 (west outlet) and 10 (snow area) from the littoral zone of the lake and from 3 & 4 (vegetation area), 5 (west outlet) and 6 &7 (inlet area) from the bank of lake. The mean carbon content in the litters from the littoral zone was 33.39 ± 4.29% or 0.36 ton/ha. The maximum carbon content was found in the site 5 (38.556 %) where there was higher number of vegetation around the sampling plot and the minimum in site 1 which is actually the east outlet (27.929%) where there were very few vegetations.

Similarly, in case of litters from the bank, the mean carbon content was 11.12 ± 5.39 %. The maximum was found in site 4 (17.24 %) and minimum in site 7 (6.402%).The mean carbon content in the litters collected from the littoral zone was 3 fold higher than that of collected from the bank of the lake.

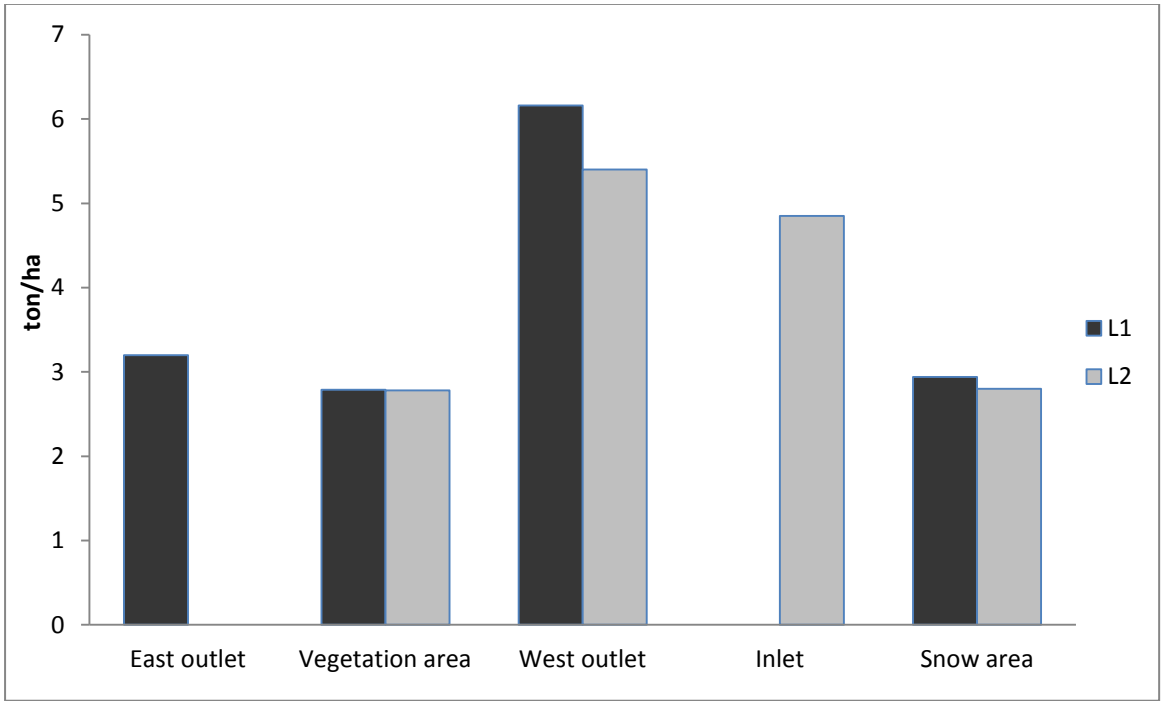


Figure 4.7: Carbon content in litters from littoral zone and bank of the lake

The total carbon content in the litters of the littoral zone was found out to be 0.18 ton/ha which is equivalent to 1.33 tons.

4.3 Nutrient content in different components of lake

4.3.1 Water

4.3.1.1 Nitrogen

The nitrogen level varied from 0.7 mg/l (site 1) to 4.2 mg/l (site 9) with the mean of 1.5980±1.05 mg/l. The concentration was found to be lower in sampling plots where there was snow at the adjacent bank and highest in the east outlet (Figure 4.8).

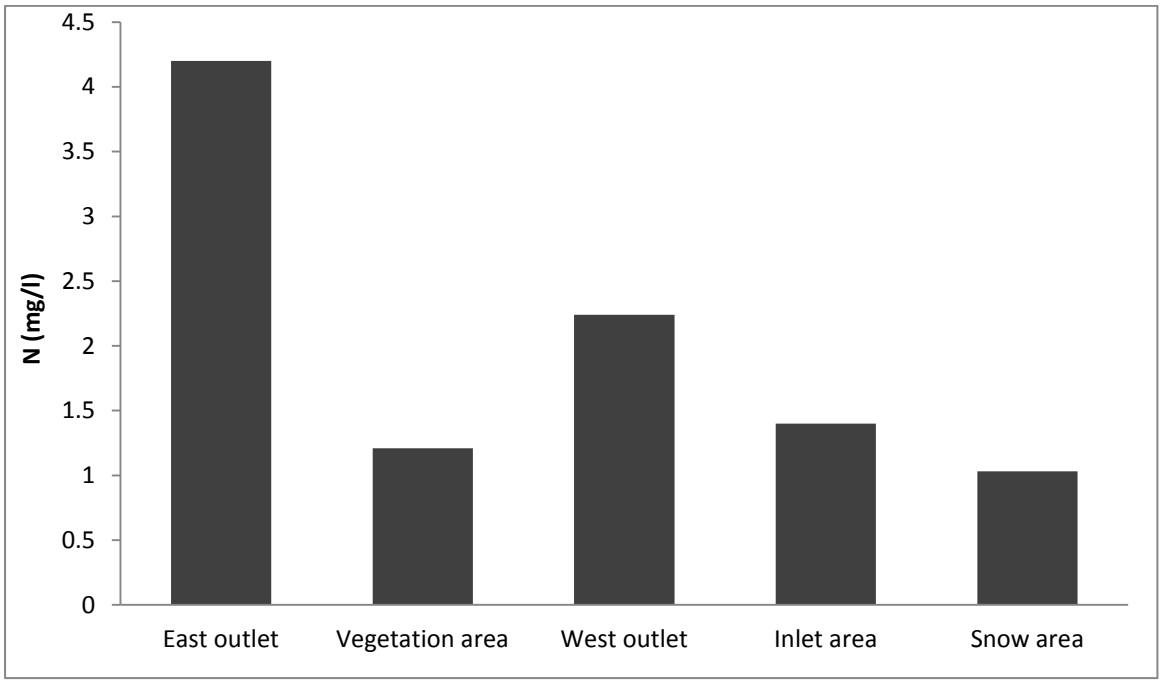


Figure 4.8: Nitrogen content in water

The mean values of nitrate, nitrite and ammonia concentration in water were 0.3245±0.06 mg/l, 0.025±0.05 mg/l and 0.00503±0.003 mg/l respectively. Nitrite was not detected in site 6 and site 7 i.e near the inlet.

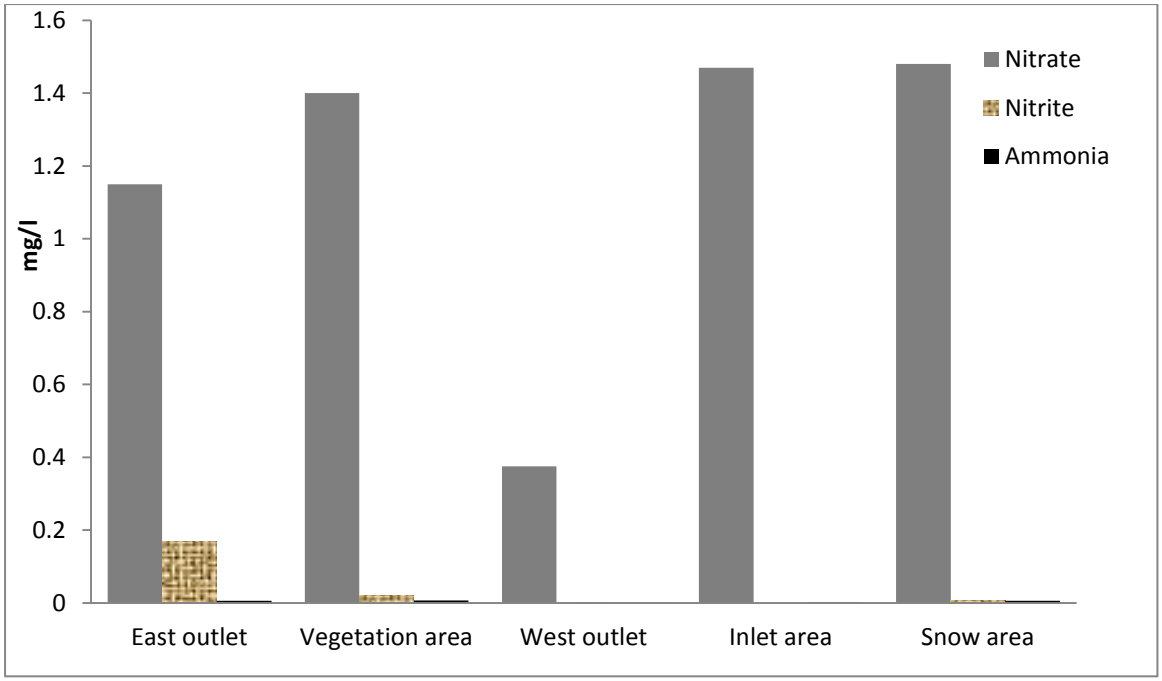


Figure 4.9: Nitrate, nitrite and ammonia in water

3.1.2 Phosphorous

The mean concentration of phosphorous in the form of ortho-phosphate was 0.405±0.236 mg/l. The site 10 had the lowest and the site 2 had the highest phosphate concentration. That is the area with the snow adjacent had the lowest concentration of phosphate while site 2 with the vegetations around had higher concentrations.

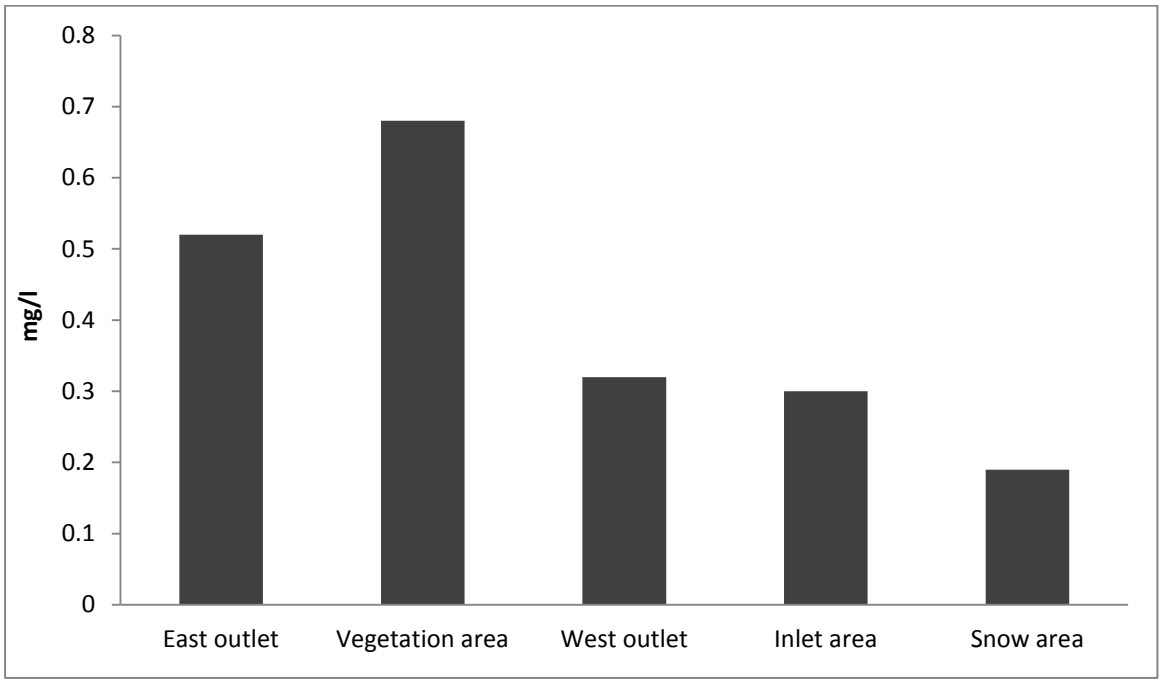


Figure 4.10: Ortho-phosphate in water

4.3.1.3 Potassium

The mean potassium concentration in water was 0.64±0.55 mg/l with the highest concentration in site 4 where the area was shaded by the vegetations and lowest in the sampling sites near west outlet.

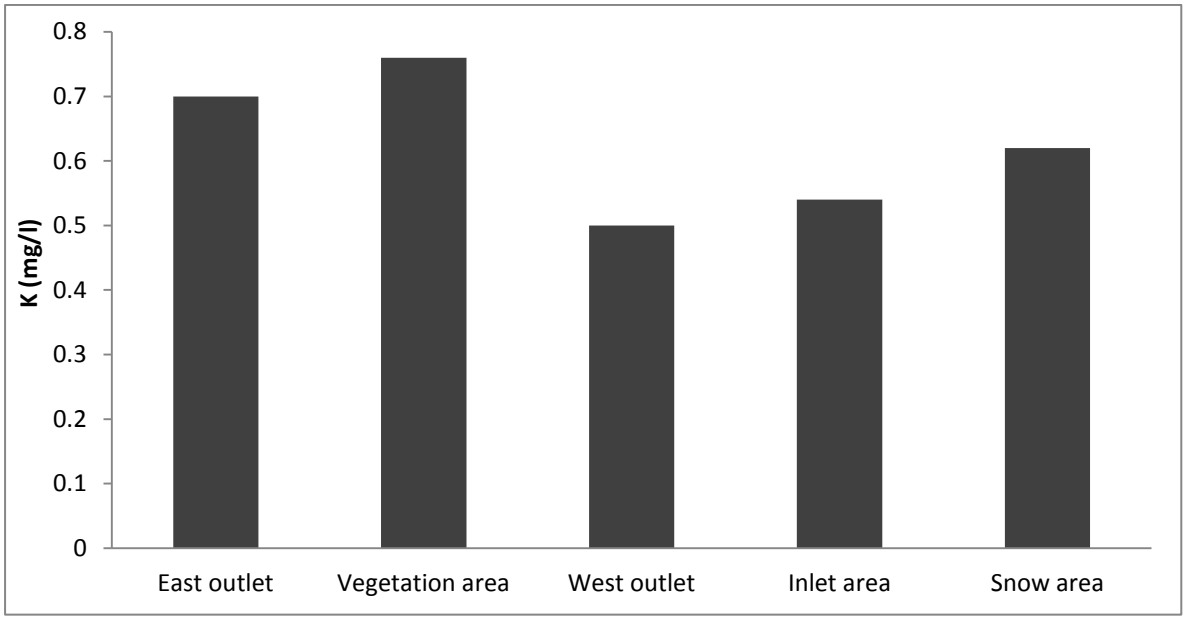


Figure 4.11: Potassium in water

4.3.2 Soil

4.3.2.1 Nitrogen

The mean total nitrogen content in the littoral zone and bank of the lake were 0.395 ± 0.19% and 0.390 ± 0.21% respectively.

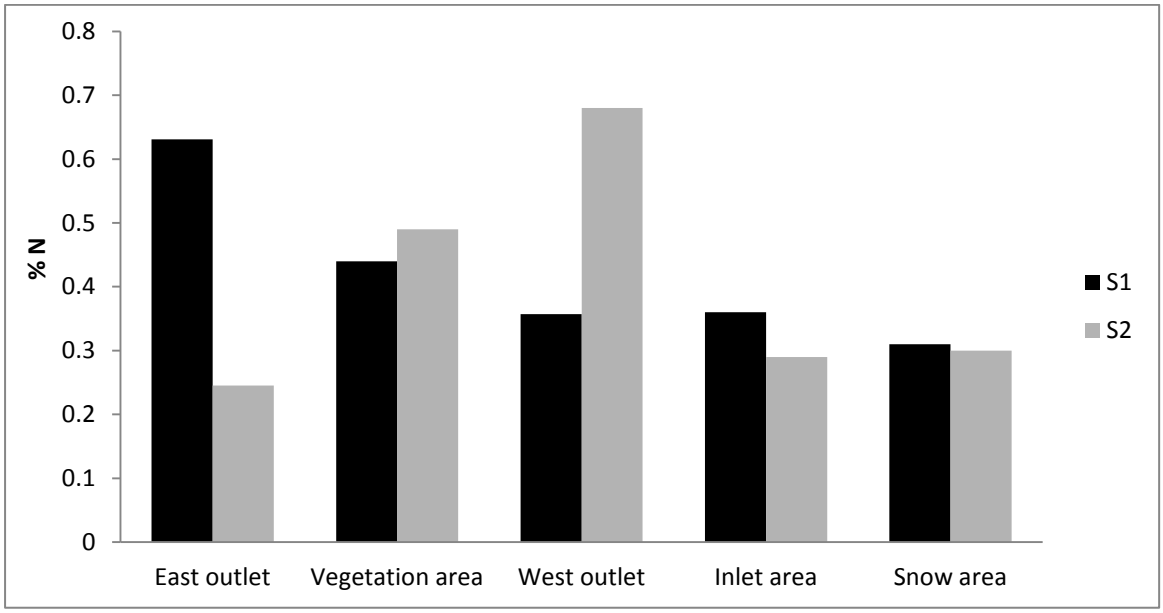


Figure 4.12: Nitrogen in soil from littoral zone and bank of the lake

The maximum concentration was in site 2 and minimum in site 6 in case of the littoral zone and it was maximum and minimum in site 2 and 10 in the soil from the bank of the lake. As in case of water, the concentration of it was also found to be greater near the outlet and lesser in the inlet.

Nitrate in the soil from littoral zone varied from 3.23 to 6.65 (mg/l) with the mean of 5.51±1.34 mg/l.

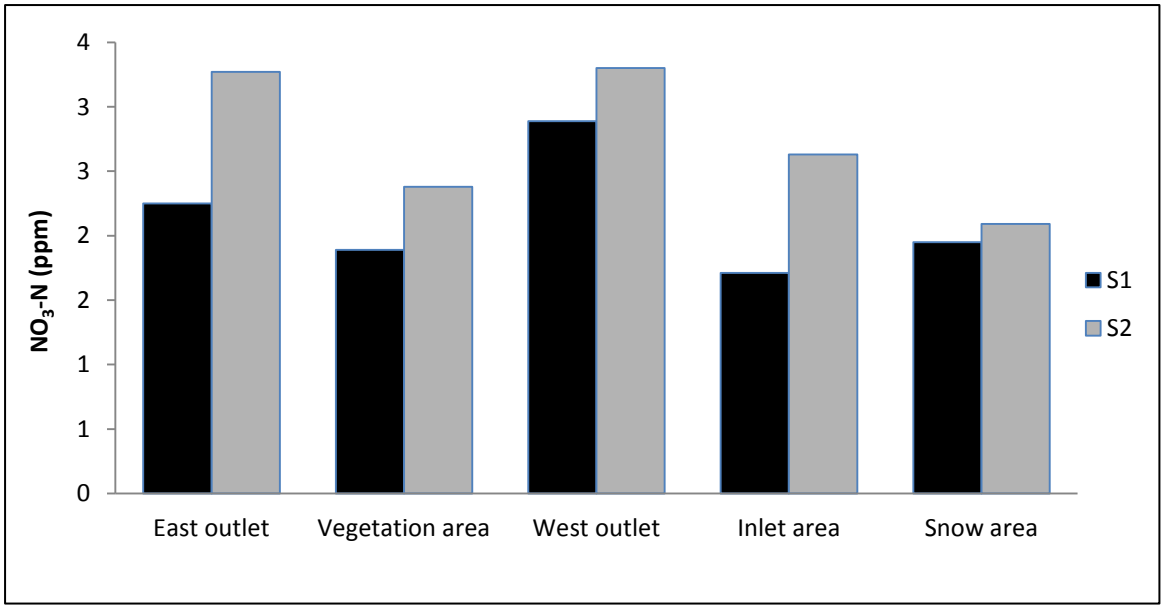


Figure 4.13: Nitrate in soil from littoral zone and bank of the lake

Similarly in the soil from the bank of the lake, its value ranged from 3.45 to 9.03 mg/l with the mean of 6.55± 2.28 mg/l.

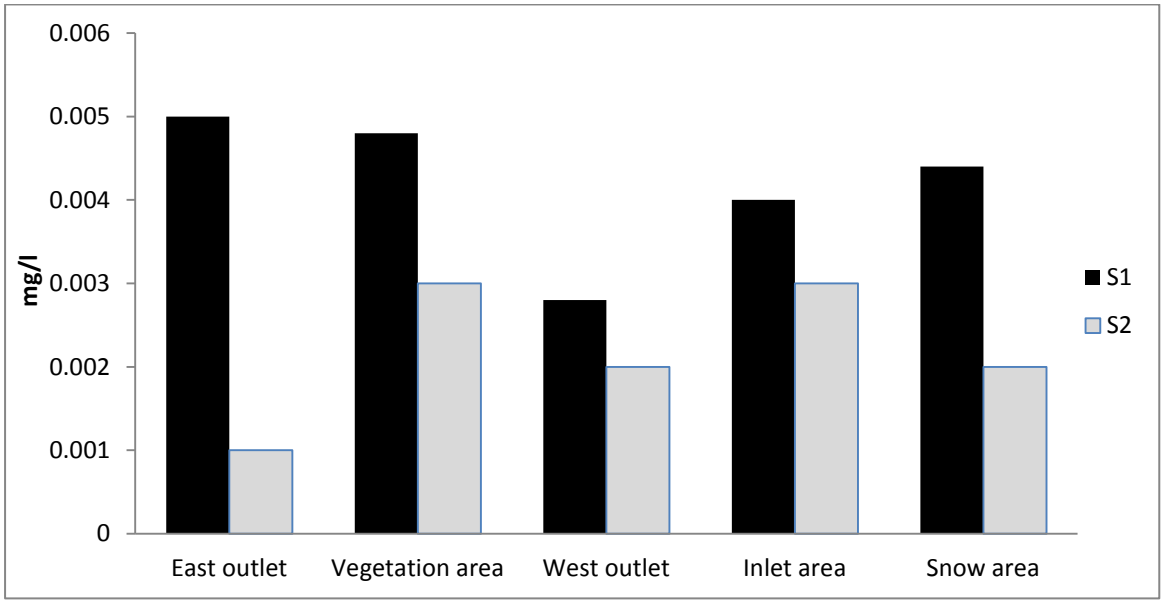


Figure 4.14: Nitrite in soil from littoral zone and bank of the lake

Nitrite in the soil collected from the littoral zone of the lake ranged from 0.0019 to 0.007 mg/l while it ranged from 0.0007 to 0.0036 mg/l in case of soil collected from the bank. The mean nitrite concentrations were 0.004± 0.002 mg/l and 0.002± 0.001 mg/l respectively for the sediments samples from the two zones.

Ammonia in soil from littoral zone ranged from 0.034 to 0.12 mg/l with the mean of 0.0705±0.024 mg/l. Similarly the ammonia content in soil from the bank, varied from 0.043 to 0.215 mg/l with the mean 0.103± 0.054 mg/l. However the concentration of ammonia was slightly greater in the east outlet.

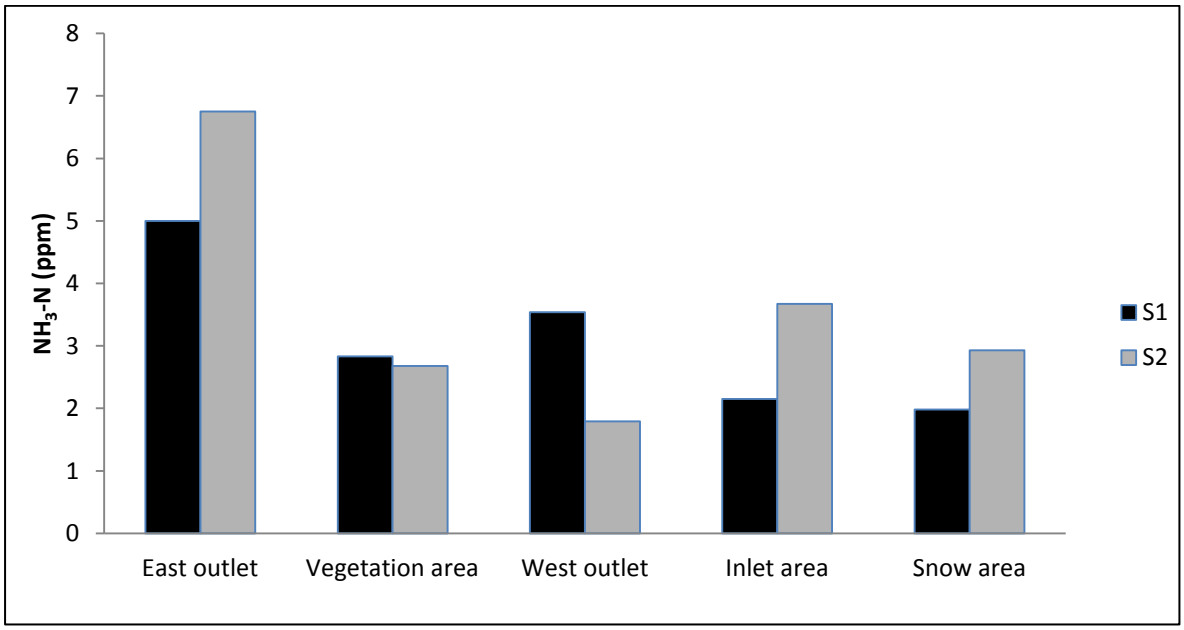


Figure 4.15: Ammonia in soil from littoral zone and bank of the lake

The result of ANOVA analysis showed that there was no significant difference between the nitrogen, nitrate and ammonia content in the soil collected from the littoral zone and the bank of the lake (ANOVA test, p=0.929 for nitrogen; p=0.232 for nitrate ; and p=0.098 for ammonium). But there was the significant difference between the nitrite concentration (ANOVA test, p=0.008).

4.3.2.2 Total Phosphorous

The phosphorous concentration in the soil collected from the littoral zone of the lake varied from 1.58 mg/l to 32.5 mg/l while in the soil collected from the bank varied from 6.61 to 473.75 mg/l. The mean phosphorus concentrations were 12.62±9.64 mg/l and 16.37±17.91 mg/l respectively for the two zones. ANOVA analysis showed no significant difference between the phosphorous content in the soil collected from the two zone (p=0.563). However its concentration was found to be higher in the west outlet.

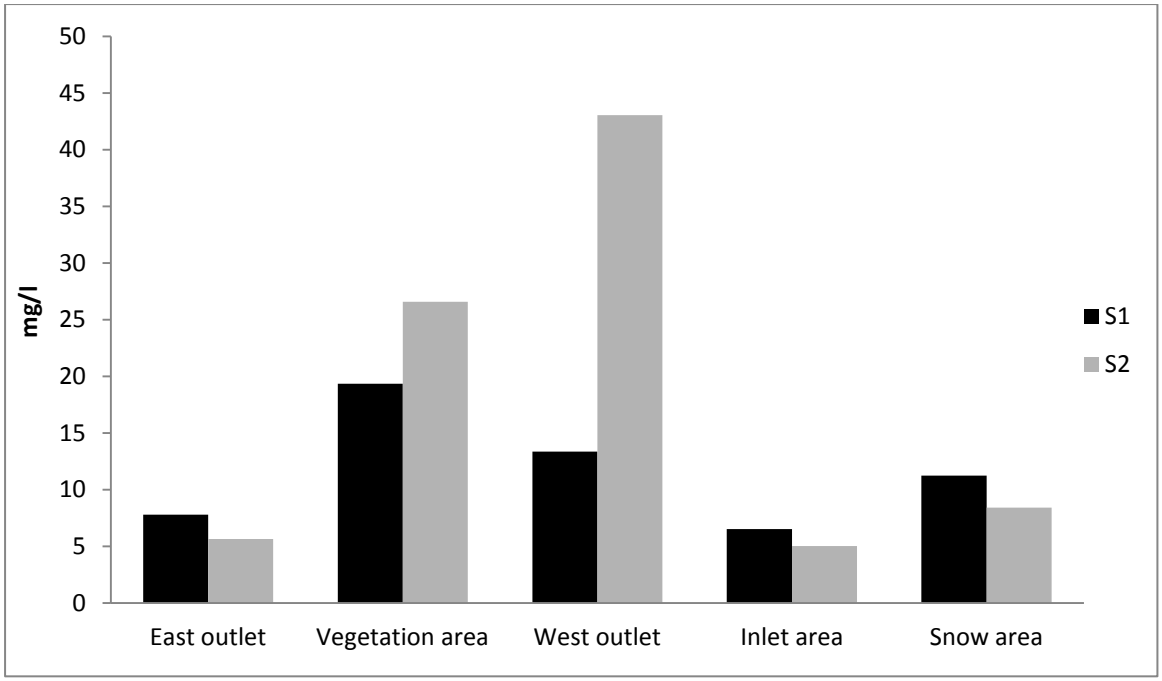


Figure 4.16: Phosphorous in soil from littoral zone and bank of the lake

4.3.2.3 Total Potassium

In the figure S_1 represents the potassium concentration for soil from the littoral zone which varied from 11.5 mg/l to 222.5 mg/l with the mean of 97.4±73.05 mg/l. Similarly S_2 represents the concentration of potassium for the bank soil which varied from 6.61 mg/l to 473.75 mg/l with the mean of 108.25±138.85 mg/l. The concentration of potassium was found to be higher near the vegetation area while it was lowest near the snow area.

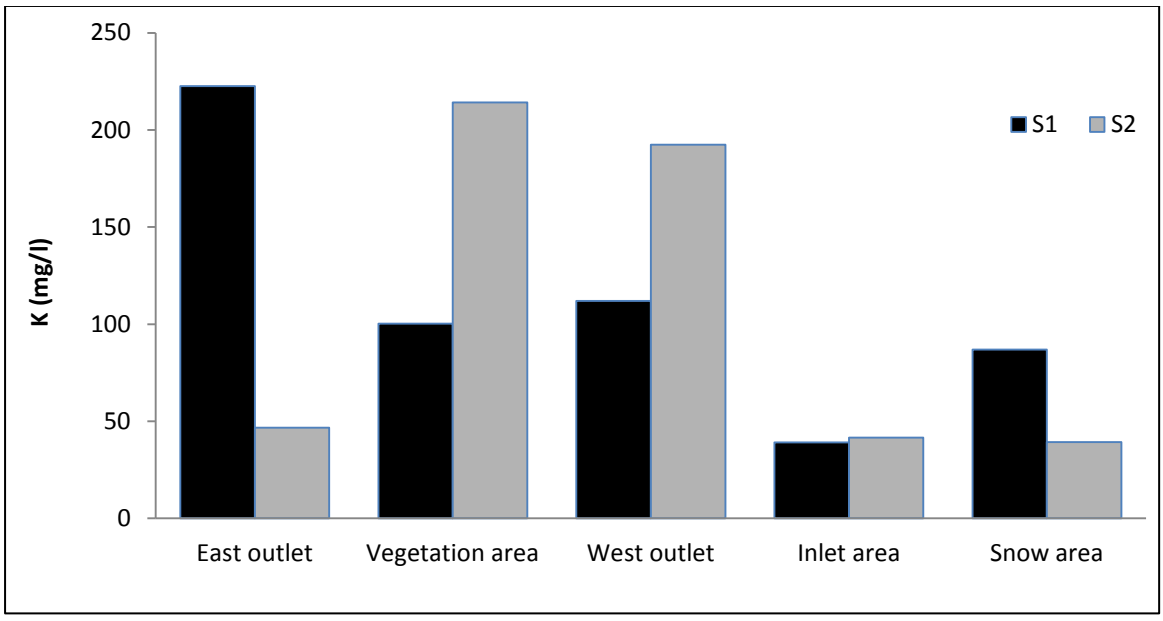


Figure 4.17: Potassium in soil from littoral zone and bank of the lake

From the ANOVA analysis it was found that there was no significant difference between the potassium content in the littoral zone and bank of the lake (F=0.048,df=1;18, p=0.83).

4.3.3 Macrophytes

4.3.3.1 Nitrogen

As mentioned previously, only one species was found from inside the lake. And they were found only in vegetation area (2 & 4), near inlet (7) and snow area (8) with the frequency of 40%. Nitrogen concentration varied from 1.05% to 3.325% with an average of 2.41±1.29 %.The maximum concentration was calculated in site 4 (3.675%) and minimum in site 8 (1.05%).

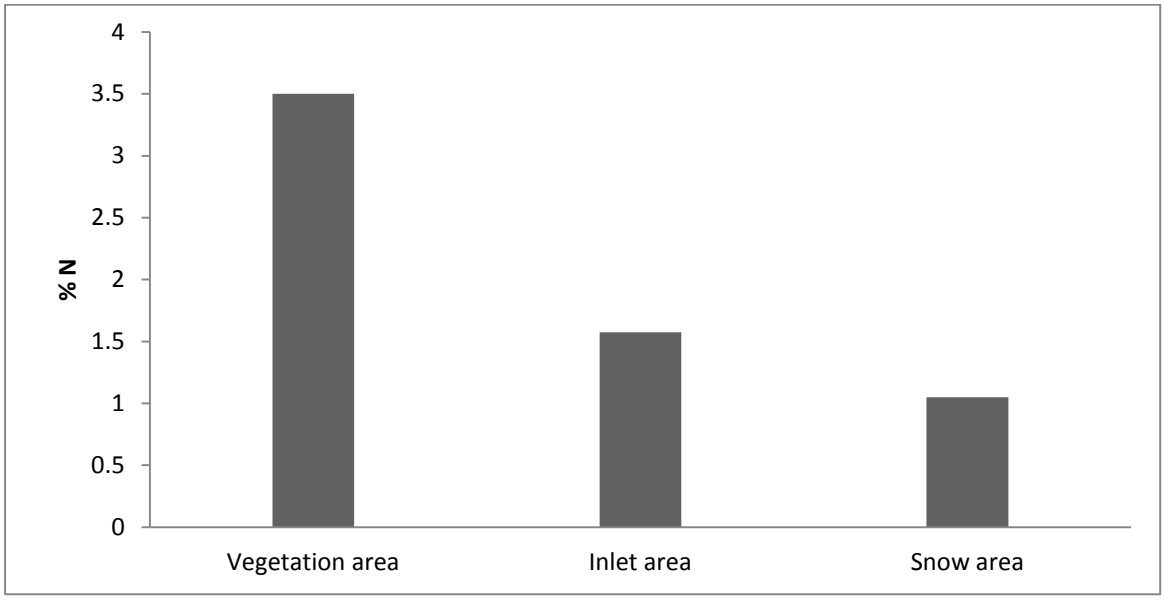


Figure 4.18: Nitrogen concentration in macrophytes

4.3.3.2 Phosphorous

Phosphorous was calculated to be very low in the macrophytes. They were found to be 0.128%, 0.119%, 0.0004% and 0.0404 % at sampling plots 2, 4, 7, and 8 respectively with the mean of 0.072%. The maximum was found in site 2 (0.128%) near the vegetation area and minimum in site 7 (0.0044 %) near inlet.

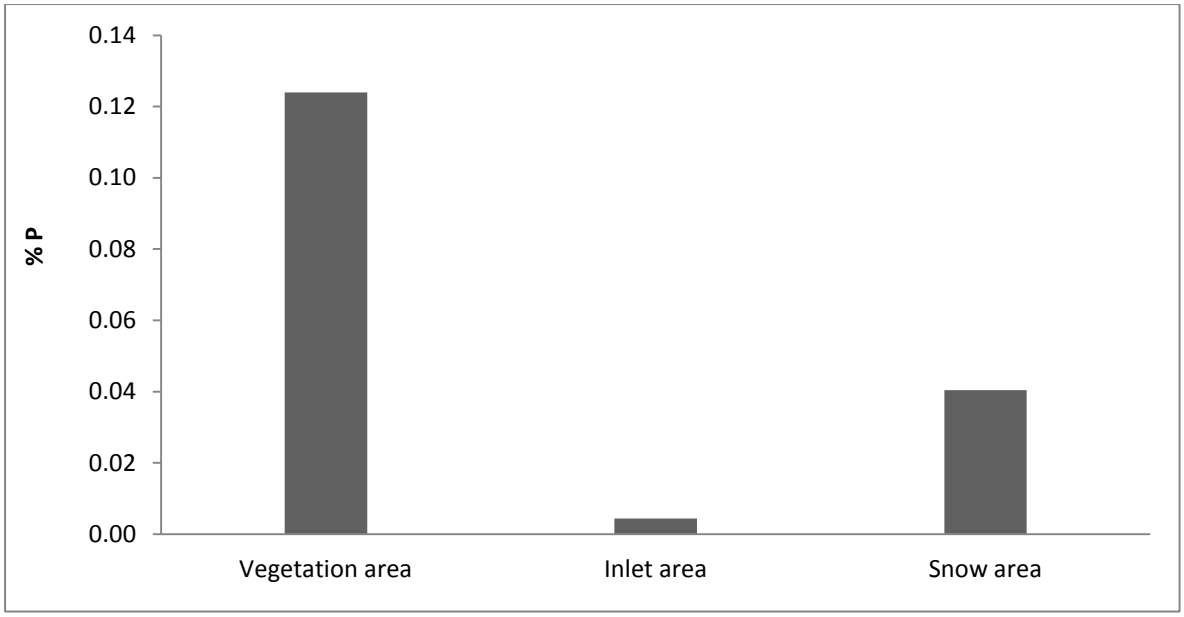


Figure 4.19: Phosphorous concentration in macrophytes

4.3.3.3 Potassium

The concentration of potassium varied from 0.0004% to 0.0019% in the sampling plots 2, 4, 7 and 8 respectively with an average of 0.0009%. The maximum concentration was found in site 2 (0.0019%) near outlet with some vegetations and minimum in site 4 (0.0004%) which was shaded with large number of vegetations.

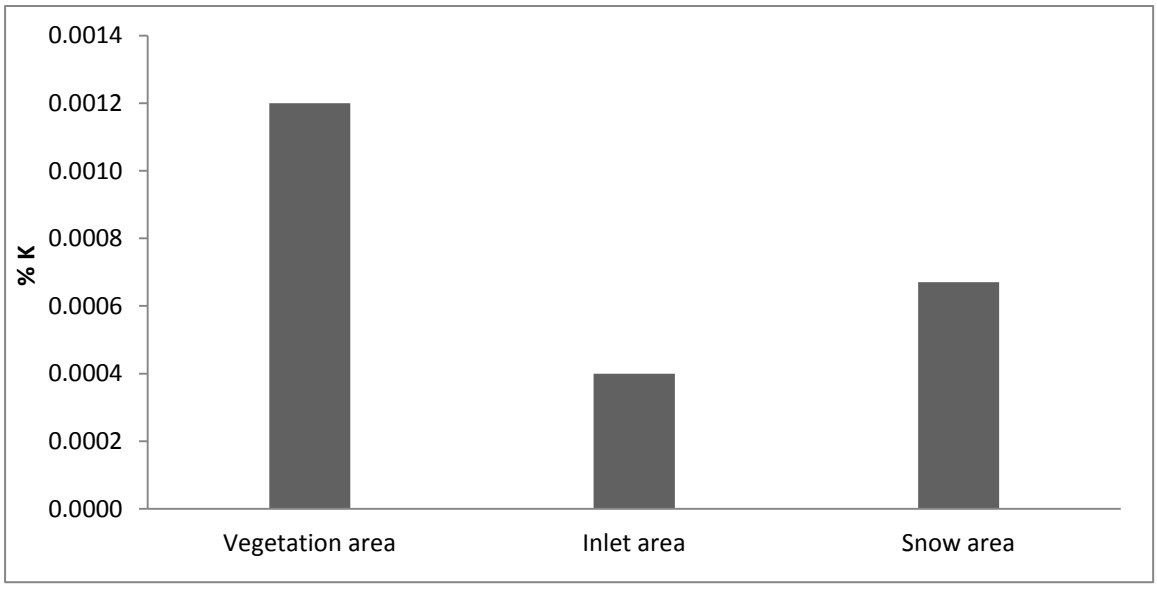


Figure 4.20: Potassium concentration in macrophytes

4.3.4 Litter

4.3.4.1 Nitrogen

Litters were found in all sampling plots except plot 8 and 9. In case of the littoral zone, litters were collected from sampling point 1 (east outlet), 2 & 4 (vegetation area), 5 (east outlet) and 10 (snow area) and from site 3&4 (vegetation area), 5 (east outlet) and 7 (inlet area), from the bank of the lake.

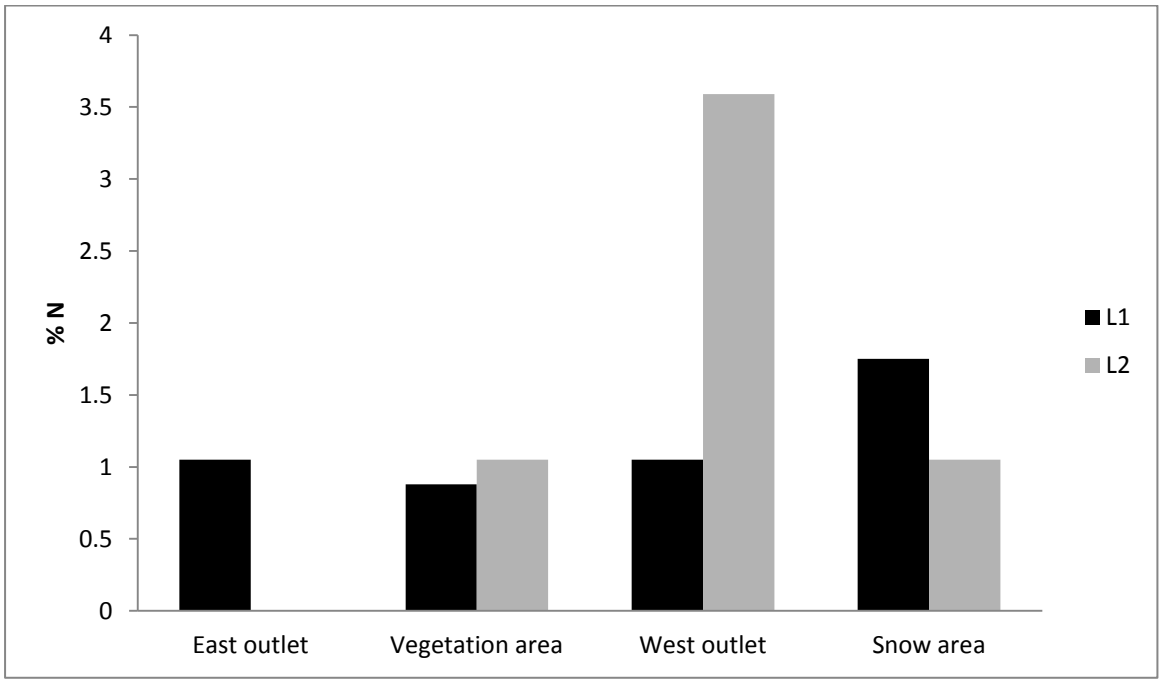


Figure 4.21: Nitrogen concentration in litters from littoral zone and bank of the lake

Nitrogen concentration in the litter collected from the lake varied from 0.875% to 1.75% with the mean of 1.12±0.36% while for that collected from the bank litter the concentration varied from 0.525% to 5.6% with an average of 2.275%. However, no significant difference was found between them (ANOVA test; p=0.456).

4.3.4.2 Phosphorous

The mean phosphorous concentration in the litter collected from the lake was 0.0632± 0.06%. While for those collected from the bank, the mean phosphorous concentration was 0.00232± 0.001%. The maximum phosphorous was found in site 1 and site 2 of the littoral zone while in site 5 and 6 respectively in case of the bank of the lake (Figure

4.22). No litters were found in other sites. There was no significant difference in the phosphorus concentration between the littoral zone and bank of the lake (ANOVA test, p=0.053).

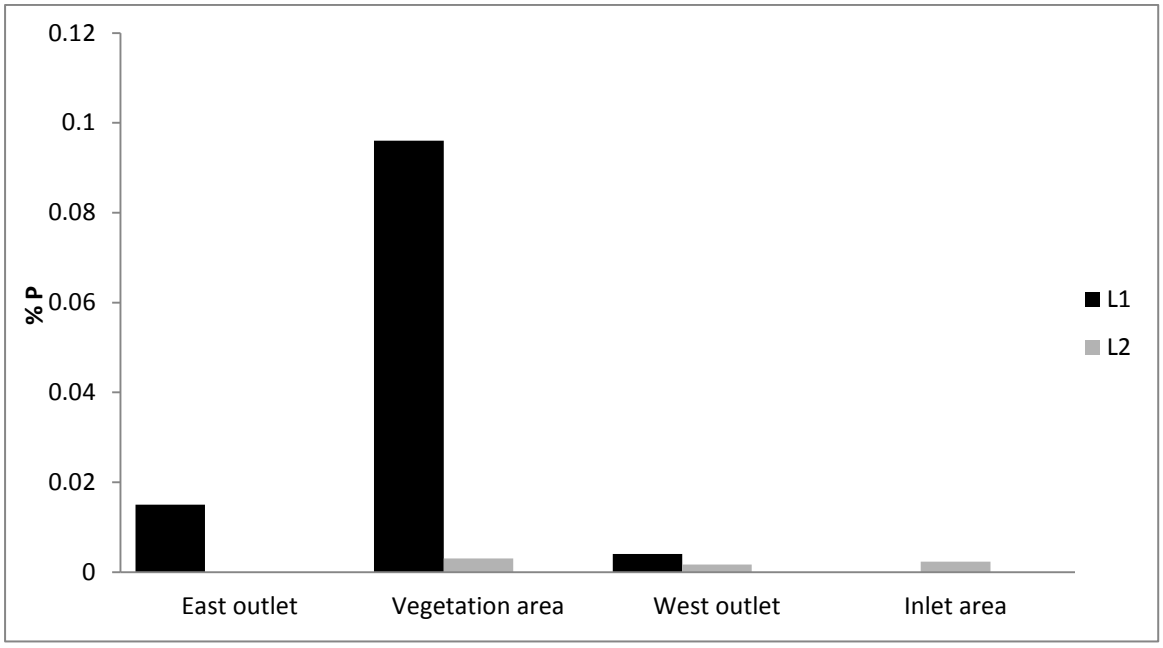


Figure 4.22: Phosphorous concentration in litters from littoral zone and bank of the lake

4.3.4.3 Potassium

The potassium concentration in the litter collected from the lake and the bank varied from 0.005 % to 0.0015% and 0% to 0.0006% respectively (Figure 4.23). The mean potassium concentration of the litter collected from the lake and the bank was 0.001±0.0005 % and 0.00037±0.0002% respectively.

Thus, There was significant difference between the potassium content in the litters collected from the littoral zone and bank of the lake (ANOVA test; p=0.023).

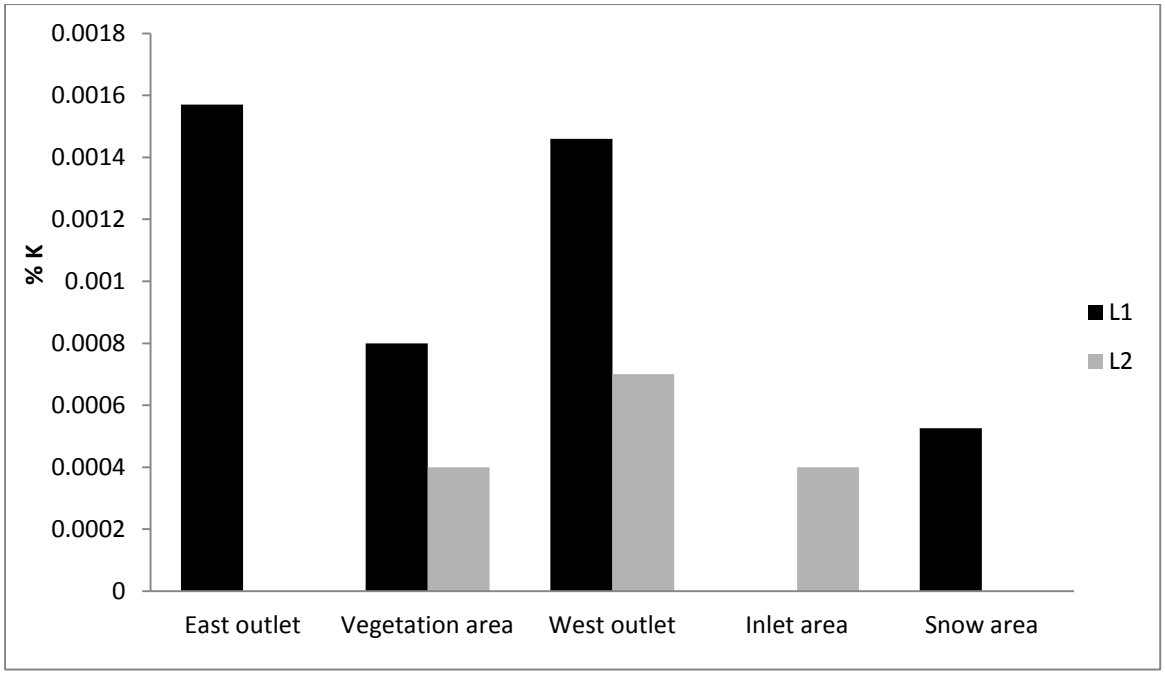


Figure 4.23: Potassium concentration in litters from littoral zone and bank of the lake

4.4 Relationship between carbon and nutrients

4.4.1 Water

For determining the relationship between carbon and NPK, Pearson correlation was calculated. Although the correlation result showed positive trend between nutrients i.e. nitrogen (0.516), phosphate (0.205) and potassium (0.291) and carbon content, the trend was quite clear in case of the nitrogen and carbon.

Similarly, multiple regression analysis showed that there was combined effect of NPK in the carbon availability (R= 0.582) and it also showed that the nitrogen, phosphorous and potassium represented 33.8% of the variability in carbon content (R^2=0.338) with the equation C= 2.594N+5.383P+3.297lnK.

The individual regression analysis of the TOC with NPK is shown in the figure below which also depicted that the relationship is stronger with the nitrogen.

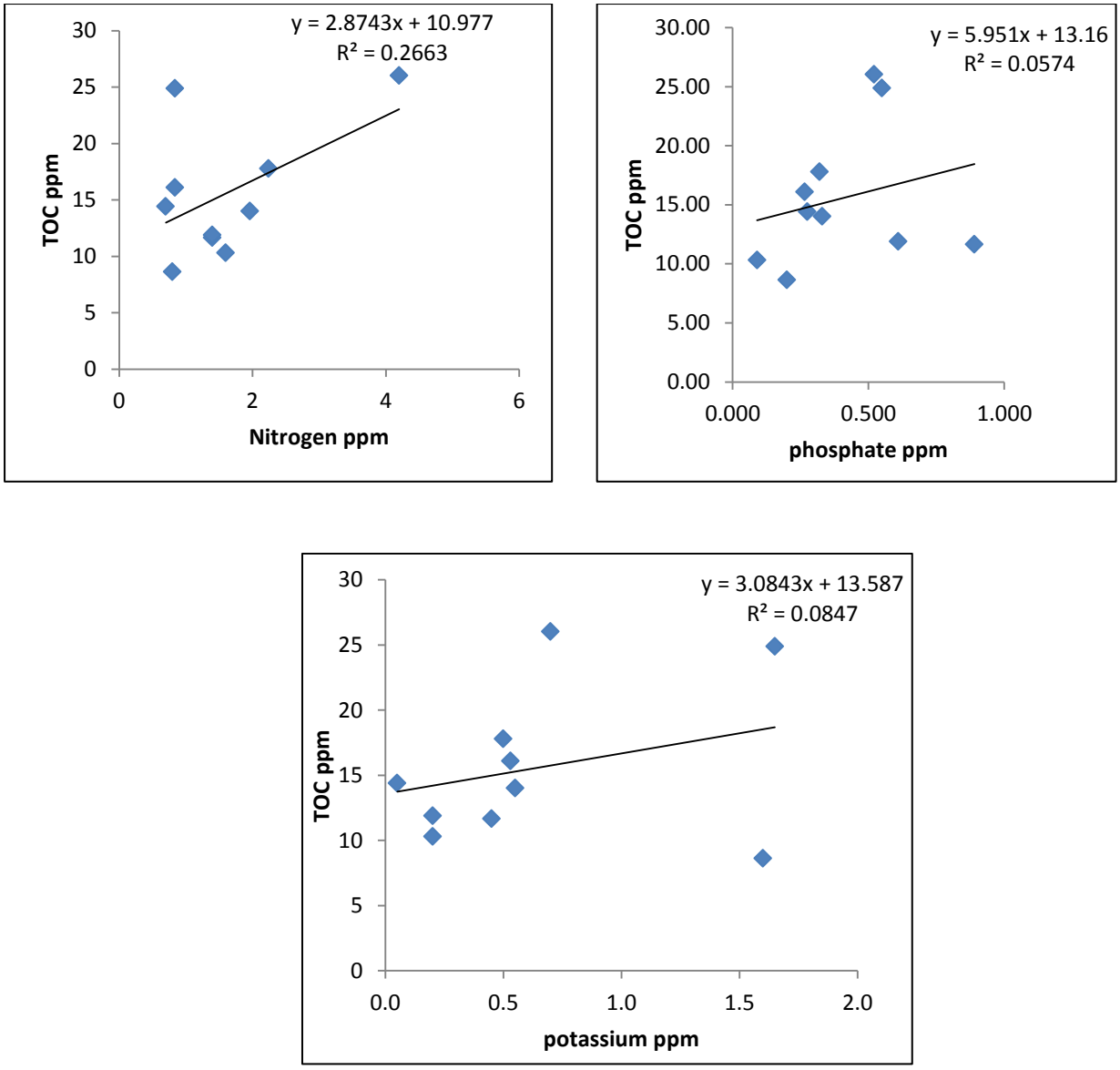
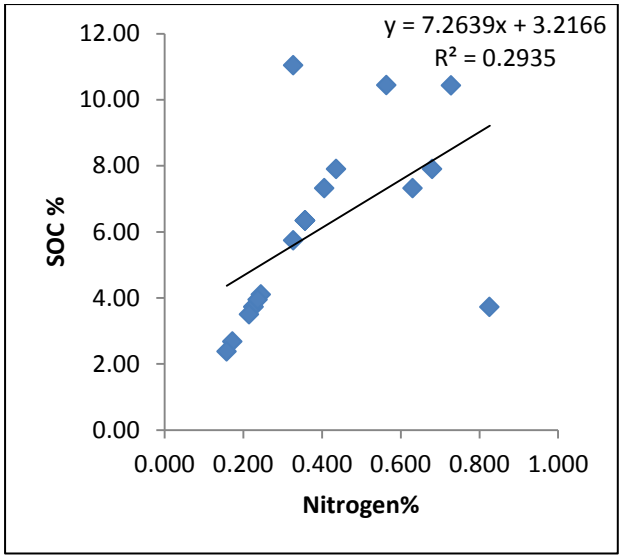
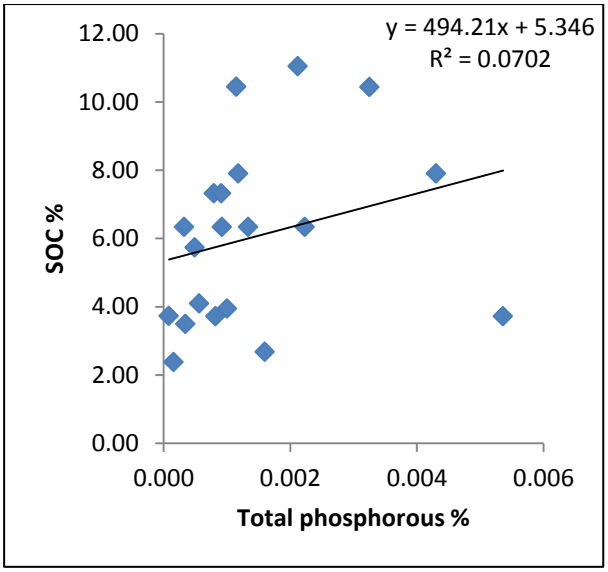


Figure 4.24: Relationship between TOC and NPK in water

4.4.2 Soil

Similarly, a positive trend was observed between nutrients i.e. nitrogen (r= 0.920), total phosphorous (r=0.469) and total potassium (r=0.6) in case of sediment collected from lake; however, a quite clear trend was observed with nitrogen at the 0.01 level. The figure below (fig 4.25) shows the relationship of SOC with NPK individually. Again from the regression analysis, the value obtained for R and R^2 were 0.965 and 0.931 respectively which indicate that the nitrogen, phosphorous and potassium represented 93.1% of the variability in carbon content in the soil from the littoral zone while the equation derived was C= 18.869N+0.04P-0.02K.





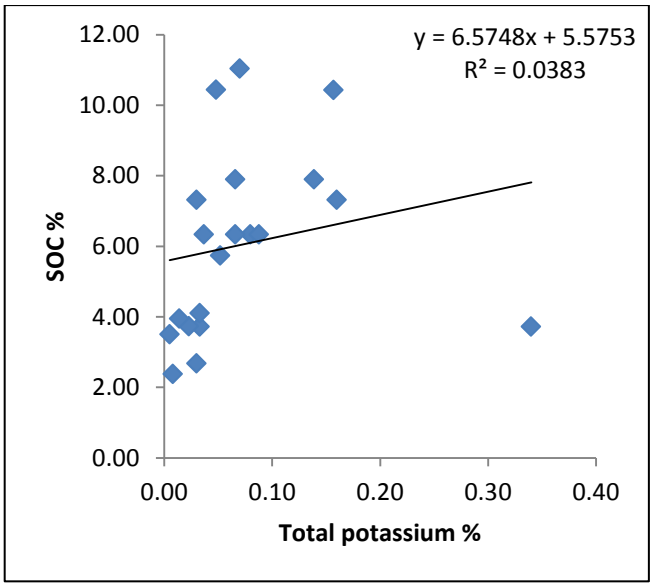


Figure 4.25: Relationship between SOC and NPK in soil

Similar trend was found in case of soil collected from the lake bank. Although the trend was between all the nutrients (N=0.155, P=0.446 and K=0.387) positive, they results were not significant. R and R^2 value obtained from regression analysis were 0.718 and 0.516, respectively. This indicates that the nitrogen, phosphorous and potassium represented 51.6 % of the variability in the carbon content in bank of the lake. As a whole, the correlation of SOC was found to be significant with the nitrogen at p=0.001 while with phosphorous and potassium at 0.05 level. The value of R and R^2 were 0.663 and 0.440, respectively.

Chapter 5: Discussions

5.1 Morphology of lake

The area of the lake was found out to be 24.57 ha with the shoreline length or the perimeter of 2755m. The more shoreline length, there will be more surface for the land water interaction. Thus the lake posses the maximum chances of nutrient inflow and outflow. Similarly the shoreline development was calculated to be 1.56 which is greater than 1. That depicted that the lake was not in completely circular in condition, generally resulting in greater the potential for enrichment from near shore development because lakes with a high shoreline development index have stronger ties to riparian habitats and they receive more terrestrial inputs of nutrients and organic matter (Noges 2009).

5.2 Water quality of the lake

The average pH of the water was approximately neutral (6.54 ±0.85) and it fluctuated from 6.0 to 8.4. The fluctuation in pH can be attributed to the combined effects of temperature, CO_2 balance, liberation of ions, and the buffering capacity of water (Schutte & Elsworth 1954). Values of pH between 7.0 and 8.0 are optimal for supporting a diverse aquatic ecosystem. A pH range between 6.5 and 8.5 is generally suitable. Considering it, the average pH of this lake was suitable for aquatic life forms. Lami *et al*. (2007) also recorded the pH range between 6.2 to 8.2 in the high altitude lake of Khumbu valley. The exact neutral pH was recorded for the Gosaikunda Lake (Raut *et al*. 2012). But it was slightly higher in the Gokyo Lake (8.1). pH is also considered as an important factor in regulating the exchange of nutrients between sediments and the water (Watts 2000). At low pH, P release from bottom sediments is stimulated (Hu *et al*. 2001).

Similarly, the lake was quite cold (5.47±0.5°C). Tartari *et al*. (1998) recorded similar result for some of the lakes in the Everest region. For Gokyo third lake it was 6°C, 7.5°C for the second Gokyo lake and 3.7°C - 5.5°C for the pyramid lake. But when compared to the lakes of lower altitude such as Mudka (26.68 ± 0.86^{0}C), Belkot (26.43 ± 0.46^{0}C) and Jhilmila Tal (18.2 ± 0.15^{0}C), the temperature was found to be lower than these lakes. This is due to the altitudinal difference as mentioned by Leopold (2000). Similarly, the surface temperature of the Tilitso lake (4920m) was slightly higher i.e. 8ºC and the conductivity was found to be more than 3 times greater than this lake (130-150 µS/cm).This may be due to the turbid condition of the lake due to the glacier silt (Aizaki *et al*. 1987).

Similarly, the conductivity of the Gosaikunda Lake was more than 3 times lower than this lake and the turbidity was also lower (Aizaki *et al*. 1987).

5.3 Carbon content

5.3.1 Water

In the normal condition, the surface water consists of less than 10 ppm of TOC (Furlong 2004). However, the lake had slightly higher TOC content (15.57±5.86)mg/l. The TOC concentration in the moraine lakes of the everest region (5140m, 5152m, 5800m and 63500m) were found to vary from 0.0039-0.00215 mg/l (Youngqin *et al*. 2006) which is very less in comparision to Kalchuman lake, this may be due to the low terrestrial productivity which results in generally low DOC concentrations as in the arctic lakes (Sobek *et al*. 2007). Similarly, the POC varied from 0.86- 2.6 mg/l and this variability may be due to mainly phytoplankton production (Canuel & Zimmerman 1999). And the macrophytes are also listed as among important autochthonous POC sources (Bianchi & Argyrou 1997). Among different form of the carbon, DOC (13.9 ±5.2 mg/l) and POC (1.57±0.59 mg/l), DOC was found to be the dominant one in this lake as mentioned by (Wetzel 2001).

In accordance with Polish legislation and German legislation (LAWA 1998), TOC boundary values for particular surface water quality, the water quality was found to be match with the water quality class III. The value of POC (0.25 to 3.69 mg/l) in Kalchuman lake was found to be lower than the lakes in the subtropical regions such as Phewa and Begnas lake of Pokhara valley as reported by Rai (1999) where they ranged from 0.45 to 4.4 mg/l and 0.67 to 4.38 mg/l, respectively. POC values depend on both the temperature and the season, and since the temperature in the subtropical region is greater than the sub alpine zone, the POC may have become lower in the Kalchuman Lake. Similarly, increases in water pollution in the Phewa, Begnas and Rupa may also cause increases in the POC parameter (Baealkiewicz & Siepak 1994a).

5.3.2 Soil

The soil's organic carbon of the lake in both littoral and bank of the lake (6.33±2.81% and 5.79±2.5%) was lower than that of Ghodaghodi Lake (11.149±7.516 %). The main reason may be the altitudinal variation because the SOC in soil seemed to decrease with the increase in the altitude (Olsson *et al*. 2009). The soil organic carbon in temperate humid wetlands Gahana, Ohio was also found to be higher than this lake for the same reason

whose value was 1.76% to 30.53% according to Bernal (2008). And another factor, may be the bulk density because it also posses strong negative correlation with the SOC (Curtis & Post 1964). The bulk density of the sediments from the Ghodaghodi Lake was 449.104 ± 226.610 kg/m3 and for this lake it was slightly higher, i.e 459.16±61.83 kg/m3. Contrasted to the Ohio and Kalchuman lake, very small amount of SOC (0.5%) was calculated for the yellow river delta, China (Wang *et al*. 2010). This may be because the river delta keeps on flooding every year and the organic matter does not get time to be deposited and decomposed. Similar result was obtained from the study carried out in Paraná River (Thomaz *et al*. 2001) where the carbon content was found to be extremely lower (< 0.1 ppm) when compared to this lake. It may be due to the fact that lentic environments may be associated with inputs of organic matter from the well-developed littoral zones, as well as from phytoplankton which is more abundant in these environments (Thomaz *et al*. 2001).

Although no significant difference was seen between the SOC content in the sediment from the littoral zone (6.33±2.8%) and the bank of the lake (5.79±2.5%), the significant differences were found in the carbon content among the different textures of the soil found in the lake. The maximum carbon content was found in the silty loam (7.79%) and minimum in the sandy soil (2.38%). This is because retention power of sandy soil is lower than the other soil and additionally, the pore space distribution and small soil pores has a major impact on the abundance of bacteria and fungi and might be responsible for higher rates of carbon mineralization (Raiesi 2006).

5.3.3 Macrophytes

Only one aquatic plant was found in the lake may be due to the nitrogen limiting condition in the lake sediment as the primary source of nitrogen, phosphorous and other nutrient for the macrophytes is the sediment (Barco *et al*. 1991). Thus the amount of the carbon stored were also comparatively less than that of water and soil. Plants obtain carbon from the atmosphere in the form of carbon dioxide but aquatic plants use carbon dioxide dissolved in the water which depends on the acidity of the water. Above pH 5.0, some of the carbon dioxide molecules form bicarbonate ions (Limgis 2001). In case of this lake the pH was 6.54±0.85, thus the macrophytes use them in the form of bicarbonate. The reason behind the less abundance of the macrophytes in the lake may be due to the texture of the soil. Because according to Barko & Smart (1986), texture of the soil determines the type and the abundance of macrophyte species that can survive in a

location. According to Burke *et al.* (1989), the increase in the clay and the silt content stimulate the plant production increasing the water holding capacity but in case of this lake most of the sediments were silty loam consisting less amount of silt and clay.

According to Maqbool (2013), the mean carbon content in the macrophytes were calculated to be 43.2 % highest in *Typha Latifolia* and minimum in *Lycopus europus* in Lake Manabal in Kashmir. But in case of this lake it was very less only 1.405%. The reason behind it is the characteristic of the macrophytes. The emergent macrophytes posses more biomass and the submerged one posses less biomass which will directly affect the carbon content. And since the *Typha Latifolia* and *Lycopus europus* are the emergent macrophytes and in Kaal taal, it was submerged one, the carbon content may have become less. Again emergent aquatic macrophytes had a great amount of fibers because of their more developed support system, as compared with floating aquatic vegetation (Esteves 1998). Emergent plants, therefore, must have a higher carbon concentration than floating plants, because this element is the main component of the plant support system.

Similarly, the carbon content in the submerged macrophytes of the tropical lagoon in San-Francisco was found to be lower than the macrophyte found in the Kalchuman Lake. It was 0.29% for *Najas marina* and 0.355% for *Ceratophyllum demersium* (Esteves & Suzuki 2010) but in the macrophyte from Kalchuman Lake it was 1.405±0.435%. The carbon content is directly related to the biomass of the macrophytes and the biomass is directly related to the nutrient content in the lake. Thus due to the less nutrient content in the tropical lagoon, there may have been the decrease in the biomass and ultimately the carbon content.

5.3.4 Litter

The carbon content in litter was found to be higher than that found in macrophytes. Actually the litter found in the littoral zone was not from the macrophytes. They were from the adjacent vegetation and were carried out and deposited in the zone by the action of wind. Since the biomass of the terrestrial vegetations is more than the macrophytes present in the lake, the litter had higher carbon content than macrophytes. The carbon content in the litter of this lake was lower (33.39± 4.29%) than that reported by Kochsiek (2010) in their study (41.58±0.3%) in irrigated and rainfed no-till agricultural systems since they were from the agro- forestry.

Thus in total, the lake's littoral zone was found to store 176.27 tons of carbon. So like the forest, the lake can also be considered in the CDM mechanism to tackle with climate change.

5.4 Nutrients

5.4.1 Water

The main source of nutrients in the lake is allochthonous i.e. input from land and decomposition of litters. Similar condition was seen in this lake. Because, the nutrient concentration near the inlet of the lake (N= 1.96%, PO_4-P=0.33 mg/l, K= 0.55 mg/l) were comparatively lower than the sampling plots near the outlet of the lake (N= 4.2 %, PO_4-P= 0.52 mg/l, K= 0.7 mg/l). The mean total nitrogen concentration of the lake (1.598±1.05mg/l) was lower than that recorded by Okino & Satoh (1986) in Rara Lake (18-30 mg/l) while higher than that recorded by Aizaki *et al*. (1987) and Tartari *et al*. (1998) in Tilicho Lake (0.10 to 0.22 mg/l) and in Gokyo Lake (0.21mg/l). The reason behind it may be the altitude as high-altitudes lakes tended to have also lower N concentrations than the lowland lakes (Noges 2009).

But reversely, the concentration of NO_3 and PO_4 in Jagdispur Reservoir was calculated to be 0.2 mg/l and 0.39 mg/l respectively (Gautam & Bhattrai 2008) which was relatively lower than this lake. The reason behind it may be due to the construction of dike harnessed by rock fill which prevents flow of the nutrient from the surrounding to the water body. Similarly, the higher values of nitrate may be attributed to the oxidation of ammonia by nitrifying bacteria and biological nitrification (Seike *et al*. 1990).

Again according to Neupane (2012), the concentration of NO_3-N was calculated to be 0.64±0.45 mg/l and the nitrite concentration was found to be less than 0.1 mg/l in all the sites of the Ghodaghodi Lake. In case of this lake, both the nitrate and nitrite (0.025±0.05 mg/l) were found to be lower. Their higher concentration may be due to the eutrophic condition of the Ghodaghodi Lake as mentioned by (Neupane 2012). Another reason may be the diffusion of nutrient into the water from sediment (UNEP-IETC 1999). According to UNEP-IETC (1999), the high concentration of dissolved inorganic nitrogen in the surface sediments results in diffusion of these nutrients into the overlying water. And in case of this lake as well, the nitrogen content in the sediments (0.395±0.19%) was higher than that of the water (1.59±1.05 mg/l). The algae can utilize these inorganic nitrogen compounds such as nitrate, nitrite and ammonium as well as organic nitrogenous compounds like urea, uric acid and amino acids for their nitrogen needs (Agrawal 1999).

According to Forsberg & Ryding (1980), the lake was found to be oligotrophic based upon the concentration of total nitrogen.

5.4.2 Soil

In lake's sediment, the concentration of total nitrogen and phosphorous was found to be higher (0.0032%) than Lake Victoria finger ponds of Netherlands (Kilonzi 2003). The sediments from the Victoria Lake were from the depth of 1.5m but in case of this lake it was taken from the surface of the lakebed, which may be the main reason for the higher concentration of the nutrients in Kalchuman Lake as there is strong negative relationship between nutrient abundance and depth (Lami 2007).

Similarly, the concentration of Nitrogen in the sediments of Jagdispur reservoir was calculated to be lower than the lake for the similar reason. Based on Healey & Hendzel (1979) for N deficiency criterion (C: N ratio < 9 no deficiency, 9-15 moderate and > 15 severe), the lake has severe deficiency of the nitrogen. Nitrogen (N), while not considered the limiting nutrient in most cases for freshwater lakes, is nonetheless an essential nutrient for algal and rooted plant growth (Wetzel 2001).

The C: N ratio of soil is also an index of mineralization potential of soil with C: N ratios of soil greater than 25 to 30 associated with soils where N concentrations limit decomposition (Paul & Clark 1989; Prescott *et al*. 2000; Xue *et al*. 2009). But in case of this lake it was only 16±0.5, hence the N concentration does not limit the decomposition.

5.4.3 Macrophytes

In case of the Kalchuman Lake, the nitrogen concentration in the plant was found to be higher than what found by Burke (2011) in *Typha latifolia* (1.3%) and *Scirpus acutus* (1.5%) in Arcatas wetland in California. The main reason is the type of the macrophyte. Because, the species found in the lake was the submerged one and those species are the emergent ones. And according to Gopal (1990), emergent aquatic macrophytes presenting more structural tissues usually have less nitrogen and phosphorous than floating and submerged species. Similar result was found in the submerged macrophytes *Najas marina* (0.186%) and *Ceratophyllum demersum* (0.0228%) of tropical lagoon of San Francisco (Esteves & Suzuki 2010).

Compared to the lake Kalchuman, the constructed wetland had lower concentration of the nitrogen in the macrophyte while higher phosphate concentration was in macrophytes. The lower concentration of nitrogen in the Kalchuman Lake might be due to the fact that

the lake has severe N deficiency in the sediments as per the Healey & Hendzel (1979) classification. As a result the abundance of macrophytes was also found to be lower.

5.4.4 Litter

The nitrogen concentration in the litter was higher in the lake than those found by Burke (2011) in *Typha latifolia (*0.006%) and *Scirpus acutus* (0.014%) in the Arcatas wetland of California. Most of the litters in the Kalchuman Lake were found to constitute the leaves and twigs of terrestrial vegetation which automatically varies from the nutrient content of the emergent vegetations in Arcatas wetland.

5.5 Relationship between carbon and nutrients

5.5.1 Water

The pearson correlation showed that there was positive correlation between the carbon and nutrients. Similar result was also found by Silveira (2005) in his study. The study also showed that the DOM is an important source of mineralizable C and its production is also influenced by nutrient (N and P) condition of the soil such as chemical forms and availability.

Similarly, the correlation between the nitrogen and the carbon was more clear and higher as compared to the phosphorous and the potassium which also explains that the nitrogen was the factor with the highest predictive capacity for carbon content in water in the lake (Annex VII). This was also supported by Yang *et al*. (2012) who also found significant correlation ($p < 0.01$) between nitrogen and DOC in the study carried out in Lake Okeechobee watershed. Pedrosa *et al*. (2007) also found similar result in the study carried out in Lake Seston of Southern Brazil with the R^2 value of 0.852.

5.5.2 Soil

In case of soil collected from the littoral zone, there was a positive correlation between carbon content and nutrients i.e. nitrogen (0.920), total phosphorous (0.469) and total potassium (0.6) but correlation ($p= 0.01$ level) was significant only with nitrogen. The regression analysis showed that the value of R and R^2 was 0.965 and 0.931 respectively which means nitrogen, phosphorous and potassium represented 93.1% of the variability in carbon content.

Similarly, in case of soil collected from the bank of the lake, there was a positive correlation between nitrogen ($p=0.155$), phosphorus ($p=0.446$) and potassium ($p=0.387$) and carbon content of the soil but the significant correlation was obtained only in case of

nitrate at the level of 0.05. Also, regression analysis result showed that the R value increased to 0.718 and R^2 was calculated to be 0.516. This indicates that the nitrogen, phosphorous and potassium represented 51.6 % of the variability in the carbon content in the bank of the lake and the combined effect of the nutrients were more than the individual effect in the carbon.

Similar result was found by Wang (2010) in wetland of Yellow River Delta, China and the correlation was much stronger at the freshwater site. Niraula (2012) also reported a significant positive correlation ($p< 0.0001$) between OM and nitrogen in his study carried out in Beeshazari Lake.

This is also consistent with the findings of Martinova (1993), who discovered correlation coefficients of r=0.9-0.95, for associations between total nitrogen and organic carbon in the sediments of 176 Russian lakes.

Chapter 6: Conclusion and Recommendations

6.1 Conclusion

The area of Kalchuman Lake was found to be 24.57 ha with the depth of 25.6m and volume of water was calculated to be 6.4Mm^3. Similarly, the lake's littoral zone was found to be the significant storehouse of carbon even on its small portion as it stored 176.27 tons of carbon and among all; more was stored in the sediments. However, their concentration varied with texture.

Similarly, nitrogen was found to be higher in macrophytes whereas potassium was extremely higher in sediments especially, the sediments from the bank of the lake. Likewise the concentration of potassium was negligible in case of the macrophytes and litters. Correlation between carbon and nutrients showed a positive trend in case of water and sediment. However, the relation was stronger between carbon and nitrogen in water and was significant in case of the sediments with nitrogen in the littoral zone and with nitrate in bank of the lake, depicting nitrogen and its compound as the factor with the highest predictive capacity for carbon. Similarly, the multiple regression analysis again showed that the combined effect of the nutrients were stronger than the individual effect.

Thus, from this study, it can be concluded that the lake, especially the soil, also posses high potential of storing the carbon, and its storing capacity is highly dependent on the nitrogen concentration in water and sediment. Thus the conservation of lakes is necessary thereby providing more economic and environmental friendly solutions to tackle climate change problem.

6.2 Recommendations

- The detail study on carbon sequestration potential of lakes is necessary.
- Carbon in relation to nutrients must be clearly understood.
- Lakes should also be enrolled in CDM mechanism to tackle with climate change.
- Conservation of the lakes are necessary so as mitigate the problem of climate change.

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Appendices

Annex I

1. Sampling sites with geographical coordinates

Sample no	Water and Macrophytes		Sediments and litters					
	Littoral zone		Littoral zone			Lake bank		
	Latitude	Longitude	Sample no	Latitude	Longitude	Sample no	Latitude	Longitude
1	28º 30'16"	84º47' 55"	1	28º 30'16"	84º47' 55"	11	28 º30'15"	84 º 47'54"
2	28º 30'16"	84º48' 05"	2	28º 30'16"	84º48' 05"	12	28 º 30'15"	84 º 48'03"
3	28º 30 '15"	84º48' 12"	3	28º 30 '15"	84º48' 12"	13	28 º30'13"	84 º 48'11"

4	28 º 30'14"	84º48' 16"	4	28 º 30'14"	84º48' 16"	14	28 º30'14"	84 º 48'19"
5	28 º 30'15"	84 º 48'21"	5	28 º 30'15"	84 º 48'21"	15	28 º 30'16"	84 º 48'25"
6	28º 30'17"	84º48' 21"	6	28º 30'17"	84º48' 21"	16	28 º 30'17"	84 º 48'22"
7	28º 30'21"	84º48' 18"	7	28º 30'21"	84º48' 18"	17	28 º 30'22"	84 º 48'19"
8	28º 30'24"	84º48' 12"	8	28º 30'24"	84º48' 12"	18	28 º 30'26"	84 º 48'12"
9	28º 30'25"	84º48' 04"	9	28º 30'25"	84º48' 04"	19	28 º 30'26"	84 º 48'03"
10	28º 30'20"	84º48' 57"	10	28º 30'20"	84º48' 57"	20	28 º 30'20"	84 º 47'56"

Annex II

ORIGINAL DATA

1. Original data of Water

S. N	Temperature(ºC)	pH	Conductivity(µS/cm)	Turbidity(NTU)	TOC (mg/l)	DOC(mg/l	POC (mg/l)	Nitrite-N(mg/l)	Nitrite (mg/l)	Nitrate-N(mg/l)	Nitrate (mg/l)	Ammonia-N(mg/l)	Ammonia(mg/l)	Nitrogen(mg/l)	Phosphate(mg/l)	Potassium(mg/l)
1	5.9	6.6	16.32	5.34	26.03	23.427	2.6	0.0050	0.17	0.26	1.15	0.0050	0.00607	4.2	0.52	0.7
2	5.6	6.1	39.0	18.6	11.66	10.44	1.22	0.014	0.045	0.225	0.996	0.0050	0.00607	1.4	0.89	0.45
3	5.2	7.8	49.9	2.6	11.89	10.701	1.19	0.0030	0.01	0.37	1.64	0.0030	0.00364	1.4	0.61	0.2
4	5.7	6.1	41.8	31.8	24.88	22.3	2.58	0.0010	0.0030	0.35	1.55	0.01	0.01214	0.84	0.55	1.65
5	4.1	8.4	39.7	2.79	17.79	16.011	1.78	0.0004	0.0010	0.375	1.66	0.0010	0.00121	2.24	0.32	0.5
6	5.8	6.0	39.9	3.56	14.01	12.6	1.41	0.0	0.0	0.38	1.68	0.0015	0.00182	1.96	0.33	0.55

7	5.8	6.1	47.9	3.38	16.09	14.481	1.61	0.0	0.0	0.285	1.26	0.0010	0.00121	0.84	0.265	0.53
8	5.2	6.0	41.5	2.4	8.63	7.767	0.86	0.0020	0.0070	0.345	1.528	0.0060	0.00729	0.8	0.2	1.6
9	5.7	6.1	39.5	1.51	14.41	12.969	1.44	0.0033	0.011	0.28	1.24	0.0080	0.00971	0.7	0.275	0.05
10	5.7	6.2	33.1	5.63	10.31	9.279	1.03	0.0020	0.0070	0.375	1.66	0.0010	0.00121	1.6	0.09	0.2
Mean	**5.47**	**6.54**	**38.9**	**7.76**	**15.57**	**13.9**	**1.57**	**0.025**	**0.025**	**0.324**	**1.4**	**0.004**	**0.0050**	**1.59**	**0.405**	**0.64**
S.D	**0.54**	**0.851**	**9.2**	**9.8**	**5.9**	**5.3**	**0.59**	**0.05**	**0.05**	**0.06**	**0.25**	**0.003**	**0.003**	**1.05**	**0.236**	**0.55**

2. Original data for soil

Sample no	pH	Moisture(%)	Dry matter(%)	Texture	SOC%	Bulkdensity(kg/m^3)	TOC(ton/ha)	Nitrogen%	Total phosphorous(mg/l)	Total potassium(mg/l)
WS1	5.21	54.09	45.91	silty loam	7.32	389.12	24.2	0.631	7.95	222.5
WS2	5.24	77.07	22.93	silty loam	10.43	380.28	33.7	0.728	32.5	217.5
WS3	5.75	28.01	71.99	silty loam	7.32	458.37	28.5	0.406	9.13	41.62
WS4	5.65	49.92	50.08	loamy sand	2.68	588.4	13.4	0.173	16.44	41.65
WS5	5.37	47.24	52.76	silty loam	6.34	473.28	25.5	0.357	13.37	111.997
WS6	6.07	13.9	12.9	sandy	2.38	490.68	9.9	0.158	1.58	11.5
WS7	6.09	56.22	43.78	silty loam	10.44	391.97	34.8	0.564	11.48	66.77
WS8	5.66	57.53	42.47	silty loam	6.34	463.82	24.9	0.357	22.33	122.0
WS9	5.73	46.15	53.85	loamy sand	3.72	486.67	15.4	0.226	8.18	46.68
WS10	5.3	70.03	29.97	silty loam	6.34	468.98	25.3	0.357	3.24	91.9
Mean	**5.6**	**50.01**	**42.66**		**6.33**	**459.16**	**23.56**	**0.395**	**12.6**	**97.4**
S.D	**0.32**	**18.42**	**16.96**		**2.81**	**61.83**	**8.29**	**0.19**	**9.24**	**73.05**
BS1	6.4	16.29	83.71	silty loam	4.1	736.0	25.65	0.245	5.64	46.68
BS2	4.3	40.58	59.42	silty loam	3.72	956.28	30.24	0.826	53.62	473.75

BS3	5.42	24.98	75.02	sandyloam	5.74	884.29	43.14	0.327	4.92	71.8
BS4	5.32	21.39	78.61	silty loam	11.04	557.39	52.3	0.327	21.2	96.9
BS5	4.31	33.3	66.7	silty loam	7.9	896.81	60.22	0.68	43.06	192.38
BS6	4.63	22.63	77.37	silty loam	6.34	807.0	43.5	0.357	9.2	51.7
BS7	5.86	6.82	93.18	loamy sand	3.73	1042.61	33.05	0.226	0.84	31.6
BS8	5.83	65.31	34.69	silty loam	7.9	698.65	46.9	0.436	11.8	91.9
BS9	6.21	38.07	61.93	sandyloam	3.95	1126.46	37.82	0.237	10.04	19.17
BS10	6.9	7.33	92.67	loamy sand	3.5	1290.0	38.378	0.215	3.46	6.61
Mean	**5.52**	**27.67**	**72.33**		**5.79**	**899.55**	**41.15**	**0.39**	**16.37**	**108.25**
S.D	**0.89**	**17.55**	**17.55**		**2.5**	**216.18**	**10.24**	**0.21**	**17.91**	**138.85**

Sample no	**NO_3-N(mg/l)**	**Nitrate(mg/l)**	**NO_2-N(mg/l)**	**Nitrite(mg/l)**	**NH_3-N(mg/l)**	**Ammonia(mg/l)**	**C:N**
WS1	1.5	6.65	0.0017	0.0050	0.5	0.121	16.0
WS2	1.38	6.1	0.0013	0.0040	0.0526	0.064	14.0
WS3	1.38	6.1	0.0010	0.0030	0.046	0.056	18.03
WS4	0.73	3.23	0.0023	0.0076	0.07	0.086	15.49
WS5	1.78	7.84	0.0008	0.0028	0.071	0.085	17.759
WS6	0.89	3.9	0.0008	0.0028	0.058	0.071	15.06
WS7	1.225	5.4	0.0016	0.0053	0.02774	0.0337	18.51

WS8	1.36	5.99	0.0014	0.0046	0.037	0.0449	17.759
WS9	1.06	4.67	0.0006	0.0019	0.054	0.066	16.46
WS10	1.189	5.23	0.0020	0.00658	0.064	0.0777	17.75
Mean	**1.25**	**5.51**	**0.001**	**0.004**	**0.098**	**0.0705**	**16.68**
S.D	**0.3**	**1.34**	**0.0005**	**0.002**	**0.14**	**0.024**	**1.5**
BS1	1.28	5.67	0.00034	0.0010	0.135	0.164	16.73
BS2	0.912	4.03	0.0006	0.0020	0.0536	0.065	15.0
BS3	1.78	7.89	0.0010	0.0033	0.0358	0.043	17.55
BS4	1.7	7.54	0.0010	0.0033	0.0735	0.089	10.713
BS5	2.03	9.03	0.0006	0.0020	0.0586	0.071	12.0
BS6	1.98	8.77	0.0010	0.0033	0.057	0.069	17.76
BS7	1.26	5.6	0.0011	0.0036	0.058	0.071	16.5
BS8	2.17	9.5	0.0008	0.0026	0.113	0.137	18.11
BS9	0.905	3.98	0.00062	0.0020	0.178	0.215	16.67
BS10	0.78	3.45	0.0002	0.0007	0.0874	0.106	16.28
Mean	**1.47**	**6.55**	**0.0007**	**0.002**	**0.085**	**0.103**	**15.73**
S.D	**0.52**	**2.28**	**0.00031**	**0.001**	**0.044**	**0.054**	**2.48**

3. Original data for Macrophytes and Litter

Sample no	Macrophytes					Litters									
	Moisture %	Carbon %	Nitrogen %	Phosphorous %	Potassium %	Moisture%		Carbon%		Nitrogen%		Phosphorous %		Potassium%	
						L1	L2	L1	L2	L1	L2	L1	L2	L1	L2
1	-	-	-	-	-	73.4	-	27.93	-	1.05	-	0.015	-	0.00157	-
2	96.17	1.7	3.325	0.128	0.0019	-	-	30.35	-	0.88	-	0.165	-	0.00101	
3	-	-	-	-	-	-	41.39	-	16.91	-	0.525	-	0.0011	-	0.00034
4	98.09	0.85	3.675	0.119	0.00046	68.7	56.94	36.17	17.24	0.88	1.575	0.027	0.0042	0.00062	0.0004
5	-	-	-	-	-	69.2	51.95	38.56	9.79	1.05	3.59	0.044	0.0014	0.00146	0.00066
6	-	-	-	-	-	-	35.18	-	8.037	-	1.05	-	0.0032	-	0.00044

7	97.16	1.27	1.575	0.0044	0.0004	71.01	54.79	-	4.925	-	1.05	-	0.0017	-	0.0
8	96	1.8	1.05	0.0404	0.00067	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	75.78	-	33.95	-	1.75	-	0.0656	-	0.000526	-
Mean	**96.86**	**0.562**	**0.03**	**0.0003**	**0.00086**	**71.62**	**45.9**	**33.39**	**11.12**	**1.12**	**1.89**	**0.0632**	**0.0023**	**0.0011**	**0.00037**
S.D	**0.97**	**0.76**	**0.05**	**0.0006**	**0.0007**	**2.96**	**9.87**	**4.29**	**5.39**	**0.36**	**1.85**	**0.06**	**0.001**	**0.0005**	**0.0002**

ANNEX III

ANOVA tests (Analysis of the Variance)

1. Carbon content and bulk density in the soil samples from littoral zone and bank of the lake

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Carbon	Between Groups	1.453	1	1.453	.204	.657
	Within Groups	128.186	18	7.121		
	Total	129.638	19			
Bulkdensity	Between Groups	30732.800	1	30732.800	.501	.488
	Within Groups	1104433.200	18	61357.400		
	Total	1135166.000	19			

2. Analysis of variance for the carbon content in various textures

ANOVA

Carbon

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	66.220	3	22.073	5.569	.008
Within Groups	63.419	16	3.964		
Total	129.638	19			

3. NPK and bulk density in littoral zone and bank of the lake

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Nitrogen	Between Groups	.000	1	.000	.008	.929
	Within Groups	.721	18	.040		
	Total	.721	19			
Total phosphorous	Between Groups	70.613	1	70.613	.347	.563
	Within Groups	3659.216	18	203.290		
	Total	3729.828	19			

Total potassium	Between Groups	587.235	1	587.235	.048	.830
	Within Groups	221554.278	18	12308.571		
	Total	222141.513	19			
Nitrate	Between Groups	5.356	1	5.356	1.529	.232
	Within Groups	63.041	18	3.502		
	Total	68.397	19			
Nitrite	Between Groups	.000	1	.000	9.050	.008
	Within Groups	.000	18	.000		
	Total	.000	19			
Ammonia	Between Groups	.005	1	.005	3.040	.098
	Within Groups	.031	18	.002		
	Total	.036	19			

ANNEX IV

Correlation and Regression analysis

1. Water (Correlations)

Correlations

		TOC	Nitrogen	Orthophosphate	Potassium	Nitrate	Nitrite	Ammonia
TOC	Pearson Correlation	1	.516	.205	.291	-.190	.540	.349
	Sig. (2-tailed)		.127	.569	.415	.598	.107	.322
	N	10	10	10	10	10	10	10

Regression analysis of carbon with NPK

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.582[a]	.338	.008	5.84418

a. Predictors: (Constant), Ln_potassium, Orthophosphate, Nitrogen

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.949	4.672		2.558	.043
	Nitrogen	2.594	1.906	.466	1.361	.222
	Orthophosphate	5.383	23.385	.079	.230	.826
	Ln_potassium	3.297	4.372	.253	.754	.479

a. Dependent Variable: TOC

2. Soil

Correlation between carbon and NPK in soil from littoral zone

		Carbon	Nitrogen	Total phosphorous	Total potassium	Nitrate	Nitrite	Ammonia
Carbon	Pearson Correlation	1	.920**	.469	.600	.604	.053	-.306
	Sig. (2-tailed)		.000	.171	.067	.064	.884	.389
	N	10	10	10	10	10	10	10
	Sig. (2-tailed)	.389	.962	.488	.258	.734	.639	
	N	10	10	10	10	10	10	10

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

Correlation between carbon and NPK in soil from bank of the lake

Correlations

		Carbon	Nitrogen	Total phosphorous	Total potassium	Nitrate	Nitrite	Ammonia
Carbon	Pearson Correlation	1	.155	.205	-.014	.743*	.441	-.212
	Sig. (2-tailed)		.669	.571	.969	.014	.202	.557
	N	10	10	10	10	10	10	10
	N	10	10	10	10	10	10	10

*. Correlation is significant at the 0.05 level (2tailed).

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

Regression analysis of carbon with NPK in littoral zone of Kalchuman lake

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.965[a]	.931	.897	.90424

a. Predictors: (Constant), Totalpotassium, Totalphosphorous, Nitrogen

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.346	.732		.474	.653
	Nitrogen	18.869	2.742	1.290	6.880	.000
	Total phosphorous	.040	.039	.131	1.021	.347
	Total potassium	-.020	.008	-.528	-2.707	.035

a. Dependent Variable: Carbon

Regression analysis of carbon with NPK in littoral zone of Kalchuman lake

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.718[a]	.516	.273	2.14134

a. Predictors: (Constant), ln_potassium, ln_phosphorous, Nitrogenpercent

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.294	2.998		.098	.925
	Nitrogenpercent	-15.536	7.952	-1.283	-1.954	.099
	ln_phosphorous	3.839	2.248	.815	1.708	.139
	ln_potassium	4.407	2.783	.906	1.583	.164

a. Dependent Variable: Carbon percent

Annex V
Photos

Photo 1: Kalchuman Lake

Photo 2:Settlement in Prok VDC

Photo 3: Inlet of lake

Photo 4:Collecting water sample

Photo 5:Texture determination in lab

Photo 6: Sediment sample for SOC determination in sediment

Photo 7: Determination of nitrate in lab

Photo 8: Spectrophotometer used in lab

Photo 9: SOC determination in lab

Photo 10: Potassium determination in lab

Photo 11: Hot air oven

Photo 12: Kalchuman lake