ASSESSING THE INFLUENCE OF HUMAN SETTLEMENTS ON THE PLANT DIVERSITY IN WETLANDS OF PHOBJI AND GANGTEY, BHUTAN

Senior Thesis submitted for partial fulfillment of requirement of

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Declaration

I hereby declare that the thesis titled, "Assessing the influence of human settlement on the plant diversity in the wetlands of Phobji and Gangtey, Bhutan" is based on my own research. I have not committed to any form of plagiarism or academic dishonesty. All the resources used in this writing has been cited and acknowledged.

Date: 14th December, 2018

Signature: PEMA LHAMO

List of Abbreviations

UWICER: The Ugyen Wangchuck Institute for Conservation and Environmental Research

SPAL: Soil and Plant Analytical Laboratory

GIS: Geographic Information System

NSSC: National Soil Service Center

RSPN: Royal Society for Protection of Nature

RGoB: Royal Government of Bhutan

DoFPS: Department of Forest and Park Services

NBC: National Biodiversity Center

IUCN: International Union for the Conservation of Nature

GISD: Global Invasive Species Database

UD: Undisturbed area

HS: Human Settlement area

pH: Potential Hydrogen

Ca: Calcium

Mg: Magnesium

K: Potassium

P: Phosophorus

N: Nitrogen

Glossary of Bhutanese Terms

Dzongkhag: District

Geowg: Block

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Abstract

Plant diversity in the wetlands of Phobji and Gantey represents an important aspect of the overall wetland ecosystem. However, over the years, the increasing trend in population has initiated the building of many infrastructures and accommodations which lie at close proximity to the core wetland area. This accelerates the expansion of land use to the core wetland area posing a huge threat to the plant diversity of the wetlands. This research thus studied the plant diversity in human settled area and core undisturbed area with an objective to assess the influence of human settlement on the plant diversity. A belt transect method was used for the purpose of vegetation survey and Shannon Wiener diversity was calculated using the relative dominance. Plants were analyzed for their diversity, richness, life forms, dominance and invasive nature. Additionally, soil and water parameters were also tested to see the current situation of the pH and nutrient levels.

A total of 136 species belonging to 39 families was identified in both the areas. Some of the dominant species identified were *Trifolium repens, Rumex napelensis* and *Pedicularis denticulata*. An endemic plant species *Euphrasia bhutanica* was also identified in one of the plots of the undisturbed areas. Two species of orchid was also found along with the endemic plant. Shannon Wiener diversity index showed the highest index of 3.14 in one of the plots in human settlement area. The overall diversity index and species richness was found to be higher in the undisturbed areas. Soil analysis did not show much of a difference in physical and chemical parameters except for a slight difference in potassium content. Similarly, water parameters did not show much difference but only showed variation in calcium content.

The findings of the study indicated towards the increasing influence of human settlement in the wetland.

Keywords: Wetland; Plant diversity; Soil and Water Properties

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CHAPTER ONE

Introduction

1.1 Background

Wetlands constitute around 6% of the total land on earth and harbors many biodiversity. They are also important for the world as they act as a carbon sink which absorbs the carbon content from the atmosphere (Meng et al., 2016). Literature defines wetlands as an ecotone referring to the transitional phase between dry land and water which makes it neither a terrestrial nor an aquatic ecosystem (Hammer, 1989). Citing Sonam Choden who currently works under the watershed management in Bhutan, wetland is a generic term under which there are many types. The different types of wetlands present in Bhutan include bogs, peats, fens, lakes, marshes, streams and rivers which are some of general types of wetlands (Dolkar et al., 2017). Wetlands constitute an important part of the ecosystem for many organisms. Amongst the many wetlands in Bhutan, the Gantey-Phobjikha wetland is one of the most diverse wetlands which harbors as many as 300 threatened and vulnerable species including the black-necked crane (*Grus nigricollis*). ("Bhutan's third Ramsar Site", 2012). Along with harboring various bio-diverse species, the wetlands also render some ecosystem services. The wetlands are known for their ability to control floods, ground water replenishment, sediment retention, shoreline protection from storms and many more ("Wetland ecosystem service", n/d). Moreover, wetlands also have the ability to retain the optimum parameters like water and soil to a certain extent (Zedler, et al 2005).

Wetlands, along with being one of the important ecosystems, is also one of the threatened ecosystems in the world. (Phuntsho, 2014). These threats and risks are usually imposed by varying factors. The changes in the wetlands are often attributed to climatic conditions but human intervention and developmental activities have also contributed to the degrading ecosystem of the wetland and its organisms (Lhendup et al, 2011). Moreover, studies have also found that the plant composition and its adaptability changes along with the human disturbances such as grazing, building infrastructures and agriculture activities (Casanova et al., 2011) Additionally, there are risks of native plant species being overtaken by invasive and alien plants (Heywood, 2008). Thus, it becomes essential to conduct more research on the root causes and current situation of any degradation in the plant diversity.

This study, thus was carried out to identify the various plant species in two areas; human settlement areas with prevalence of houses, roads and agriculture farms and the undisturbed core area where human disturbance is comparatively less.

1.2 Problem statement

The conserved wetland area in Gangtey-Phobjikha is considered to be one of the largest in the country and is also a part of RAMSAR convention which makes it an area of international importance. However, over the past few years, a growing number of population has led to building more infrastructures. Additionally, most people come to see the black necked cranes which has boosted tourism industry in the area, leading to more hotels and other commodities. It is also being said that a lot of waste water coming from these hotels are directly being dumped in the drainage, ultimately leading to the nearby adjoining river. Moreover, agriculture farming is one of the main source of livelihood in the area and these farms lie at a close proximity from the wetlands. There are possibilities of NPK influx in the soil of the core wetlands from the agricultural lands. This situation especially, has created a need to assess the growing negative impact of human interventions on the plant diversity in the areas. However, it is not certain whether the variations are evident in terms of plant diversity and also, soil and water parameters. Thus, it is important to first access the plant diversity and at the same time, access the current soil and water conditions before establishing any relation between these two variables.

1.3 Research Objective(s)

The primary objective of the study is to analyze the human settlement impact on the plant diversity in the conservation site of the wetlands of Phobji and Gangety.

The research thus, specifically aims to:

- Assess and compare the plant diversity in areas in human settled area and undisturbed core wetland areas.
- Compare and analyze the soil and water parameters between the human settled areas and comparatively undisturbed core wetland area.

1.4 Research questions

- How are the plant diversity and composition different in undisturbed core wetland area and human settled areas?
- Which plant species is the dominant?
- Are there any traces of alien or invasive plants?
- What are the variations in soil parameters like pH, NPK content, moisture and organic carbon content in human settled areas and undisturbed (comparatively) areas?
- What are the variations in water parameters like pH, EC, Mg, and Ca content?
- How has the temperature and population dynamics changed over the years?

1.5 Justification

Wetlands in Phobjikha serves as a wintering ground for the vulnerable black necked cranes. The wetland has gained international importance as it was signed under the RAMSAR convention. This makes it all the more important to carry out research on the possible risks of human intervention to the wetlands.

There are not enough research done and with growing number of population, the degree of risk posed on the wetlands has started to intensify. Moreover, human settlements and the core wetland area lie at close proximity to each other thus, research needs to be done in order to provide evidence of the impact human settlement has on the wetlands. This research not only serves as a base for future studies but also might help in making stronger policies regarding the conservation area.

CHAPTER 2

Literature Review

2.1 Plant diversity in wetlands

Plant diversity is one of the indicators that show the health and condition of the wetlands. Even a small scale wetland can harbor diverse communities of plant species which increase the richness and diversity of that region (Flinn et al., 2008).Some of the important indicators of plant's resilience include species richness, diversity index and growth structure. These are however affected by a variety of factors such as physical changes, climate change, human interventions and invasive plants ("Threats to Wetlands"). According to Baker (1971), the human interventions is one of the main reasons for changes in the life forms and evolution. Additionally, Zangmo (2014) found a variation in the plant diversity due to various reasons like human intervention and invasive species in the wetlands of Gangtey- Phobjikha. Thus, one way of measuring the plant diversity is by using the Shannon Weiner index which shows even the slightest of variations in plants and also shows the abundance of the species (David, 2017).

2.2 Human Settlements and Degradation of Wetlands

Human settlement is defined as any form of dwellings or infrastructure in which human beings are able to live. The settlement varies from clusters to sparsely connected houses. The dwellings are, in some context, adjoined by agriculture fields and also accompanied by road connections ("Human Settlements and their", 1977). This, according to Joseph, is one of the major causes of wetland degradation. The livelihood activities of human, especially in terms of agriculture on the outskirts of the wetlands, is said to have negative effect on the soil composition as the upper soil particles from the agricultural fields are eroded and deposited in the wetland areas (Joseph, 2012). This is said to have a negative impact on the plant diversity as eutrophication in the wetlands can either lead to growth of invasive plants or decrease the diversity of the species growing altogether (Joesph, 2012; Subha et al., 2014).

2.3 Human Demographics and Land Use in Phobji-Gangtey Gewogs.

Population record of Phobji and Gangtey shows a count of 375 and 325 households respectively (Wanduephodrang Dzongkhag Administration, 2018). The approximate number of people in Phobji and Gangtey, as per the census records of 2017, is 3126 and 2251 people respectively. Moreover, Dolkar et al., (2017) reported that the population in both the Gewogs has been increasing over the years. This is attributed to various reasons such as better health care systems, better living standards but most importantly, livelihood activity through tourism industry due to the black necked cranes. Phobjikha valley (both Gangtey and Phobji gewogs), has seen an unprecedented growth in the number of buildings and roads as a way to accommodate more tourists (RSPN, 2017). Additionally, over the years, the land use in Phobjikha has seen many changes as the agriculture land over the past 32 years increased by 30%. While agricultural lands increased by 1.3%, studies revealed a decrease in forest and marsh land by 1.1% and 0.6% respectively (Chaudhary, 2017). In terms of agriculture farming, RSPN (2017) reported potato as the mostly grown crop in both the valleys and some of these farms lie at a close proximity to the core wetland areas.

2.4 Soil Parameters

The plant diversity depends on the soil type as the retention capability of the soil can determine how much nutrients the plant will get. Additionally (Teejuntuk et al., 2003) mentions that soil type and soil parameters have a huge impact on the plant distribution and growth. Each soil type is associated with the type of plant species that grow in the area. Moreover, the change in land use in terms of plant variety can make the soil vulnerable to erosion and runoffs (Wilmshurst, 2012). Currently, Gangtey-Phobjikha's landscape and topography, according to Caspari et al., (2008), has wide and flat valley features with a gradient type water beds. This enables the sediment preservation in most part of the area.

2.5 Water Parameters

Surface water are at high risk of getting polluted due to anthropogenic activities (Shahabudin et al., 2018). The main polluter is the untreated grey water discharge from the households near the streams, in and around the core roosting ground of the black necked cranes. Moreover, traces of solid wastes were found along the main stream in Gangtey and Phobjikha valley which clearly indicates the risk of the human intervention on the stream (RSPN, 2017).However, the current situation of the stream in Phobji- Gangtey seems to be comparatively healthy as opposed to being polluted. According to Wangchuk et al., (2018), the pH of the stream in Phobjikha was found to be slightly alkaline during the post-monsoon. The study also revealed that the electric conductivity of the streams in Phobjikha post-monsoon was 18.45 ± 4.65 µS/cm (micro-Siemens per centimeter). This was found to be influenced by the amount of dissolved ions and temperature. In the context of the streams of Phobjikha, it was found that the increase in electric conductivity seemed to decrease the macro-invertebrate diversity of the stream. The study also revealed that the growing pressure from adjacent anthropogenic activity seem to affect water parameter in subtle ways only. This, as Jennesen et al., (1994) identified, can be attributed to the natural subsidizing effect of the wetlands, especially from the adjacent polluters. One way of finding out the type of land use is by determining the calcium and magnesium content in the surface water. Calcium and magnesium are naturally found in water so their build up or reduction in the water can help understand about nutrient eutrophication (Potasznik et al., 2015).

CHAPTER 3

Methodology

3.1 Study Site

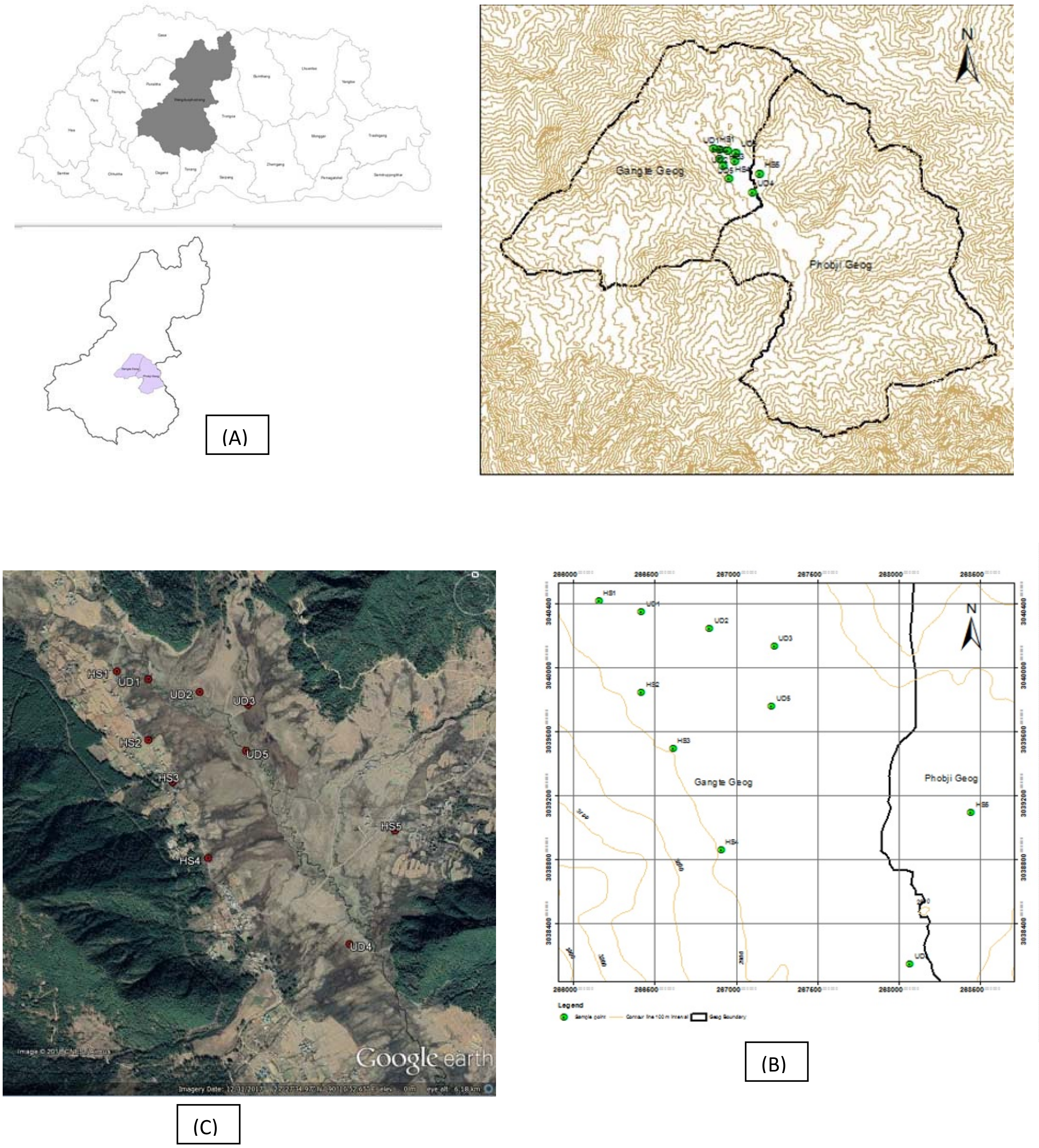

Figure 3.1 (A) Map showing the location of Dzongkhag and Gewog; (B) Topographical view of study area showing exact location of the plots; (C) Satellite view of study area. (Map prepared by Sangita Pradhan, GIS, Simtokha)

The Phobji-gangtey wetlands is located in Wangduephodrang district at an elevation of 2900 m above sea level and covers up to 161.9 km^2.("Black Necked Crane Conservation", n/d). It is one of the largest wetlands in the country and also the wintering grounds for one of the migratory black necked crane which has been listed as vulnerable by the International Union for the Conservation of Nature (IUCN). The wetland in Phojikha was also identified as wetland of international importance listed under RAMSAR convention. The study site covered an approximate distance of 1000 meters along the Gangtey and Phobji wetlands. For every plot selected, the slope, altitude and aspect ratio was measured using the Garmin etrex 10 GPS.

Phobji and Gantey fall in the category of cool temperate zone. The average temperature, recorded for 10 years till 2017 was found to be 8.2 degree Celsius and the average maximum temperature was recorded to be 14.7 degree Celsius. The average lowest temperature recorded was 0.2 degree Celsius ("Climate book of Bhutan", 2018). The average maximum rainfall, for the past twenty years till 2015, was recorded in July and the average minimum was recorded in the month of December (RSPN, 2014).

3.2 Survey Methods

3.2.1 Vegetation survey

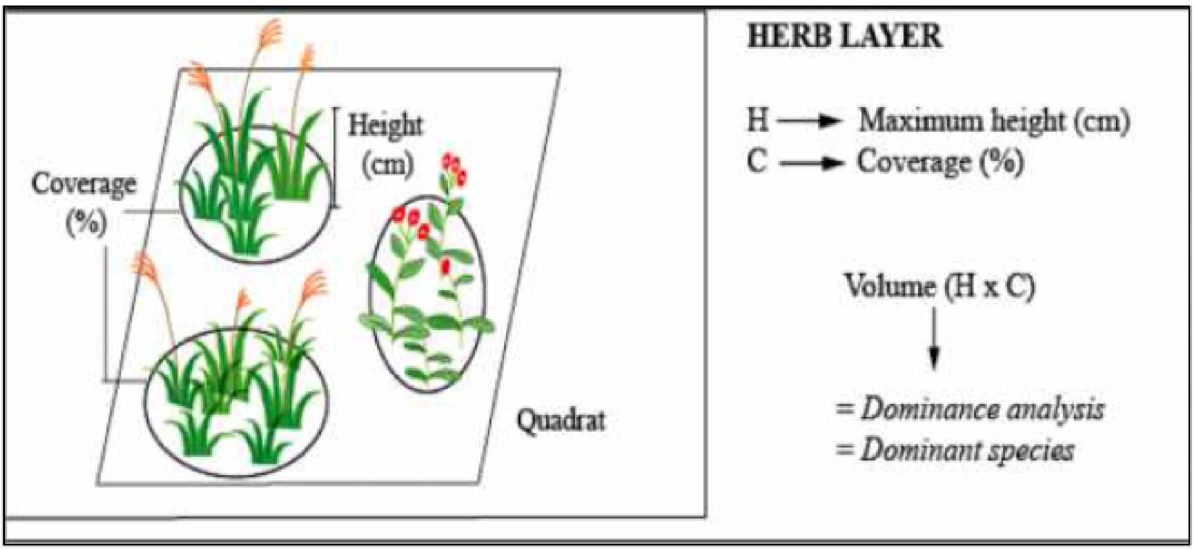

Figure 3. 2 Visual representation of vegetation survey (source: Wangda, 2006)

For the purpose of vegetation survey, the study site was classified as 'human settled area' and 'undisturbed core area', whereby the human settled area consisted of built infrastructures like houses, farmlands, roads and, the undisturbed area covered the core reserved area which serves as the main roosting area of the black necked crane. Survey and sampling was done in ten plots of which, the two classified areas comprised of five plots each. The vegetation survey was done in accordance to the standard procedures followed by Wangda et al., (2006). A ground layer level of vegetation survey was conducted. A belt transect system was exercised while surveying the vegetation of the plot which was divided into 10 quadrats (1 x 1 m) to ensure maximum identification of species. In each of the quadrat, all identifiable plant species was listed with the help of the two plant experts. The names of the plants were listed based on books like 'Flora of Bhutan' (Grierson et al., 1983), 'The Orchids of Bhutan' (Cribb et al., 2002) and 'Weeds of Bhutan' (Parker, 1992. The height (cm) of the tallest plant belonging to each species was measured till the tip of the foliage and also estimated for the percent coverage in each quadrat. As for the unidentifiable plants, a herbarium was prepared for further identification at the National Biodiversity Center, Thimphu Bhutan.

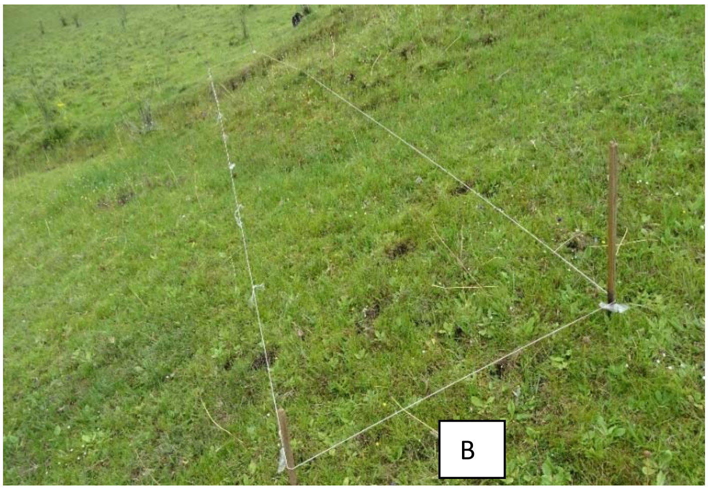

Figure 3. 3 (A) Division of plots into 1 x 1m quadrats. (B) One whole plot (1 x 10m)

3.2.2 Soil sample collection and analysis

A total of ten soil samples, five each from human settled area and undisturbed core area was extracted using auger at the depth of 20 cm (Rowell, 2014) as illustrated in Figure 3.4 (A). Each sample consisted of a composite mix from the ten quadrats. On-spot pH was measured for all the samples using the LDD soil pH kit (Figure 3.4 B). The soil parameters were tested in Soil and Plant Analytical Laboratory (SPAL), National Soil Service Center in Simtokha, Bhutan. The tests followed the standard methods (Black et al., 1965) of SPAL. Prior to the tests, the sample was air-dried and sieved using 2mm mesh size sieve.

Figure 3. 4 (A): Soil sample collected at 20 cm depth using auger; (B): Field Soil pH testing kit

3.2.3 Soil sampling and analysis

Physical properties such as texture and color was determined for the samples. “Texture by hand” method was used to determine the soil texture, where a small lump of soil was felt with hands and matched with the most fitting description of soil types. The color of the soil was determined based on the color index of ‘Standard Soil Color Chart’ (Oyama et al., 1967).

For chemical properties, parameters such as pH, Carbon content, total nitrogen, available phosphorus, and available potassium were tested. The pH was determined by pH-H_2O method of the soil solution. Soil-water suspension was made in a ratio of 1:2.5 and the pH was determined using the PHM 83 automatic pH meter.

To determine the organic carbon, Walkey and Black’s method was used. It exercised the wet combustion process where excess potassium dichromate was titrated with ammonium ferrous sulphate and diphenylamine as an indicator. The Organic carbon was determined using the following formula:

$$\% \, O.C = \frac{(B - A) \times N \times 0.396 \times Mc}{W}$$

where,

B= ammonium ferrous sulphte used in blank titration

A=ammonium ferrous sulphate used for the sample

N=Nomality of the ammonium ferrous suplhate

W= weight of the sample in g

Mc= moisture correction factor (0.396).

In order to determine the total nitrogen, Kjeldahl's digestion method was exercised. The soil particles were digested with sulphuric acid in the presence of selenium catalyst where organic nitrogen gets converted to ammonium sulphate. The ammonium content was determined through the flow analyzer.

Available phosphorus was determined using Bray and Krutz method No I. The resultant phosphorus-molybdenum blue is formed as a result of adding HCl and NH_4F to the soil mixture. Phosphorus-molybdenum blue was then taken for analysis in segmented flow analyser.

The available potassium was determined using $CaCl_2$ extract process where the soil mixture is shaken with 0.01 M calcium chloride in a ratio of 1:10. The extracted potassium was taken for determination in the segmented flow analyzer.

3.2.5 Water sample collection and analysis

A total of ten water samples, five each from human settled area and undisturbed core area was collected and taken for analysis in the lab. Parameters like pH. Electirc conductivity, Calcium (mg/l) and magnesium (mg/l) were tested.

3.3 Data analysis

3.3.1 Vegetation survey analysis

Data compilation and analysis was done using Microsoft Excel 2013 using the pivot table program. For calculating the relative abundance of the species, the volume of the plant species was calculated. The height (cm) of the tallest plant of a species was multiplied with its corresponding coverage percentage. The following equation was used in order to measure the relative dominance in percentage:

RD(%)= volume of the individual plant species /Total volume *100

For measuring the diversity index, the Shannon Weiner index of plant diversity (H') was applied as follows:

$H' = \sum_{i=1}^{s} -(P_i * \quad LnP_i) \qquad P_i = \frac{n_i}{N}$ where, H’= Shannon Weiner index

ni= Numc n_i = Number of individuals of species "

N = Total number of individuals of all species,

P_i = Relative abundance of species

S = Total number of species

3.3.2 Dominant Analysis

Dominant analysis was conducted in order to determine the dominant species in both the sites (Ohsawa, 1984). In a community with only a single dominated plant species, the relative dominance is counted as 100%. In terms of two dominated plant species, the relative dominance was counted as 50%, for three dominated species, 33.3% and so on. The dominant species was identified as the ones which had the least deviation from the actual percent share of the plant species and the expected co-dominants. For this, the following formula was used:

$$d = 1/N \{\sum_{i \in T} (\chi_i - \chi')^2 + \sum_{j \in U} \chi_j^2\}$$

Where x_i= **the actual percent share** (relative basal area) of the top species (T). In a one dominated model, there is only one ‘T’ and in a two dominated model, ‘T’ is two and so on.

χ' = the ideal percent share

χ_j= the percent share of the remaining species (U)

N= Total number of speices

All the dominant species were tabulated together. A cluster analysis was performed using the POCRD version 14 to find the similarity index of the species and group them accordingly. This classified the plant with their types.

3.3.3 Soil and water data analysis

The results determined from the lab tests was compiled in Microsoft Excel 2013 for analysis. The average of the parameters from the two sites was determined and graphed accordingly to see any variations.

CHAPTER 4

Results and Discussions

4.1 Floristic Composition in Human Settled Area and Undisturbed Core Area

A total 136 species under 39 families was found in the ground level vegetation analysis. As illustrated in Figure 4.1, in the human settled area, 79 species were found belonging to 27 families where as in the undisturbed area, 106 species were found belonging to 35 families. These counts showed that more number of species belonged to the comparatively less disturbed core wetland area.

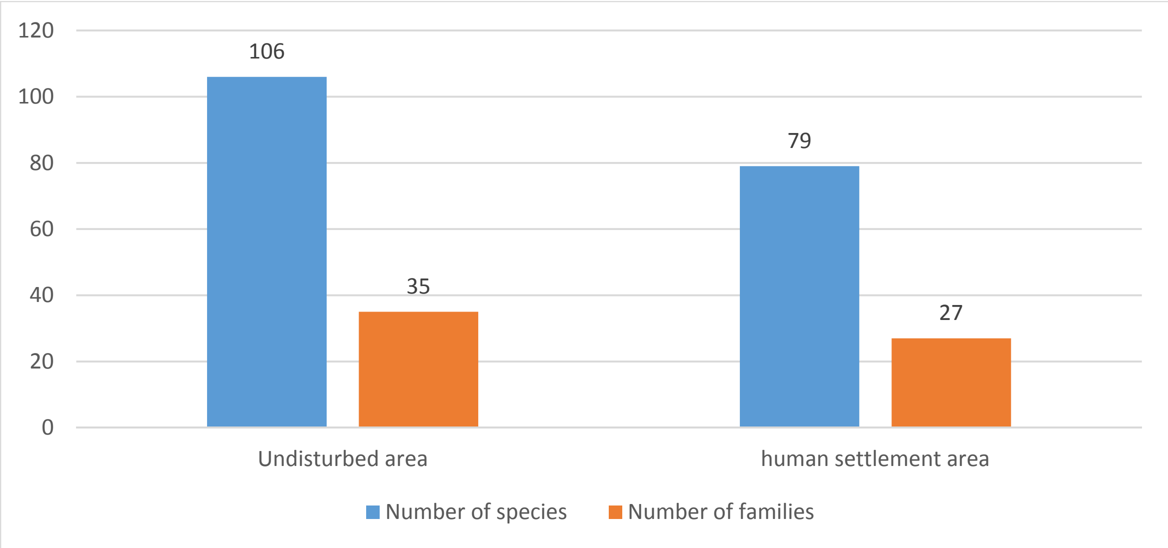

Figure 4. 1 Count of species and families in undisturbed and disturbed area

The most dominant family among the 39 families identified was *Compositae* which accounted to a total of 17 species. This was followed by *Cyperaceae* and *Gramineae* which comprised of 16 species each (Annexure table 2). This findings aligned to the study of Zangmo (2014) who also found *Compositae* as the dominant family in the wetlands of Gangtey and Phobji. This shows that over the span of four years, the dominant family did not change and is still being dominated by *Compositae.* Other families included *Rosaceae* with 11 species, *Scrophulariaceae* with 9 speices, *Polygonaceae* also with 9 species and *Ranunculaceae* with 4 species. *Euphorbiaceae, Gentianacea, Araceae*, and *Caryophyllaceae* consisted of 3 species. The families that consisted of two species were *Berberidaceae, Convallariaceae, Geraniaceae, Labiatae, Hypericaceae , Juncaceae , Leguminosae , Orchidaceae , Plantaginaceae, Primulaceae, Saxifragaceae , Sphagnaceae , Umbelliferae .*

The other 13 families namely, *Alismataceae, Araliaceae, Aristolochiaceae, Boraginaceae, Commelinaceae, Dennstaedtiaceae, Droseraceae, Ericaceae, Hypoxidaceae, Melanthiaceae, Morinaceae, Rubiaceae, Selaginellaceae, Violaceae*, and *Zingiberaceae* each had only one species. *Chusua pauciflora* and *Satyrium nepalense var. nepalense* were the only two species belonging to the *Orchidaceae* family which were found only in the undisturbed area. This could be attributed to less human disturbances in the undisturbed areas which might have had an impact on the growth of the plant species. Brundrett (2014) also mentions that some of the major risks imposed on the growth of the orchids is by habitat fragmentation, rural land clearing and cattle grazing among others factors. These factors usually take place at a close proximity of the orchid growing areas. In the context of Gnagtey and Phobji, the human settlements are located adjacent to the study area which might also be reason why only two species were found in the undisturbed area.

In terms of relative basal dominance, *Cyperaceae* had the highest percentage followed by *Compositae* and *Primulaceae* family in both the study area as shown in Figure 4.2.

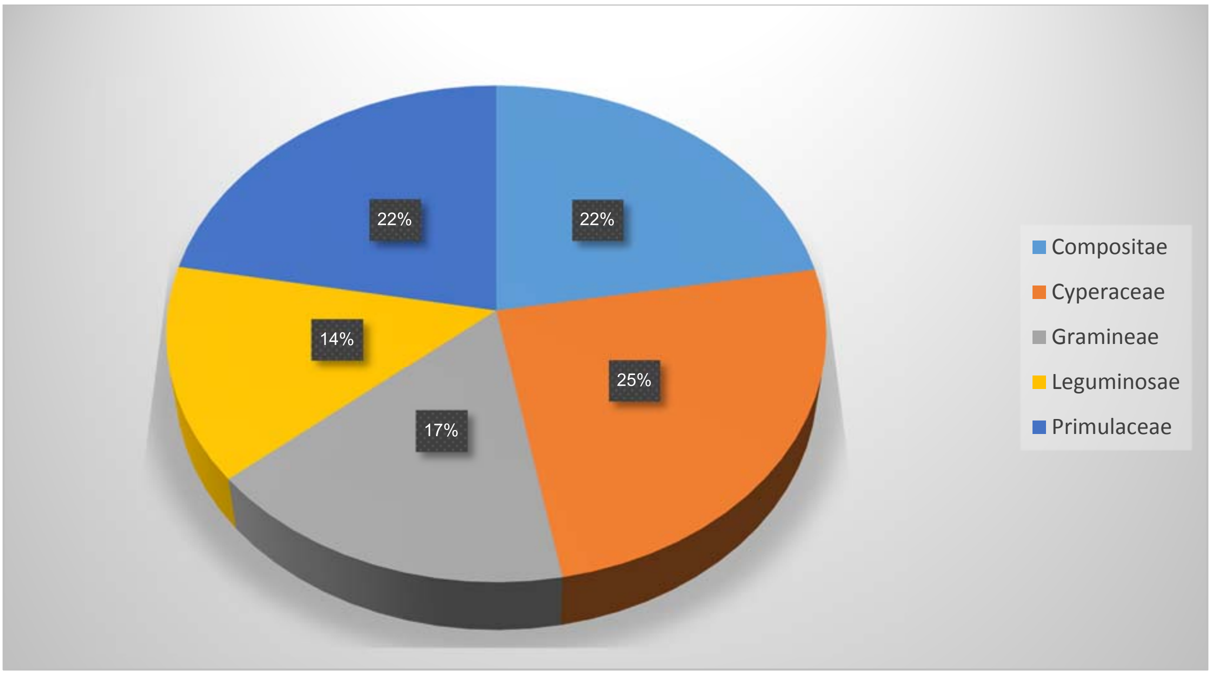

Figure 4. 2 Percentage of five families with high relative dominance.

In the context of individual species, 18 among the 79 identified species were exclusively found in the human settlement area. Similarly, 57 of the 106 identified species belonged exclusively to the undisturbed areas. Of the 136 species identified, 60 species were commonly found in both the areas. Some of the species found in both human settled area and undisturbed areas like *Cirsium falconeri, Trifolium repens, Rumex nepalensis* , *Spergula arvensis* are invasive and alien (GISD;Zangmo, 2017). Records showed that two of the identified species found exclusively in the human settled area, namely *Galium aparine* and *Galinsoga parviflora* were alien species and invasive in nature (NBC; Zangmo, 2017). This indicates that due to human intervention, plant species which are alien and invasive in nature are introduced in the wetland area. According to Early et al., (2016), invasive alien species poses a threat to the existing native species as their invasion rate is quicker and accelerated with disturbances such as agriculture land expansion and climate change. It can be seen that the native species are at a higher risk of suffering negative impact in terms of diversity as human settlements lie close to the core wetland.

4.2 Plant Diversity and Richness

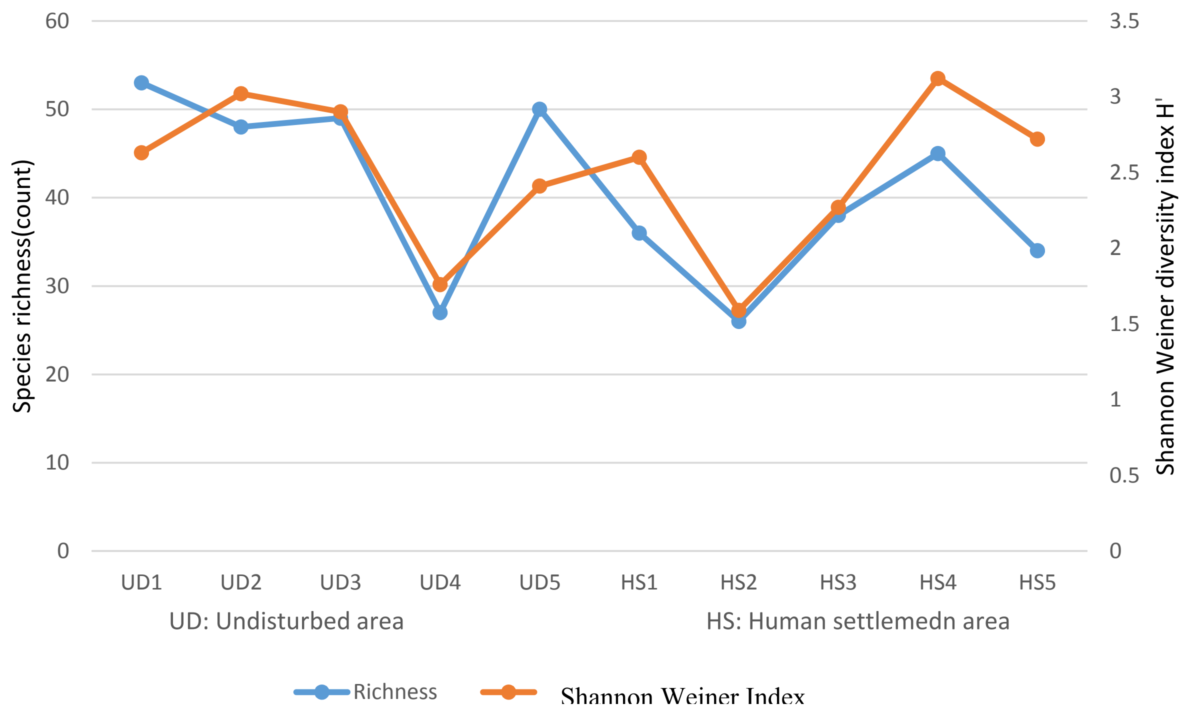

Figure 4. 3 Species richness and Shannon Weiner index of the study area.

The results from the Shannon Weiner's diversity index showed a high diversity index in HS4 of the human settlement area with an index of 3.12 (Figure 4.3) This plot was located below the roadside which could be a reason for growth of invasive or alien plants, ultimately leading to the increased diversity. In a similar study, Zangmo (2014) also found that diversity along the roadside had the highest diversity index. Overall, average diversity index of the undisturbed area was 2.54 whereas the average diversity index of the human settled areas was 2.46. Although the overall diversity index of the undisturbed area was a bit higher than the human settled area, there was only a slight difference in the indices. (Figure 4.3)

In terms of species richness, the highest richness was recorded in UD1 of the undisturbed area with 53 species identified. In terms of human settlement, the plot with the highest diversity index was found to have the highest number of species. Overall, the species richness was found to be higher in the undisturbed area corresponding to the diversity index. Even in the case of the plot with the high diversity index, the species richness was comparatively higher than the rest of the plots in human settlement areas (Figure 4.3)

4.3 Life Form Classification

The most prevalent type of life in both the study areas was dominated by herbs, specifically the perennial herbs constituting almost up to 90% of the plant composition in the undisturbed area (fig 4.3). Annual herbs was comparatively found in lesser percentage than the perennial herb. Grasses was also found to constitute a relatively large portion of the life forms among the others, following the herbs. As illustrated in figure 4.3, interestingly, in one of the plots in the undisturbed areas, grasses constituted about 80% of the total life form composition. This could be attributed to the fact that the plot was used for the purpose of animal grazing. Cattles and horses were seen openly grazing in those plots. According to a study, the grazing of animals seemed to accelerate the growth of grasses. (Yuan et al., 2016). This could be the reason why a huge portion of the plant species falls under the grass family in the study area.

Only a single type of bamboo species, *Yushania microphylla* was found. According to Wangchuk et al., (2014), *Yushania microphylla* was found to be tolerant to cattle grazing through above and below morphological modification. This suggests why *Yushania microphylla* might have been the only bamboo species that was identified in the study area.

In terms of ferns, only four species namely *Selaginella sp., Sphagnum palustre, Sphagnum sp., Pteridium aquilinum* were identified. (Figure 4.4).

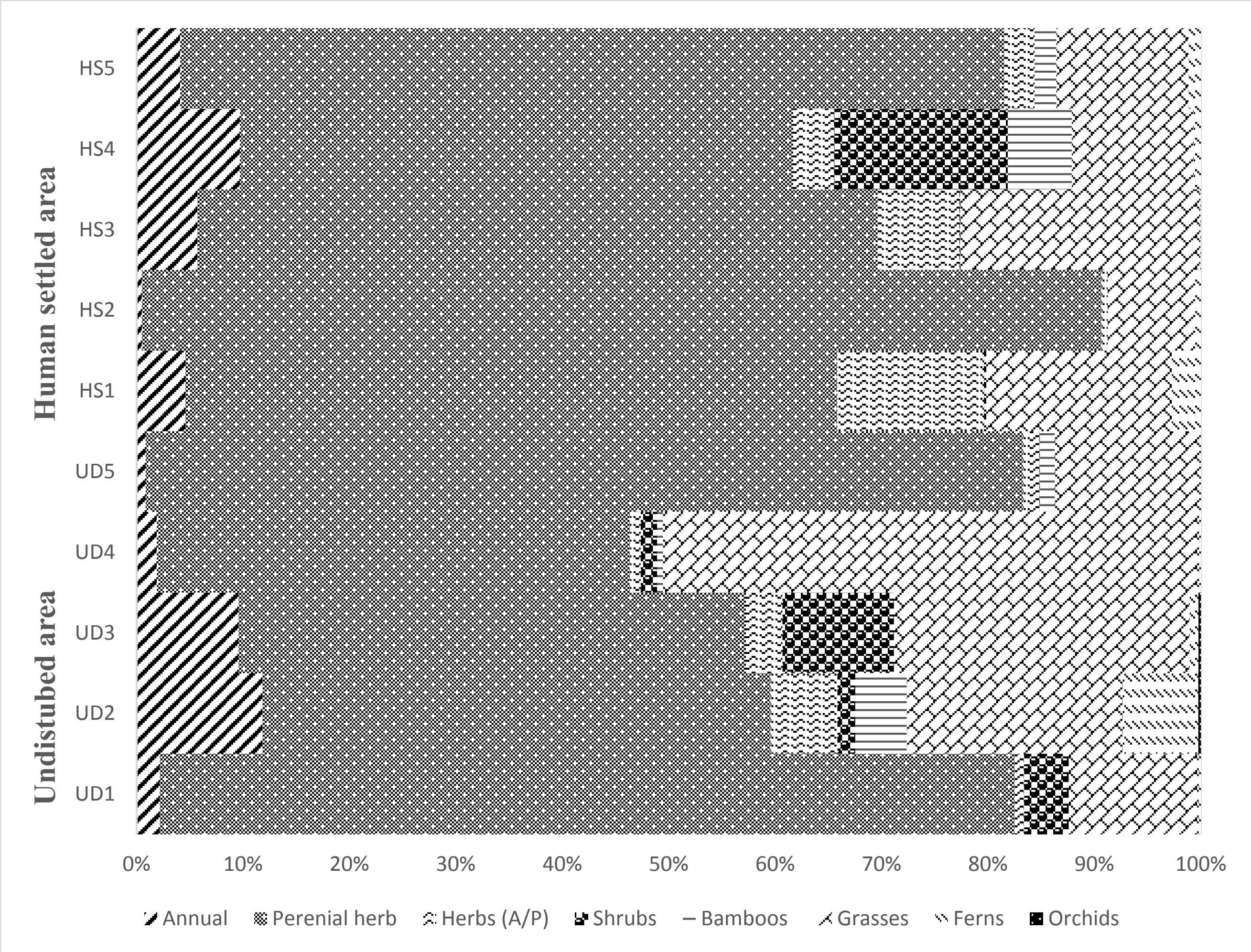

Figure 4. 4 Life form distribution of the plots in undisturbed and undisturbed areas.

4.4 Dominant Analysis

Dominant Analysis found a total of 13 species in the undisturbed areas whereas in the human settled area, there were a total of 19 dominant species (Table 4.1). Among the ten plots, the highest number of dominant species was found in human settled area. In the human settled area, the common dominant species was *Trifolium repens.* Studies have shown that *Trifolium repens* was introduced in Bhutan in order to use a fodder for the livestock but now, it has spread to a lot of places which is negatively influencing the native plants (Roder, 2007). This might be the reason why *Trifolium repens* was found as one of the dominant species in human settlement area.

In terms of the undisturbed area, the common dominant species was *Primula denticulata*. The prevalence of this species is common in Western and Central parts of Bhutan (NBC) which is why it was found in abundance in the study area.

Table 4. 1 Dominant species in undisturbed and human settlement area.

	Undisturbed area					Human settlement area				
Species	UD1	UD2	UD3	UD4	UD5	HS1	HS2	HS3	HS4	HS5
Euphorbia wallichii	24.38									
Cirsium falconeri	23.53			5.59	15.29			4.90		
Trifolium repens	9.87				30.81	30.58	36.12	43.25		26.52
Anaphalis nepalensis	6.12				17.57					
Eragrostis nigra	5.80							10.33		
Primula denticulata		26.50	32.15	32.15					15.52	
Eleocharis congesta			42.35	42.35						
Carex rara				3.61		5.26				
Carex nigra				1.97		6.07				4.24
Potentilla sundaica				1.81						
Senecio vulgaris				1.67						
Potentilla eriocarpa				1.54						
Rumex nepalensis					8.37	6.14				16.28
Ranunculus chinensis						11.41				
Hypericum petiolulatum						9.10				
Primula denticulata						3.68				
Bromus hordeaceus						3.63				
Plantago erosa						3.34				5.27
Senecio raphanifolius							36.12			3.15
Mimulus nepalensis								6.62		
Poa annua								4.70		
Stellaria reticulivena								4.40		
Plantago erosa								3.80		
Senecio laetus										10.08
Anemone rivularis										3.15

The study also found that *Trifolium repens* and *Rumex nepalensis* are dominant species in both the plots of the study area. These are alien and invasive species and being a dominant species, it suggests that some native species might have been overtaken by these species.

4.5 Soil Results

In terms of soil texture, the common type of soil in Phobji and Gangtey was silt-loam with high organic matter and ranged from brown to black in hue (Annexure table 4). According to Finch et al., (2014), soil having such properties are potentially fertile with a good water holding capacity. This indicates that the soil in Gangtey-Phobji might be fairly fertile, has good water holding capacity and good for vegetation growth. The soil of the study area did not reveal much of a difference in the chemical parameters. In terms of total nitrogen, the undisturbed area had a percentage of 2.04% as compared to the human settlement area with a percentage of 1.52%. Similarly, in terms of carbon content, undisturbed area showed 11.83% as compared to human settlement area with over 9.62%. (Figure 4.5)

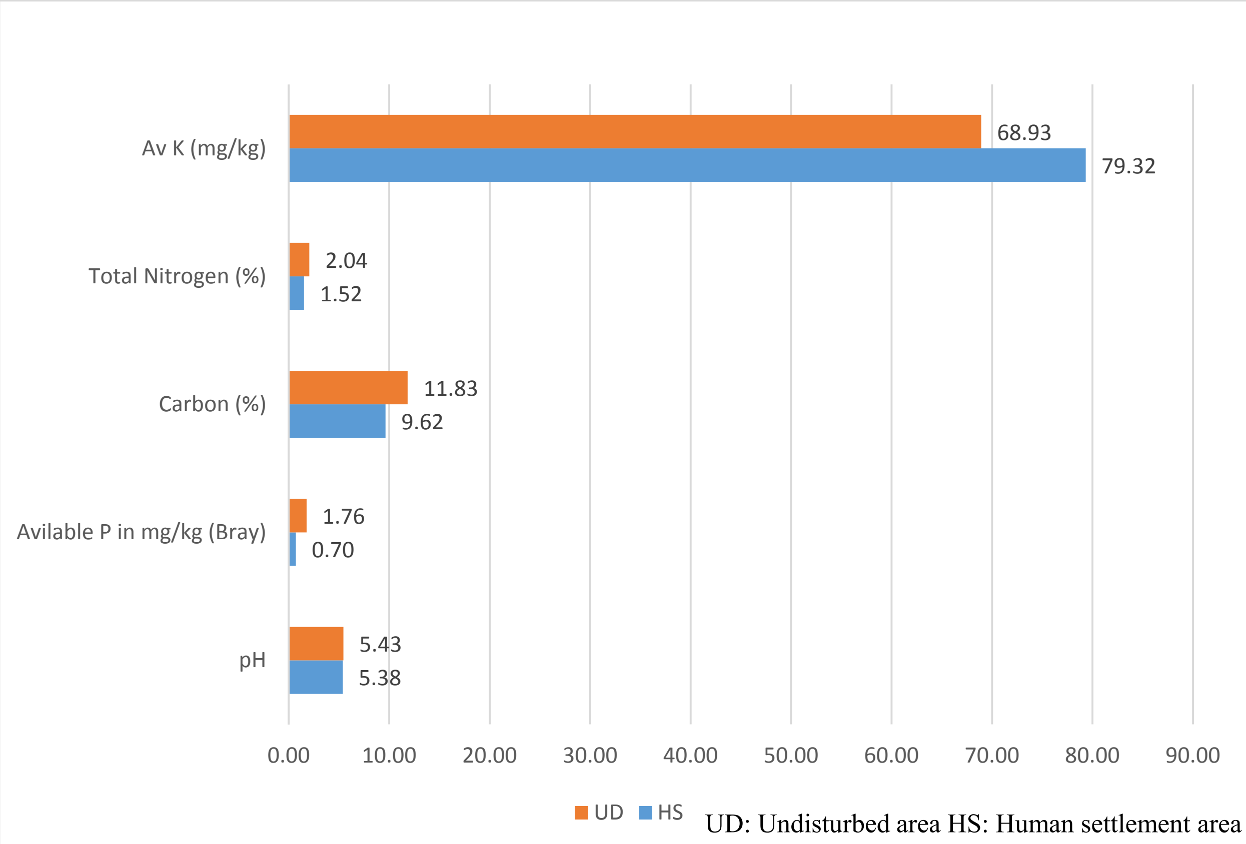

Figure 4. 5 Average values of pH, available phosphorus (mg.kh), total nitrogen (%), carbon (%), and available phosphorus (mg/kg)

As illustrated in figure 4.5, difference was slightly more evident in terms of available potassium content. Human settlement area had a slightly more available potassium (mg/kg) than the undisturbed areas. According to Väänänen (2008), the input of phosphorus in the water surrounded areas have increased due to human intervention and the phosphorus content in the soil nearby agricultural land have considerably increased. This might be the reason why the phosphorus in the human settled areas near the agriculture fields have a higher value of 79.32 (mg/kg) as compared to 68.93 in the undisturbed area. Overall, there are only slight variations in the soil parameters. This, according to

Jamyang (2018), is due to the resilience effect of the wetlands. The soil, water and plants of the wetlands are able to maintain its optimum parameters which is why there are not many variations. As the trend of human intervention is not that drastic, the soil and water parameters are able to maintain its normal standards.

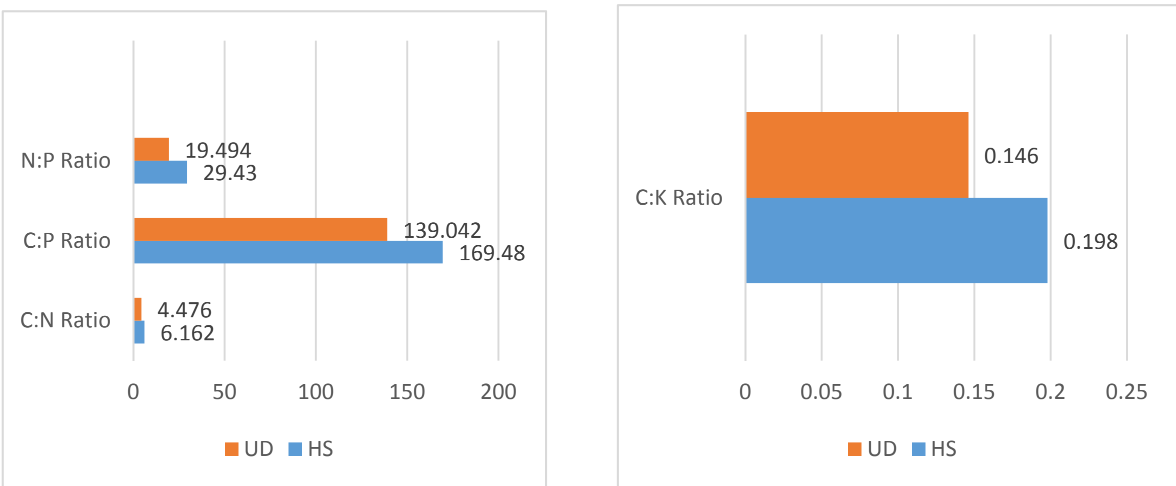

Figure 4. 6 Ratios between the nutrients (UD: Undisturbed area; HS: Human settled area)

Similarly, even in terms of the ratio between macro-nutrients level, there was not much difference amongst the variables. However, the carbon and potassium ration showed a slight difference. Overall, the variations in the soil parameters were not very evident but there are slight differences in parameters like potassium. The less variations in the ratios might also be attributed to the individual values of the macronutrients which did not show much variations in the study area (Figure 4.5). These similarity in the variations indicates that the soil parameters have not seen a drastic variations due to human settlements. However, Wangda (2018), mentioned that the variability trend might increase in the coming years if the human interventions keep expanding. The slight difference that is being detected is one of the indicator that variations will increase.

4.6 Water Results

The result showed that the water sample analysis like electric conductivity, pH, calcium and magnesium, did not show much of a difference in the study areas. The study showed a constant direct electric conductivity (EC) of 0.10. However, the average pH was recorded 6.39 in human settled area followed by 6.20 in the undisturbed area (Figure 4.7). This indicates that the water in Gangtey and Phobji is slightly acidic.

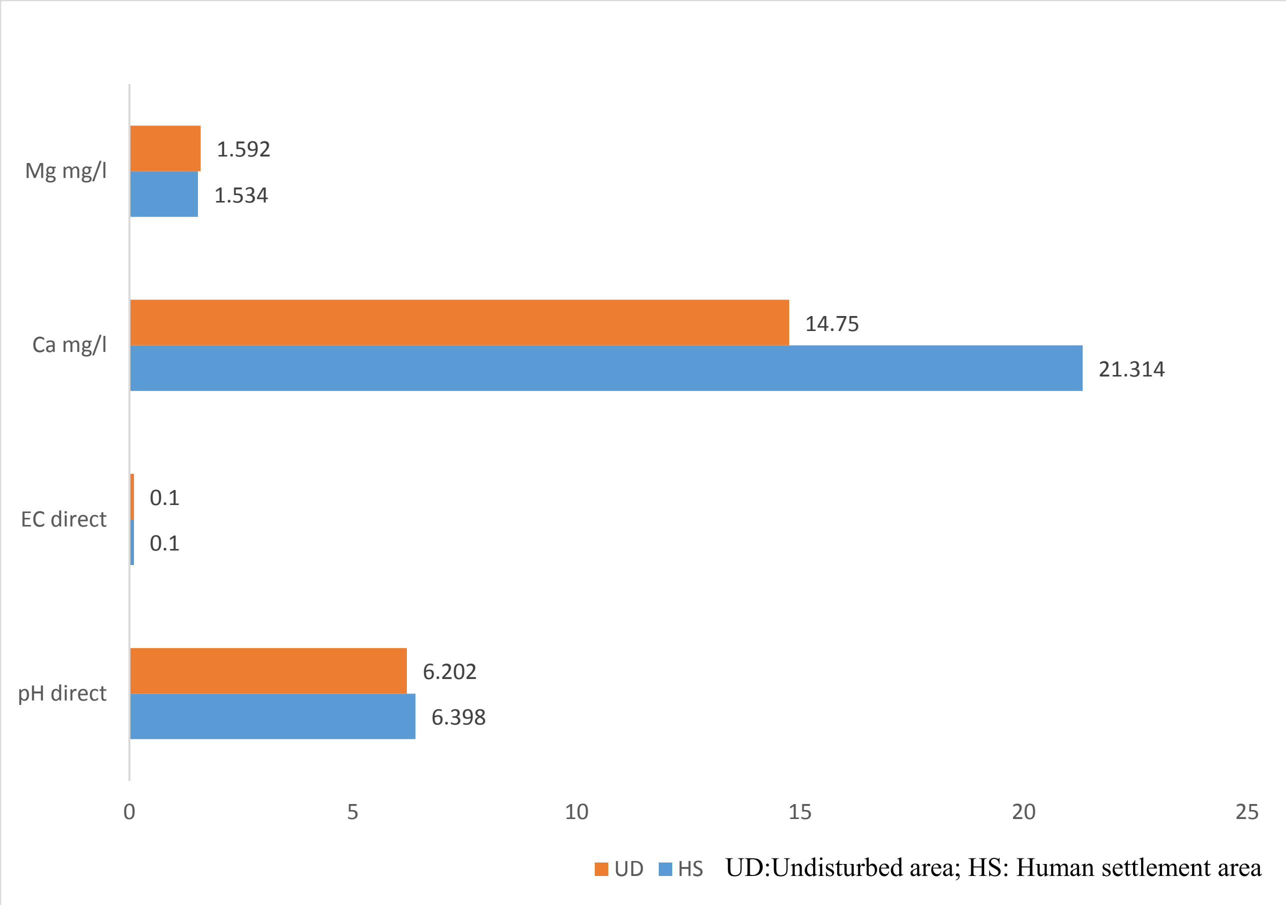

Figure 4. 7 Average values of Mg (mg/l) content, Ca content (mg/l), EC direct and pH direct of water samples from Undisturbed and human settlement areas.

As shown in the figure, the Magnesium content showed a similar value (1.5-1.6mg/l) in the study area. However, the calcium content of 21.31 mg/l in the human settled area is found relatively higher than the undisturbed area with only 14.75 mg/l. This was similar to the findings of Potasznik et al., (2015), where the calcium content in the water nearby forest area was less than the water found near agriculture land. This can indicate that there may be calcium retention in the water, from the fertilizers applied in agriculture fields.

CHAPTER 5

Conclusion and Recommendations

The wetlands of Phobji and Gangtey is undeniably homing a lot of diverse plant species. However, one of the major risks imposed on these diversity is human settlements. Over the years, Gantey and Phobji has seen a rise in population and with that, a lot of other accommodations and infrastructures has started to rise in number as well. The effect of these interventions are starting to show in the plant diversity as seen in the result and discussion section. The diversity pattern showed slight variations, especially in terms of species richness. The wetland in Phobji and Gangtey were mostly dominated by plant species such as *Trifolium repens, Anaphalis nepalensis, Primula denticulata*, *Eleocharis congesta* and *Rumex nepalensis*. Some of these species are alien and invasive in nature which increases the risk it poses on the overall plant diversity.

The life forms found in the study area included perennial herbs, annual herbs, shrubs, bamboos, orchids, ferns and grasses. The most prominent among these life forms was the perennial herbs which accounted almost up to 80% of the total life forms. Grasses also accounted a huge amount of the life forms which can be attributed to the grazing activity that happens in both the disturbed and undisturbed area. Under the orchid life form, only two species were found namely *Chusua pauciflora* and *Satyrium nepalense var. nepalense*. Only a single type of bamboo *Yushania Microphylla* was found in both the study areas. *Selaginella sp., Sphagnum palustre, Sphagnum sp., Pteridium aquilinum* were some of the ferns that was found in the wetlands. Interestingly, an endemic plant *Euphrasia bhutanica* (NBC) was also identified in the undisturbed area.

In terms of soil parameters and water parameters, the variations in the parameters tested were not drastic. Only some parameter like potassium content in soil and calcium content in water had a huge variation. Overall, currently, the soil and water parameters indicated that there is only a little negative impact of human settlement on soil and water in the wetlands. However, the slight variations also indicate the starting trend of these negative issues.

In a nutshell, it can be said that the negative impact of human settlement is starting to show indications, especially through the number and type of species that are present in the wetlands. Even in terms of other variables like soil and water, the impact is slowly shown in the parameters. However, if the trend keeps on increasing, the impacts might reaches a drastic phase where it will no longer able to maintain the optimum ranges. Thus, a strict policy needs to be made in order to reduce the impact of these human settlement. Wastewater and agriculture field runoffs should have a proper channeling and treatment facilities rather than being dumped in the streams adjoining the core wetland area. Animal grazing in the wetlands should be reduced as much as possible and other alternative provisions need to be made available. Proper waste management system needs to be introduced in the area .Additionally, frequent research and monitoring needs to be done in order to closely monitor the situation of plant diversity and other variables in the wetlands. More detailed study needs to be done in soil and water parameters in order to find any traces of eutrophication. The findings from this study can be used as a baseline for future studies in order to find any sort of significant changes in the variables of the ecosystem.

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Annexure

Annexure Table 1 Floristic composition of the study sites. Relative Dominance indicated by RD in %.

			Undistrubed sites					Human settlement				
Plot ID			**UD1**	**UD2**	**UD3**	**UD4**	**UD5**	**HS1**	**HS2**	**HS3**	**HS4**	**HS5**
Plot size (m^2)			10	10	10	10	10	10	10	10	10	10
Aspect (degree)			SE (160)	SW (220)	E (120)	NE (60)	SE (125)	NE (50)	NE (39)	NE (40)	NE (60)	W (300)
Altitude (m)			2853	2847	2854	2839	2847	2876	2881	2886	2872	2843
Relative Dominance (%)			RD	RD	RD	RD	RD	RD	RD	RD	RD	RD
Perennial herbs	**Family**	**LF**										
Euphorbia wallichii	Euphorbiaceae	P	24.38				15.29				0.08	
Cirsium falconeri	Compositae	P	23.53	0.21	2.32	5.59	0.52	0.37	1.14	4.90	4.27	
Trifolium repens	Leguminosae	P	9.87	0.16	4.01		30.81	30.58	36.12	43.25	4.96	26.52
Anaphalis nepalensis	Compositae	P	6.12		4.31		17.57				1.56	
Senecio raphanifolius	Compositae	P	2.62				0.56		43.70	0.09		3.15
Cyanotis vaga	Commelinaceae	P	1.87		0.08	0.11					1.91	0.36
Senecio laetus	Compositae	P	1.68						0.61		0.97	10.08
Primula denticulate	Primulaceae	P	1.57	26.50	11.57			3.68		0.03	15.52	0.57
Clinopodium umbrosum	Labiatae	P	1.34		1.51		0.64				0.30	
Euphorbia longifolia	Euphorbiaceae	P	0.98				0.24					
Potentilla leuconota	Rosaceae	P	0.92		0.55	0.86	0.06	0.71		0.38	2.04	1.53
Geranium nepalense	Geraniaceae	P	0.91				0.32				0.50	0.85
Potentilla sanguisorba	Rosaceae	P	0.68									
Prunella vulgaris	Labiatae	P	0.46	2.92	0.49	0.84	0.39	2.27	0.88	0.36	6.25	2.37
Ophiopogon clarkei	Convallariaceae	P	0.45				0.10				0.33	
Persicaria capitata	Polygonaceae	P	0.37		0.16		0.36	0.10	0.87	0.55	2.88	
Roscoea alpine	Zingiberaceae	P	0.36									
Ligularia hookeri	Compositae	P	0.29									
Hypoxis aurea	Hypoxidaceae	P	0.25		0.95							
Potentilla sundaica	Rosaceae	P	0.22	1.03	9.06	1.81	0.13	0.14	0.14	0.62	0.70	0.77
Viola biflora	Violaceae	P	0.22									
Hemiphragma heterophyllum	Scrophulariaceae	P	0.21	1.17	1.00						0.39	
Agrimonia pilosa	Rosaceae	P	0.21				1.25				0.67	

Aster tricephalus	Compositae	P	0.19									
Thalictrum chelidonii	Ranunculaceae	P	0.14									
Fragaria nubicola	Rosaceae	P	0.12	0.17			0.43			0.15	4.19	0.68
Potentilla polyphylla	Rosaceae	P	0.12	0.90	3.29	0.50	0.20	0.26	0.05	0.31	0.25	
Rumex acetosella	Polygonaceae	P	0.08				0.69					
Persicaria runcinata	Polygonaceae	P	0.07				0.66	1.69		0.12		
Plantago erosa	Plantaginaceae	P	0.06	0.08		0.07	1.15	3.34	3.31	3.80	2.43	5.27
Pedicularis daltonii	Scrophulariaceae	P	0.04									0.15
Sanguisorba filiformis	Rosaceae	P		5.72								
Pedicularis siphonantha	Scrophulariaceae	P		3.29		0.38						
Aster flaccidus	Compositae	P			3.90						0.12	
Parochetus communis	Leguminosae	P			0.33		0.36					
Cirsium lipskyi	Compositae	P			0.19	0.18		0.28		0.22	0.13	
Pedicularis flexuosa	Scrophulariaceae	P				1.43						
Pedicularis gracilis	Scrophulariaceae	P				0.29						
Rumex nepalensis	Polygonaceae	P					8.37	6.14	2.25	0.27		16.28
Hydrocotyle himalaica	Umbelliferae	P					0.42					
Lagotis kunawurensis	Scrophulariaceae	P					0.22					
Mimulus nepalensis	Scrophulariaceae	P					0.12	0.21		6.62		
Geranium procurrens	Geraniaceae	P					0.07					
Acanthocalyx nepalensis	Morinaceae	P						0.04				
Persicaria nepalensis	Polygonaceae	P							0.07			
Mazus delavayi	Scrophulariaceae	P								0.14	0.89	0.05
Anemone rivularis	Ranunculaceae	P		0.14	3.09							3.15
Selinum wallichianum	Umbelliferae	P		1.21		0.25						
Aletris gracilis	Melanthiaceae	P		1.17	0.19							
Saxifraga strigosa	Saxifragaceae	P		0.98	0.22							
Primula denticula	Primulaceae	P				32.15						
Agrimonia eupatoria	Araceae	P		0.20			0.63					
Anemone rupicola	Ranunculaceae	P		0.17	0.36		0.06	0.04		0.06		0.93
Ranunculus chinensis	Ranunculaceae	P		0.02			0.47	11.41	1.03	1.97		0.87
Typhonium diversifolium	Araceae	P			0.07		0.16					
Polygonatum cirrhifolium	Convallariaceae	P									0.17	
Fragaria daltoniana	Rosaceae	P					0.19			0.06	0.33	
Arisaema consanguineum	Araceae	P									0.13	
Artemisia vulgaris	Compositae	P										2.55
Cynoglossum furcatum	Boraginaceae	P										1.30

Schoenoplectus juncoides	Cyperaceae	P		1.73								
Sub Total			80.32	47.74	47.67	44.45	82.44	61.26	90.16	63.92	51.98	77.43
Perennial and annual mix herbs												
Stellaria reticulivena	Caryophyllaceae		0.47		0.15		0.30	1.63	0.60	4.40	1.66	1.05
Arorus harpilay	Aristolochiaceae		0.28									
Plantago depressa	Plantaginaceae		0.08									
Stellaria patens	Caryophyllaceae		0.06			0.06	0.58	0.09				
Sagittaria tangtsungensis	Alismataceae			0.87	0.96			0.77		0.21		
Hypericum petiolulatum	Hypericaceae			2.28	0.12	0.95	0.43	9.10		3.08		1.79
Saxifraga filicaulis	Saxifragaceae			2.26	0.65		0.15	2.18			0.17	
Polygonum plebeium	Polygonaceae			0.47	0.92							
Persicaria humilis	Polygonaceae			0.28	0.63							
Gentiana pedicellata	Gentianaceae			0.13								
Senecio diversifolius	Compositae						0.08					
Aster inuoilaris	Compositae										2.01	
Sub Total			0.89	6.28	3.43	1.01	1.54	13.77	0.60	7.69	3.83	2.84
Annual herbs												
Spergula arvensis	Caryophyllaceae	A	0.03				0.04	0.79		2.65	0.10	
Euphorbia prostrata	Euphorbiaceae	A	1.66									
Senecio vulgaris	Compositae	A				1.67	0.28					
Fagopyrum dibotrys	Polygonaceae	A					0.22				1.51	2.16
Drosera peltata	Droseraceae	A		4.27	5.96							
Halenia elliptica	Gentianaceae	A		1.94	0.97							
Euphrasia bhutanica	Scrophulariaceae	A		0.80	0.58							
Gentiana capitata	Gentianaceae	A			0.82							
Sonchus asper	Compositae	A			0.26							
Sonchus oleraceus	Compositae	A			0.18							
Pseudognaphalium affine	Compositae	A					0.13			0.13	4.30	
Galium aparine	Rubiaceae	A						0.40	0.23			
Pseudognaphalium hypoleucum	Compositae	A						0.05			1.81	
Galinsoga parviflora	Compositae	A								0.07		
Gentiana sp	Gentianaceae	A		0.01	0.04							
Persicaria pubescens	Polygonaceae	A						0.74				
Eleocharis sp.	Cyperaceae	A										0.32
Hypericum elodeoides	Hypericaceae	A			0.67			2.42				
Schoenoplectus fuscorubens	Cyperaceae	A		0.95			0.17					
Luzula multiflora	Juncaceae	A		3.55		0.23			0.27	2.86	1.99	1.61

Bulbostylis densa	Cyperaceae	A	0.49	0.32	0.10			0.18				
Sub Total			2.18	11.82	9.58	1.90	0.84	4.58	0.49	5.71	9.71	4.10
Shrubs												
Berberis asiatica	Berberidaceae	S	2.06									
Berberis aristata	Berberidaceae	S	1.57								2.93	
Potentilla eriocarpa	Rosaceae	S	0.57		0.48	1.54	0.07	0.24		0.06		
Cotoneaster microphyllus	Rosaceae	S			9.95							
Hedera nepalensis	Araliaceae	S			0.04							
Gaultheria pyroloides	Ericaceae	S		1.68								
Rosa sericea	Rosaceae	S									13.40	
Sub Total			4.20	1.68	10.48	1.54	0.07	0.24	0.00	0.06	16.33	0.00
Grasses												
Eragrostis nigra	Gramineae	G	5.80	0.39	21.42				3.50	1.48	2.36	0.53
Carex nigra	Cyperaceae	G	2.82	2.21		1.97	3.82	6.07	1.46	10.33	5.89	4.24
Poa annua	Gramineae	G	1.27	0.68			1.39	0.59	1.13	4.70	0.33	1.64
Phalaris minor	Gramineae	G	0.77		3.36							
Carex foliosa	Cyperaceae	G	0.59									
Carex remota subsp. rochebrunii	Cyperaceae	G	0.34			0.49						
Brachypodium sylvaticum	Gramineae	G	0.25				1.19					0.65
Carex duthiei	Cyperaceae	G	0.20	1.85			0.11	0.66	0.43		0.45	0.93
Agrostis pilosula	Gramineae	G	0.08		1.40						1.00	
Festuca rubra subsp. clarkei	Gramineae	G	0.08									
Eleocharis congesta	Cyperaceae	G		10.17	0.69	42.35		1.21	0.11	0.70	0.69	2.55
Eleocharis palustris	Cyperaceae	G		1.06								
Carex rara	Cyperaceae	G		0.96		3.61		5.26				
Carex echinata	Cyperaceae	G		0.95	0.63		0.28					
Bromus himalaicus	Gramineae	G		0.76		0.62						
Kyllinga odorata	Cyperaceae	G		0.63	0.16							
Cyperus cyperoides	Cyperaceae	G		0.39	0.14				0.05	0.31		
Fimbristylis ovate	Cyperaceae	G		0.24								
Eleusine indica	Gramineae	G				0.84						
Tripogon filiformis	Gramineae	G				0.51				0.70		
Poa pratensis	Gramineae	G					4.05		0.53	2.24		
Poa nepalensis	Gramineae	G					2.85					
Luzula effuse	Juncaceae	G					0.04					
Bromus hordeaceus	Gramineae	G						3.63	0.44	0.18		
Poa sikkimensis	Gramineae	G							0.46	1.64		1.55

Cynodon dactylon	Gramineae	G							0.09			
Cyperus squarrosus	Cyperaceae	G								0.31	0.33	
Digitaria cruciate	Gramineae	G									0.39	0.36
Sub Total			12.22	20.29	27.80	50.39	13.74	17.42	8.21	22.58	11.45	12.43
Bamboo												
Yushania microphylla	Gramineae	B		4.85		0.56	1.37				6.03	2.06
Sub Total				4.85		0.56	1.37				6.03	2.06
Ferns												
Selaginella sp.	Selaginellaceae	F	0.13									
Sphagnum palustre	Sphagnaceae	F	0.06	3.79	0.41			1.09		0.04	0.67	1.14
Sphagnum sp.	Sphagnaceae	F		3.31	0.41	0.15		1.64				
Pteridium aquilinum	Dennstaedtiaceae	F							0.53			
Sub Total			0.19	7.10	0.82	0.15	0.00	2.73	0.53	0.04	0.67	1.14
Orchids												
Chusua pauciflora	Orchidaceae	O		0.24								
Satyrium nepalense var. nepalense	Orchidaceae	O			0.22							
Sub Total			0.00	0.24	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total			100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Annexure Table 2 List of families with relative dominance value

	Values									
Row Labels	**Sum of UD1**	**Sum of UD2**	**Sum of UD3**	**Sum of UD4**	**Sum of UD5**	**Sum of HS1**	**Sum of HS2**	**Sum of HS3**	**Sum of HS4**	**Sum of HS5**
Alismataceae		0.87	0.96			0.77		0.21		
Araceae		0.20	0.07		0.79				0.13	
Araliaceae			0.04							
Aristolochiaceae	0.28									
Berberidaceae	3.63								2.93	
Boraginaceae										1.30
Caryophyllaceae	0.56		0.15	0.06	0.92	2.51	0.60	7.05	1.76	1.05
Commelinaceae	1.87		0.08	0.11					1.91	0.36
Compositae	34.42	0.21	11.16	7.44	19.15	0.69	45.45	5.41	15.17	15.79
Convallariaceae	0.45				0.10				0.50	
Cyperaceae	4.45	21.45	1.72	48.42	4.39	13.38	2.06	11.64	7.37	8.04
Dennstaedtiaceae							0.53			
Droseraceae		4.27	5.96							
Ericaceae		1.68								
Euphorbiaceae	27.01				15.53				0.08	
Gentianaceae		2.07	1.84							
Geraniaceae	0.91				0.38				0.50	0.85
Gramineae	8.26	6.68	26.18	2.52	10.86	4.22	6.16	10.94	10.11	6.77
Hypericaceae		2.28	0.80	0.95	0.43	11.52		3.08		1.79
Hypoxidaceae	0.25		0.95							
Juncaceae		3.55		0.23	0.04		0.27	2.86	1.99	1.61
Labiatae	1.80	2.92	2.00	0.84	1.03	2.27	0.88	0.36	6.55	2.37
Leguminosae	9.87	0.16	4.34		31.17	30.58	36.12	43.25	4.96	26.52
Melanthiaceae		1.17	0.19							
Morinaceae						0.04				
Orchidaceae		0.24	0.22							

Plantaginaceae	0.14	0.08		0.07	1.15	3.34	3.31	3.80	2.43	5.27
Polygonaceae	0.53	0.75	1.72		10.31	8.67	3.18	0.95	4.39	18.44
Primulaceae	1.57	26.50	11.57	32.15		3.68		0.03	15.52	0.57
Ranunculaceae	0.14	0.34	3.45		0.52	11.45	1.03	2.03		4.95
Rosaceae	2.84	7.81	23.34	4.70	2.32	1.35	0.19	1.58	21.58	2.98
Rubiaceae						0.40	0.23			
Saxifragaceae		3.24	0.86		0.15	2.18			0.17	
Scrophulariaceae	0.25	5.25	1.58	2.10	0.35	0.21		6.76	1.27	0.20
Selaginellaceae	0.13									
Sphagnaceae	0.06	7.10	0.82	0.15		2.73		0.04	0.67	1.14
Umbelliferae		1.21		0.25	0.42					
Violaceae	0.22									
Zingiberaceae	0.36									
Grand Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Annexure Table 3 Geographical parameters of the study area

Sl. No	location code	latitude	longitude	Elevation (M)	slope %	Aspect
1	UD1	27.47571	90.16618	2853	41	SE160
2	UD2	27.47476	90.17043	2847	60	SW220
3	UD3	27.47377	90.17444	2854	20	E120
4	UD4	27.45583	90.18286	2839	40	NE60
5	UD5	27.47035	90.17427	2847	0	SE125
6	HS1	27.4763	90.16355	2876	44	NE50
7	HS2	27.47114	90.16618	2881	45	NE39
8	HS3	27.46799	90.16816	2886	60	NE40
9	HS4	27.46228	90.17113	2872	60	NE60
10	HS5	27.46435	90.18666	2843	60	W300

Annexure Table 4 Soil properties of the study area

Sl. No	location code	Texture by hand			soil color		
			pH test kit	Hue	Value	Chroma	color
1	UD1	ZL	5	10YR	4	3	Dull yellowish brown
2	UD2	ZL	5	2.5 YR	1.7	1	Reddish black
3	UD3	ZCL	5.5	7.5YR	3	4	Dark brown
4	UD4	OM	5.5	10R	3	1	Dark reddish gray
5	UD5	ZL	6.5	10YR	2	3	Brownish black
6	HS1	OM	5.5	10R	3	2	Brownish black
7	HS2	ZL	5	7.5YR	3	4	Dark brown
8	HS3	OM	6	7.5YR	3	1	Brownish black
9	HS4	ZL	6	10YR	2	3	Brownish black
10	HS5	ZL	5.5	7.5YR	3	2	Brownish black

Annexure Table 5 Vegetation survey (Data form)

Location:

Plot no:

Date:

Aspect:

Altitude:

Plot size:

Inclination:

Sl/No	Species Name	Height (cm)	Coverage (%)

Photographs

(A)

(B)

(C)

(D)

(E)

Annexure Figure 1. (A): Study Area; (B): Potato Farming in Gantey; (C): Human Settlement area; D: Road trails along the study site; (E): Animal grazing in the study area; (F) & (G): Vegetation survey field work; (H), (I), (J) & (K): Lab work for soil and water analysis.