HKKH Partnership
for ecosystem management

Management-Oriented Environmental Research in

Sagarmatha National Park and Buffer Zone

HKKH Technical Paper

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Ev-K2-CNR

Project Activity Code (s): A.1.2.2

August 2009

EvK2CNR cesvi ICIMOD IUCN

supported by Cooperazione Italiana allo Sviluppo Ministero degli Affari Esteri

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This document was produced in the framework of the Project 'Institutional Consolidation for the Coordinated and Integrated Monitoring of Natural Resources towards Sustainable Development and Environmental Conservation in the Hindu Kush-Karakoram-Himalaya Mountain Complex' financed by the Italian Ministry of Foreign Affairs – DGCS.

LIST OF ACRONYMS

AKRSP	Aga Khan Rural Support Program
BZMC	Buffer Zone Management Council
CAS	Chinese Academy for Science and Technology
CBO	Community-based Organization
CC	Climate Change
CESVI	Cooperazione e Sviluppo
CFU	Community Forming Unit
CKNP	Central Karakoram National Park in Pakistan
DDO	Dobani Development Organization
DEM	Digital Elevation Model
DESE	Department of Environmental Sciences and Engineering (Kathmandu University)
DGCS	Directorate General for Development Cooperation, Italian Ministry of Foreign Affairs
DNPWC	Department of National Parks and Wildlife Conservation
DST	Decision Support Toolbox
EMM	Ecosystem Management Model
Ev-K2-CNR	Ev-K2-CNR Committee
GIS	Geographic Information System
GLOF	Glacial lake outburst flood
GPS	Global Positioning System
HKKH	Hindu Kush-Karakoram-Himalaya
HLF	Himalaya Light Foundation
ICIMOD	International Centre for Integrated Mountain Development
ICT	Information and Communication Technologies
IGSNRR	Institute of Geographic Sciences and Natural Resources Research at Chinese Academy for Science and Technology
INGO	International non-Governmental Organization
IUCN	International Union for Conservation of Nature
KU	Kathmandu University
MGPO	Mountain Glacier Protection Organization
MoU	Memorandum of Understanding
MRD	Mountain Research and Development (journal)
MSc	Master of Science
NAST	Nepal Academy of Science and Technology
NGO	Non-governmental Organization
PhD	Doctor of Philosophy (doctoral degree)
QNP	Quomolongma Nature Preserve
RDBMS	Relational Data Base Management System
SAARC	South Asian Association for Regional Cooperation
SNP	Sagarmatha National Park
SNPBZ	Sagarmatha National Park and Buffer Zone
SPCC	Sagarmatha Pollution Control Committee
SWM	Solid Waste Management
TAR-China	Tibet Autonomous Region of PR China
TRPAP	Tourism for Rural Poverty Alleviation Project
UNDP	United Nations Development Programme
UV	Ultra-violet light
VDC	Village Development Committee
WQL	Water Quality Laboratory (in Namche)
WWF	World Wildlife Fund

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1 Executive Summary

Information and understanding of system dynamics is imperative for effective management of socio-ecosystems, including protected areas. The regional project “Institutional Consolidation for the Coordinated and Integrated Monitoring of Natural Resources towards Sustainable Development and Environmental Conservation in the Hindu Kush-Karakoram-Himalaya Mountain Complex” (HKKH Partnership Project) is a partnership initiative to support the development of institutional capacities for systemic planning and management of mountain resources at local, national and regional levels.

The Project is financed by the Italian Cooperation DGCS and was implemented by The World Conservation Union (IUCN) through its Asia Regional Office (IUCN-ARO). The Executing Agencies are the International Centre for Integrated Mountain Development (ICIMOD), Ev-K2-CNR, the Italian NGO Cooperazione e Sviluppo (CESVI) and IUCN.

The HKKH Project is a multi-scale initiative, active at the regional, national and local levels in the Hindu Kush-Karakoram-Himalaya (HKKH) region with a special focus on three Protected Areas (Fig.1), namely: Sagarmatha National Park (SNP) in Nepal, Central Karakoram National Park (CKNP) in Pakistan and Qomolangma Nature Preserve (QNP) in the Tibet Autonomous Region of China (TAR-China). These Protected Areas are in different stages of evolution, from initiating the preparation of management plans to the implementation of revised management plans.

This document describes all researches that have been carried out in the framework of the HKKH Partnership Project, financed by the Italian Ministry of Foreign Affairs – DGCS, in collaboration with Ev-K2-CNR in Sagarmatha National Park and Buffer Zone

1.1 Sagarmatha National Park

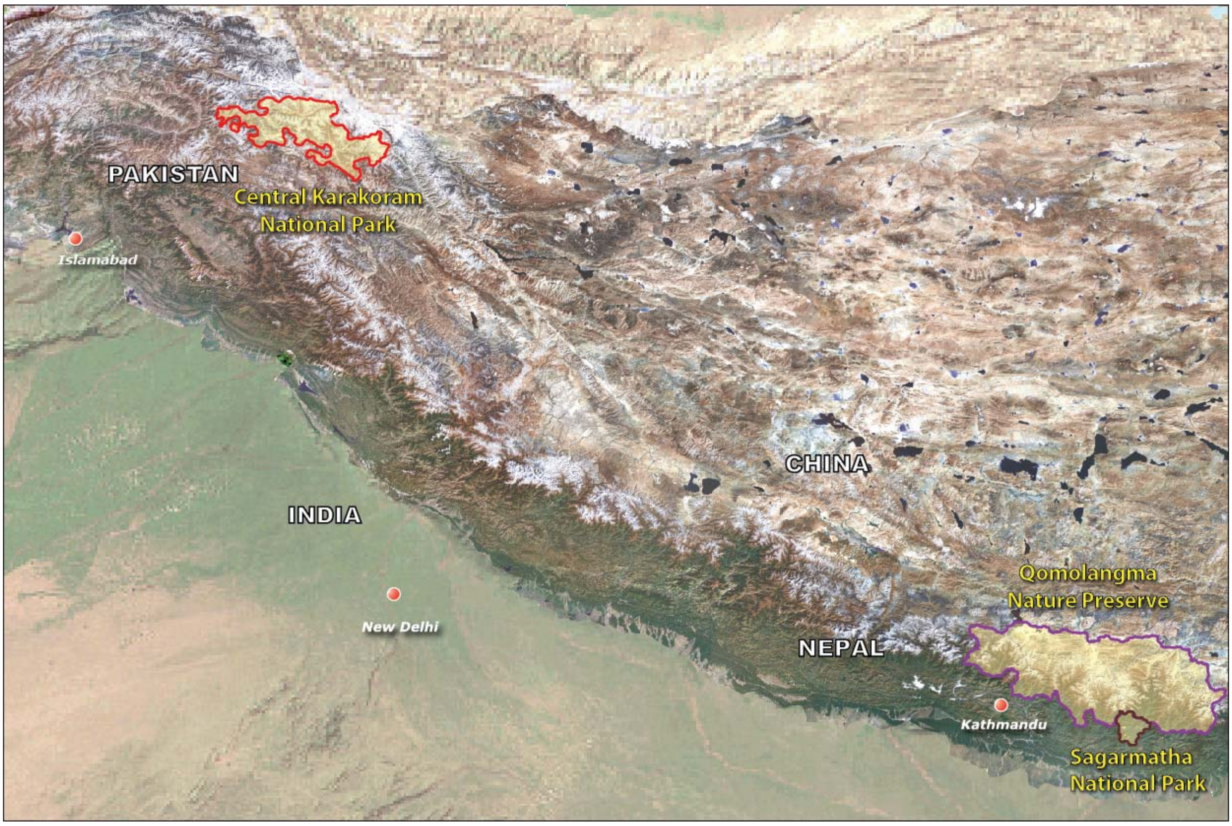

Figure 1: The Hindu Kush - Karakoram – Himalaya (HKKH) region.

Sagarmatha National Park (SNP) was established in 1976. The 1,423 square kilometer park is bordered by the Qomolangma National Nature Preserve of the Tibet Autonomous Region of China to the north, located at the southern slope of Mt. Everest. Located between 27 30' 19" to 27 06' 45" N latitude to 86 30' 53" to 86 99' 08" E longitude, the park is characterized by rugged topography and exhibits a rugged and steep topography and a wide range of altitudinal gradients in the transitional zone between the bioclimates of eastern and central Nepal, ranging from 2,845 m at Jorsalle to 8,848 m at the top of the Mt. Everest. This has favored the protected area to thrive numbers of floral as well as faunal species that are globally, nationally and economically significant.

The region was declared a protected area in 1976 and its adjoining lower region as Buffer Zone to the park in 2002. SNP is significant in terms of floral and faunal biodiversity. A total of 865 species of plants have been recorded of which 62 species are globally significant. Animals of conservation value inhabit in SNP and many of these animals are listed as endangered or threatened species. In addition, eight species of reptiles, seven species of amphibians and 30 species of butterflies have been recorded in the area. The SNP buffer zone is home to 194 species of birds of which fourteen species are globally significant. Adding the rich Sherpa culture and pristine landscape, SNP was designated as the World Heritage Site in the year 1979.

The Park has been implemented by means of a management plan since 1981. The area has gained popularity around the World after the ascent of Mt. Everest by Sir Edmund Hilary and Tenzing Norgay Sherpa in 1953 and the declaration of the area as National Park and the World Heritage site, more than 10,000 tourists started to visit the park annually after 1990. In 2000, their number even raised to over 25,000. Ever since, tourism has been the major economic sector in SNP. The tourism industry entails pressure on the park's natural resources. With its rapid social and economic development and a tourism industry with global reach SNP can substantially benefit from the application of cutting-edge management approaches and decision support tools. The key objective of the HKKH Partnership Project is to develop and facilitate the application of such tools and approaches.

1.2 Background of the research carried out in SNPBZ

Some of the key management issues facing SNP include deforestation, cultural erosion, waste generation and disposal, wanton construction of tourism structures such as hotels and lodges, excessive harvesting of medicinal and non-timber forest products, wildlife-people conflict and deteriorating monasteries. Tourism is a major source of income for the local people with an annual average of 20,000 tourists visiting the area. Increasing impact and pressure from tourism on natural resources such as firewood and waste management are going to be the key management issues.

Quantitative and qualitative ecosystem-models are a central output within the project's DST. Ev-K2-CNR has led the development of these models by an international group of modellers, thematic experts and researchers from the private and public sector, based in Nepal, Italy and the UK. This process followed an innovative approach, using collaborative system dynamics modelling to "map" complex systems. The process started with system dynamics analyses of management-relevant problem areas, identified with and by protected area management stakeholders:

- water pollution
- indoor air pollution
- forest condition and climate change
- solid waste management
- energy management
- tourism and wildlife (research in this area was carried out by CESVI and IUCN respectively and is explained in separate documents)

This step of collaborative, systemic problem identification opened up the stage for management-oriented research to be conducted from a systemic viewpoint. While collecting data and information about the identified subsystems and their key drivers within the modelling process, the research groups commissioned by Ev-K2-CNR have tried to answer key problems related to these subsystems and formulated management options, most of which can be tested by means of the socio-ecosystem model of SNPBZ within the DST. These researches are documented in detail in this document.

2 Water pollution

2.1 Authors

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Table 1: researchers involved in water pollution research

Tribhuvan University, founded in 1959, is the first university and the pioneer institute of higher education in Nepal. The University mainly operates from premises around the city of Kirtipur, through its faculties in Humanities and Social Sciences, Management, Law and Education. Tribhuvan has been a partner for Ev-K2-CNR in a number of projects, and is actively involved in research activities within the framework of the HKKH Partnership Project.

2.2 Introduction

Environmental degradation has been recorded in the Khumbu region as a result of increasing pressure on natural resources caused by a largely uncontrolled sprawl of the tourism industry. These phenomena have a clear spatial distribution, cumulating along the trekking routes. The environmental pollution problem is now no longer confined to solid waste. Water resources along the trails are being contaminated from improper discharge, human waste and garbage dumping. Sewage and toilet waste can be found piped into nearby streams and rivers (DNPWC 2007). The three major sources of water pollution can be summarized as solid waste, human faeces and fertilizers used for agriculture.

About 80% of the precipitation falls in the monsoon season from June to September. During this period, the large volume of surface water after heavy rainfall washes away the faecal material of toilets without septic tanks. Subsequently the solid components are haphazardly disposed on steep slopes and the bank of rivers and springs

The Khumbu region is drained north to south by four major rivers namely Dudh Koshi, Lobuche Khola, Imja Khola and Bhote Koshi. Dudh Koshi originates from Ngozumpa glacier and Gokyo lake system. Lobuche Khola originates from Khumbu Glacier, and Imja Khola from Imja Lake and Glaciers. The Lobuche and Imja Khola converge south of Dingboche and form Imja Khola. The Imja Khola meets with Dudh Koshi downstream of Phortse, where it remains to be called “Dudh Koshi”. Bhote Koshi originates in Tibet and it meets Dudh Koshi at Larja dobhan south of the settlement Namche Bazar. Several tributaries feed these major river systems. The major lake systems in the SNP are Imja and Gokyo.

2.3 Background

Whereas data on solid waste pollution is available for the Khumbu Region, information on other aspects of pollution (air, soil, water, etc) is very limited. Reynold et al (1998) has investigated stream water quality of and inorganic and organic micro pollutants (Camusso and Galassi 1998). Caravello et al (2007) worked on water quality assessments and the relation between water quality human health.

According to Tabei (2001) 51 kg of garbage in general was thrown by each member of expedition team to Mt Everest. In addition they dispose human excreta (faeces and urine) that have degraded the quality of environment at high altitude. Tabei (2001) estimated that 1549 kg of human wastes were produced by 13 climbing parties at the Everest base camp between 1996 – 1997, and 2469 kg from seven parties in 1998. Generally, expeditions transferred the human excreta down to Gorakhshep, where they are buried. The amount of urine per person per day in high altitude is with

2.16 liter 1.5 times higher than at lower levels. According to Tabei (2001), the total amount of urine disposed on the Khumbu glaciers till 1999 was 614520 liters for climbers, and 921780 liters for Porters and Guides. This excreta contaminates rivers downstream.

Caravello et al (2007) report a deteriorating water quality of rivers in the Khumbu valley has deteriorated with regard to microbiological and chemical pollution. Although the trace element concentrations in the upper Khumbu valley are still within normal parameters (Reynold et al 1998), but an increase in micro-pollutants of water samples can be noticed and as a side-effect of the uncontrolled growth of the tourism industry is expected increase in the future. This is a key concern since this dynamic will increase the pollution of the same water resources which are extensively used for consumption, in highly populated areas. Pollutants leak from open toilets close to the streams and water is contaminated by the use of chemical soaps for bathing, dish washing etc. In the Gokyo lakes such activities have been banned, but the compliance with this regulation is weak

2.4 Methods

To shed light on the problem of the extent and sources of water pollution, an ecological study of major water bodies in SNP has been conducted with the aim to systematically evaluate the current situation with regard to (drinking)water pollution. An ecological study of major water bodies in SNP has been conducted to systematically evaluate the current situation with regard to (drinking)water pollution, The study was carried out in the SNPBZ in 2007 September to 2009 February. It included three field visits to SNPBZ, in October 2007, May 2008 and October 2008.

S.N	Parameters	Method /instruments
1	pH	Deluxe water and soil Analysis kit (Model-191)
2	Temperature	Deluxe water and soil Analysis kit (Model-191)
3	Total dissolved solids	Deluxe water and soil Analysis kit (Model-191)
4	Conductivity	Deluxe water and soil Analysis kit (Model-191)
5	Nitrogen	Standard Curve method
6	Phosphorous	Standard Curve method
7	Iron	Atomic absorption spectrophotometer method
8	Copper	Atomic absorption spectrophotometer method
9	Lead	Atomic absorption spectrophotometer method
10	Magnesium	Volumetric method
11	Manganese	Atomic absorption spectrophotometer method
12	Zinc	Atomic absorption spectrophotometer method
13	Sodium	Atomic absorption spectrophotometer method
14	Bacteria	MPN (Most probable number method)
15	Algae	Microscope and literature

Table 2: Parameters and instruments used for analysis of water

2.4.1 water quality analysis (physical, chemical and micro-biological parameters)

Altogether 104 samples were taken of surface water bodies (mostly streams and rivers) along the major trekking routes between Lukla and Everest base camp, from Gokyo and Imja Lake and in Thame: 12 samples were collected during the first, 45 during the second and 47 samples during the third field visit. The water of the accessible rivers and surface water bodies were analyzed on the spot and in the laboratory. The samples were subjected to physical, chemical and micro-biological analysis. Physical parameters were measured on the spot with the help of a water analyzer kit (Deluxe Water and Soil Analysis Kit, Model 191).

For chemical and microbiological analysis the samples were transferred to a laboratory. Nitrogen and phosphorus content in water samples were measured at Central Department of Botany (Tribhuvan University, Kathmandu) by colorimetric method following Trivedy and Goel (1986).

Heavy metal content was analyzed of 11 samples, which were preserved in acidic medium (using concentrated $HNO3$). The Concentration of metals was measured at Environmental Assessment and Material Testing Division (Battisputali, Kathmandu) by atomic absorption spectrophotometer (AAS) and volumetric methods.

All water samples were stored at low temperature during transportation and at 4°C in laboratory prior to the analyses. Chemical and micro-biological parameters were measured at Central Department of Botany (Tribhuvan University, Kathmandu), the WQL at Khunde hospital and other laboratories in Kathmandu. Additionally, thirty samples of algae were collected for enumeration. One hundred samples of organic manure and litter were collected for nutrient analysis (Nitrogen and Phosphorus).

Bacteriological analysis was done in a temporary lab established by Ev-K2-CNR at Sherpaland Hotel in Namche, and at Central Department of Botany (Tribhuvan University, Kathmandu). It was done by most probable number (MPN) method following APHA (2005).

The activity will be continued as a water quality monitoring monitored in the future to be able to assess changes in relation to tourism development. The water quality related research activities of the HKKH project have been successful in analyzing and cataloguing quality of surface water sources in the Khumbu valley, identification of actual and potential sources of pollutants and propose measures to improve the water quality in SNPBZ.

SN	Locality/place	Description of sampling point	Sample Code	Latitude	longitude	Alt. (m)	Sample collection mission		
							First	Second	Third
1	Ghatte Khola	Before mixing to Hadikhola	A1	27.68272	86.72495	2631	NA	3/6/2008	16/11/2008
2	Hadi Khola	Before mixing to Ghatte khola	A2	27.68262	86.72503	2626	NA	3/6/2008	16/11/2008
3	Muse Khola	At the end of Muse village	A3	27.68577	86.71978	2513	NA	3/6/2008	16/11/2008
4	Thado Koshi	Thado Koshi village	A4	27.71830	86.71577	2531	NA	3/6/2008	15/11/2008
5	Ghatte Khola	Near the garbage pit at Lukla	A5	27.68585	86.73437	2850	NA	3/6/2008	16/11/2008
6	Thado Khola	Below the settlements at Phakding	A6	27.73988	86.71093	2593	7/10/2007	2/6/2008	NA
7	Dudh Koshi	Dudh Koshi at Phakding	A7	27.73983	86.71077	2587	7/10/2007	NA	15/11/2008
8	Dudh Koshi	Dudh Koshi above Jorsalle	A8	27.78250	86.72218	2777	NA	2/6/2008	NA
9	Monju Khola	Before reaching to Monju	A9	27.76977	86.72398	2767	NA	2/6/2008	14/11/2008
10	Dudh Koshi	Dudh Koshi at Phunki Tenga	A10	27.83152	86.74657	3298	NA	NA	11/11/2008
11	Phunki Tenga	Small spring mixing to Dudh Koshi at Phunki tenga	A11	27.83253	86.74562	3289	6/10/2007	20/5/2008	11/11/2008
12	Dudh Koshi	Between Pangboche and Dingboche	A12	27.84985	86.78017	3760	NA	21/5/2008	11/11/2008

13	Dudh Koshi	Between Pheriche and Pangboche	A13	0.00000	0.00000	4170	NA	21/5/2008	NA
14	Pheriche	Small spring of Pheriche before mixing to Dudh Koshi	A14	27.88930	86.81880	4279	NA	22/5/2008	8/11/2008
15	Pheriche	Side of Pheriche	A15	0.00000	0.00000	4290	NA	22/5/2008	NA
16	Imja Khola	Just below Denboche village	A16	27.88023	86.81877	4165	NA	22/5/2008	10/11/2008
17	Imja Khola	Just upper Denboche village	A17	27.89652	86.83938	4383	NA	22/5/2008	10/11/2008
18	Lobuche Khola	Below the bridge at Thokla	A18	27.92405	86.80690	4610	NA	23/5/2008	8/11/2008
19	Lobuche Khola	Near the meeting point of trail from Chola pass and Pheriche	A19	27.93705	86.80658	4843	NA	NA	8/11/2008
20	Lobuche Khola	Near Lobuche	A20	27.94707	86.80658	4919	NA	23/5/2008	8/11/2008
21	Everest Base Camp	Snow meld water from the mid of base camp	A21	28.00387	86.85597	5331	NA	25/5/2008	7/11/2008
22	Gorakhshep	Small lake just beneath the Gorekhshep	A22	27.98278	86.83073	5145	NA	25/5/2008	7/11/2008
23	Spring at Gorakhshep	Small spring between pyramid and Gorakhshep	A23	0.00000	0.00000	5100	NA	25/5/2008	NA
24	Pyramid lake	Small lake above Pyramid laboratory	A24	27.96185	86.81293	5053	NA	26/5/2008	8/11/2008
25	Pangboche	Small spring near to Pangboche joined to Imja	A25	27.85933	86.79223	4020	NA	26/5/2008	10/11/2008
26	1st lake of Gokyo	Outlet	A26	27.93088	86.70663	4661	NA	28/5/2008	3/11/2008
27	2nd lake of Gokyo	Outlet	A27	27.94033	86.69785	4716	NA	28/5/2008	3/11/2008
28	3rd lake of Gokyo	Outlet	A28	27.94887	86.71250	4720	NA	28/5/2008	1/11/2008
29	4th lake Gokyo	mid of lake side	A29	0.00000	0.00000	4850	NA	29/5/2008	2/11/2008
30	4th lake Gokyo	Outlet	A30	27.97383	86.68680	4860	NA	29/5/2008	2/11/2008
31	3 rd lake of Gokyo	Inlet	A31	27.95375	86.69333	4740	NA	29/5/2008	2/11/2008
32	Ngozumpa glacier	Glacier melt water(before mixing to water from Gokyo lake)	A32	27.93088	86.70822	4656	NA	29/5/2008	4/11/2008
33	Machhermo Khola	Below Machherma	A33	27.90133	86.71650	3929	NA	29/5/2008	4/11/2008
34	Luza Khola	Below Luza tole	A34	27.89350	86.72013	4325	NA	29/5/2008	4/11/2008
35	Dole river	Below Dole village	A35	27.86775	86.73077	4015	NA	29/5/2008	4/11/2008
36	Phortse Tenga	Dudh Koshi at Phorse Tenga	A36	27.85207	86.74365	3604	6/10/2007	30/5/2008	4/11/2008
37	Namche	Sewage treatment plant	A37	27.80268	86.70852	3353	NA	31/5/2008	14/11/2008
38	Namche	Spring from the mid of Namche	A38	0.00000	0.00000	3440	NA	31/5/2008	14/11/2008
39	Namche	Mouth of source of spring of Namche	A39	27.80415	86.71032	3414	NA	31/5/2008	NA
40	Thame Teng	Bhote Koshi above Thame	A40	27.84258	86.64450	3805	NA	NA	13/11/2008

41	Thame Khola	Small spring of Thame before mixing to Bhote Koshi	A41	27.82995	86.65692	3708	NA	1/6/2008	13/11/2008
42	Thame Khola	Just below KBC power house before mixing to Bhote Koshi	A42	27.82548	86.66473	3692	NA	1/6/2008	NA
43	Bhote Koshi	Below a bridge between Thamo and Thame	A43	0.00000	0.00000		5/10/2007	1/6/2008	13/11/2008
44	Thamo	Bhote Koshi near Thamo	A44	27.81933	86.67817	3410	NA	1/6/2008	NA
45	Theshe Khola	Before reaching to Thamo	A45	27.81728	86.68557	3405	NA	1/6/2008	13/11/2008
46	Mislung	Tap water of Mislung	A46	27.80248	86.71090	3389	NA	1/6/2008	14/11/2008
47	Namche spring	About 200 m above before mixing to Bhote Koshi	A47	27.79935	86.70740	3112	NA	1/6/2008	14/11/2008
48	Mislung spring	Before mixing to Namche spring	A48	0.00000	0.00000	3440	NA	1/6/2008	14/11/2008
49	Tok-tok Khola	Near bridge	A49	27.82200	86.71095	2661	NA	2/6/2008	14/11/2008
50	Kunde	Tap water	A50	27.82200	86.71667	3800	4/10/2007	NA	NA
51	Khumjung	Tap water	A51	27.82183	86.71683	3850	6/10/2007	NA	NA
52	Puro filter installed at Hotel Sherpaland of Namche	Drinking water filter	A52	0.00000	0.00000		6/10/2007	NA	NA
53	Aqua Everest	Bottled drinking water; collected from market at Namche	A53	0.00000	0.00000		6/10/2007	NA	NA
54	Snowy Geyser	Bottled drinking water; collected from market at Namche	A54	0.00000	0.00000		6/10/2007	NA	NA
55	Everest water	Bottled drinking water; collected from market at Namche	A55	0.00000	0.00000		6/10/2007	NA	NA
56	Phurte Khola	Above the bridge	A56	27.81817	86.68700	3470	5/10/2007	NA	NA
57	Amphulapcha cho	Small blue lake	A57	27.89330	86.76578	4977	NA	NA	9/11/2008
58	Imja lake	Near outlet	A58	27.89873	86.91375	5011	NA	NA	9/11/2008
59	Imja lake	Outlet	A59	27.89967	86.90692	5007	NA	NA	9/11/2008
60	Somare	Small spring	A60	27.86728	86.80635	4110	NA	NA	10/11/2008
61	Lukla	Tamang tole spring	A61	27.69125	86.72777		NA	NA	16/11/2008
62	Dudh Koshi	Dudh Koshi below Surke	A62	27.66640	86.70925	1941	NA	NA	16/11/2008

Table 3: Description of the water sampling sites

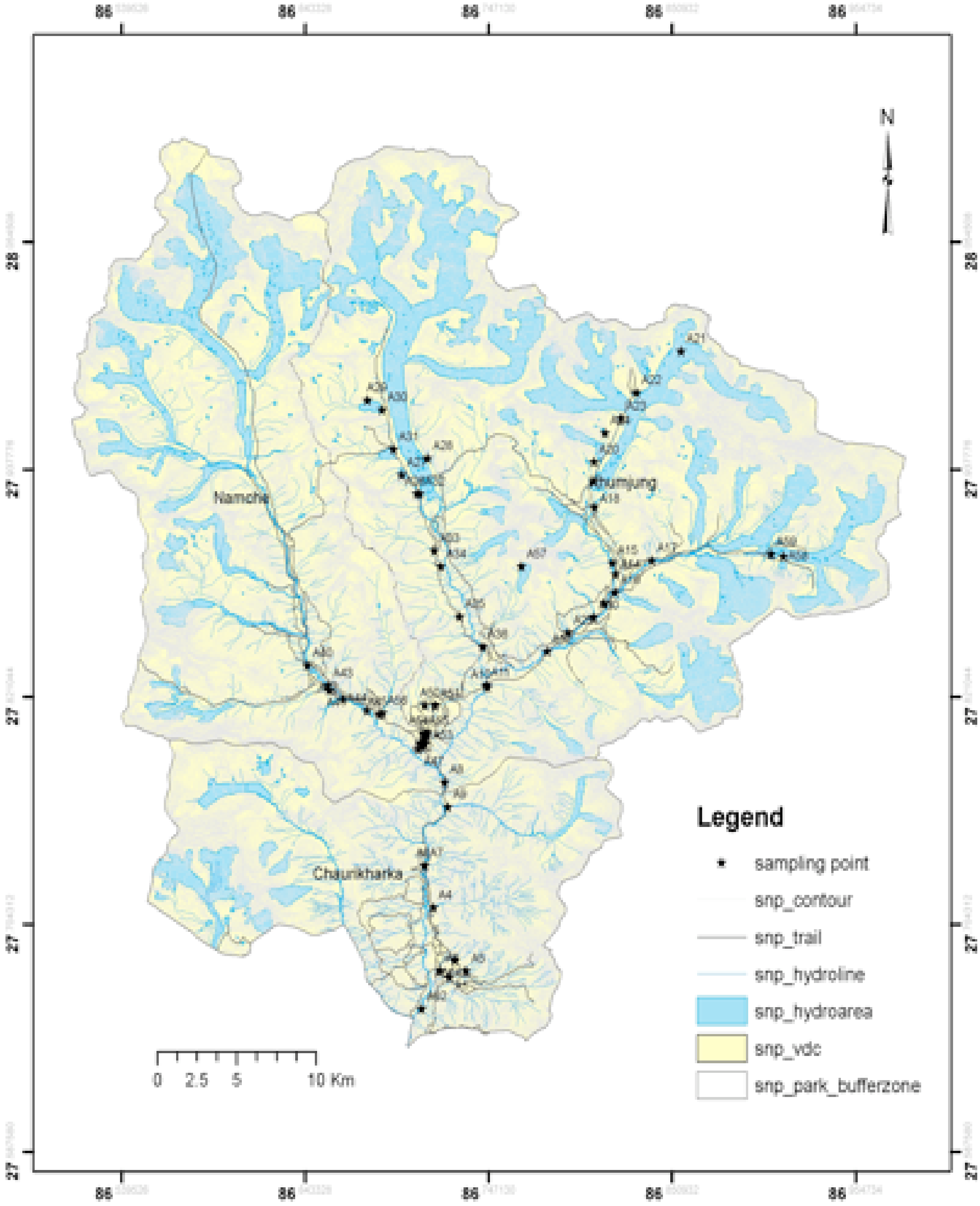

Figure 2: map showing the water sample points

2.4.2 nutrient-content analysis on different types of waste

Nitrogen, phosphorus and potassium were analyzed in samples of organic fertilizer, litter and waste dump sites. In most of the pits, the garbage was frequently burnt. Fresh (unburnt) waste samples could only be obtained from a few pits. The collected waste samples were mixed thoroughly and homogenized to obtain a single sample for the purpose of nutrient estimation. Total nitrogen was measured by Kjeldhal method, phosphorus by Stannus chloride method and potassium by flame photometer method (Jackon 1967).

2.4.3 Survey on potential and actual sources of water pollution

A field survey was carried out to identify sources and amounts of pollution by means of a structured questionnaire.

Around 20% of all households in SNPBZ were interviewed questionnaire, divided in different functional categories (large lodge, small lodges, tea shop, and residential house). A wide range of economic classes, religions and professional groups where covered. Information in production of organic waste (organic wastes), condition and management of septic tanks and toilets, use of fertilizers and location of garbage pits was collected.

Households were selected along trekking routes in all settlements between Lukla and Everest base camp, and Gokyo to Imja, including Thamo and Thame. Households were categorized into classes: lodge, small lodge, tea shop, residential home, to each group random sampling was applied.

2.4.4 Phycological analysis to assess autodepurative capacity of streams

There was an abundant growth of algae in the Gokyo lake series whereas in running water bodies, such as rivers/springs, algal growth was very poor. Therefore, water samples for phycological analysis were collected mainly from the Gokyo lake series.

Chlorophyll estimation of algae was done at Central Department of Botany (Tribhuvan University, Kathmandu) using spectrophotometer. Taxonomical identification of algae was done using relevant literatures in collaboration with Dr. Shiva Kumar Rai (PG College, Biratnagar)

2.5 Data

2.5.1 Data collected for water pollution model

CODE	Variable name	Variable Description	Spatial disaggregation	Temporal disaggregation	Other disaggregations	Units
WP4	Amount of organic fertilizer (dung+ human waste + litter)	TOTAL Amount of organic fertilizer	watershed	month		kg/m2
WP5	Composition of the organic fertilizer		settlement			Number/Number
WP7	Coefficient: amount of nutrients per kilo of human faeces and urine (TN,TP)				TN,TP	g/person/month
WP8	Coefficient:amount of nutrients per kilo of organic fertilizer (TN,TP)				TN,TP	g/kg
WP9	Coefficient:amount of nutrients per kilo of chemical fertilizer (TN,TP)				TN,TP	g/kg
WP10	Coefficient: amount of nutrients per kilo of domestic organic waste (TN,TP)				TN,TP	g/kg
WPp3a	nutrients through chemical fertilizer	TN (total nitrogen) and TP (total phosphorus) for chemical fertilizer used				TN/g and TP/g

WPp3c	amount of fertilizer required	amount of fertilizer required for production of generic crop				g fertilizer/kg crop
WP15	Percentage of each kind of septic tanks for each settlement	toilets = septic tank types	settlement			Number/Number
WP16	Percentage of Impermeability of each septic tank category	Impermeability capacity of septic tanks			Septic tanks cemented wall, stone wall, simple pit and No toilets	%
WP18	Average autodepurative capacity of the river (only chlorophyll content will be provided)	Average autodepurative capacity of the river.			TN,TP	%
WP19	Water quality river section samples	Concentration of nutrients and bacterial load in river sections, springs and lakes (average for each type (rivers sections, springs lakes) per watershed)	watershed	Nov 2007, May 2008, Nov 2008	TN,TP, Bacterial load	[concentration], coordinates
WP20	Nepali standard for river water quality/WHO standard				TN,TP, Bacterial load	
WPp1a	cost for systems and upgrades per volume unit	cost for each system and upgrade from one to the next system in relation to capacity			systems (none, open pit, stone, cemented) and upgrades (none to stone, none to cemented, stone to cemented), capacity, volume unit	NRS

Table 4: water pollution model data

2.5.2 Research raw data

S.N.	**Parameters**	**Unit**	**Samples***											
			A6	**A7**	**A36**	**A11**	**A56**	**A44**	**A50**	**A51**	**A52**	**A53**	**A54**	**A55**
1	pH		6	6.4	6.9	6.7	6.9	7	6.9	7	7	6.8	6.8	6.3
2	Sulphate	mg/l	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
3	Fluoride	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1
4	Nitrate Nitrogen	mg/l	0.113	0.226	0.056	0.056	0.113	0.113	0.113	0.113	0.113	0.903	0.903	0.903
5	TDS	mg/l	25.5	41.6	58.6	56.1	188	106.7	25.4	14.1	62	59	243.8	185.3
6	Iron as Fe	mg/l	<0.04	1.2	0.04	0.56	<0.04	0.64	0.04	<0.04	<0.04	<0.04	0.2	<0.04
7	Copper as Cu	mg/l	<0.04	1.48	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.76	<0.04
8	Lead as Pb	mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
9	Arsenic as As	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

10	Chromium III	mg/l	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
11	Chromium IV	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
12	Cadmium	mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Table 5: Chemical properties of water samples collected from SNPBZ in October 2007

SN	Locality	sample code	Physical parameters				Chemical parameters		Biological parameters		
			Temp. (°C)	pH	Conductivity (mS)	TDS (Total dissolved solid) (ppt)	Nitrate Nitrogen (mg/lit)	Inorganic phosphorus (mg/lit)	Total coli form	*Escherichia coli*	*Streptococcus faecolies*
1	Ghatte Khola	A1	14	7.4	0.02	0.01	0.93	0.15	-ve	-ve	-ve
2	Hadi Khola	A2	13.9	7.4	0.02	0.01	0.18	0.12	-ve	-ve	-ve
3	Muse Khola	A3	14.7	7.4	0.02	0.01	0.17	0.12	-ve	-ve	-ve
4	Dhado Koshi	A4	14.7	7.1	0.02	0.01	0.19	0.12	-ve	-ve	-ve
5	Ghatta khola	A5	14.3	7.3	0.01	0.01	0.50	0.06	-ve	-ve	-ve
6	Thado khola at Phakding	A6	15.5	6.8	0.02	0.01	0.71	0.15	**+ve**	-ve	**+ve**
7	Dudh Koshi above Jorsella	A8	12.5	7.3	0.03	0.02	0.32	0.03	-ve	-ve	-ve
8	Monju Khola	A9	10.5	7.2	0.02	0.01	0.47	0.05	-ve	-ve	-ve
9	Dudh Koshi	A10	8.6	7.3	0.03	0.02	1.21	0.15	-ve	-ve	-ve
10	Phunki Tenga	A11	8.6	7.5	0.02	0.01	0.65	0.12	-ve	-ve	-ve
11	Dudh Koshi	A12	13.7	7.3	0.03	0.02	0.80	0.19	-ve	-ve	-ve
12	Dudh Koshi	A13	8.5	7.3	0.03	0.02	0.47	0.14	-ve	-ve	-ve
13	Pheriche	A14	11.2	7.5	0.03	0.02	0.61	0.14	-ve	-ve	-ve
14	Pheriche	A15	9.5	7.7	0.03	0.02	0.71	0.09	**+ve**	-ve	**+ve**
15	Imja Khola	A16	9.3	7.4	0.03	0.02	0.50	0.14	-ve	-ve	-ve
16	Imja Khola	A17	8.5	7.6	0.02	0.02	0.27	0.65	-ve	-ve	-ve
17	Lobuche Khola	A18	9.5	7.1	0.03	0.02	0.90	0.46	-ve	-ve	-ve
18	Lobuche	A20	10.5	7.2	0.04	0.03	0.27	0.65	-ve	-ve	-ve
19	Everest Base Camp	A21	10	7.4	0.01	0	0.77	0.07	**+ve**	-ve	**+ve**
20	Small lake at Gorakhshep	A22	9.5	8.6	0.03	0.02	1.25	0.09	-ve	-ve	-ve
21	Spring at Gorakhshep	A23	11.2	7.7	0.03	0.02	0.86	0.28	-ve	-ve	-ve
22	Pyramid lake	A24	10.03	7	0.03	0.02	1.26	0.11	-ve	-ve	-ve
23	Pangboche	A25	11.2	7.4	0.03	0.02	0.56	0.07	-ve	-ve	-ve
24	1st lake of Gokyo	A26	12.2	8.7	0.03	0.02	0.20	0.24	-ve	-ve	-ve
25	2nd lake of Gokyo	A27	14.2	8.5	0.03	0.02	0.68	0.27	-ve	-ve	-ve
26	3rd lake of Gokyo	A28	13.5	8.3	0.03	0.02	0.20	0.02	-ve	-ve	-ve
27	4th lake Gokyo	A29	14.4	7.7	0.02	0.01	0.72	0.03	-ve	-ve	-ve
28	4th lake Gokyo	A30	14	8.1	0.02	0.01	0.65	0.08	-ve	-ve	-ve
29	3 rd lake of Gokyo	A31	9.8	9.3	0.03	0.02	0.20	0.11	-ve	-ve	-ve
30	Ngozumpa	A32	6.7	8.5	0.03	0.02	0.68	0.11	-ve	-ve	-ve

	glacier										
31	Machhermo Khola	A33	13	7.1	0.02	0.01	0.27	0.07	**+ve**	**+ve**	-ve
32	Luza Khola	A34	12.5	7.5	0.01	0	0.54	0.19	-ve	-ve	-ve
33	Dole river	A35	12	7.6	0.01	0.01	0.61	0.02	-ve	-ve	-ve
34	Phortse Tenga	A36	8.8	7.7	0.03	0.02	0.63	0.29	-ve	-ve	-ve
35	Namche	A37	9.5	6.8	0.06	0.04	0.77	0.02	**+ve**	**+ve**	-ve
36	Namche	A38	13.2	7.3	0.04	0.02	1.44	0.48	-ve	-ve	-ve
37	Namche	A39	12.4	7.5	0.03	0.02	0.54	0.14	-ve	-ve	-ve
38	Thame	A41	14.2	7	0.02	0.01	0.63	0.12	-ve	-ve	-ve
39	Thame Khola	A42	12.9	7.2	0.02	0.01	0.77	0.28	-ve	-ve	-ve
40	Bhote Koshi	A43	11.5	7.4	0.02	0.01	1.08	0.48	**+ve**	**+ve**	-ve
41	Theshe khola	A45	14.7	7.4	0.02	0.02	0.51	0.11	-ve	-ve	-ve
42	Mislung	A46	15	7.5	0.03	0.02	1.94	0.29	-ve	-ve	-ve
43	Namche spring	A47	13.5	7.7	0.04	0.02	0.97	0.25	-ve	-ve	-ve
44	Mislung spring	A48	14.4	7.5	0.04	0.03	0.63	0.12	-ve	-ve	-ve
45	Tok-tok Khola	A49	13.5	7	0.01	0.01	0.94	0.12	-ve	-ve	-ve

Table 6: Physico-chemical and biological properties of water bodies of SNPBZ in May 2008

SN	locality	Sample code	Physical parameter				Chemical parameter	
			Temp. (°C)	pH	Conductivity (mS)	TDS (Total dissolved solid) (ppt)	Nitrate Nitrogen (mg/lit)	Inorganic phosphorus (mg/lit)
1	Ghatte Khola (Lukla)	A1	8.3	8.4	0.02	0.01	0.95	0.18
2	Hadi Khola (Lukla)	A2	8.4	8.33	0.03	0.02	0.50	0.11
3	Muse Khola	A3	8.5	8.0	0.03	0.02	0.25	0.10
4	Thado Koshi	A4	8.4	7.6	0.02	0.02	0.71	0.12
5	Ghatte Khola	A5	8.0	7.9	0.01	0.01	0.72	0.03
6	Dudh Koshi	A7	6.1	7.1	0.03	0.02	0.80	0.29
7	Monjo Khola	A9	6.4	6.9	0.02	0.01	0.52	0.17
8	Dudh Koshi	A10	7.5	7.0	0.01	0.01	0.65	0.11
9	Phunki Tenga	A11	7.2	8.2	0.03	0.02	1.18	0.07
10	Dudh Koshi	A12	7.9	7.4	0.04	0.02	0.53	0.02
11	Pheriche	A14	10.4	7.5	0.03	0.02	0.67	0.11
12	Imja Khola	A16	10.1	7.5	0.04	0.03	0.48	0.32
13	Imja Khola	A17	10	7.2	0.03	0.02	0.40	0.13
14	Lobuche	A18	10.5	6.7	0.04	0.03	0.85	0.64
15	Lobuche river	A19	9.4	7.4	0.04	0.03	0.20	0.09
16	Lobuche	A20	9.3	7.8	0.04	0.03	0.47	0.66
17	Everest Base Camp	A21	7.8	7.1	0.01	0.00	0.47	0.01
18	Gorakhshep	A22	7.7	7.9	0.02	0.02	1.00	0.33
19	Pyramid lake	A24	5.2	8.1	0.03	0.02	1.25	0.09
20	Pangboche	A25	7.9	6.9	0.02	0.01	0.61	0.08
21	Gokyo lake	A26	7.0	7.23	0.03	0.02	0.14	0.26
22	Gokyo lake	A27	6.5	7.51	0.03	0.02	0.61	0.36
23	Gokyo lake	A28	7.6	7.45	0.03	0.02	0.27	0.01

24	Gokyo lake	A29	4.5	7.2	0.02	0.01	0.16	0.29
25	Gokyo lake	A30	5.0	7.5	0.02	0.01	0.16	0.24
26	Gokyo lake	A31	6.0	7.3	0.03	0.02	0.20	0.23
27	Ngozumpa glacier	A32	4.3	7.56	0.03	0.02	0.56	0.13
28	Macchermo Khola	A33	6.0	7.5	0.02	0.01	0.34	0.07
29	Luza Khola	A34	5.0	7.3	0.01	0.00	0.52	0.27
30	Dole river	A35	4.5	7.1	0.01	0.01	0.43	0.01
31	Phortse Tenga	A36	5.0	7.0	0.02	0.03	0.38	0.42
32	Namche	A37	6.6	9.0	0.07	0.04	1.26	0.01
33	Namche	A38	6.3	7.3	0.03	0.02	0.47	0.15
34	Thame Teng	A40	9.5	7.9	0.03	0.02	0.71	0.25
35	Thame	A41	8.7	6.3	0.03	0.02	0.72	0.12
36	Bhote Koshi	A43	8.4	6.8	0.02	0.01	0.54	0.13
37	Theso Khola	A45	8.1	8.4	0.02	0.01	0.28	0.12
38	Mislung	A46	6.4	7.4	0.03	0.02	1.58	0.27
39	Namche	A47	6.5	8.6	0.03	0.02	1.06	0.32
40	Namche	A48	6.3	7.8	0.04	0.02	0.95	0.26
41	Tok-tok Khola	A49	6.4	6.8	0.02	0.01	0.71	0.15
42	Amphulapcha tsho	A57	4.1	7.3	0.02	0.01	0.86	0.32
43	Imja lake	A58	4.5	7.02	0.01	0.01	0.72	0.39
44	Imja lake	A59	4.9	7.6	0.01	0.01	0.68	0.42
45	Somare	A60	8.0	8.5	0.03	0.02	0.93	0.65
46	Lukla	A61	7.7	9.0	0.06	0.04	1.18	0.38
47	Dudh Koshi	A62	8.2	7.24	0.03	0.02	0.76	0.24

Table 7: Physico-chemical properties of water bodies of SNPBZ in Oct-Nov 2008

SN	Description of site	Fe (mg/l)	Cu (mg/l)	Na (mg/l)	Mg (mg/l)	Mn (mg/l)	Zn (mg/l)	Pb (mg/l)
1	Thado Khola at Phakding	0.1	<0.04	1.0	3.7	<0.01	<0.01	<0.02
2	Lobuche Khola	0.1	<0.04	1.0	1.2	<0.01	<0.01	<0.02
3	Namche	0.1	<0.04	2.8	8.7	<0.01	<0.01	<0.02
4	Pheriche (below small bridge)	0.4	<0.04	1.0	3.7	<0.01	<0.01	<0.02
5	Ghatte Khola	0.1	<0.04	1.4	6.0	<0.01	<0.01	<0.02
6	2nd Gokyo lake	0.04	<0.04	6.4	6.2	<0.01	<0.01	<0.02
7	4th Gokyo lake	0.2	<0.04	0.4	3.7	<0.01	<0.01	<0.02
8	1st Gokyo lake	0.2	<0.04	0.6	6.2	<0.01	<0.01	<0.02
9	Ngozumpa glacier	0.1	<0.04	0.6	3.7	<0.01	<0.01	<0.02

10	Everest Base Camp	0.4	<0.04	<0.2	3.7	<0.01	<0.01	<0.02
11	Dingboche	0.7	<0.04	0.8	3.7	<0.01	<0.01	<0.02
Methods used		**AAS**	**AAS**	**AAS**	**volumetric**	**AAS**	**AAS**	**AAS**

Table 8: Heavy metal concentration in water bodies of SNP and BZ

S.N	Name of species	Class	Remarks
1.	*Actinotaenium cf.subglobosum*	Chlorophyceae	
2.	*Anabaena* sp.	Cyanophyceae	
3.	*Aphanocapsa littoralis*	Chlorophyceae	
4.	*Botryococcus cf. braunii*	Xanthophyceae	
5.	*Bulbochaete* sp.	Chlorophyceae	
6.	*Ceratoneis arcus*	Bacillariophyceae	
7.	*Chlorella vulgeria*	Chlorophyceae	
8.	*Closterium acerosum*	Chlorophyceae	
9.	*Cocconeis placentula var.euglypta*	Bacillariophyceae	
10.	*Cosmarium subspeciosum*	Chlorophyceae	
11.	*Cosmarium awadhense*	Chlorophyceae	
12.	*Cosmarium cf.sublateriundatum*	Chlorophyceae	
13.	*Cosmarium nudum*	Chlorophyceae	
14.	*Cyclotella antiqua*	Chlorophyceae	
15.	*Cylindrocapsa* sp.	Chlorophyceae	
16.	*Cylindrocystis brebissonii*	Chlorophyceae	
17.	*Cymbella cymbiformis*	Bacillariophyceae	
18.	*Cymbella lanceolata*	Bacillariophyceae	New record
19.	*Denticula* sp.	Bacillariophyceae	
20.	*Diatoma hiemale var.mesodon*	Bacillariophyceae	
21.	*Dinobryon cf.sertularis*	Chrysophyceae	
22.	*Euastrum cf. bidentatum*	Chlorophyceae	
23.	*Euastrum oblongum*	Chlorophyceae	New record
24.	*Eunotia alpine*	Bacillariophyceae	
25.	*Eunotoia lunaris*	Bacillariophyceae	
26.	*Eunotoia coralloides*	Bacillariophyceae	New record

27.	*Fragilaria capucina* var.*vaucheriae*	Bacillariophyceae	
28.	*Fragilaria crotonensis*	Bacillariophyceae	New record
29.	*Frustulia rhomboids*	Bacillariophyceae	
30.	*Gloeocapsa aeruginosa*	Cyanophyceae	
31.	*Gomphonema geminatum*	Bacillariophyceae	New record
32.	*Gomphonema sphaerophorum*	Bacillariophyceae	
33.	*Hyalotheca dissiliens*	Chlorophyceae	
34.	*Meridion circulare*	Bacillariophyceae	New record
35.	*Merismopedia glauca*	Cyanophyceae	
36.	*Mougeotia* sp.	Chlorophyceae	
37.	*Navicula perrotetti*	Bacillariophyceae	
38.	*Netrium digitus*	Chlorophyceae	
39.	*Oedogonium* sp.	Chlorophyceae	
40.	*Oscillatoria subbrevis*	Cyanophyceae	
41.	*Oscillatoria agardhii*	Cyanophyceae	
42.	*Oscillatoria brevis*	Cyanophyceae	
43.	*Oscillatoria cf.Insignis*	Cyanophyceae	New record
44.	*Pediastum duplex*	Chlorophyceae	
45.	*Penium cylindrus*	Chlorophyceae	New record
46.	*Phacus* sp.	Chlorophyceae	
47.	*Phormidium* sp.	Cyanophyceae	
48.	*Pinnularia viridis*	Bacillariophyceae	
49.	*Pinnularia braunii*	Bacillariophyceae	
50.	*Scenedesmus bijugatus*	Chlorophyceae	
51.	*Scenedesmus quadricauda*	Chlorophyceae	New record
52.	*Scenedesmus bijuga*	Chlorophyceae	
53.	*Scenedesmus cf. obliquus*	Chlorophyceae	
54.	*Sphaerocystis schrocteri*	Chlorophyceae	
55.	*Spirogyra cf amplectens*	Chlorophyceae	New record
56.	*Staurastrum* sp.	Chlorophyceae	
57.	*Stauroneis phoenicenteron*	Bacillariophyceae	
58.	*Stigonema mamillosum*	Cyanophyceae	
59.	*Surirella didyma*	Bacillariophyceae	
60.	*Synedra ulna*	Bacillariophyceae	
61.	*Tabellaria flocculosa*	Bacillariophyceae	
62.	*Zygnema* sp.	Chlorophyceae	

Table 9: Enumeration of aquatic algae of SNPBZ

SN	Description of sites	Latitude (°)	Longitude	Altitude	Chlorophyll concentraton (mg/g of

			(°)	(m asl)	algae)		
					Chl - a	Chl - b	Total Chl
1	Imja lake outlet	27.89873	86.91375	5011	0.0825	0.1234	0.2116
2	Gokyo 1st lake	27.93088	86.70663	4661	0.38876	0.20728	0.72463
3	Below Thukla				0.10085	0.07238	0.188405
4	Gokyo 2nd lake outlet	27.94033	86.69785	3708	0.18781	0.1359	0.37681
5	Thame	27.82995	86.65692	3708	0.18781	0.1359	0.37681

Table 10: Chlorophyll content of algae collected from SNPBZ

Settlements	Total of household surveyed	Total quantity of organic fertilizer production (kg)	Total quantity of organic fertilizer used in settlements (kg/sq.m)
Lukla	22	22,475	0.82
Chaurikharka	14	29,510	0.49
Phakding	70	27,375	0.40
Thado Koshi	3	9,100	0.70
Jorsalle	7	29,650	0.21
Namche	13	6,950	1.37
Kunde	8	8,750	0.87
Khumjung	6	11,875	---
Pangboche	10	7,750	0.89
Pheriche	8	5,500	0.37
Dingboche	8	6,500	1.06
Portse	6	10,750	1.09
Dole	7	5,000	0.59
Phurte	12	5,750	0.09
Thame	6	14,500	1.44
Thamo	6	4,825	0.91

Table 11: Amount of fertilizer used in different settlements in SNPBZ

Settlements	Total number of Households	Total of Households surveyed	Total number of Toilets in surveyed Households	Total number of septic tanks in surveyed Households	Number (percentage) of different types septic tanks**			No of household surveyed without toilet
					A	B	C	
Lukla	153	22	97	36	7 (19.4)	20 (55.6)	9 (25.0)	2
Chaurikharka	45	14	21	17	1 (5.9)	2 (11.8)	14 (82.4)	0
Phakding	24	7	46	5	0 (0)	4 (80.0)	1 (20.0)	4
Dhadokoshi	7	3	2	2	0 (0)	0 (0)	2 (100)	1
Jorsella	22	7	29	11	0 (0)	6 (54.4)	5 (45.5)	1
Namche	141	13	77	19	3 (15.8)	9 (47.4)	7 (36.8)	3
Kunde	69	8	11	11	0 (0)	1 (9.1)	10 (90.1)	1
khumjung	163	6	17	8	0 (0)	2 (25.0)	6 (75.0)	0
Tangboche	6	7	20	16	0 (0)	5 (31.3)	11 (68.8)	1
panboche	105	10	23	17	0 (0)	7 (41.2)	10 (58.8)	1
Pheriche	18	8	19	11	0 (0)	7 (63.6)	4 (36.4)	2
Dingboche	80	8	25	18	0 (0)	15 (83.3)	3 (16.70	1
Lobuche	7	4	9	3	0 (0)	3 (100)	0 (0)	3
Gorekshep	6	4	12	5	0 (0)	5 (100)	0 (0)	1
Porste	82	6	12	10	0 (0)	3 (30.0)	7 (70.0)	0
Dole	10	7	14	12	0 (0)	4 (33.3)	8 (66.7)	2
Gokyo	9	4	22	7	0 (0)	5 (71.5)	2 (28.6)	1
Phurste	12	12	19	11	0 (0)	5 (45.5)	6 (54.5)	5
Thame	60	6	14	8	0 (0)	5 (62.5)	3 (37.5)	1
Thamo	45	6	13	9	0 (0)	5 (55.6)	4 (44.4)	2

Table 12: Frequency of toilets and various types of septic tanks in the settlements of SNPBZ

S.N	Type of fertilizer	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Remarks
1.	Fresh litter	1.50	0.91	3.35	
2.	Decomposed litter	0.952	0.632	1.06	
3.	Litter + Cow dung	2.10	0.59	2.35	
4.	Litter + pig dung	1.56	0.57	1.72	
5.	Litter + Toilet waste	0.78	0.68	1.39	
Average		1.15	0.68	1.71	
Per ha contribution (kg)		92	54.4	136.8	

Table 13: Concentration of nitrogen, phosphorus and potassium in various organic fertilizers

2.6 Findings

The quality of water in river and streams in SNPBZ is generally good in relation to the WHO and Nepali standard for drinking water. However, a process of declining quality of water sources has begun. A drop in water quality parameters of water bodies along the major trekking routes has been found. The pollution is caused by anthropogenic activities, foremost through waste water, especially open toilets, from the tourism industry and solid waste disposal.

2.6.1 <u>Biological contamination</u>

Bacterial presence (*Escherichia coli* and *Streptococcus faecolies*) has been recorded in the water samples collected from a spring in Phakding, in the Dudkoshi riversection between Jorsalle and Dudhkoshi bridge, at Namche Bazzar, near garbage pit, Pheriche, Phungi Tenga, Thado Khola at Phakding, Everest Base Camp, Machhermo Khola, and in Bhote Koshi below Thame (Figure 3).

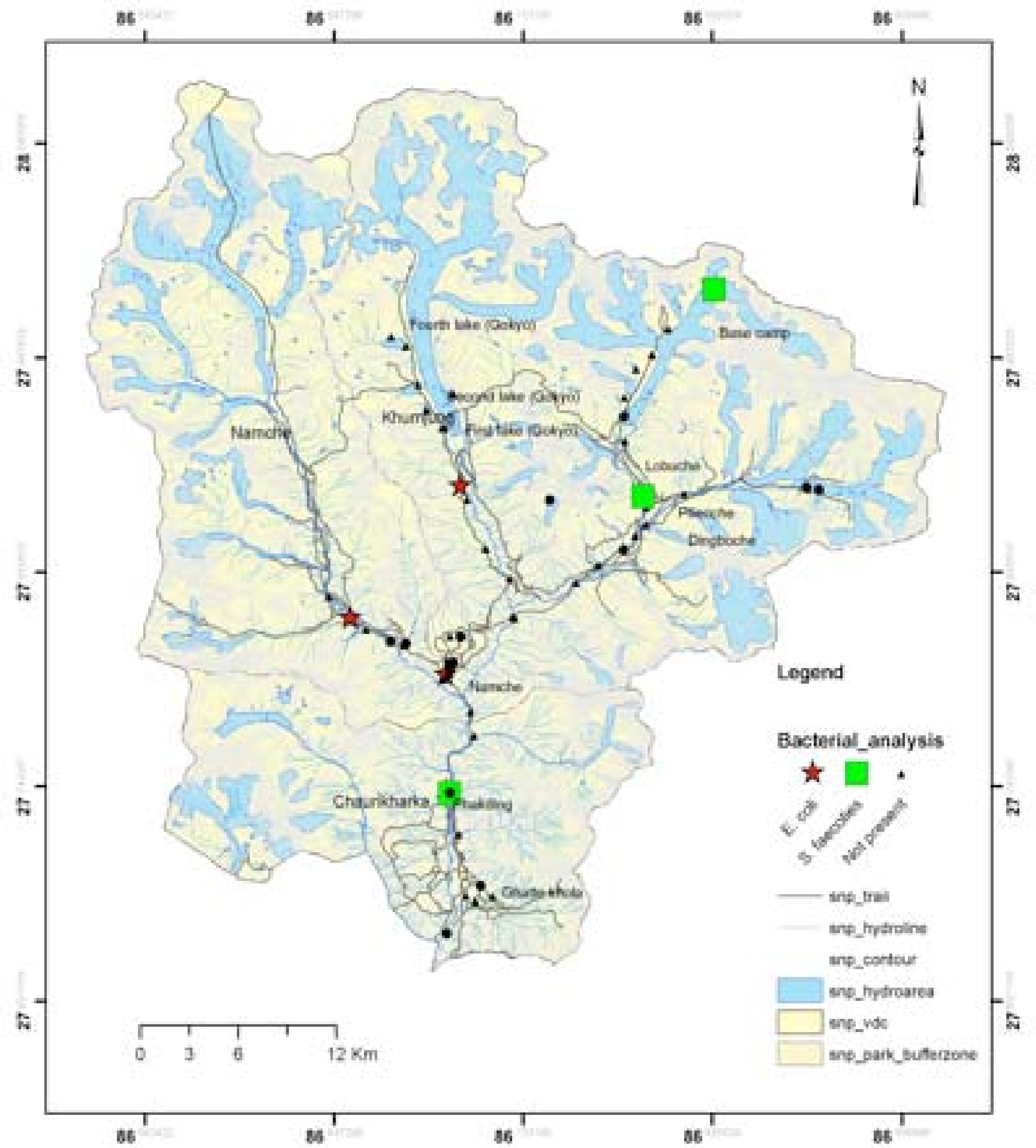

Figure 3: map showing the sample locations with microbiological contamination

2.6.2 Nitrate

Nitrate in all water samples is within the threshold for drinking water (Tables 3-5) according to WHO as well as Nepalese standards. However, the nitrate content of the water in SNPBZ has increase in relation to earlier studies (Figure 4): Compared to Reynolds et al (1998) who found a NO_3-N content of 0.15 to 0.17 mg/l in upper Khumbu valley's melt water streams this study founds values as high as 1.94 mg/l.

2.6.3 Phosphorus

Total phosphorous content in all water samples was below the WHO and Nepalese standard for drinking water, but higher than the USEPA (1986) standard, which determines the predestination for algae blooms. Phosphorus content in water samples from SNPBZ range between 0.02 and 0.66 mg/l (Figure 5), whereas USFPA (1986) criteria for streams/river water is 0.1 mg/l, for streams entering lakes is 0.05 mg/l and for lake reservoirs between 0.01 and 0.03 mg/l

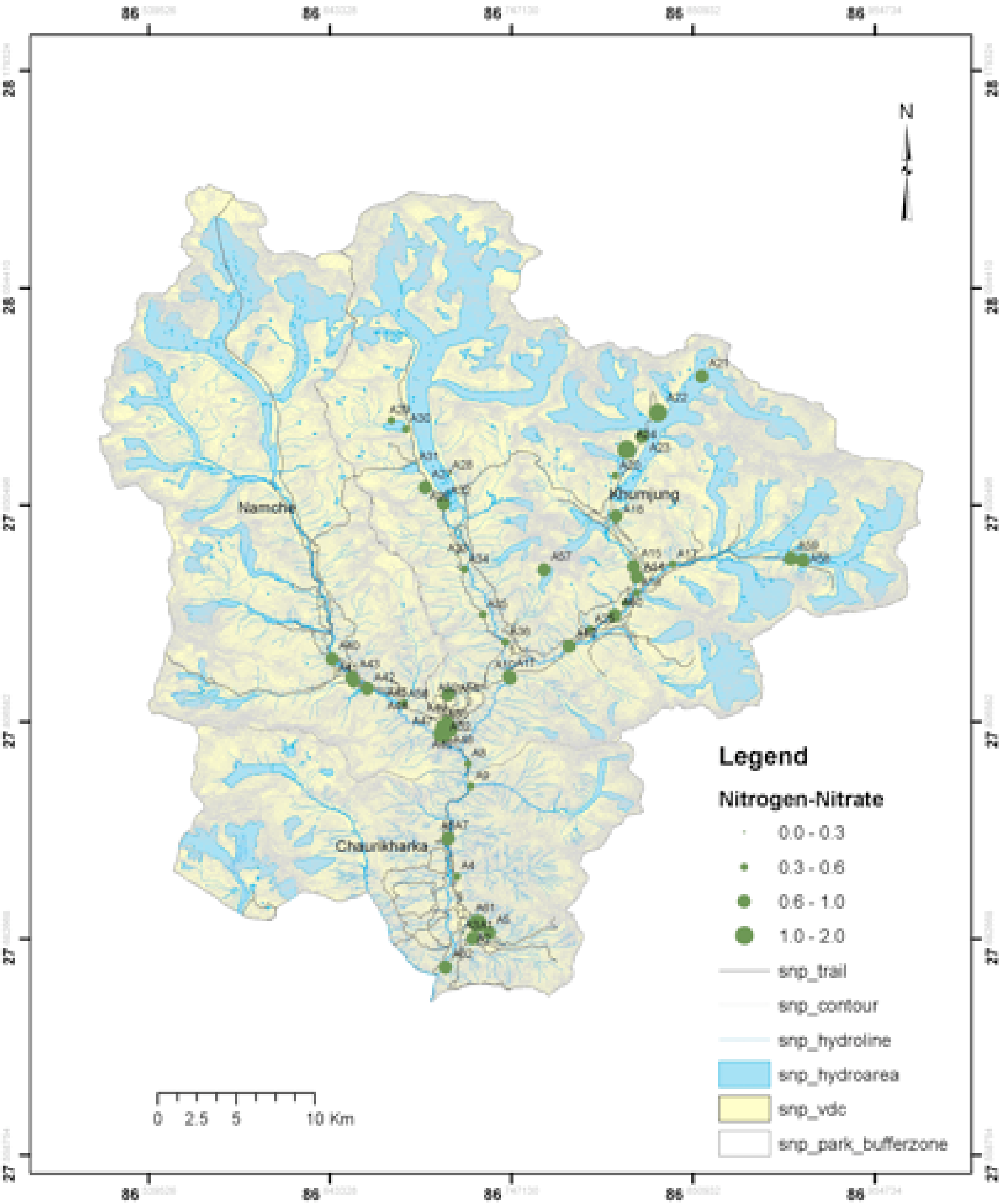

Figure 4: map showing nitrogen content of water samples

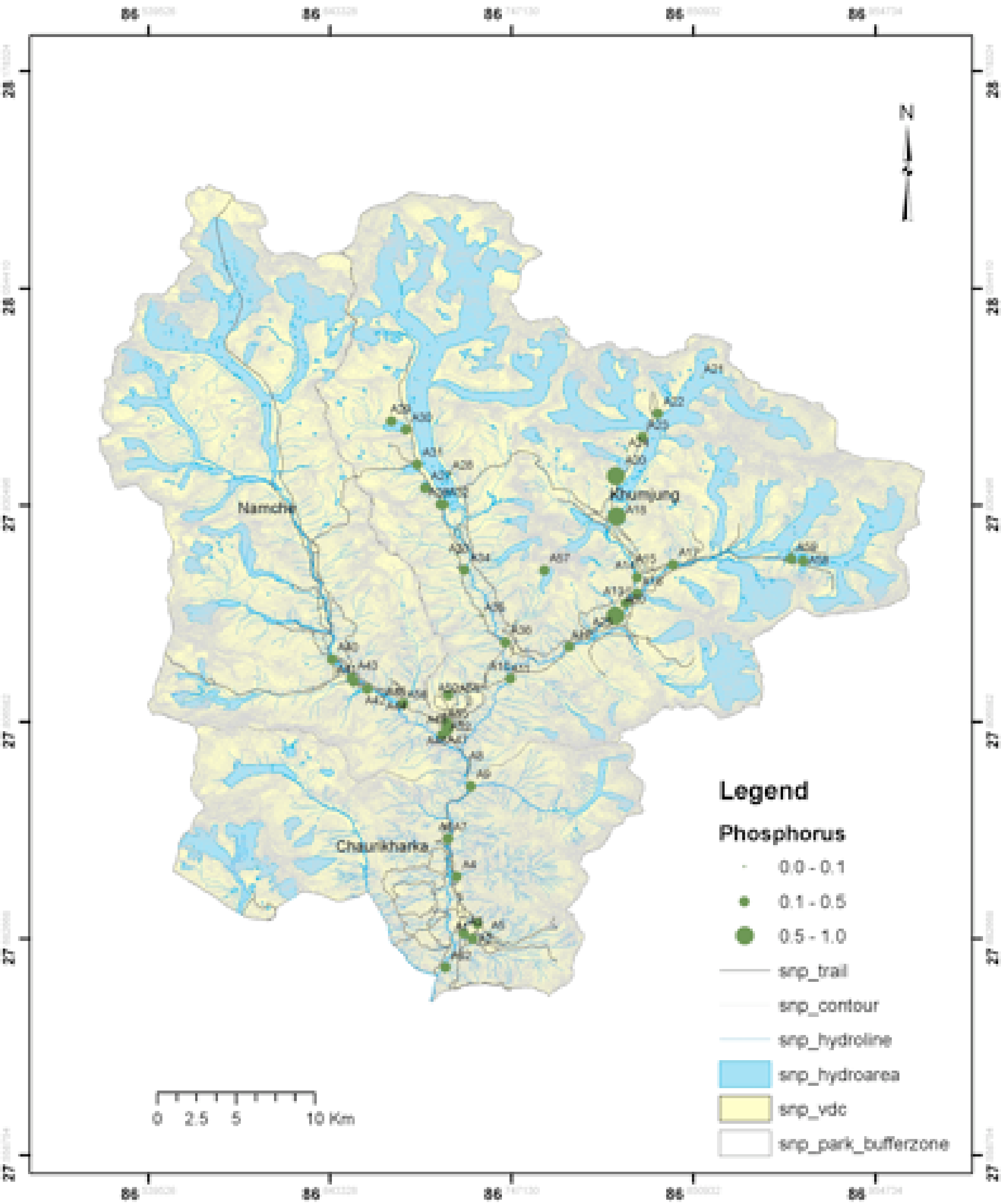

Figure 5: map showing phosphorus content of water samples

2.6.4 Heavy metals

Iron (Fe) content of six water samples is above the WHO and Nepalese standard for drinking water, which sets the threshold for Fe content at 0.3 mg/l. The samples showed higher values, such as 1.2 mg/l (Table 6) at Jorselle Dudhkoshi riversection ,0.56 mg/l at Phunki Tenga, Dudhkoshi,0.64mg/l in Bhote Koshi near Thame, 0.4mg/l at Pheriche (below the small bridge), 0.4 mg/l at Everst base camp and 0.7mg/l at Denboche (Figure 8). Copper (Cu) content was above the standard threshold (1.0 mg/l) at Jorsalle and Dudh Koshi Bridge with 1.48 mg/l.

2.6.5 Other parameters

Total dissolved solids (TDS), pH, Sodium (Na), Magnesium (Mg), Lead (Pb) and Manganese (Mn) were found to be within the limits for safe drinking water. Earlier reports (Reynolds et al 1998) analyzed Na content at 1.61 mg/l, whereas this study found with 0.2-6.4 mg/l lower contents on an average (Figure 6), instead, Magnesium was with 1.2 and 8.7 mg/l (Figure 7) higher than the values found by earlier studies (0.11 and 0.52 mg/l. Based on conductivity data, water quality in the Khumbu region is still excellent (<0.25 ds/m).

2.6.6 Algae

Altogether 62 species of aquatic algae have been recorded from the study area (Table 7). Ten of these species of algae are new records for Nepal. Chlorophyll content in algae ranged between 0.188 and 0.724 mg/g. Chlorophyll content was higher in the algae from Gokyo Lake and lower in the algal sample from below Thukla (Table 8).

2.6.7 Fertilizer use

Total annual production of organic fertilizer in SNPBZ was estimated at about 2197t. A household produces on an average 1.7t per annum which is used at a rate of.82 kg/sqm on the farm land (Table 9). Different types of organic fertilizers are used. Fertilizer consists either of decomposed litter, or litter + cow dung, or litter + pig dung, or litter + human waste from septic tanks, depending on the availability of matter and cultural practices. The Nitrogen, phosphorous and potassium content of the different types of organic fertilizers (Table 10) varies. Nitrogen ranges from 0.78 to 1.5% (average 1.15%); phosphorous between 0.57 to 0.91% (average 0.68 %); and potassium 0.72 to 3.35% (average 1.71 %). The average rate with which organic fertilizer is applied is 80t/ha (0.8kg/sqm). This is higher than the recommended dose (30t/ha for potato crop). At this rate, nitrogen, phosphorous and potassium if brought out to the fields at around 97kg/ha, 54.4kg/ha and 136.8 kg/ha respectively, whereas the recommended dose of organic fertilizer in potato crop is: 70kg/ha, 50kg/ha and 40 kg/ha for nitrogen, phosphorous and potassium respectively. Only two households in the Namche Bazaar were found to use of chemical fertilizer, which is not sold in the market in SNPBZ.

2.6.8 Sanitation

Twenty percent of the households in SNPBZ do not have septic tanks. Generally, houses without tank are situated along the trekking routes. Most of the households, especially lodges, maintain stone-walled septic tanks, which feature a permeability of 40-50%, as the cost for cement is relatively high and the cementing process is difficult due to cold climate. The few septic tanks with cemented wall showed less than 10 % permeability. In some cases, lodges had no septic tanks at all and discharge the waste directly into water bodies (e.g. Phakding, Jorselle) (Table 11). Litter toilets are most common in the settlements Chaurikharka, Kunde, Khumjung, Phortse, Thame. These settlements have not been able to substantially profit from mainstream tourism and agriculture is still a common livelihood activity for people in these settlements. The organic fertilizer generate from litter is used on potato fields.

Three types of septic tanks were observed in SNPBZ: A) with cement wall, B) with stone wall (non-cemented), and (C) simple pit (including litter toilet). Only 4.66% of toilets feature a septic tanks with cement wall. 47.45% of the toilets consist of a simple pit and 47.88% feature a stone wall. About 80% of the garbage pits constructed by SPCC and the local community are situated near water courses – some of them within a distance of five meters from the water surface. In some locations (e.g. Phakding) waste is disposed directly on the riverbank and in the stream. It seems like pits close to water courses are being flooded regularly during the rainy season, whereby contaminating river water.

2.7 Discussion

The present findings reveal that the presence of pollutants in the water bodies of SNPBZ is an increasing trend, however, the current level of contamination does not pose a health hazard yet - It is within the limits of the Nepalese and WHO standards, except a few places at certain particularly hazardous locations or exposed to particularly hazardous practices. Non-scientific solid waste management, open defecation and poor condition of septic tanks, and direct disposal of toilet waste to water courses or on the exposed surface, are major sources of river water pollution.

The condition of toilets and septic tanks in the Khumbu region is not satisfactory, especially the condition of public toilets at Namche and Chukung. Lack of septic tanks (at Somare, Pheriche), leachate from septic tanks (at Gorakhshep), lack of toilets (at Thamo), and high permeability of the septic tanks in general are the major problems.

Agriculture in SNPBZ is based on organic fertilization. The average rate of use of organic fertilizer is 80 t/ha (i.e. 0.8kg/sqm). To meet the high demand of vegetables by the tourism industry (especially potatoes), farmers are tempted to use organic fertilizer at excessive amounts, far higher than recommended for potato crop to maximize the yield.

2.8 Management options

2.8.1 <u>Build septic tanks (evaluation of this option in the model possible)</u>

Leaching of fecal matter (human waste) into surface water bodies and groundwater is a major source of contamination for drinking water sources. Where central waste treatment facilities are lacking, fecal matter is commonly collected in a septic tank. Septic thanks are is either emptied, in which case the matter is transported to central waste treatment plants for processed or dried out and composted for use as fertilizers. In residential areas in SNPBZ, forest litter is used in toilets instead of water The latter technique is applied in these cases, where the “septic tank” functions as a composting place for the matter before the manure is used as fertilizer on agricultural land. Due to a lack of water direct leaching of pollutants from these septic tanks into water bodies is small compared to other sources of pollution (see below)

However, along the trekking routes, a significant number of tea shops and a few hotels are not equipment with a septic tank at all. Since in these places are used as a way station by a large number of visitors they produce a high amount of fecal matter. At Jorsalle, for example, hotels/tea shops situated above the river bank are not equipped with any septic tank facility whatsoever. The effluent from the toilets, which are operated with water drain directly over the cliff onto the bank of Dudhkoshi river. At Somare, a tea shop area next to Pangboche, two toilets had no septic tank and the faecal matter directly contaminates a small spring, which is used by local people. Similar situations are found in many other places in SNPBZ

No organization in SNPBZ is dedicated to the problems related to the disposal of human feaces and protection of water bodies from contamination. therefore the lack of management of toilets and septic tanks is and will remain one of the most neglected sanitary/environmental issues of SNPBZ, closely related with a growing tourism industry. It is urgently suggested that park authority and buffer zone management committee work together to ensure that every hotels/tea shops has a proper toilet and septic tank. The toilets and septic tanks should be located at least 100 m away from water bodies and water courses.

Septic tanks built out of stone are the most viable option for tourism enterprises in SNBPZ. This kind of septic tank has the advantage of low construction cost also for tanks with a high volumetric capacity, as required for such enterprises The impermeability of septic tank depends on the depth of the tanks, soil texture (high if soil texture is fine) and the distance from the water sources. The impermeability of cemented septic tanks is generally higher. However, due to high transportation cost of the construction material cemented septic tanks are economically not viable for small hotels and tea shops, especially in high altitude.

Considerations regarding the proper construction and locations of septic tanks in order to improve their permeability include the high permeability of open, uncovered stone walls. Tanks should be built well below the soil surface, especially, on slopes. Another way to improve the impermeability of stone wall septic tanks is plastering them with concrete and layering the bottom of the tank with pebbles.

This measure minimizes the contamination of surface runoff water from stone wall septic tanks during the rainy season. The estimated cost (in NRS) for the construction of the discussed types of septic tanks are listed below:

Site	**Types of septic tanks**		
	Cemented wall (A)	**Stone wall (B)**	**Simple pit (C)**

Above 4000m altitude	NRs.150,000	Rs 100,000	Rs 15,000
Below 4000m altitude	NRs. 80,000	Rs 60,000	Rs 10,000
Size	1000 cubic feet	1000 cubic feet	-

Table 14: cost to build different types of septic tank

The "Per person-per day cost of a cemented wall septic tank" is around NRs. 4 to 7 depending on the altitude and about NRs. 3 to 5 for stone walled septic tanks. This cost includes construction cost, 5 % maintenance cost for 20 years, taking into account the number of tourists and households using a toilet.

2.8.2 Improve management of septic tanks

The traditional practice of using forest litter in toilets for composting organic manure should not be discouraged. The use of this kind of manure does not pose a health hazards to farmers and preserve the water sources, since the matter is well composted and dried before application. Instead, this traditional practice has helped to sustain agricultural productivity in areas where a major fraction of animal dung – usually the main source of manure – is used for space heating and thus removed from the nutrient cycle.

The impermeability of cemented septic tanks is generally higher than that of stone tanks, which, however, causes the tank to fill up more rapidly. Without doubt, the perfect impermeability and the regular evacuation of the matter for proper disposal is the best option in terms of environmental pollution. However, currently in SNPBZ, there are no proper mechanism to dispose this waste safely, so that the purpose of a septic tank is to dry out the matter and compost it as far as possible to reduce the volume. for this reason prefect permeability at the cost of a rapid filling up of the tank is not preferable as long as there is a lack of a waste treatment facility.

As a consequence of this problem, a septic tank management system which consists of two separate tanks is the best option of tourism enterprises in SNPBZ. Upon repletion of the first septic tank, the second one would be used, whereas the first tank lies idle for a few months until the matter is dried out and composted. At that point, the manure is comparatively easy and harmless to dispose of. Residential households accumulate much lower amounts of feaces, so that the drying and composting process can tank place by means of one single tank, if no water flushing is used.

2.8.3 Check use of chemical fertilizers

Due to scarcity of firewood and a lack of adequate electricity supply, more than 80% of animal dung is used for space heating. The dependency of people on dung as source of energy is so high that some hotels and Gumba hire laborers specifically to collect dung from public places. Used as energy source, dung is removed from the nutrient cycle in an area which relies to a great extent on fertilization to grow crops. Another organic manure consists of forest litter mixed with human excreta. This organic manure has recently be substituted by chemical fertilizers in some places. Currently, only a few farmers have switched to chemical fertilizers, however, with the rapid socio-economic transformation taking place in the Khumbu area, the frequency and amount of use of chemical fertilizers is expected to increase in the near future, as local people may perceive collecting litter in the forest as too labor intensive work. With an increase of chemical fertilizers the chemical contamination of water sources through phosphorus and nitrogen-composites would increase significantly. Therefore the use of chemical fertilizers should be discouraged.

A key aim should be to regain dung as fertilizers space heating could take place by burning biomass briquettes (e.g. bee hive briquettes), whereby increasing the proportion of dung in organic manure. This will mitigate the need of local farmers to using chemical fertilizers. The overall availability of organic manure can also be increased by encouraging people to use biodegradable waste from kitchen and other sources for composting. It is assumed that if sufficient organic manure is available locally, people would refrain from using chemical fertilizers, which are in comparison very expensive

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3 Indoor Air Quality and Respiratory Health in Thame, SNP

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Table 15: researchers involved in indoor air pollution research

Kathmandu University was started in 1991. The University operates from its premises at Dhulikhel, Kathmandu and Bhaktapur, through its six schools: School of Management, School of Science, School of Engineering, School of Medical Sciences, School of Arts, and School of Education. Though young, the institute has managed to become a point of reference for young Nepalese, and offers a number of modern facilities and laboratories to analyze environmental issues. The University, that strongly supports fieldwork and applied research in national parks, is actively involved in the research activities of the HKKH Partnership Project.

CEPTE/KU is an energy research unit currently being formed under the School of Engineering, Kathmandu University, Nepal. CEPTE/KU concentrates on applied R&D activities and consultancy service in all components of power generation, transportation, operation and maintenance as well as development of end-use technology covering both supply-side and demand-side energy management.

DESE fulfills the need of highly competitive, skilled and trained manpower in the areas of research, development, impact assessments, standards monitoring, management, conservation, legal measures, policy formulation, implementation and other relevant environmental field. The department also pursues research relevant to local national, regional and global significance. Focus is also given to collaborative researches with national and international organizations and academic institutions

3.2 Introduction

Biomass burning as an energy source in poorly ventilated households is known to result in high prevalence of respiratory morbidity and has been linked to chronic obstructive pulmonary disease (COPD) in subjects older than 40yrs, both smokers and non-smokers.

The aim of this research was to identify the impact on prolonged indoor air pollution on people's health. To isolate this effect respiratory function was tested in subjects living in an environment with marginal outdoor pollution (remoteness from traffic pollution or industry) but extended exposed to extended indoor air pollution. The study was conducted in the households and local people of Thame settlement in the Sagarmatha National Park (SNP), Solukhumbu district, where respiratory parameters were tested and indoor air pollution measures. The village is characterized by a heavy reliance on biomass fuel and a lack of chimney in most households.

3.3 Background

The majority of the (rural) population in developing countries rely on dung, wood, crop waste or coal to meet their most basic energy needs. The dependency on such fuels for cooking and heating on open fires or stoves without chimneys pollutes indoor environments through pervasive smoke or haze. Smoke generally contains a range of health-damaging pollutants including small soot or dust particles (particulate matter or PM) as well as gaseous pollutants such as carbon monoxide (CO). The suspended PM is able to penetrate deep into the lungs whereas the CO can be poisonous because of its higher affinity to bind with haemoglobin. Notably, in most of the developing world, exposure is particularly high among women and children as they spend most of their time near the domestic hearth.

It has been found that indoor air pollution resulting from the combustion of solid fuels use is responsible for significant deaths due to pneumonia, chronic obstructive pulmonary disease (COPD) and lung cancer. Compared with women who cook and heat with electricity, gas and other "clean" fuels, women exposed to indoor smoke are very prone to suffer from such illnesses. It has to be noted that despite the recent trend away from primary biomass fuels to alternative cleaner energy source, the long term exposure in the past might still show its adverse effects in old age.

Due to national park regulations and relative wealth brought about by the flourishing tourism industry local people in SNP have recently shifted to the alternative cleaner energy sources and modern cooking stoves. Use of electricity and improved stoves with chimneys are commonly used in this area, but ancient practices of using solid fuels and traditional stoves is still widely common in remoter areas out of reach for the benefits of the tourism industry. In addition, the remoteness of SNP from the major industrial areas of Nepal renders it relatively free from major outdoor pollution which are commonplace in urban areas of the country. For these reasons, SNP and the village of Thame was found a suitable site for this research.

3.4 Methods

The methods used for data collection were:
Spirometry, a method for assessing lung function by measuring the volume of air a patient can expel from his lungs after a maximal expiration.
CO Breathe Analyzer for the measurement of exhaled CO. It is an instrument used for the diagnosis of carbon monoxide levels in the blood stream. The subjects inhale air as deeply as possible, holding it for a while, and then exhale slowly through the device.

Figure 6: Portable spirometer

A set of questionnaires was developed. A local doctor assisted the respondents in answering the questions about clinical history, smoke habits, presence of respiratory symptoms

Figure 7: CO breathe analyzer

HOBO CO logger was used to measure indoor CO in the kitchen as and indicator of indoor air quality (IAQ). The HOBO CO samplers are equipped with electrochemical sensors which convert CO gas into an electric signal to log concentrations in ppm. Inside the HOBO, two electrodes are immersed in a highly conductive electrolyte solution (sulphuric acid) which converts CO to CO2 in the presence of oxygen. The voltage drop across the resistor is measured using Ohm's law (V= IR) and related to the CO concentration.

Figure 8: HOBO CO logger

An UCB monitor was used to measure PM2.5. The UCB particle detector relies on sensors from commercially available smoke detectors. Two sensors are utilized in the UCB – an ionization chamber and a photoelectric sensor. For the purpose of this study, only the photoelectric sensor will be discussed. The photoelectric chamber works on the principle of optical scattering. Particles scatter light released from a light emitting diode. A photodiode measures the intensity of scattered light. The monitor records changes in light intensity as mV signals, which are then converted into mass (mg/m3) by software using different algorithms. These electrical signals are stored in data logger, part of the UCB device. Onboard software can be programmed for sampling duration, different modes of sampling, and the like. The UCB sampler was placed in the kitchen 1.5 m above the floor and 1.0 m from the edge of the stove. Any changes in distance were recorded on the sampling data form. The details of this protocol are developed by University of California at Berkeley and are available at http://ceihd.berkeley.edu/heh.IAPprotocols.htm.

Figure 9: UCB sampler

Figure 10: Measurement of CO and PM2.5 in tradition kitchen in Thame

The field survey included all people of Thame above 14 years of age.

No. of Household included	35
Total no. of population (above 14 yrs of age)	94
No. of population not present during study (not included)	14

Population present in the settlement (out of 94)	80

No. of participants (out of 80)	68
No. of population unable to perform (out of 80)	2
No. of rejection (out of 80)	10

The health spirometry test was performed additionally oin 34 subjects from other villages. The number of subjects with type is presented below:

Thametyang (neighbor village of Thame in 10 minutes walking distance):	14
Students from outside the Thame:	8
Porters:	7
Incinerator staff of Namche:	5

3.4.1 <u>Questionnaire</u>

Q.No. Basic Information

Identifying Household

Name of the Village/VDC/Ward no.	
Number	Household (HH) / Office / Institution / Business
Date of Interview	......./……./……. Time: (a.m./p.m.)
Name of interviewer	

1. Informant's background

1.	Age	
2.	Gender	
3.	Educational status	
4.	Occupation	
5.	Religion	
6.	Ethnic group	
7.	Family type (Valid only for HH)	

2. Family Size (Valid only for HH)

Details of family members using the same kitchen			
Family member	Age/ Number		Occupation
Son	Below 16		
	Above 16		
Daughter	Below 16		
	Above 16		
	Below 30	Above 30	

Relative			
Father			
Mother			
Grandfather			
Grandmother			

ENERGY

1. Fuel Types and Users (Household / Office / Business)

Using the fuel list below, what types of fuel do you use for the following purposes? (List in order of importance using numbers shown below)									
Wood =1 Dung = 2 Agricultural residues = 3 Other residues = 4 Charcoal = 5	Kerosene (Paraffin) = 6 Bottled gas (LPG) = 7 Solar cooker = 8 Solar electric (solar PV) = 9 Grid electricity = 10					Batteries = 11 Wax candle = 12 Pico Hydro = 13 Water Mill (IWM/TWM) = 14 Other = 15			
Purpose	Fuel Priority								
	1st choice	Qty/m	Cost/m	**2nd choice**	Qty/m	Cost/m	**3rd choice**	Qty/m	Cost/m
Cooking (including drinks)									
Lighting									
Space heating									
Heating water for Drinking/ Bathing / Bed warming / Washing									
Beer brewing									
Cooking food/drink for selling (excluding beer)									
Cooking animal feed									
Grinding grains									
If fuel is used for another type of household task, please specify task (s)	Task 1: Task 2:								
Past history about fuel and stove:									

*Fuel wood in Bhari/Month, electricity in W/Month or kWh/Month, LPG in cylinder/Month, Liquid fuel in litre/Month, Grinding (in Mana/Muri/Pathi) per month

Fuel wood quantity:

Species:
Volume:
Burned quantity: weighing before: weighing after:

Kerosene:

Consumed per cooking:

Gas:

One cylinder for………….month/days

3. House types

Based on construction function: **Traditional / Semi-Modern/Modern**
Based on function type: **Commercial/Residential**

4. Kitchen Detail

Sketch of kitchen with outline plan, indicating the following (Take photo from four sides)

- Position of the fire/stove — Position of door (s)
- Position of window (s) — Ventilation if any other than window(s)
- Orientation of kitchen (use compass)
- Dimensions of the kitchen

Windows and Doors

Type of openings	Glazed	Unglazed	Typical elevation		
Windows	(Single / double)	(tin / metal / wood)	Window 1	Window 2	Window 3
Doors			Door 1	Door 2	
Ventilation other than window(s)	Position		Orientation	Type/size	

Stoves (Chulo)

Type of stove (If multiple stoves are found to be used tick them according to priority)	For Cooking			Space Heating		
	L (m)	B (m)	H (m)	L (m)	B (m)	H (m)
1. Three-stone or two-stone fire						
2. Shielded mud fire or mud stove (including chimney stove)						
3. Ceramic stove (made of fired clay)						
4. Metal stove one pot / two pots / three pots / Nepal made or foreign made						
5. Briquette stove						
6. kerosene stove						
7.Gas stove						
8. Solar cooker						
9. Grid-powered electric stove						
10. Other type of stove						
Smoke Extraction Pipe Chimney / Hood Chimney / Pipe Chimney with water heating provision						
Chimney						

NAME .
SURNAME .
DATE OF BIRTH **AGE** **MALE□** **FEMALE □**
HIGHT **WEIGHT** **JOB** ...
SMOKE **.HOW MANY CIGARETTES/DAY** **..SINCE** ..
HAS YOUR HOUSE A CHIMNEY?.......... **.SINCE** .
KIND OF FUEL
MEDICAMENTS
.

MMRC Dyspnea Scale

0	Not troubled with breathlessness except with strenuous exercise		
1	Troubled by shortness of breath when hurrying on the level or walking up a slight hill		
2	Walks slower than people of the same age on the level because of breathlessness or has to stop for breath when walking at own pace on the level		
3	Stops for breath after walking about 100 yards or after a few minutes on the level		
4	Too breathless to leave the house or breathless when dressing or undressing		
Do you cough several times most days?		Yes	No
Do you bring up mucus most days?		Yes	No

	L	%predicted
FEV1		
FVC		
CO MMEF		

1. How many hours do you spend in the kitchen?

2. How long do you stay in Thame in a year?

3. If not whole year, where do you spend rest of your time?

3.5 Data

A comprehensive data set for indoor air pollution and health status (particularly related to respiratory health) was collected during the study:

<u>Spirometry:</u> FEV1 (Forced Expiratory Volume), FVC (Forced Volume Vital Capacity), MMEF (Maximum Mid-expiratory Flow)
Breathe Carbon monoxide (CO) - ppm in exhaled air

<u>Indoor air pollution:</u> PM2.5 in kitchen during cooking time
CO (ppm) during cooking

Health: Blood Pressure, Pulse, oxygen in blood, height and weight

Data on ventilation efficiency, amount of fuelwood and dung used for cooking and space heating, disaggregated by building type, were acquired:

Variables	**Value by type of building**		**Unit**
Efficiency of ventilation system	**Residential**	**Commercial**	
Traditional system	20	35	%
Modern system	95	90	%

Table 16: Efficiency of ventilation system

Variables	**Type of building**		**Unit**
	Residential	**Commercial**	
average indoor air CO concentration (g/m3)	92.32	46.53	g/m3

Table 17: Average indoor air CO concentration

Energy source	**CO emission (gm/kg)**
Firewood	3.48
Dung	4.967

Table 18: Amount of CO emission fuel type

Variables	**Value by type of building**		**Unit**
	Residential	**Commercial**	
Dung used for space heating	120.5	1237.5	kg/month
Fuelwood used for space heating	30	450	kg/month
Dung used for cooking	245.75	843.75	kg/month
Fuelwood used for cooking	127.5	273.75	kg/month

Table 19: Amount of dung and fuelwood used for space heating and cooking

3.6 Findings

The concentration of CO emitted from the improved cooking stove (ICS) and traditional cooking stove (TCS) is shown in figure 2 and 3.

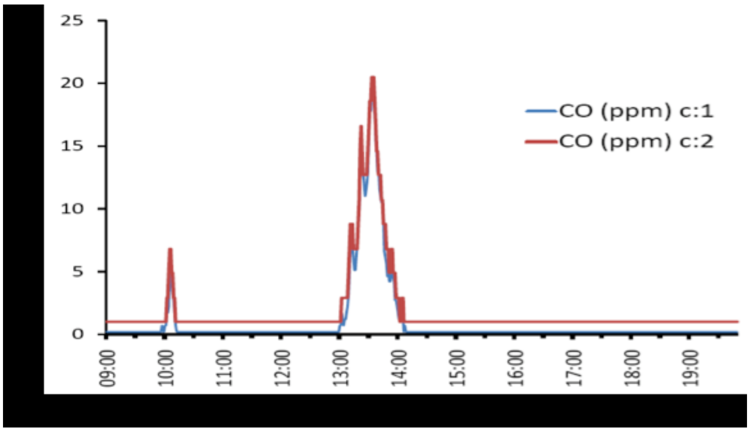

Figure 11: Concentration of CO (ppm) emitted from the Improved Cooking Stove

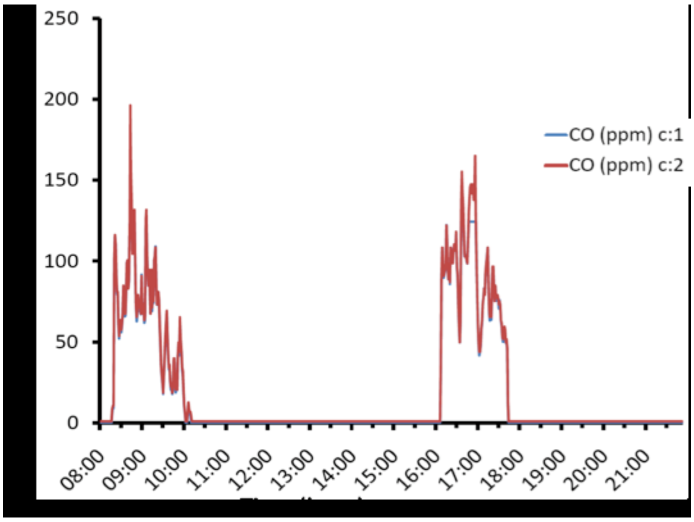

Figure 12: Concentration of CO (ppm) emitted from the Traditional Cooking Stove

The average indoor air CO concentration for 8 hours has been found to be between 5 and 30 ppm, depending on different stove types (Figure 11 and Figure 12). The average maximum CO concentration was found to be 81.5ppm with 26.3ppm in cooking hours and 10.6 ppm in general (in average for 8 hours).

The highest concentration of about 200 ppm was observed at the time of cooking (ca. 2 hours average) using traditional stoves with chimney only. The minimum concentration was recorded while no cooking was done as well as when the electric heater was used for cooking. The average 8 hours concentration is within the range of allowed concentration of ca. 50 ppm for 8 hours time weighted concentration (NIOSH, OSHA, USA). However, in the case of TCS, the repeated exposure to the enhanced concentration (ca. 200 ppm for 2 hours) could lead to the severe deterioration of respiratory system and associated sickness such as asthma and COPD. The average 8-hrs time-weighted concentration agrees well with other similar studies from rural Nepal (ca. 3 – 18 ppm for ICS and 9 – 39 ppm for TCS) (ENPHO, 2008).

The concentration of PM25 varied between 0.4 mg/mg^3 and $1 mg/m^3$. The maximum concentration of about 1 mg/m^3 was observed for both stove types, namely traditional stoves with no chimneys as well as modern stoves with ventilation from pipes and chimneys. Similar concentrations of PM2.5 were reported for both types of cooking stoves in other parts of rural Nepal such as Dolkha, Dang and Ilam (ENPHO, 2008).

The results obtained on health assessment of the subjects are shown in Figure 13 and Figure 14

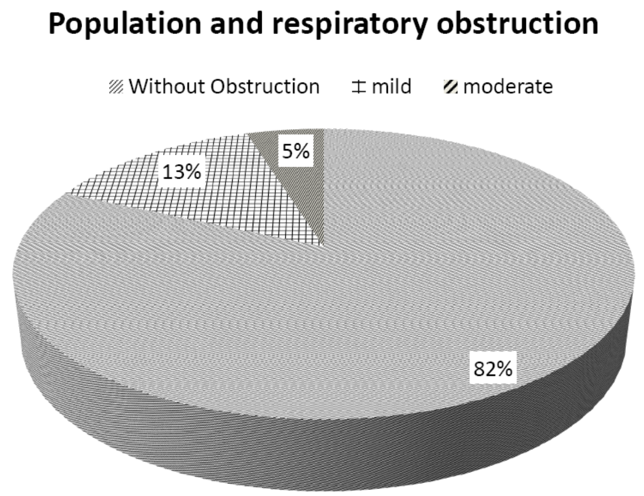

Figure 13: Illustration of the population having respiratory obstruction shown by spirometer test.

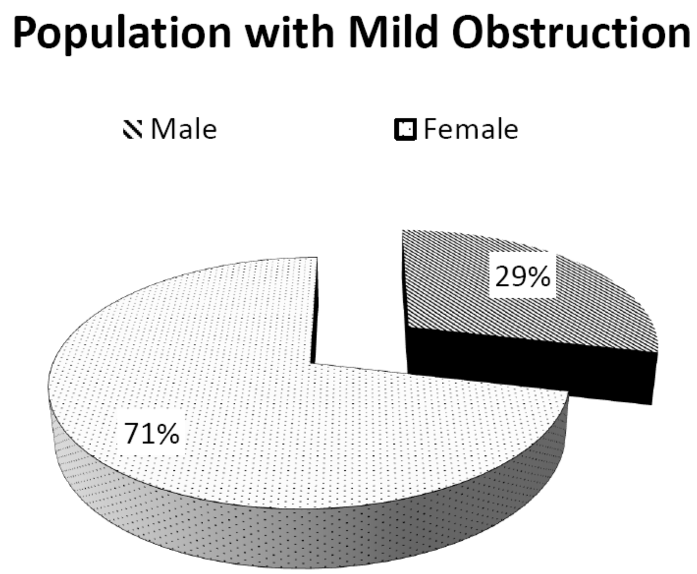

Figure 14: Percentage of male and female having mild obstruction

The spirometer test indicates that majority of the population (82%) have no respiratory obstruction. Notably, figure 4 and 5 also indicate that out of the 18% of the population 71% is women. This is clear that women are the one to spend most of their time in the kitchen and are thus affected by the IAQ. Similar studies in other parts of the developing world have also shown that the women and children suffer most by the IAQ (Schei et al, 2004; Balakrishnan et al. 2004). Despite having ICS replacing the TCS in the kitchen, earlier exposure to the IAQ could be the cause of the respiratory obstruction. However, detailed study is still required to determine the extent of respiratory problems and differentiate from the present one to the past.

3.7 Discussion

A comprehensive data set for indoor air pollution and health status (particularly related to respiratory health) was collected during the study period. Based on the analysis of the findings, a detailed study plan could be developed covering whole SNPBZ.

In this research, we investigated indoor air pollution in the houses of Thame VDC, Nepal which is unaffected by the mobile emission sources. The results showed that the emission of CO was dependent of the stove types and the ventilation system used. Therefore the improved stoves with effective ventilation could help to reduce the indoor CO and PM. Additionally, the results also indicated that the female population has higher chances of having COPD because they spend more time in the Kitchen.

3.8 Management options

Building new chimneys (evaluation of this option in the model possible)

The kitchens of most houses in upper Khumbu are equipped with open fireplaces for cooking (and heating in winter), or so called “traditional stoves” or “semi-traditional stoves” as wood burning unit. Due to a lack of chimney for any kind of fume outlet, these facilities emit fumes directly into the kitchen area. Many of the houses in addition lack appropriate ventilation, resulting in a constant haze consisting of CO2, CO, NOx Carbon particulate matter and other health threatening substances permanently covering the low kitchen (and living room ceiling), constituting a severe health hazard to the inhabitants. Often, the kitchen is the central living and meeting place of the household, but especially women in SNPBZ spend a lot of time indoors during meal preparation and housework. In SNPBZ, many households have turned their kitchen into a teahouse to attract tourists whereby increasing the amount of time exposed to the fumes. It is not surprising that this condition poses a severe health hazard to inhabitants and visitors, consequently cases of CPOD and other pulmonary diseases are frequent in the area.

The best measure to improve peoples health and decrease the occurrence of pulmonary diseases in the area is a preventive one; to improve the circulation of not contaminated air in the kitchen, which can be achieved by allowing the fumes to escape the kitchen area through a chimney.

The most effective measure to improve indoor air quality whereby improving people’s health and decreasing the occurrence of pulmonary diseases in the area is a preventive one: to eliminate sources of pollution or to reduce their emissions into the kitchen area. In many cases (e.g., gas stoves) source control is also a more cost-efficient approach to protecting indoor air quality than increasing ventilation because increasing ventilation can increase energy cost. Indoor emissions can be reduced by allowing the fumes to escape the kitchen area through a chimney.

Many of the modern household in the SNPBZ are using a special heating stove for space heating (heating room) especially in the dinning room where wood and cattle dung are burned in closed system. This feature has long pipe that emits the smoke produced directly outside the building. So, it prevents emission of smoke inside room avoiding indoor air pollution problem.

Chimney	1 set	NRs 35000.00-NRs 40000.00	Includes transportation and labor cost
Modern space heating stove	1 set	NRs 12000.00-15000.00	Includes transportation and labor cost

Table 20: Cost entailed for construction of a chimney and improving stove

3.9 References

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4 Forest condition and anthropogenic pressure on forests in SNP

4.1 Authors

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Table 21: researchers involved in forest condition and climate change research

Nepal Academy of Science and Technology (NAST) is an independent apex body established in 1982 to promote science and technology in the country. The Academy is entrusted with four major objectives: advancement of science and technology for all-round development of the nation; preservation and further modernization of indigenous technologies; promotion of research in science and technology; and identification and facilitation of appropriate technology transfer. The academy has been a major partner with Ev-K2-CNR for the last 20 years, especially in managing the International Laboratory-Observatory Pyramid.

4.2 Introduction

Eastern Himalaya, which also includes Sagarmatha (Mt Everest) region, has been identified as a globally important region for biodiversity (Olson & Dinnerstien 1998), and has been included in the biodiversity hotspots (Myers *et al*. 2000). Over the past 50 years the Sagarmatha region has become a premier international mountaineering and trekking destination. This has brought adverse impacts on regional forests and alpine vegetation (Bjonnes 1980, Stevens 2003). Such impacts include the over harvesting of alpine shrubs and fuel-wood, overgrazing, accelerated erosion, and uncontrolled lodge building (Byers 2004). Large areas surrounding the main permanent settlements in the region are extensively deforested and natural forests are partly replaced with semi natural *Pinus wallichiana* woods (Buffa *et al.* 1998).

The forested land in Sagarmatha National Park (Area: 1,148 km2) is described to be only 21.5 km2 sharing 1.87% of the total land area. Much of the park is above the tree-line, which is dominated by alpine tundra and lichen. Forests are located only in low-altitude, southern rim of the park. Most of the forest consists of temperate forest (3,200m- 3,800m), and sub-alpine forest, and alpine shrub (3,800m-4,000m) (Byers 1978). The upper limit of forest is distinctly visible on the steep slopes of the valleys, while tongues of forest follow the valleys north that die out by 4,000m (Stevens 1996).

In order to ensure sustainable use of natural resources, long term consequences on natural resources should be evaluated to promote tourist activities and other associated disturbances. The forests of such high mountain areas require safeguarding, not only because of their economic values but for their biological diversity and the part they collectively play in soil and water conservation in the fragile topography. Consequently the need for a research study to enhance scientific knowledge on the impact of climate change and human activities on vegetation and forest condition in SNP was identified and carried out whereby protection and management of of high altitude ecosystem, namely SNPBZ should be supported

4.3 Background

Quantifying biodiversity patterns and identifying the mechanisms that create them are essential for understanding ecosystems and for the conservation and management of biodiversity (Gaston 2000). Altitudinal gradient is an important factor affecting species composition and structure (Whittaker 1972). In Himalaya, there is decline in species richness, tree density, basal area and primary productivity with increasing altitude (Singh & Singh, 1992; Carpenter, 2001). Disruption of forest structure by natural and anthropogenic disturbance alters species richness and other ecosystem properties. Moreover, species diversity is affected by multi-environmental factors.

As an ecological unit in the highest region of the world (also a world heritage site), the area is of important scientific value with unique plant diversity and endemic species. Comprehensive ecological study on vegetation is still lacking

- The study area consists of extreme environmental conditions, topographic gradients, and anthropogenic pressure on vegetation.
- The study area is prone to heavy human disturbance due to continuous tourist flow and excess use of natural resources. The increasing demand of fuel-wood, fodder and grazing land has been the eminent threat to mountain vegetation.
- The climate change impacts are more pronounced in high altitudes, and no permanent plots had been established in SNP for long-term monitoring.

The present research project had two-pronged activities aiming to attain a short-term and long-term objective. The immediate objective was to investigate forest conditions of SNP and the long-term was to monitor climatic effects on vegetation. The specific objectives of the project defined as its activities are as follows:

I. Long-term monitoring activities:

- Set-up permanent sampling plots at timberline to study vegetation and tree ring study in the SNP for long-term study and monitoring climate change effects;
- Collect samples of tree cores preferably *Juniper recurva* and *Abies spectabilis* and examine the rings to understand impact of climate change and reconstruct environmental history of the region.

II. Short-term activities:

- To observe the variation in forest community characteristics, both qualitative and quantitative, in relation to human disturbance, elevation and forest types;
- To prepare an inventory and enumeration of the flora of the region and evaluate plant species diversity pattern
-

The results of this research include an Assessment of forest condition in Sagarmatha National Park and documentation of plant database of the region. An analysis of human disturbance and its relation with structural and floral attributes of vegetation of SNP. Identification of a study for vegetation distribution at various altitudes in the SNP.

In process is the generation of primary information on impact of the climate change by using state-of-art technology in dendrochronlogy, and setting up baseline for long-term study in climate change effects at the timberline.

The scientific goals and benefits set by the study are that of long-term. However, implications could be foreseen for local mountain communities as the results will detect signals of climate change in the remote ecosystem. The project will be a true scientific collaboration where Nepali and Italian researchers will work together in promoting transfer of technology and knowledge sharing. It will also involve university graduate students from both the countries, Nepal and Italy, who will work for their Master thesis while assisting in the research activities. This kind of mentorship will ensure the future of conservation and sustainable management of natural resource in the fragile ecosystems of high altitudes.

4.4 Methods

During the project period, the team conducted three in-depth forest surveys in SNP. Two permanent plots were established at treeline for long-term monitoring of climate change effects on vegetation and 105 teporary plots covering all three watershed of SNP (Bhotekoshi, Dudhkoshi and Imja rivers) were investigated for forest parameter measurements and observations.

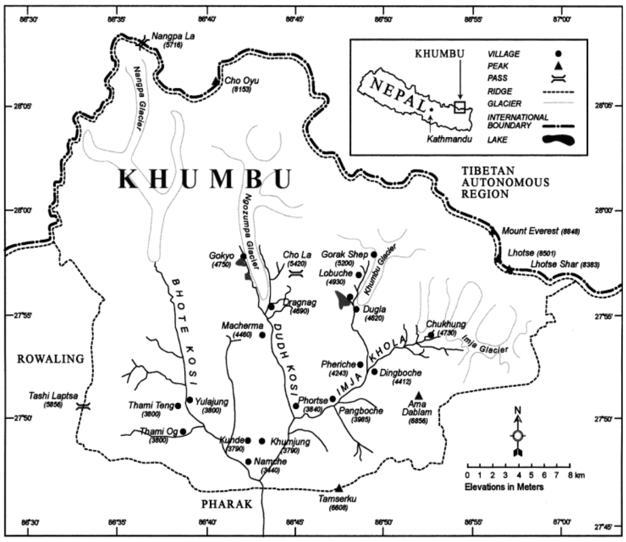

Figure 15: Study area (SNP including Bothekoshi, Dudhkoshi and Imja wastersheds

The study area covers forest, shrub-lands and alpine grasslands; altitude ranging from 2800m to 5000 m above sea level. Stratified random sampling method was adopted for forest survey and sampling. Stratification of the forest area was carried out on the basis of forest types. classified according to FAO Land Cover Classification System (LCCS), version 2. Five typical forest types were investigated: Broadleaved Closed Forest, Broadleaved Open Forest, Multilayer Mixed Forest, Needleleaved Closed Forest and Needleleaved Open Forest.

Out of 300 random points generated covering all five types of forests, 105 plots (35% of the total) measuring 20x20m (0.04 ha) in size were located by means of GPS topographic maps and satellite images of the area and visited for sampling, measurements and observation. Some of the plots had to be dropped due to inaccessibility (steep, torrential river) and time constraints. Within the visited plots 10x10m (0.01 ha) subdivisions where used for pole category; 5x5m (0.0025 ha) for shrub level vegetation and regeneration and 1x1m for ground vegetation.

Table 22 presents the geographical information of the all 105 sampled plots in the study area of the Sagarmatha National Park. The plots were distributed between the latitudes of 27.7314 E (Plot # SNP-034) and 27.8808 E (Plot # SNP-212), and longitudes of 86.6908 N (Plot # Satermo-2) and 86.8016 N (Plot # Imja-098). Similarly, the altitudes of the plots varied between 3,155 (Plot # Phurte-1B) m and 4,190m asl (Plot # SNP 212). All the plots were in slope mountain, nearly 60% of which were in steep slope of >30^0. On the aspect of the total sampled plots, majority (>57 plots) were north facing (north, north-east, north-west).

Table 22: Geographical Information of sampled plots in Sagarmatha National Park, Nepal

SN	Plot Name	Lat N Deg.	Long E Deg.	Alt. m	Aspect	Incl.º
1	Chhuwa-12	27.8299	86.7469	3358	W	32
2	Chhuwa-13	27.8392	86.7505	3579	N	40
3	Chhuwa-14	27.8273	86.7542	3790	N	
4	Dole-6A	27.8657	86.7861	3785	E	36
5	Dole-6B	27.8661	86.7359	3780	E	38
6	Dole-7A	27.8643	86.7336	3940	E	30
7	Dole-7B	27.8652	86.7333	3950	E	30
8	Khunde-5A	27.8177	86.7027	3902	E	30
9	Khunde-5B	27.8186	86.7027	3895	SE	25
10	Panboche	27.8530	86.7838	3965	NW	40
11	PhortseTenga-8A	27.8426	86.7412	3612	NE	40
12	PhortseTenga-8B	27.8402	86.7422	3580	NE	35
13	Phungi-9A	27.8326	86.7506	3389	SW	26
14	Phungi-9B	27.8325	86.7518	3410	S	30
15	Phurte-1A	27.8069	86.6933	3157	S	30
16	Phurte-1B	27.8060	86.6937	3155	S	20
17	Phurte-2A	27.8086	86.6954	3357	S	30
18	Phurte-2B	27.8082	86.6962	3355	S	35
19	Phurte-3B	27.8117	86.6964	3563	S	30
20	Phurte-4A	27.8139	86.6972	3723	SW	42
21	Phurte-4B	27.8135	86.6976	3707	SW	42
22	Satermo-1	27.8015	86.6936	3338	NE	10
23	Satermo-2	27.8006	86.6908	3538	NE	10
24	Tenboche-10A	27.8350	86.7555	3667	SW	36
25	Tenboche-10B	27.8351	86.7563	3642	S	36
26	Tenboche-11A	27.8353	86.7606	3847	SW	3
27	Tenboche-11B	27.8353	86.7625	3846	S	34
28	Imja003	27.8395	86.7596	3632		10
29	Imja004	27.8393	86.7569	3662	NW	
30	Imja016	27.8593	86.7971	3958	NW	36
31	Imja024	27.8396	86.7587	3686	NW	
32	Imja029	27.8368	86.7715	3717	NW	45
33	Imja035	27.8588	86.8013	4071	W	15
34	Imja044	27.8497	86.7883	3954	N	30
35	Imja050	27.8523	86.7965	4015	NW	22
36	Imja067	27.8564	86.7964	3951	NW	36
37	Imja074	27.8478	86.7902	4053	E	40
38	Imja077	27.8383	86.7568	3671		
39	Imja078	27.8452	86.7771	3735	NW	40
40	Imja081	27.8500	86.7900	3907	NW	15
41	Imja085	27.8467	86.7781	3775	NW	42
42	Imja094	27.8488	86.7938	4040	NW	30
43	Imja097	27.8501	86.7956	4053	NW	30
44	Imja098	27.8541	86.8016	4091	NW	20
45	Imja104	27.8379	86.7562	3750		40
46	Imja118	27.8555	86.8012	4075		30
47	Imja119	27.8504	86.7964	4071	NW	25
48	Imja124	27.8363	86.7729	3929	N	35
49	Imja140	27.8435	86.7833	4002	N	
50	Imja148	27.8328	86.7674	3887	N	40
51	Imja150	27.8383	86.7576	3733		30
52	Imja154	27.8437	86.7803	3886	W	23
53	Imja155	27.8550	86.8003	4041	N	20
54	Imja162	27.8374	86.7531	3686	W	
55	Imja163	27.8388	86.7801	3991		5
56	Imja168	27.8376	86.7742	3894	NW	25
57	Imja169	27.8375	86.7689	3803	W	25
58	Imja176	27.8375	86.7518	3615	W	34

59	Imja179	27.8380	86.7684	3775	NE	20
60	Imja183	27.8408	86.7815	4039	E	45
61	Imja185	27.8331	86.7668	3846		30
62	Imja191	27.8382	86.7743	3869	NW	
63	Imja195	27.8490	86.7798	3836		30
64	Imja200	27.8360	86.7686	3851	NW	15
65	Imja201	27.8384	86.7686	3770	NW	20
66	Imja209	27.8371	86.7635	3810	N	30
67	Imja218	27.8355	86.7502	3631		20
68	Imja229	27.8341	86.7643	3786	S	30
69	Imja238	27.8334	86.7651	3781	S	35
70	Imja264	27.8433	86.7709	3785	S	25
71	Imja271	27.8410	86.7619	3606	S	30
72	Imja292	27.8429	86.7703	3763	SE	30
73	SNP010	27.8169	86.7174	3820	W290N	22
74	SNP013	27.8481	86.7457		W330N	35
75	SNP015	27.8456	86.7457	3765	W300N	40
76	SNP017	27.8190	86.7146	3850	N70E	20
77	SNP021	27.8179	86.7285	3760	N65E	26
78	SNP034	27.7314	86.7171	3840	N10E	20
79	SNP052	27.8187	86.7278	3770	N50E	30
80	SNP082	27.7353	86.7149	3830	N75E	22
81	SNP-170	27.8510	86.7480	3850	W290N	34
82	SNP-125	27.8493	86.7480	3750	W285N	38
83	SNP-181	27.8248	86.7268	3650	N25E	25
84	SNP-205	27.8249	86.7266	3650	N75E	32
85	SNP130	27.8149	86.7206	3860	N	7
86	SNP137A	27.8170	86.6911	3675	W	34
87	SNP-259	27.8155	86.6920	3675	S225W	34
88	SNP138	27.8161	86.7024	3950	N75E	35
89	SNP141	27.8169	86.7202	3860	N65E	12
90	SNP143	27.8180	86.7154	3810	N75E	16
91	SNP152	27.8798	86.7267	4135	N70E	30
92	SNP153	27.8159	86.7214	3850	N25E	12
93	SNP160	27.8169	86.7070	3900	W285N	8
94	SNP164	27.8235	86.7312	3630	NE	5
95	SNP187	27.8193	86.7226	3810	W280N	28
96	SNP190	27.8192	86.7072	3880	N20E	14
97	SNP194	27.8180	86.7214	3840	N65E	26
98	SNP199	27.8153	86.7048	3920	W	8
99	SNP203	27.8175	86.7284	3780	N50E	20
100	SNP207	27.8769	86.7288	4120	N45E	30
101	SNP212	27.8808	86.7248	4190	N25E	40
102	SNP220	27.8139	86.7273		SE	35
103	SNP227	27.8117	86.6964	3555	SW	40
104	SNP282	27.8288	86.7389	3490		40
105	SNP296	27.8683	86.7332	3970	90E	45

In addition to the survey, in 2007, two permanent plots were established, one at Pangboche (alt. 4050m asl) and the other at Debuche (alt. 3850m asl). Inside each plot, dead and standing trees with a diameter (height: ≥ 1.3m) were mapped. Their height and diameter were measured, species identified, and core sampling taken. Regeneration (<10cm, dbh <5cm) were counted and mapped in sub-plot. These plots have been designed as permanent ones and maintained for future references. For the climate-growth relationship analyses, tree cores were extracted using increment borer. In the laboratory, the samples were mounted and sanding was done for tree-ring measurement. A Dendro-Lab has been set-up at Nepal Academy of Science and Technology with support of Ev-K2-CNR to facilitate the work. Chronologies development for trees is progress. Then a stand or population averaging will be done after standardization procedures necessary in order to reduce the noise and maximize the climate signal. Digital filtering, cubic smoothing spline, ARMA modes and other techniques will be applied for this purpose using specific software packages (PPPBASE). The GPS position of the plots is presented in Table 23

Pangboche Yaren		***Debuche***	
Latitude N	Longitude E	Latitude N	Longitude E
86.79885	27.85166	27.83988	086.77560
86.79809	27.85108	27.83893	086.77437
86.79773	27.85126	27.84021	086.77438
86.79712	27.85145	27.83965	086.77368

Table 23: GPS position of two permanent plots

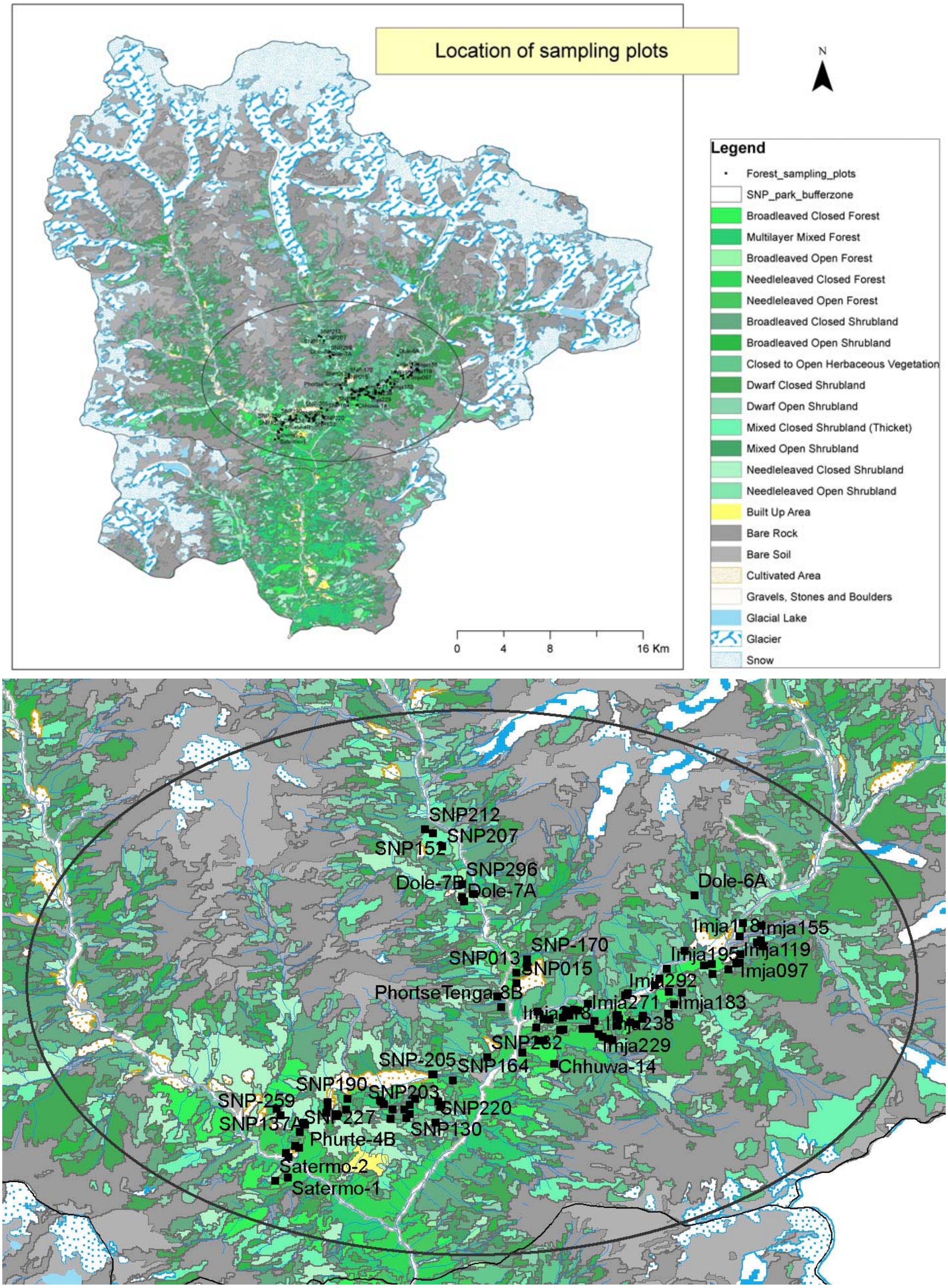

Figure 16: Location of sampling plots in the Sagarmatha National Park, Nepal

The field studies and surveys were completed in three visits. The first field mission was carried in May 2007. It completed field survey in 27 sampling sites of Dudhkoshi and Bhotekoshi. The second visit was in Sep/Oct 2007, which included 45 sampling plots in Imja river valley. The final field mission was concluded in May 2008, which covered 35 sampling plots that covered the remaining areas of Dudhkoshi and Bhotekoshi valleys.

The collected data was logged in computer and analyzed using standard statistical tools. Vegetation association, species diversity, and other quantitative parameters were analyzed at various altitudes. Besides, other variables such as aspect, steepness of slope, disturbance gradient, and forest types were considered. Primary data were tabulated using MS Excel. The results will be interpreted and concluded on the basis of findings.

Available information for dendroclimatic analyses will also be considered where available. Response function analysis will be applied to indexed tree-ring and climate series in order to compute the most significant growth responses to monthly climate influence and assess the percent of high frequency variance explained by climate. Once the dendroclimatological analysis is completed disturbance history will be reconstructed by detecting abrupt growth changes in radial growth in the increment cores collected from the sampled trees. An abrupt growth change is a sudden increase in ring-width >166% over the previous four years or a sudden decrease in ring width >40% over the previous four years. Data

4.5 Data

The field survey included measurement of tree height (m), diameter at breast height (cm) and observation of any disturbances including that of anthropogenic origin. These data were used to generate various floristic and structural parameters. The floristic composition of the forests (tree species only) are compiled in Table 3, which depict scientific names with Authors reference, English and vernacular names, family, uses and flowering time (months). The diversity index (Shannon's H) for each plot was calculated for each plot and is presented in Table 4. Exposure and litter coverage percent were also estimated (Table 4, Figures 3 and 4).

4.5.1 Plant specimen and floristic data

All vascular plant species within the sample plots were recorded covering various elevations and habitats. In addition, plant species en-route were also observed and collected for voucher specimen. Herbarium specimens of each species were preserved and verified using standard techniques. Plants were identified at species or subspecies level with standard references. Specimens were verified at the National Herbarium, Godavari and Central Department of Botany, Tribhuvan University, Kirtipur. An MSc thesis specifically dealing on ground vegetation diversity is under preparation.

4.5.2 Forest structure and community characteristics

Primary data were collected from field survey by means of temporary sampling plots. Sampling parameters of the trees included height, diameter at breast height, coverage, and seedling and sapling density, exposure to light. Height and DBH of all the trees in the plots greater than 1.3 m heights were measured. The field data was tabulated in field data sheets. The vegetation data were quantitatively analyzed for abundance, density and frequency. Shannon and Weiner's Diversity Index H' (Shannon and Weiner 1963) was also computed. The basic characterization of the plots by these parameters are given in Table 26

Average basal area (sq cm/sq m per ha) of each tree species was calculated using Diameter at Breast Hight (DBH). Similarly, the basal area in % of the total plot area, mean DBH, and maximum DBH were calculated likewise. The stem number of each plot was used to calculate the density (stem number per ha) and relative density (%). An overview of the tree species found is presented in Table 25. The structural parameters for species including frequency of occurrence are presented in Table 27 and Table 28. The diameter class and height class of each tree species is presented in Table 29 and Table 30 for temporary and Table 31 and Table 32 for permanent plots, respectively.

4.5.3 Human impact on forest condition

Canopy cover and frequency of human activities were considered to categorize the disturbance. Remains of cut stumps and wounded trees in the sampling plots were counted and measured. Human activities like logging, lopping, thinning and coppicing in the sampling plots were noted. Any kind of sign showing collection and/or extraction of fuel wood, leaf-litter, medicinal and aromatic plants from the forest area were determined were carefully observed and noted. The data is shown in Table 24

Table 24: Disturbance Regime in the Sampled Plots

SN	PlotName	Cut Stump	Litter Coll.	Trail	Grazing	Dead trees	Grass Cut	Fuel wood Collection
1	Chhuwa12	P		P				P
2	Chhuwa13	P		P				P
3	Chhuwa14	P		P				P
4	Dole6A	P						P
5	Dole6B	P			P			P
6	Dole7A	P						P
7	Dole7B	P			P			P
8	Khunde5A	P						
9	Khunde5B							
10	Panboche	P						
11	PhortseTenga8A	P	P		P			
12	PhortseTenga8B	P		P	P	P		
13	Phungi9A	P		P	P			P
14	Phungi9B	P		P	P			P
15	Phurte1A	P		P		P		
16	Phurte1B	P						
17	Phurte2A	P			P			
18	Phurte2B			P				
19	Phurte3B	P						
20	Phurte4A	P						
21	Phurte4B							
22	Satermo1	P						
23	Satermo2	P						
24	Tenboche10A	P			P			P
25	Tenboche10B	P	P	P	P			P
26	Tenboche11A	P		P				P
27	Tenboche11B			P	P			P
28	Imja003	P						
29	Imja004	P	P					P
30	Imja016	P	P		P			P
31	Imja024		P		P			P
32	Imja029	P	P		P			P
33	Imja035	P	P		P			P
34	Imja044	P	P			P		P
35	Imja050	P	P					P
36	Imja067	P	P					P
37	Imja074		P		P		P	P
38	Imja077	P	P		P	P		P
39	Imja078	P	P					P
40	Imja081	P	P		P			P
41	Imja085	P	P					P
42	Imja094	P	P					P
43	Imja097	P	P					P
44	Imja098		P					P
45	Imja104	P						P

46	Imja118	P	P					P
47	Imja119	P						
48	Imja124	P			P			P
49	Imja140		P		P			P
50	Imja148		P		P			P
51	Imja150	P	p		P	P		P
52	Imja154	P			P			P
53	Imja155		P					P
54	Imja162	P			P			P
55	Imja163							P
56	Imja168				P			P
57	Imja169	P	P					P
58	Imja176	P			P			P
59	Imja179	P	P					P
60	Imja183	P						
61	Imja185		P		P			P
62	Imja191	P						
63	Imja195	P	P					P
64	Imja200		P		P			P
65	Imja201	P	P		P			P
66	Imja209	P	P		P			P
67	Imja218	P			P		P	P
68	Imja229	P	P		P			P
69	Imja238	P			P			P
70	Imja264		P		P		P	P
71	Imja271	P	P		P		P	P
72	Imja292		P		P			
73	SNP010	P						
74	SNP013	P	P	P				
75	SNP015	P	P	P				
76	SNP017	P						
77	SNP021	P	P	P				P
78	SNP034	P	P	P				P
79	SNP052	P	P	P	P			P
80	SNP082	P						
81	SNP125	P		P				P
82	SNP130	P	P	P				P
83	SNP137A							
84	SNP138	P	P					P
85	SNP141	P		P				P
86	SNP143	P	P	P				P
87	SNP152	P		P				P
88	SNP153	P		P				
89	SNP160	P		P				
90	SNP164			P				
91	SNP170	P		P				
92	SNP181	P		P				P
93	SNP187	P	P	P				P
94	SNP190	P						
95	SNP194	P						
96	SNP199	P						
97	SNP203	P	P	P	P			P
98	SNP205	P		P				P
99	SNP207	P						
100	SNP212	P		P				P
101	SNP220			P				
102	SNP227	P						P
103	SNP259		P		P			P

104	SNP282			P				
105	SNP296	P		P				P
	TOTAL	**84**	**45**	**33**	**38**	**5**	**4**	**70**

Note: Disturbance Regime: Extremely high = 4 P; High = 3 P; Moderate = 2 P; Less = 1 P; Intact = 0 P
No evidence of fire in the studied plots.

Sn	Species	English	Nepali	Sherpa	Family	Use	Flower/Cone
1	*Abies spectabilis* (D. Don) Mirbel	Himalayan silver fir	Gobre salla	Tashing	Pinaceae	Medicinal, Construction, Fuelwood	Apr-May
2	Acer campbellii Hooker fil. & Thomson ex Hiern	Cambell's maple	Phirphire		Aceraceae	Fodder, Minor construction	Feb-Apr
3	*Betula utilis* D. Don	Himalayan silver birch	Bhohpatra	Takpa	Betulaceae	Medicinal, Construction, Fodder	Jun-Sep
4	Bhatkuri						
5	*Juniperus recurva* Buchanan-Hemilton ex D. Don	Juniper	Dhoopi	Syukpa	Cupressaceae	Incense	Jun-Jul
6	*Ligustrum* sp		Kanike		Oleaceae	Fodder	Apr-Jul
7	*Lyonia ovalifolia* (Wallich) Drude		Angeri	Rongle	Ericaceae	Medicinal, Poisonous, Poor Fuel	Mar-May
8	*Pinus wallichiana* A. B. Jackson	Blue pine	Gobre salla	Metong	Pinaceae	Timber, Resin	
9	*Rhododendron arboreum* Smith	Rhododendron	Lali gurans	Tongmar	Ericaceae	Medicinal, Utensil, Firewood	Mar-Apr
10	*Rhododendron barbatum* Wallich ex G. Don	Giant blood rhodo.	Chimal		Ericaceae	Toxic	Apr-Jun
11	*Rhododendron campanulatum* D. Don		Chimal	Kalma	Ericaceae	Medicinal, Excellent fuelwood	Apr-Jun
12	*Rhododendron campylocarpum* Hooker fil.		Chimal		Ericaceae	Fuelwood	May-Jun
13	*Rhododendron fulgens* Hooker fil.		Chimal		Ericaceae	Fuelwood, Poisonous	May-Jun
14	*Rhododendron hodgsonii* Hooker fil.				Ericaceae	Fuelwood	Apr-May
15	*Salix sikkimensis* Anderson	Willow	Bains	Changma	Salicaceae		May
16	*Sorbus microphylla* Wenzig			Bajhar	Rosaceae	Fodder	Jun
17	*Tsuga dumosa* D. Don Eichler	Himalayan hemlock	Thingre salla		Pinaceae	Construction, incense	May-Jun

Table 25: List of tree species recorded in Sagarmatha National Park, Nepal

Table 26: Basic forest pameters of the Sampled Plots

SN	Plot Name	Dominant Spp	Forest Type	Div.Ind. (H')	Expo. %	Litter %
1	Chhuwa12	RCa, As, Bu	Betula/Rhodo	1.808	15	10
2	Chhuwa13	Bu, Rb	Betula/Rhodo	1.838	10	15
3	Chhuwa14	As, Bu, Rca	Betula/Rhodo	1.498	25	5
4	Dole6A	Bu	Betula/Juniper	0.757	55	40
5	Dole6B	Bu	Betula/Juniper/Rhodo	0.875	55	60
6	Dole7A	Bu	Rhodo/Betula	0.779	70	20
7	Dole7B	Bu, As	Betula/Abies	1.105	40	10
8	Khunde5A	As	Juniper/Abies	0.430	60	75
9	Khunde5B	As, Jr	Juniper/Abies	0.990	30	30
10	Panboche	As	Betula/Abies	0.910		
11	PhortseTenga8A	As	Abies	0.000	20	15
12	PhortseTenga8B	Bu	Betula/Lyonia	0.769	20	25
13	Phungi9A	As	Mixed	1.162	40	20
14	Phungi9B	As	Abies	0.400	25	20
15	Phurte1A	As	Abies	0.616	30	30
16	Phurte1B	As	Abies	0.621	25	10
17	Phurte2A	As	Abies	0.145	30	40
18	Phurte2B	As, Pw	Abies	0.834	60	15
19	Phurte3B	As	Abies	0.000	40	15
20	Phurte4A	As	Abies	0.000	25	40
21	Phurte4B	As	Abies	0.000	30	20
22	Satermo1	Rb, As, Bu	Abies/Rhodo	1.906	35	30
23	Satermo2	Bu	Mixed	0.832		
24	Tenboche10A	As	Abies	0.340	40	10
25	Tenboche10B	As, Rca	Abies/Rhodo	0.991	30	10
26	Tenboche11A	As	Juniper/Rhodo	1.081	35	40
27	Tenboche11B	As, Jr	Juniper/Abies	0.861	50	10
28	Imja003	Bu	Betula	1.176	20	60
29	Imja004	As, Rca	Multilayer	1.629	30	80
30	Imja016	As, Bu	Betula/Abies	1.243	40	
31	Imja024	Bu, As	Betula/Abies	1.311	20	80
32	Imja029	Bu, As	Betula	1.456	60	40
33	Imja035	As, Jr, Bu	Betula/Abies	1.759	20	30
34	Imja044	As, Bu	Betula	0.989	40	90
35	Imja050	As	Betula/Abies	0.506	50	50
36	Imja067	As	Betula/Rhodo	0.315	30	
37	Imja074	As,Bu	Betula/Abies	1.080	40	40
38	Imja077	Bu, As	Betula	0.933	30	
39	Imja078	Bu	Betula/Sorbus	0.446	30	40
40	Imja081	Bu, As	Betula/Abies	0.999	40	50
41	Imja085	Bu	Betula/Abies	0.826	30	30
42	Imja094	Bu	Betula/Sorbus	1.078	25	80
43	Imja097	Bu, As	Betula/Abies	1.039	20	70
44	Imja098	As ,Bu	Betula	1.125	80	30
45	Imja104	Bu, As	Betula/Abies	0.914	30	100
46	Imja118	As ,Bu	Betula/Abies	0.999	70	15
47	Imja119	Bu	Betula	1.103	20	50
48	Imja124	Rc	Rhodo/Sorbus	0.571	20	30

49	Imja140	Rc	Rhodo	0.426	20	70
50	Imja148	Rc	Mixed	1.286	40	
51	Imja150	As ,Bu	Rhodo	1.377	30	
52	Imja154	Bu, As	Betula/Rhodo	1.475	75	60
53	Imja155	Bu, As	Betula	0.940	30	25
54	Imja162	Bu, As	Mixed	1.915	20	90
55	Imja163	Rc	Rhodo	0.676	30	
56	Imja168	As	Abies	0.143	80	
57	Imja169	As	Mixed	0.961	80	80
58	Imja176	Bu, Lo	Lyonia	1.722	20	60
59	Imja179	As ,Bu	Betula/Abies	1.189	40	80
60	Imja183	Jr	Juniper	0.000	80	
61	Imja185	Rcy, Jr	Rhodo	1.408	50	50
62	Imja191	Ac, Bu	Acer	1.626	70	90
63	Imja195	Bu, As	Betula	1.338	20	65
64	Imja200	As	Abies	0.365	80	90
65	Imja201	Bu, As	Mixed	1.639	80	80
66	Imja209	Sm, Bu	Sorbus	1.550	20	60
67	Imja218	As	Abies	1.305	10	70
68	Imja229	As	Abies/Rhodo/Juniper	1.145	50	
69	Imja238	As	Abies/Rhodo/Juniper	1.124	70	
70	Imja264	As	Abies/Rhodo/Juniper	0.976	30	
71	Imja271	Jr	Juniper	0.000	50	
72	Imja292	As	Abies/Rhodo/Juniper	0.752	40	50
73	SNP010	Bu, RCy	Betula/Rhodo	0.918	30	20
74	SNP013	Bu, RCy	Betula	0.200	30	40
75	SNP015	Bu	Betula	0.168	40	35
76	SNP017	Bu, RCy	Mixed Betula/Rhodo/Abies	0.259	70	30
77	SNP021	Bu, RCy	Betula/Rhodo	0.954	70	30
78	SNP034	Bu	Betula/Rhodo	0.006	60	40
79	SNP052	Bu, RCy	Betula/Rhodo/Lyonia	0.224	65	35
80	SNP082	Bu, As	Betula/Rhodo/Lyonia	0.610	20	30
81	SNP125	Bu, Lo	Betula/Lyonia	0.938	60	25
82	SNP130	Bu, As, RCy	Rhodo/Betula/Abies	0.725	75	25
83	SNP137A	As, Bu	Mixed Abies/Juniper/Betula	0.898	15	30
84	SNP138	As	Abies/Juniper	0.171	60	40
85	SNP141	As, Bu, RCy	Abies/Betula	0.526	55	45
86	SNP143	Bu	Brtula/Rhodo	0.723	65	35
87	SNP152	Bu, RCy, Sm	Betula/Sorbus/Rhodo	0.695	20	40
88	SNP153	As, Bu, RCy	Abies/Betula/Rhodo	0.364	60	40
89	SNP160	As	Abies	0.700	55	45
90	SNP164	Bu	Betula/Rhodo	0.721	30	40
91	SNP170	Bu	Betula/Rhodo	0.965	55	25
92	SNP181	Bu	Betula/Lyonia	0.547	70	30
93	SNP187	As, Bu	Betula/Abies	0.913	45	35
94	SNP190	As	Abies	0.305	55	45
95	SNP194	Bu, As	Betula/Abies	0.256	65	35
96	SNP199	As	Abies/Rhodo	0.787	65	35

97	SNP203	Bu	Betula/Juniper	0.178	30	30
98	SNP205	RCy, Bu	Betula/Rhodo	0.858	60	30
99	SNP207	Bu, Sm	Betula/Sorbus/Rhodo	0.349	10	50
100	SNP212	Bu	Betula/Sorbus/Rhodo	0.810	10	55
101	SNP220	As, RCy	Mixed Abies/Rhodo	0.032	10	30
102	SNP227	As	Abies	0.311	45	55
103	SNP259	As	Abies/Juniper	0.606	60	40
104	SNP282	Pw	Pinus	0.652	10	40
105	SNP296	Sm, Jr, As	Mixed Sorbus/Abies/Rhodo	0.800	35	30

As = *Abies spectabilis*; Ac = *Acer campbelli*; Bu = *Betula utilis*; Jr = *Juniperus recurva*; Pw = *Pinus wallichiana*; Qs = *Quercus semicarpifolia*; Rb = *Rhododendron barbatum*; Rca = *Rhododendrom campanulatum*; Rcy = *Rhododendron campylocarpum*; Sm = *Sorbus microphylla*

Table 27: Structural parameters of tree species in Sagarmatha National Park

Sn	Species	BA	RBA	ABA	Mean DBH	Max DBH	Stem	RSN	Dens	Plots	FO
1	*Abies spectabilis*	500419.5	43.7	11.9	24.0	116.5	1097	26.1	274	81	77
2	*Betula utilis*	413284.0	36.1	9.8	23.1	81.0	1027	24.4	257	72	69
3	*Rhododendron campylocarpum*	86749.5	7.6	2.1	10.6	104.0	922	21.9	231	60	57
4	*Sorbus microphylla*	36213.3	3.2	0.9	10.3	22.0	266	6.3	67	40	38
5	*Juniperus recurva*	35713.2	3.1	0.9	10.6	67.0	283	6.7	71	34	32
6	*Rhododendron campanulatum*	18616.4	1.6	0.4	10.1	22.5	205	4.9	51	9	9
7	*Pinus wallichiana*	15291.1	1.3	0.4	23.6	46.5	24	0.6	6	4	4
8	*Rhododendron barbatum*	11974.2	1.0	0.3	15.3	54.5	60	1.4	15	3	3
9	*Lyonia ovalifolia*	7545.0	0.7	0.2	8.6	20.0	120	2.9	30	13	12
10	*Acer campbellii*	6013.4	0.5	0.1	14.8	34.0	41	1.0	10	7	7
11	*Rhododendron arboreum*	4240.6	0.4	0.1	10.3	23.5	64	1.5	16	6	6
12	*Salix sikkimensis*	2598.3	0.2	0.1	10.4	22.0	35	0.8	9	9	9
13	*Tsuga dumosa*	2206.2	0.2	0.1	53.0	53.0	1	0.0	0	1	1
14	Bhatkuri	1771.6	0.2	0.0	9.2	22.5	23	0.5	6	6	6
15	*Ligustrum* sp	1121.4	0.1	0.0	6.5	14.8	25	0.6	6	5	5
16	*Rhododendron fulgens*	417.2	0.0	0.0	8.5	12.0	7	0.2	2	1	1
17	*Rhododendron hodgsonii*	188.9	0.0	0.0	5.4	7.0	8	0.2	2	1	1
	TOTAL	**1144363.8**	**100.0**	**27.2**	**15.0**	**116.5**	**4208**	**100.0**	**1052**		

Abbreviations and units: BA: Basal Area (sq cm); RBA: Relative Basal Area (%); TBA: Total Basal Area (m^2ha^{-1}); DBH: Diameter at Breast Height (cm); RSN: Relative Stem Number (%); FO: Frequency of Occurrence (%)

Table 28: Structural parameters of tree species in permanent plots, Sagarmatha National Park, Nepal

Sn	Species	BA	RBA	ABA	Mean DBH	Max DBH	Stem	RNO	Dens.
Panboche Yaren									
1	Abies spectabilis	79059.2	70.7	7.9	24.9	68	120	27.0	120
2	Betula utilis	27831.9	24.9	2.8	11.6	40	204	45.8	204
3	Sorbus microphylla	4785.0	4.3	0.5	5.7	39	117	26.3	117
4	Rhododendron campilocarpum	132.7	0.1	0.0	13.0	13	1	0.2	1
5	Juniperus recurva	53.4	0.0	0.0	4.7	6	3	0.7	3
0	TOTAL	111862.1	100.0	11.2	13.6	68	445	100.0	445
Debuche									
1	Betula utilis	84990.3	45.7	8.5	24.0	63.0	149	14.4	149
2	Abies spectabilis	68228.8	36.7	6.8	8.5	99.0	359	34.7	359
3	Acer campbelli	17106.3	9.2	1.7	8.1	28.5	243	23.5	243
4	Sorbus microphylla	15030.5	8.1	1.5	7.4	36.0	279	27.0	279
5	Rhododendron campilocarpum	751.5	0.4	0.1	14.0	21.0	4	0.4	4
0	TOTAL	186107.6	100.0	18.6	10.4	99.0	1034	100.0	1034

Table 29: Diameter class distribution of tree species

SN	Species	Diameter Class (cm)																							
		0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105	105-110	110-115	115-120
1	Abies spectabilis	23	203	190	183	173	122	85	56	21	15	5	8	1	4		2	1	0	0	0	1	0	1	2
2	Betula utilis	13	222	280	195	93	62	56	29	19	15	16	5	8	7	3	3	1	0	0	0	0	0	0	0
3	R. campylocarpum	30	503	307	73	5	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
4	Sorbus microphylla	14	131	83	28	5	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
5	Juniperus recurva	23	143	69	31	9	1	4	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
6	R. campanulatum	7	112	59	22	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Pinus wallichiana	0	0	3	6	5	0	4	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	R. barbatum	5	16	17	11	7	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Lyonia ovalifolia	9	75	30	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Acer campbellii	0	15	18	4	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	R. arboreum	1	48	9	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Salix sikkimensis	8	18	6	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Tsuga dumosa	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Bhatkuri	15	6	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
15	Ligustrum sp	3	19	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	R. fulgens	0	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	R. hodgsonii	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	**153**	**1522**	**1077**	**564**	**309**	**189**	**153**	**89**	**44**	**33**	**23**	**14**	**9**	**12**	**4**	**5**	**2**	**0**	**0**	**0**	**3**	**0**	**1**	**4**

Table 30: Height class distribution of tree species

				Height Class (cm)															
Sn	Species	Mean	Max.	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Total
1	Abies spectabilis	7.5	30.0	32	167	219	210	213	131	63	23	12	9	5	5	3	1	1	1094
2	Betula utilis	7.5	22.0	53	110	245	323	131	52	36	44	4	6	9	3	0	0	10	1026
3	R. campylocarpum	3.6	8.5	60	226	594	37	5	0	0	0	0	0	0	0	0	0	0	922
4	Juniperus recurva	4.0	10.5	7	161	86	19	6	4	0	0	0	0	0	0	0	0	0	283
5	Sorbus microphylla	4.4	9.5	22	44	124	57	7	0	0	0	0	0	0	0	0	0	0	254
6	R. campanulatum	6.4	16.5	0	52	98	34	1	2	0	0	2	0	0	0	0	0	0	189
7	Lyonia sp	4.8	8.0	5	13	81	19	2	0	0	0	0	0	0	0	0	0	0	120
8	R. arboreum	3.4	12.0	3	40	17	3	0	0	1	0	0	0	0	0	0	0	0	64
9	R. barbatum	5.3	8.5	0	12	37	8	3	0	0	0	0	0	0	0	0	0	0	60
10	Acer campbellii	5.3	8.0	4	2	7	24	4	0	0	0	0	0	0	0	0	0	0	41
11	Salix sikkimensis	4.5	7.0	1	13	18	3	0	0	0	0	0	0	0	0	0	0	0	35
12	Ligustrum sp	4.2	8.0	1	8	15	0	1	0	0	0	0	0	0	0	0	0	0	25
13	Pinus wallichiana	10.6	19.0	0	0	0	2	4	2	8	6	1	1	0	0	0	0	0	24
14	Bhatkuri	2.4	5.0	7	7	9	0	0	0	0	0	0	0	0	0	0	0	0	23
15	R. campanulatum	3.7	5.0	0	10	6	0	0	0	0	0	0	0	0	0	0	0	0	16
	TOTAL	6.0	30.0	195	873	1563	739	377	191	108	73	20	16	14	8	3	1	11	4192

Abb. R. = Rhododendron

Table 31: Diameter class distribution of tree species in permanent plots, SNP, Nepal

		Diameter Class (m)																			
Sn	Species	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
Panboche Yaren																					
1	Abies spectabilis	13	8	8	14	16	19	15	10	6	4	3	1	2	1	0	0	0	0	0	0
2	Betula utilis	11	84	69	23	5	3	7	1	1	0	0	0	0	0	0	0	0	0	0	0
3	Sorbus microphylla	52	58	4	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
4	R. campilocarpum	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Juniperus recurva	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	Total	78	151	82	38	21	23	22	12	7	4	3	1	2	1	0	0	0	0	0	0
Debuche																					
1	Betula utilis	5	10	19	23	27	19	17	13	7	5	1	1	2	0	0	0	0	0	0	0
2	Abies spectabilis	211	70	19	18	9	11	6	7	2	0	0	0	1	0	1	1	0	0	0	3
3	Acer campbelli	67	100	50	20	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Sorbus microphylla	75	138	58	6	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
5	R. campilocarpum	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	Total	359	318	147	68	42	32	23	21	9	5	1	1	3	0	1	1	0	0	0	3

Table 32: Height class distribution of tree species in permanent plots, SNP, Nepal

				Height Class (m)										
Panboche Yaren														
Sn	**Species**	**Mean**	**Max**	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1	*Abies spectabilis*	6.88	13.6	9	13	22	24	36	14	2	0	0	0	0
2	*Betula utilis*	5.95	11.1	0	26	73	74	29	2	0	0	0	0	0
3	*Sorbus microphylla*	3.49	9.1	6	73	34	1	3	0	0	0	0	0	0
4	*R. campilocarpum*	5.40	5.4	0	0	1	0	0	0	0	0	0	0	0
5	*Juniperus recurva*	2.19	2.53	1	2	0	0	0	0	0	0	0	0	0
0	Total	5.53	13.6	16	114	130	99	68	16	2	0	0	0	0
Debuche														
1	*Betula utilis*	10.29	17.7	0	7	6	12	38	44	25	12	5	0	0
2	*Abies spectabilis*	3.86	20.5	130	132	30	19	22	8	10	4	2	1	1
3	*Acer campbelli*	5.54	16.8	2	48	99	66	23	4	0	0	1	0	0
4	*Sorbus microphylla*	4.24	12.1	7	104	151	15	1	0	1	0	0	0	0
5	*R. campilocarpum*	6.50	8	0	0	1	1	2	0	0	0	0	0	0
0	Total	5.30	20.5	139	291	287	113	86	56	36	16	8	1	1

4.6 Findings

4.6.1 Exposure and Coverage

Table 4 presents estimated exposure to the light of the sampling plots. Majority of the sampled plots fall under exposure class 20-40% (Figure 17). There were eight plots with exposure less than 20% and similar numbers of plots with more than exposure 80%. In average, the exposure was 41.4%, that is, the canopy coverage was about 58.6%. The average litter coverage on the ground was estimated to be 41.5%. The coverage variation, however, varied between 10% and over 90% (Figure 18).

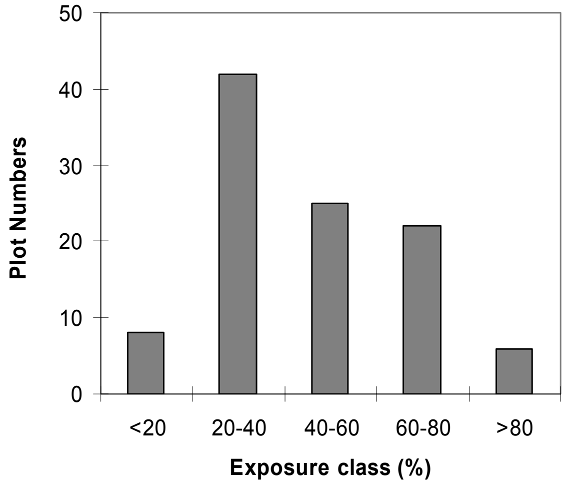

Figure 17: Exposure percent of sampled plots in the Sagarmatha National Park, Nepal

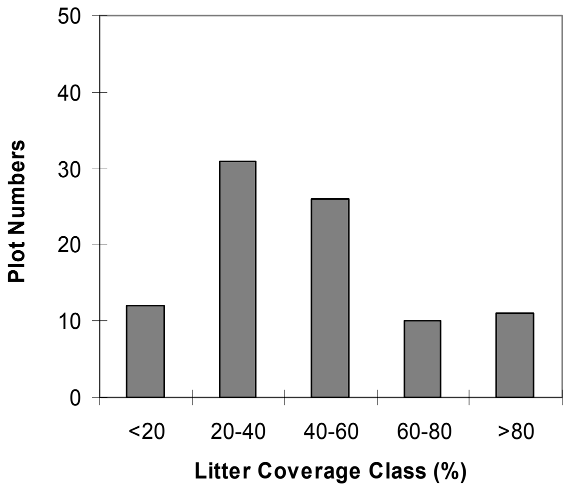

Figure 18: Litter coverage percent of sampled plots in the Sagarmatha National Park, Nepal

4.6.2 Floristic Composition and biodiversity

Altogether 17 species of trees was recorded from the 105 sampling plots in the Sagarmatha National Park They represented 11 genus and eight families. Family Ericaceae contained six *Rhododendron* and one *Lyonia* species, while Pinaceae included three evergreen tree species of *Abies spectabilis, Pinus wallichiana* and *Tsuga dumosa*. The other families containing one species each were: Aceraceae, Cupressaceae, Oleaceae, Salicaceae and Rosaceae. All the species have local value, either medicinal (*Abies*, *Betula*, *Lyonia* and *Rhododendron*), timber (*Abies*, *Pinus* and *Tsuga*) or fire wood (*Rhododendron*). Few were used as fodder, such as *Acer*, *Ligustrum* and *Sorbus* (compare Table 25).. Most of them have their flowering or cone maturity during spring, and few in summer.

In the permanent plots, one at Panboche Yaren Forest (Alt. 4050 m asl) five tree species were recorded, viz. *Abies spectabilis*, *Betula utilis*, *Sorbus microphylla*, *Rhododendron campylocarpum* and *Juniperus recurva*. The second permanent plot Debuche Forest (Alt. 3850 m asl) hosts also five species, among them *Acer campbellii* and lacked *Juniperus recurva*.

All plots have a rather low diversity index. The highest diversity index recorded was 1.915 (Shannon's H)[1] was found in Plot Imja 162 where the dominating species are *Abies spectabilis* and *Betula utilis*. A similar situation is found in Plot Satermo 1, where *Rhododendron barbatum* is the dominating species along with *Abies* and *Betula*. Low diversity indices (below 0.1) wer found in eight plots: PhortseTenga-8A, Imja-183, Imja-271, Phurte-3B, Phurte-4A, Phurte-4B, SNP-034 and SNP-220.

4.6.3 Floristic composition

Forest composition varies with altitude and aspect. The lower valley is dominated by conifera species. On slopes, especially on south-facing aspects, *Pinus wallichiana* is common up to 3,400m. At higher elevation from 3,000 to treeline (4,050m), *Abies spectabilis* is most widely distributed. *Juniperus recurva* forms isolated stands on south-facing slopes as high as 4,000m where it has been protected as a sacred tree or associated with a temple or hermitage. Mixed forests of *Betula utilis* and Rhododendrons cover extensive northern-slope areas between 3,000 - 4,200m. Beyond the tree-line are shrub forests containing Rhododendron and willow. Alpine vegetation, e.g. dwarf Rhododendrons exist above 4,900m on north-facing slopes (Byers 1978).

In the study of vegetation structure in Eastern Nepal Himalaya, Ohsawa (1983) classified an Abies Zone above 3000m asl, which was dominated by *Abies spectabilis*. In the gaps of the forest, he recorded deciduous tree species such as *Sorbus* sp., *Betula utilis*, while under closed canopy he observed several species of *Rhododendron*. Bhuju and Rana (2000) reported *Abies spectabilis*, *Pinus wallichiana*, *Juniperus recurva*, *Betula utilis*, *Rhododendron arboretum* and *R. campanulatum* from Namche and Tengboche. Yoda's (1967) observations have recorded *Quercus semicarpifolia* with *Betula cylindrostachys* and *Abies psectabilis*. Beside these species, he observed *Tsuga dumosa* and species of *Juniperus* and *Rhododendron*.

Stevens (1996) mentioned eight major tree species in Khumbu area: *Abies spectabilis*, *Pinus wallichiana*, *Betula utilis*, *Rhododendron campanulatum*, *R. arboretum*, *Juniperus recurva*, *J. wallichiana* and *Salix sikkimensis*. The temperate and subalpine conifer, birch, and rhododendron are major components of SNP forests. The present study has recorded most of these species, except *Quercus semicarpifolia*, which was noticed at lower altitude in buffer zone of SNP.

4.6.4 Structural Parameters (compare Figure 24, Figure 25,Figure 26, Figure 27, Figure 28, Figure 29 and Figure 30)

Based on the collected data, SNP's forests are characterized by an average BA of 27.2 m^2 ha^{-1} and 1,052 stems ha^{-1}. The maximum diameter at breast height (DBH) found was 116.5 cm (*Abies spectabilis*). Among the species, *Abies spectabilis* had the highest BA with a value of 43.7% relative basal area (RBA) followed by *Betula utilis* with an RBA of 36.1% and a relative stem number (RSN) of nearly 25%. The third dominating species, *Rhododendron campylocarpum,* shares 7.6% of RBA though the species' density is as high as 231 stems ha^{-1} with an RSN of 21.9%. The remaining species have RBAs below 3% and RSNs below 10%.

All tree species shows high stem numbers of 5-10 cm in diameter. The number of trees gradually decreases for classes with a thicker stem. This is an indication the forests in CNP are in sustained regenerating condition. However, when considering the characteristics between the different species, both dominant species, *Abies* and *Betula,* showed gaps between the classes, indicating rcent logging. A similar pattern can be observed with *Sorbus*.

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1 The Shannon diversity index (H) is commonly used to characterize species diversity in a community. Shannon's index accounts for both abundance and evenness of the species present. The proportion of species i relative to the total number of species (pi) is calculated, and then multiplied by the natural logarithm of this proportion (lnpi). The resulting product is summed across species, and multiplied by -1 (see formula below). The index rises with increasing diversity, peaking at a maximum value for occurrence of all species in equal numbers

$$H = -\sum_{j=1}^{S} p_j \ln p_j$$

The observation of height characters supportes the findings based on an analysis of the diameters. The maximum height observed was 30 m - an individual of *Abies spectabilis*. *Betula utilis* has been observed to have a maximum height of 22 m followed by *Pinus wallichiana* with 19 m. Most trees have a height of 4-6 m, the occurrence of individuals gradually decreases with increasing height-classes. However, the trend is not continuous but shows gaps between the classes when considering individual species. Again, this supports the observed past disturbances through logging.

Looking at the permament plots, Panboche features a total basal area of 11.2 m^2 ha^{-1} and a density of 445 stems ha^{-1}, while Debuche features a basal area of 18.6 m^2 ha^{-1} and a density of 1,034 stems ha^{-1}. The higher density of the plot at Debuche is caused predominantly by regenerating trees of smaller size of species *Abies spectabilis*. The predominanty occuring tree at Pangoboche is *Abies* and *Betula* in Debuche. Similar gaps in the diameter class-distribution and height class-distribution as in the temporary plots, indicating logging in the recent past could be observed.

Looking at the frequency of occurrence (FO) of the different species in the 105 temporary sampling plots, *Abies spectabilis* accounts for 77%, that is in 81 plots out of 105. *Betula utilis* accounts for 69%, while *Rhododendron campylocarpum*, *Sorbus microphylla* and *Juniperus recurva* account for 57%, 38% and 32% respectively. The remaining species occurred in less than 10 plots in total.

4.6.5 Age Structure (compare Figure 20, Figure 21, Figure 22, and Figure 23)

The correlation between age and diameter of *Betula utilis* is statistically significant for both permament splots, Panboche Yaren (n = 19, r = 0.752, P = 0.0002) and Debuche (n = 25, r = 0.767, P < 0.0001). This relationship was used to estimate the age of all tree individuals. In the age histogram, *Betula utilis*' population from Panboche Yaren forest as well that from Debuche showed a bell-shaped distribution pattern indicating a poor regeneration rate in recent years. This pattern is contrary to the findings obtained by looking at the diameter class distribution earlier.

Also for *Abies*, the correlation between age structure and diameter at Breast Height (DBH) class distribution of the trees was found statistically significant for both the sites, Panboche (n = 77, r = 0.851, P < 0.001) and Debuche (n = 58, r = 0.815, P < 0.001) (Figure 14). This relationship was used to estimate the age of all trees of the permanent plots. The population of *Abies spectabilis* showed a bell-shaped size distribution pattern in Panboche Yaren forest, while it was inverse J in Debuche.

The average age of *Betula utilis* at Pangboche site is 72 years. Individuals in the 60–70 year-old age class (trees that established themselves in the 1940s) accounted for the largest age class (34.21%) followed by 70-80 year-old and 50-60 year-old age classes, accounting for 21.57% and 18.63% of the tress, respectively. The majority of trees (86.26%) are between 50 and 100 years old and established themselves successfully between 1910s and the 1960s. However, in recent decades (1961–2007), establishment of new trees has been very poor as compared to previous decades with young individuals (< 50 years) accounting only for 5.39% of the total population.

Similarly, in Panboche Yaren, the average age of *Abies spectabilis* was found to be 64 years. The 60–69 year-old age class (trees that established themselves in the 1940s) account for the largest age class (16.7%) followed by 50-60 and 70-80 year-old age classes, accounting 14.2% and 13.3%, respectively. The majority of trees (58.3%) are between 50 and 100 years old - they successfully established themselves between 1910s and the 1960s. However, in recent decades (1961–2007), regeneration has been poor as compared to previous decades with young individuals (< 50 years) accounting for 31.7% of the total population.

In Debuche, the average age for *Betula utilis* is 108 years, i.e. higher than Panboche Yaren. The 90–100 year-old age class (trees that established themselves in the 1910s) account for the largest age class (10.1%) followed by70-80 and 100-110 year-old age classes, both accounting for 8.7%. Few individuals (8.7%) are below 50 years of age. This site is dominated by those individuals who successfully established themselves in the late quarter of the 19th century to the early quarter of 20th century.

Unlike in Panboche Yaren, the age distribution of *Abies Spectabilis* in Debuche shows an inverse J-shaped type, indicating accelerating recruitment of individuals in the recent decades. The average age is only 32 years for Debuche. The 20–99 year-old age class (trees that established themselves in the 1910s) account for the largest age class (73.8%). The majority of trees (89.7%) are below 50years old, which successfully established themselves between 1960 and the 2000s, whereas old individuals

(>100 years) account for only 1.7% of the total population. Debuche is dominated by young individuals of *Abies Spectabilis*

Age-class histograms for *B. utilis* show that some trees could be dated back to the mid eighteenth century. Establishment in this population occurred at low rates before 1900s in Yaren but high rates in Debuche. However, regeneration has declined substantially since the 1950s in both sites.

	Betula utilis		***Abies spectabilis***	
Age class Years	Debuche	Panboche Yaren	Debuche	Panboche Yaren
00-10	0	0	0	0
10-20	1	0	0	7
20-30	2	0	265	12
30-44	5	0	34	7
40-50	5	11	23	12
50-60	9	38	16	17
60-70	10	70	11	20
70-80	13	44	4	16
80-90	11	18	0	7
90-100	15	6	0	10
100-110	13	5	1	4
110-120	12	1	1	4
120-130	7	2	1	1
130-140	11	6	0	2
140-150	6	2	2	1
150-160	11	0	1	0
160-170	4	1	0	0
170-180	2	0	0	0
180-190	3	0	0	0
190-200	3	0	0	0
200-210	2	0	0	0
210-220	0	0	0	0
220-230	1	0	0	0
230-240	1	0	0	0
240-250	0	0	0	0
250-260	2	0	0	0
Total	149	204	359	120

Table 33: Age class frequency of Betula utilis and Abies spectabilis in permanent plots

4.6.6 Biomass

Empirically, biomass is measured by felling of different tree species in the plot, and analysing fresh weight and oven-dry weight of stem, branches and leaves. For national parks, this method is no applicable. Therefore, biomass was calculated with reference to previous studies. Since there is lack of volume table and/or density for other species, biomass computation has not been possible for all tree species on this basis, but only for *Abies spectabilis.* Table 34 presents stem biomass calculated for *Abies spectabilis* (with reference to Abies pindrow) in the sampling plots of forest in Sagarmatha Nagtional Park. The average stem biomass for the species was found 36.9 ton/ha. However, it ranged between 146.7 t/ha in plot Imja169 to 0.1 t/ha in plot SNP010.

The stem biomass was obtained by multiplying stem volume by the wood density (following Sharma and Pukkala 1990). The logarithmic form of the equation adopted to estimate stem volume is:

$$\ln (V) = a + b \ln (d) + c \ln (h) \qquad \text{(I)}$$

Where,

ln means logarithm (here: logarithm to the base 2.71828)

V is Stem volume

a, b and c parameters

Stem Biomass (SB) is estimated for all trees (DBH>10cm) following (Sharma and Pukkala 1990; Brown 1997) as-

$$SB = SV \times SD \qquad \text{(II)}$$

Where,

SB is Above Ground Biomass

SV is Stem Volume (From Equation I)

SD is Stem Density (Following Sharma and Pukkala 1990)

Table 34: Stem Biomass of Abies spectabilis in Sagarmatha National Park, Nepal

SN	Plot Name	Dominant Spp	Forest Type	Biomass (t/ha)
1	Chhuwa12	RCa, As, Bu	Betula/Rhodo	35.7
2	Chhuwa13	Bu, Rb	Betula/Rhodo	13.3
3	Chhuwa14	As, Bu, Rca	Betula/Rhodo	41.9
4	Dole6B	Bu	Betula/Juniper/Rhodo	1.2
5	Dole7B	Bu, As	Betula/Abies	19.9
6	Khunde5A	As	Juniper/Abies	41.1
7	Khunde5B	As, Jr	Juniper/Abies	6.1
8	Panboche	As	Betula/Abies	36.3
9	PhortseTenga8A	As	Abies	85.2
10	Phungi9A	As	Mixed	78.4
11	Phungi9B	As	Abies	92.7
12	Phurte1B	As	Abies	106.9
13	Phurte2B	As, Pw	Abies	27.5
14	Phurte2A	As	Abies	43.3
15	Phurte 3A	As	Abies	48.2
16	Phurte3B	As	Abies	59.6
17	Phurte1A	As	Abies	78.6
18	Phurte4A	As	Abies	74.0
19	Phurte4B	As	Abies	27.2
20	Satermo2	Bu	Mixed	15.0
21	Tenboche10A	As	Abies	79.0
22	Tenboche10B	As, Rca	Abies/Rhodo	93.6
23	Tenboche11A	As	Juniper/Rhodo	54.7
24	Tenboche11B	As, Jr	Juniper/Abies	30.3

25	Imja003	Bu	Betula	6.4
26	Imja004	As, Rca	Multilayer	34.6
27	Imja016	As, Bu	Betula/Abies	6.3
28	Imja024	Bu, As	Betula/Abies	30.5
29	Imja029	Bu, As	Betula	18.0
30	Imja035	As, Jr, Bu	Betula/Abies	8.0
31	Imja044	As, Bu	Betula	27.3
32	Imja050	As	Betula/Abies	24.9
33	Imja067	As	Betula/Rhodo	13.2
34	Imja074	As,Bu	Betula/Abies	24.5
35	Imja077	Bu, As	Betula	99.4
36	Imja078	Bu	Betula/Sorbus	0.1
37	Imja081	Bu, As	Betula/Abies	12.3
38	Imja085	Bu	Betula/Abies	21.2
39	Imja094	Bu	Betula/Sorbus	2.0
40	Imja097	Bu, As	Betula/Abies	11.9
41	Imja098	As ,Bu	Betula	2.0
42	Imja104	Bu, As	Betula/Abies	126.8
43	Imja118	As ,Bu	Betula/Abies	9.6
44	Imja119	Bu	Betula	3.4
45	Imja148	Rc	Mixed	1.0
46	Imja150	As ,Bu	Rhodo	55.6
47	Imja154	Bu, As	Betula/Rhodo	4.7
48	Imja155	Bu, As	Betula	16.4
49	Imja162	Bu, As	Mixed	40.6
50	Imja168	As	Abies	81.6
51	Imja169	As	Mixed	**146.7**
52	Imja179	As ,Bu	Betula/Abies	77.3
53	Imja195	Bu, As	Betula	14.6
54	Imja200	As	Abies	54.2
55	Imja201	Bu, As	Mixed	8.5
56	Imja209	Sm, Bu	Sorbus	0.3
57	Imja218	As	Abies	50.3
58	Imja229	As	Abies/Rhodo/Juniper	91.3
59	Imja238	As	Abies/Rhodo/Juniper	41.8
60	Imja292	As	Abies/Rhodo/Juniper	21.7
61	SNP010	Bu, RCy	Betula/Rhodo	**0.1**
62	SNP017	Bu, RCy	Mixed Betula/Rhodo/Abies	1.7
63	SNP130	Bu, As, RCy	Rhodo/Betula/Abies	16.5
64	SNP137A	As, Bu	Mixed Abies/Juniper/Betula	15.5
65	SNP259	As	Abies/Juniper	65.4
66	SNP138	As	Abies/Juniper	37.6
67	SNP141	As, Bu, RCy	Abies/Betula	33.6
68	SNP153	As, Bu, RCy	Abies/Betula/Rhodo	44.8
69	SNP160	As	Abies	51.0
70	SNP170	Bu	Betula/Rhodo	0.5
71	SNP187	As, Bu	Betula/Abies	28.8
72	SNP190	As	Abies	50.6
73	SNP194	Bu, As	Betula/Abies	15.4
74	SNP199	As	Abies/Rhodo	46.1
75	SNP220	As, RCy	Mixed Abies/Rhodo	29.2
76	SNP227	As	Abies	54.1

77	SNP282	Pw	Pinus	12.3
78	SNP296	Sm, Jr, As	Mixed Sorbus/Abies/Rhodo	19.2
79	SNP082	Bu, As	Betula/Rhodo/Lyonia	16.1
	Average			36.9

As = Abies spectabilis; Ac = Acer campbelli; Bu = Betula utilis; Jr = Juniperus recurva; Pw = Pinus wallichiana; Rb = Rhododendron barbatum; Rca = R. campanulatum; Rcy = R. campylocarpum; Sm = Sorbus microphylla. Note: Per tree Biomass 2.9 t

Biomass (*A spectabilis; Density = 480kg/m3*)

4.6.7 Disturbance Regime

The disturbance regime included measurement of all cut stumps found in the surveyed plots. Similarly, observations were made that would indicate any kind of anthropogenic disturbance, such as trail traversing the plots, litter collection, grass cutting, grazing and fuel-wood collection (lopping and collection signs). The observation made was simply present or absent, and is presented in Table 13 and Figure 10. Cut stumps were recorded in the permanent plots as well.

Various types of disturbances originating from human activities such as cut stumps, litter collection, trails, grazing of cattle, grass cutting and fuel-wood collection were noticed in the study site. Dead tree due to natural cause was noticed but very few, while there was no evidence of fire so far in the sampled plots. Out of 105 sampling plots, cut stumps were recorded in 84 plots (freq. 80%; Table 13). Similarly, fuel-wood collection was noticed (such as lopping, remains of cut woods etc.) in 70 plots (freq. 66.7%). Litter collection and grazing were found in 45 plots (42.9%) and 38 (36.2%) respectively. Trail was notice in 33 plots; however, it is assumed that all plots having cut stumps and/or fuel-wood collections were visited by human at times. Dead trees and grass cutting evidences were noticed in only few plots, that is, 5 and 4 plots respectively.

Among the tree species, the highest frequency of occurrence of cut stumps was found with *Betula utilis*, in 46 plots out of 105. This was followed by *Abies spectabilis* and *Rhododendron campylocarpum* with 31.4% each, that is, occurring in 34 plots. The mean diameter (measured at stump height) of such cut stumps was 22.5 cm for *Betula*, 23.6 cm for *Abies* and 18.1 cm for *Juniperus recurva*. The total basal area (per ha) of cut stumps of all tree species was 3.6 m^2ha^{-1}, where *Betula* and *Abies* had highest contribution with 2.8 m^2ha^{-1} together. On the other hand, the total stem density was 132 stems ha^{-1}, where *Betula*, *Abies* and *Rhododendron campylocarpum* shared 37, 28 and 35 stems ha^{-1} respectively.

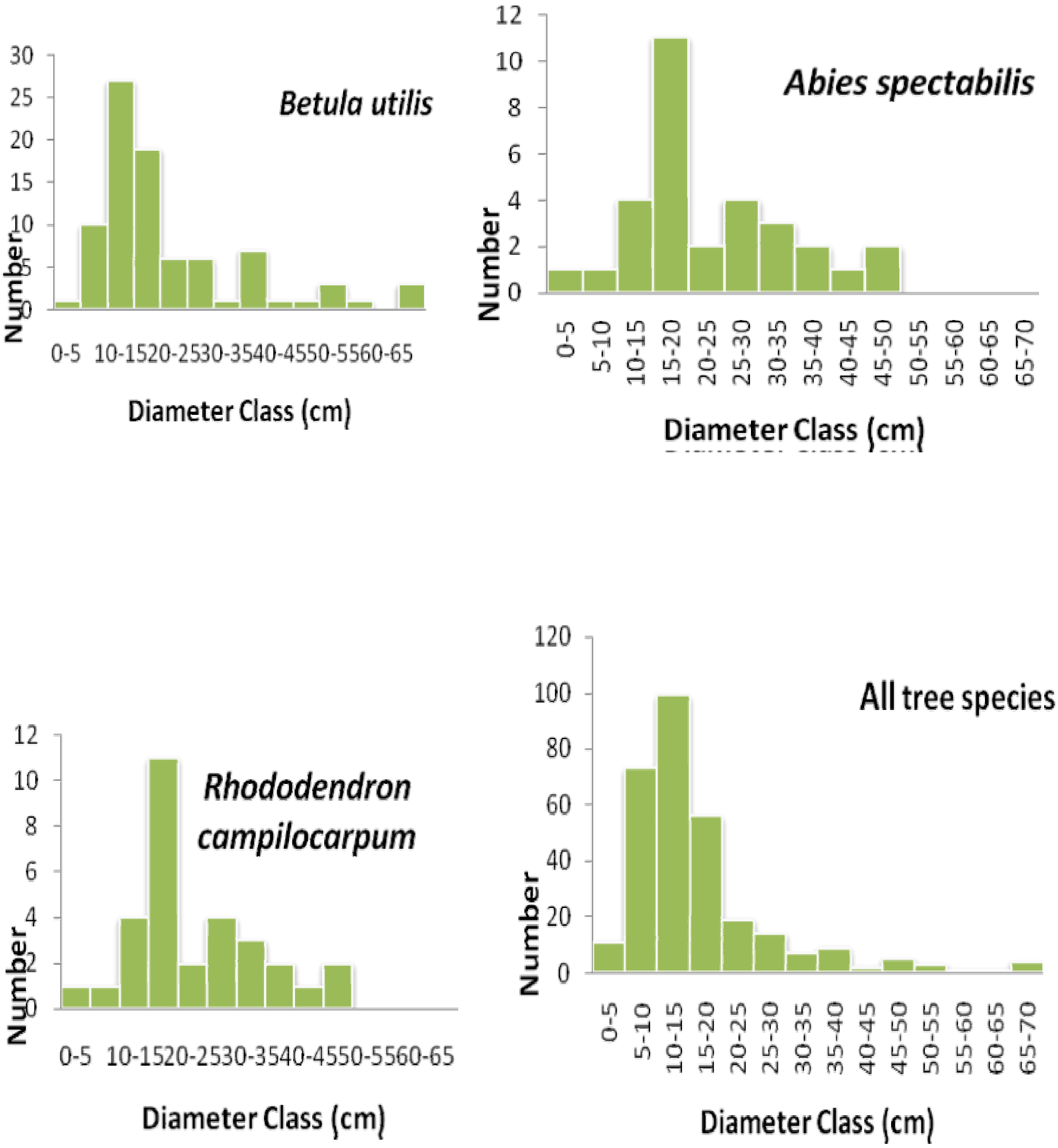

Figure 19: Diameter class distribution of cut stumps of Abies spectabilis in Sagarmatha National Park, Nepal

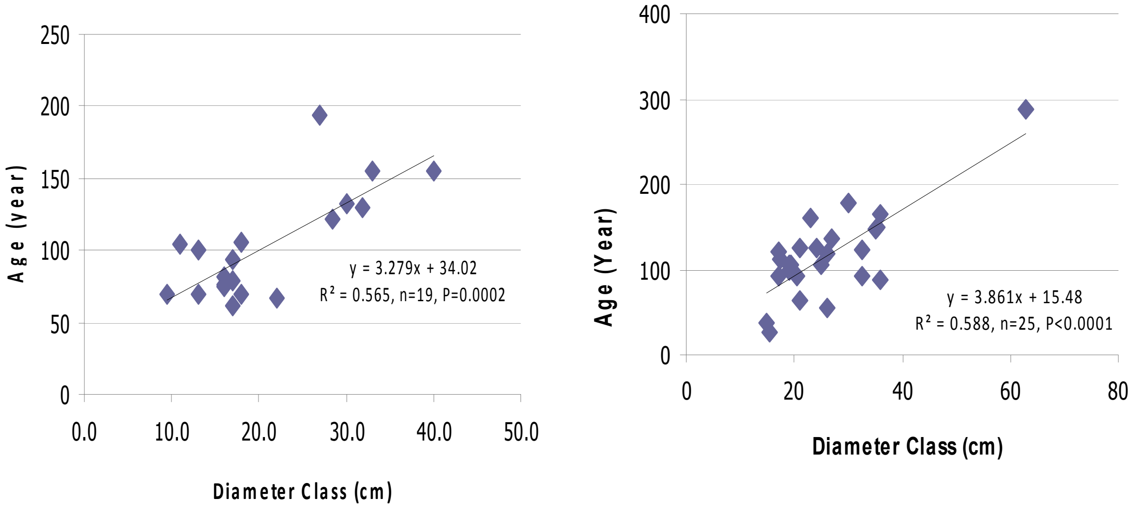

Figure 20: Age DBH Relationship of Betula utilis in (a) Panboche Yaren and (b) Debuceh, SNP

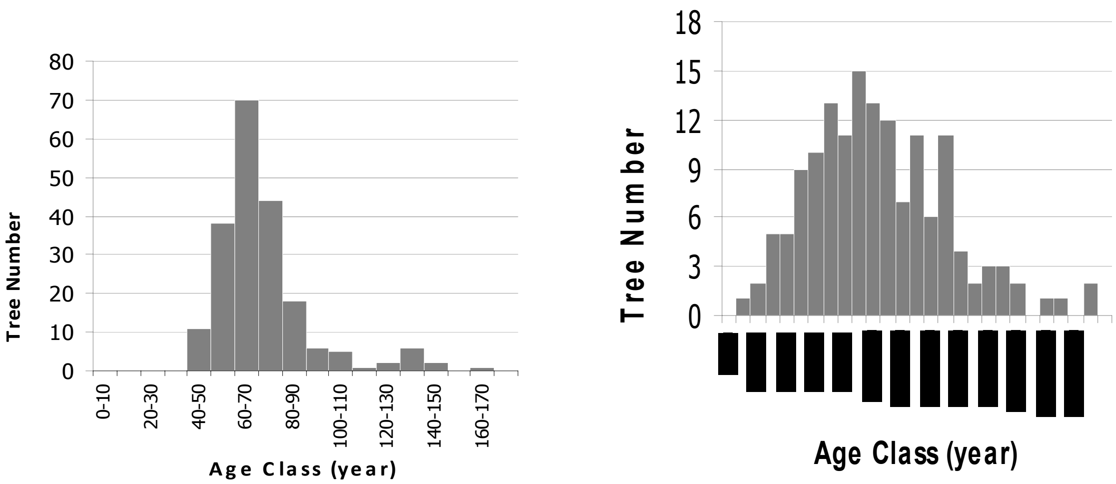

Figure 21: Age histogram of Betula utilis in (a) Panboche Yaren and (b) Debuceh, SNP

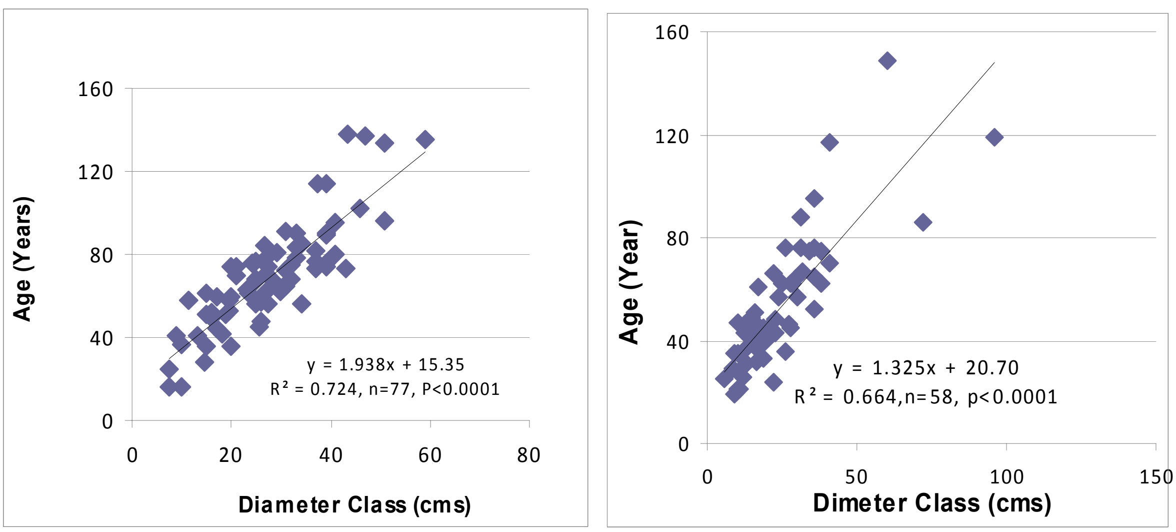

Figure 22: Age DBH Relationship of Abies spectabilis in (a) Panboche Yaren and (b) Debuche, SNP

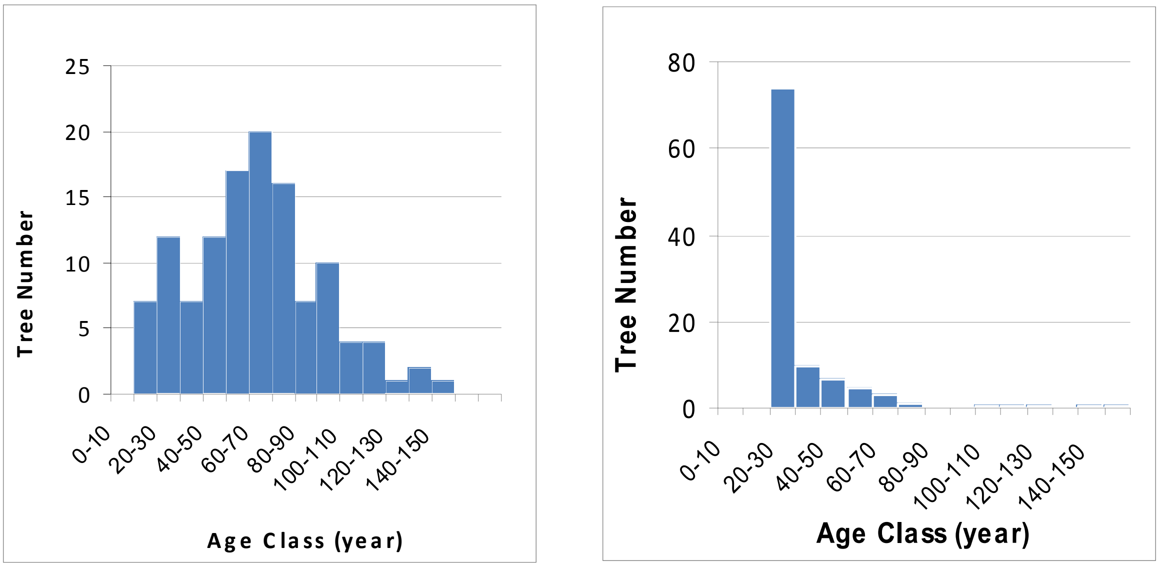

Figure 23: Age histogram of Abies spectabilis in (a) Panboche Yaren and (b) Debuche, SNP

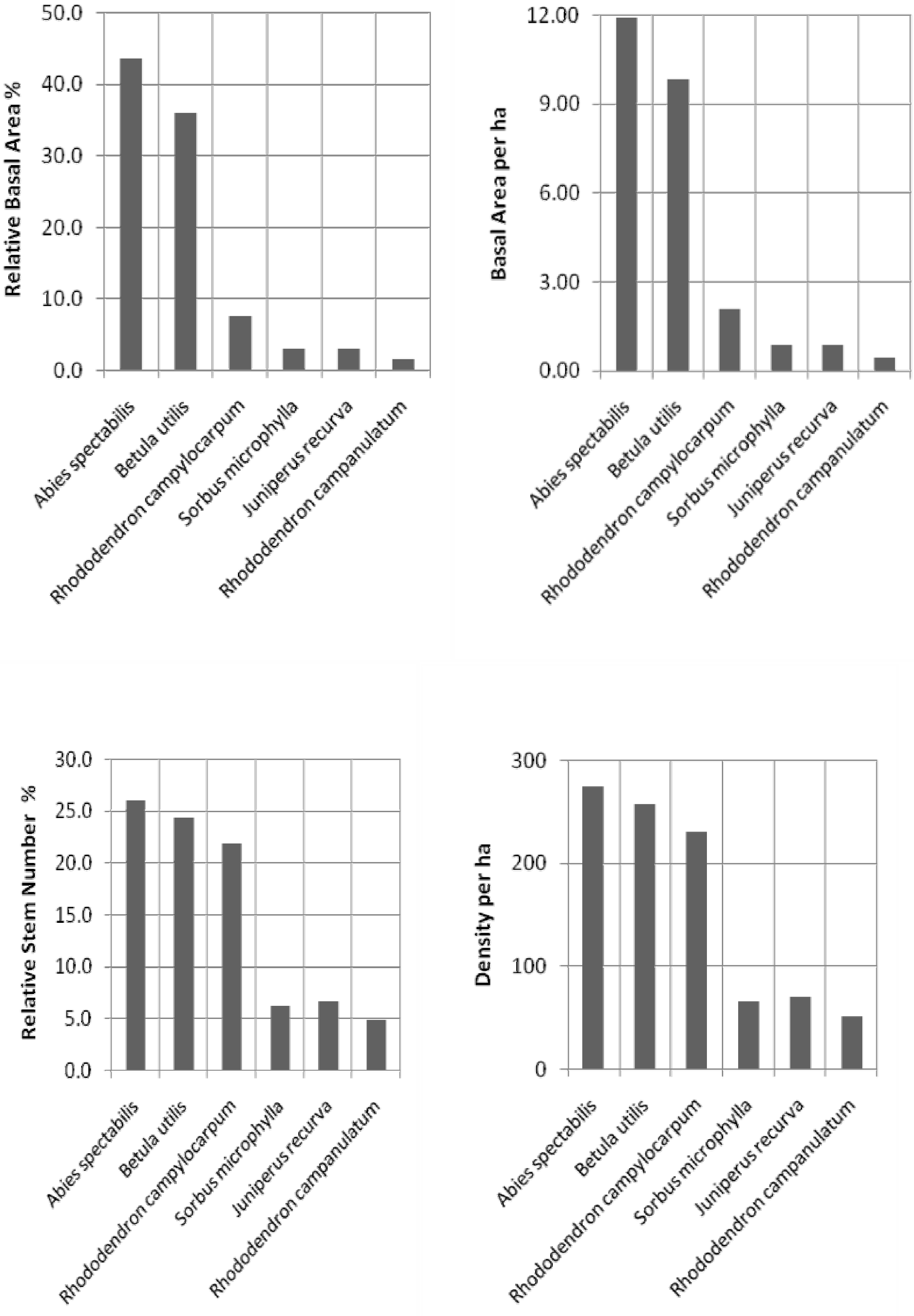

Figure 24: Structural characters of major tree species in the Sagarmatha National Park, Nepal

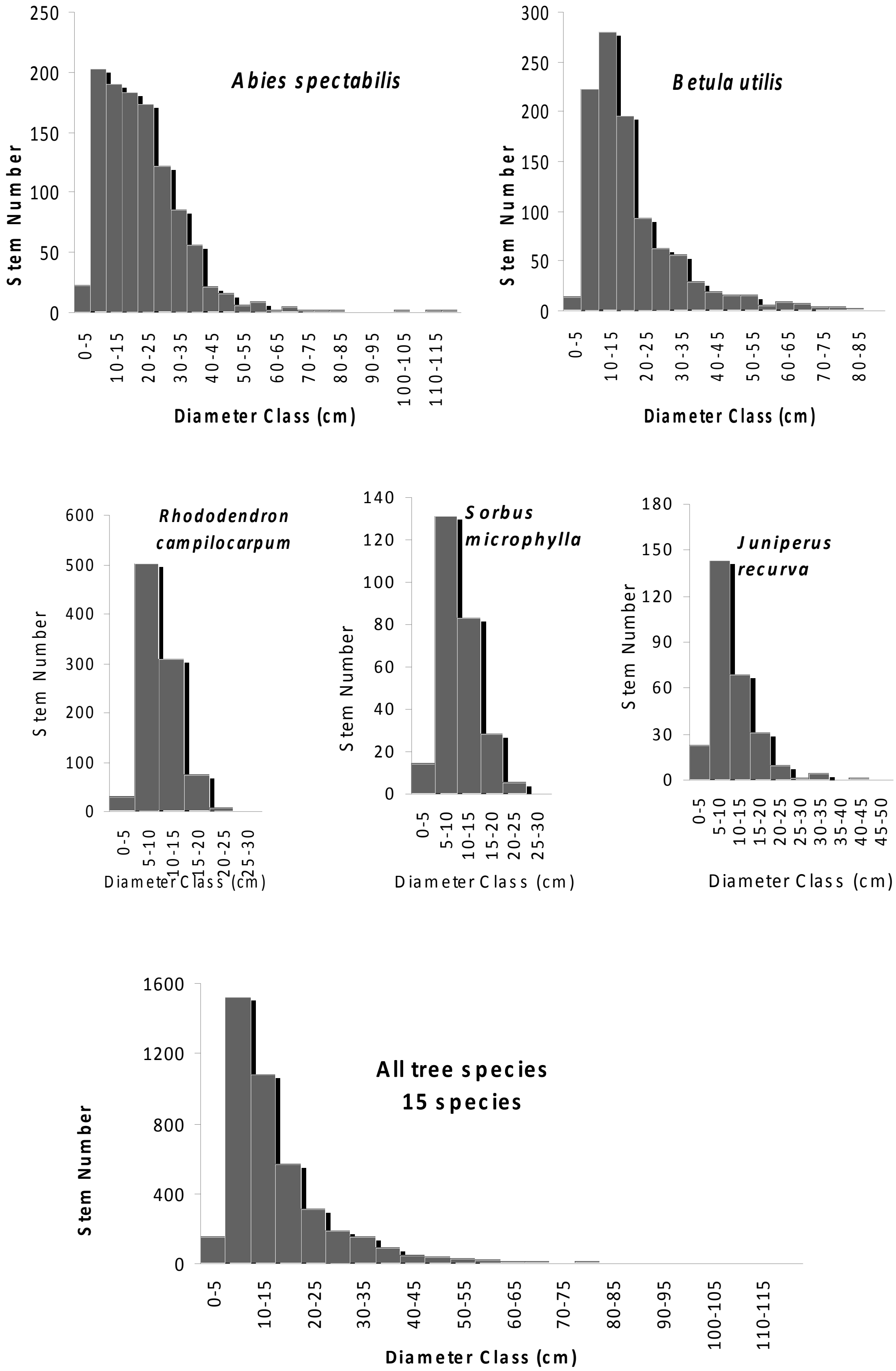

Figure 25: Diameter class distribution of major tree species in the Sagarmatha National Park, Nepal

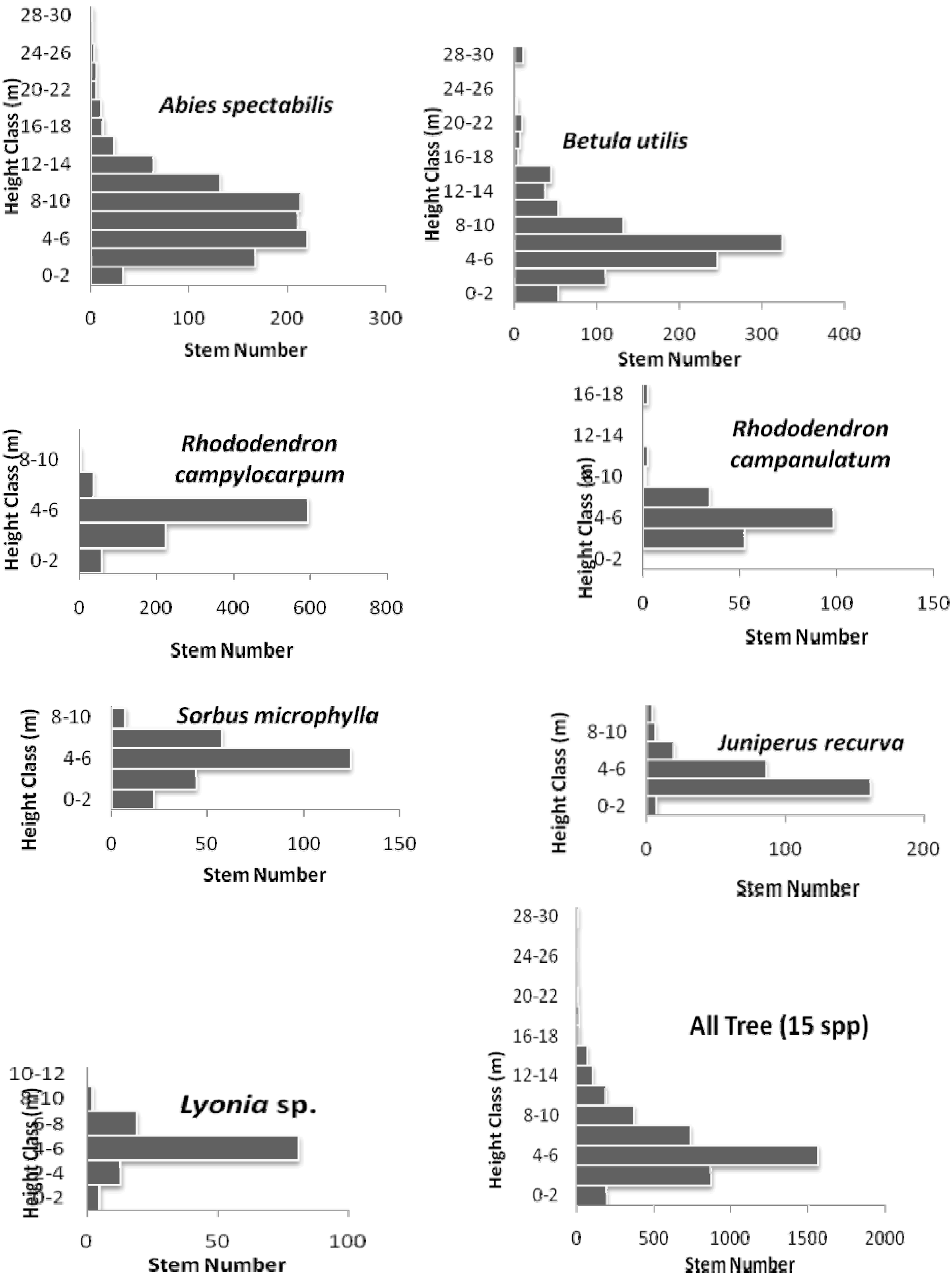

Figure 26: Height class distribution of major tree species in the Sagarmatha National Park, Nepal

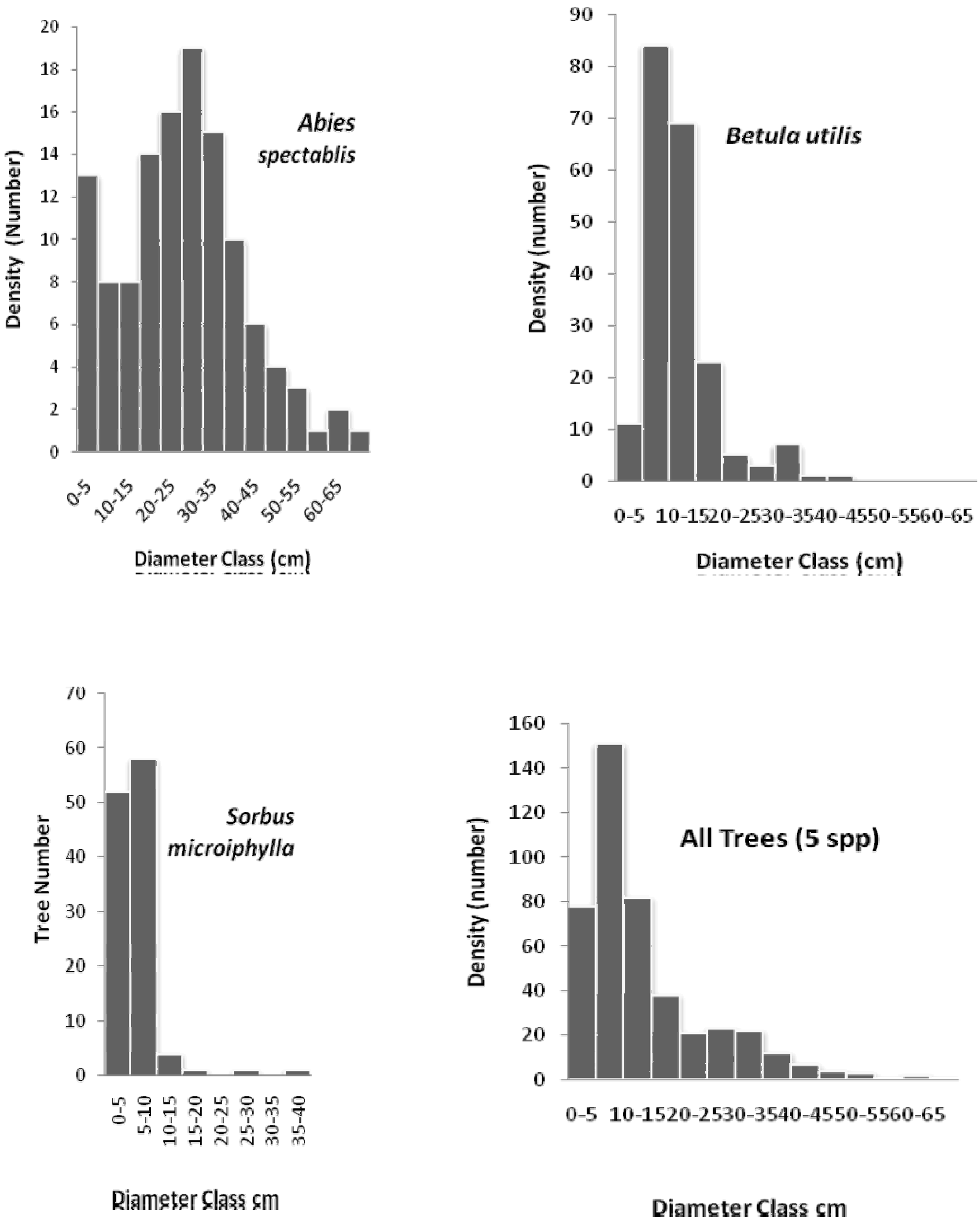

Figure 27: Diameter class distribution of major tree species in Panboche Yaren (Permanent Plot, Sagarmatha National Park, Nepal)

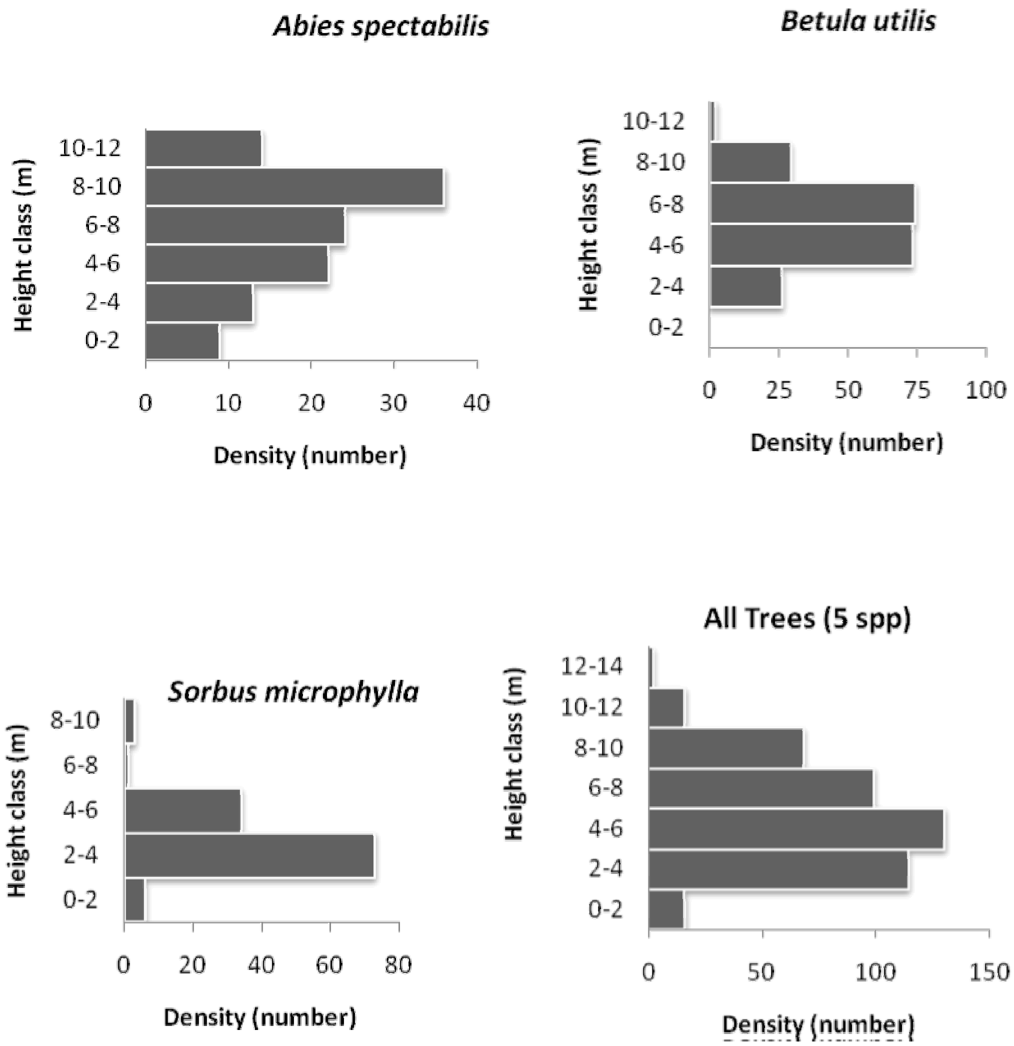

Figure 28: Height class distribution of major tree species in Panboche Yaren (Permanent Plot, Sagarmatha National Park, Nepal)

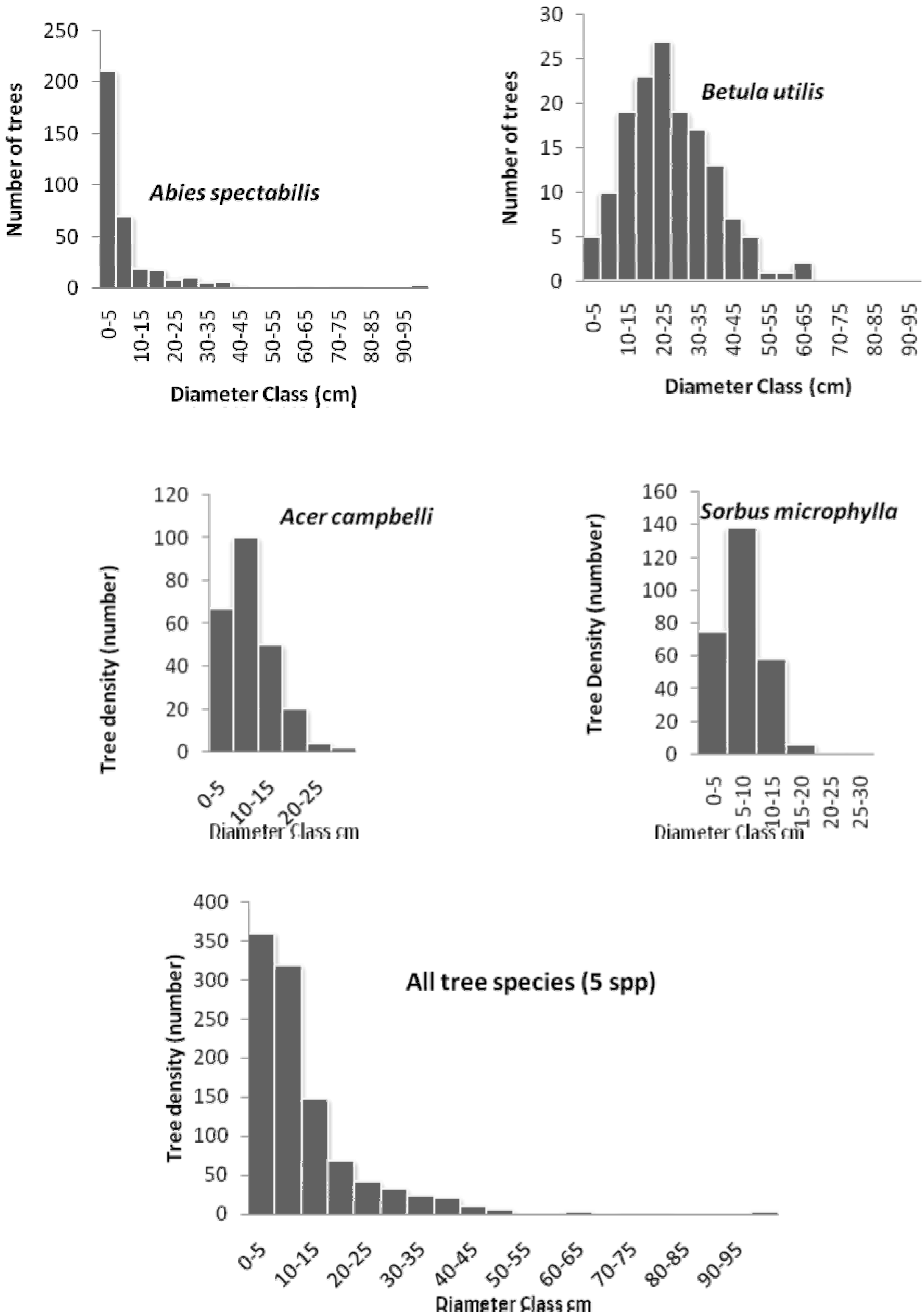

Figure 29: Diameter class distribution of major tree species in Debuche (Permanent Plot, Sagarmatha National Park)

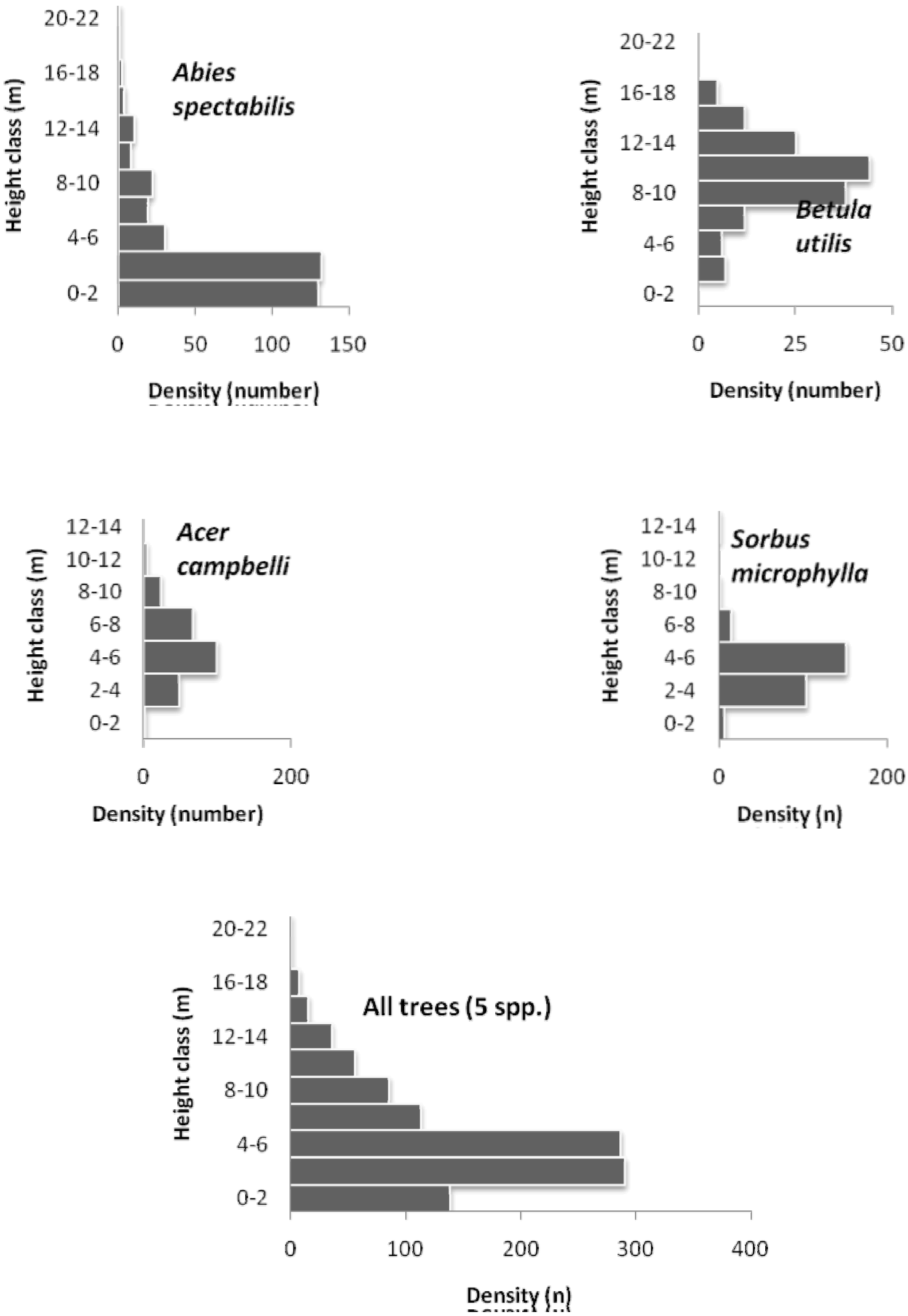

Figure 30: Height class distribution of major tree species in Debuche (Permanent plot, Sagarmatha National Park, Nepal)

4.7 Discussion

4.7.1 Structural Characteristics and Disturbance Regime

In his study in eastern Himalaya, Yoda (1967) described L-shaped (inverse J) distribution of forest diversity (tree species), e.g. stands, consisting of one dominent species (Pinus plot) characterized by vigorous and continuous regeneration of a stable structure under steady influence by man and livestock. Abies stands showed the convex type of DBH distribution: a well-closed canopy layer at an intermediate height associated with scattered big emergent trees and poorly developed understoreys. It was suggested that a sort of periodic regeneration of the forests caused by certain catastrophic events resulted in this particular pattern.

In the study of ecology and vegetation of eastern Nepal, Ohsawa (1983) reported two types of Abies forests, 1) even-aged forests developed on alluvial fans or river beds, and 2) mixed forests with deciduous species such as *Acer* spp, *Betula utilis* and *Sorbus cuspidata*. In an even aged forests of *A. spectabilis*, uprooting or wind break of aged trees are very common. The uprooting trees had very shallow rooting. Death of aged *Abies* occurred mainly as falling due to heavy winds. On the ground layer of such wind broken *Abies*, many young saplings were regenerating. The Diameter distribution class of *Abies* is a bimodal type, reflecting the flush of young trees in the gaps. At the periphery of the gaps, many deciduous trees such as *Sorbus* spp, *Betula utilis* are growing up. Under the closed canopy, *Rhododendron hodgsonii*, a tall shrub species, reaching 3m in height, is composing the shrub layer. The association of *A. spectabilis* with *R. hodgso*nii is very common in the Abies zone.

In montane evergreen broad-leaved forest (alt. range 1,000-3,000 m asl) in the Bhutanese Himalayas, Ohsawa (1991) discovered three types of diameter class frequency for canopy species: emergent, sporadic and inverse J-types. The emergent species grow fast, overtop others and are of even-aged population, e.g. *Betula alnoides*. The sporadic are of various age invading at different types, e.g. *Quercus* spp, *Schima wallichii*. The inverse J-type has many populations in small diameter size showing good regeneration, e.g. *Castanopsis tribuloides*. Similarly, in the dry valleys of the Bhutanese Himalaya, Wangda and Ohsawa (2006) described three upper conifer species of *Abies densa*, *Tsuga dumosa* and *Juniperus recurv. The study* revealed only two types of regeneration (uni-modal and sporadic) showing high stem density at large diameter classes.

The present study observes inverse J-distribution patterns of forests. However, looking at single species, sporadic distribution or gaps between the diameter classes were seen which fit the gaps left behind by cut stumps that were recorded in the sampling plots. It is assumed that the human activity, such as tree cutting for fuel-wood, is largely responsible for this pattern.

Various researchers such as Bjonness (1980), Byers (1987, 2004), Stevens (1993, 2003), Buffa *et al.* (1998) have been showing a serious concerned on human interference, specifically fuel wood collection, in SNP forests, for decades. It has been reported that Sherpas traditionally only burn dead wood (Bjonness 1983). This conservation practice, however, has been abandoned, as tourism became the main economic activities after 1950s. Before the ban on logging for fuel wood collection restrictions, imposed after the declaration of the Sagarmatha National Park in the late 1970s, it was common to fell trees for fresh branches for fuel wood (Stevens 1996). Just before this declaration, local people felled many trees to stockpile for future uses (personal comm. Mingma Sherpa 2007).

the present study finds the most prominent disturbance to be cut stumps, which occurred in 80% of the sampled plots. In the newly planted forested areas, some cut stumps could originate in management practices for thinning purpose. However, for many sites this could not have been the reason. In addition, signs of continued fuel wood collection were noticed in at least 70 sampled plots (66.7%). Grazing by livestock, mainly the yaks was also a prominently observed disturbance phenomenon in the studied plots.

Because of cold temperature and harsh environment, the plant growth rate in high altitudes is comparatively low. Thus, the regeneration is poor even in natural condition. When the anthropogenic activities such as indiscriminate cutting, lopping are not checked, the problem is compounded. The regeneration of forest vegetation in SNP is hindered by human interferences. The current practice of fuel-wood collection in restricted manner is positive in this direction.

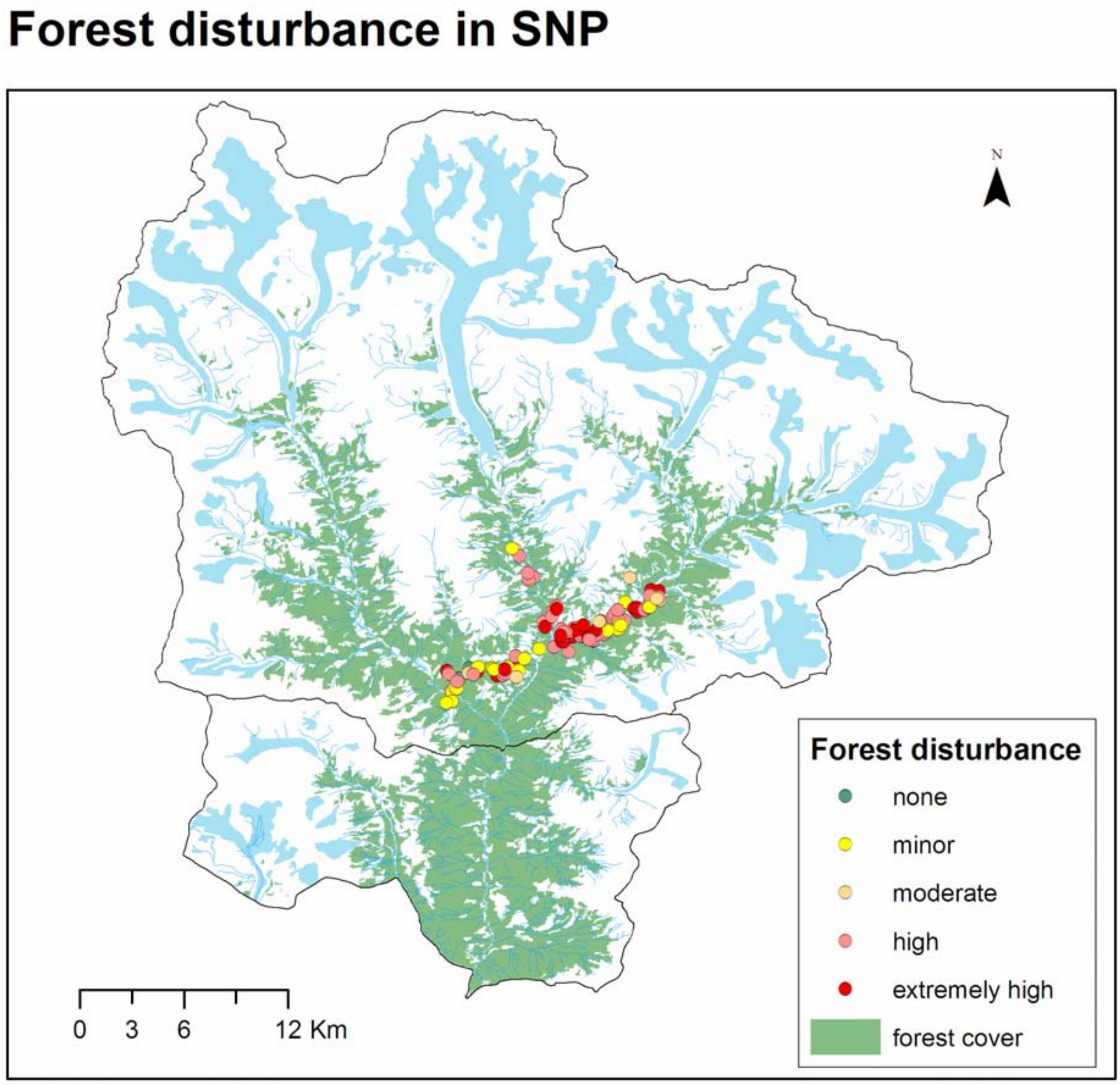

Figure 31: map showing intensity of anthropogenic forest disturbances in SNP

Forest disturbance in SNP

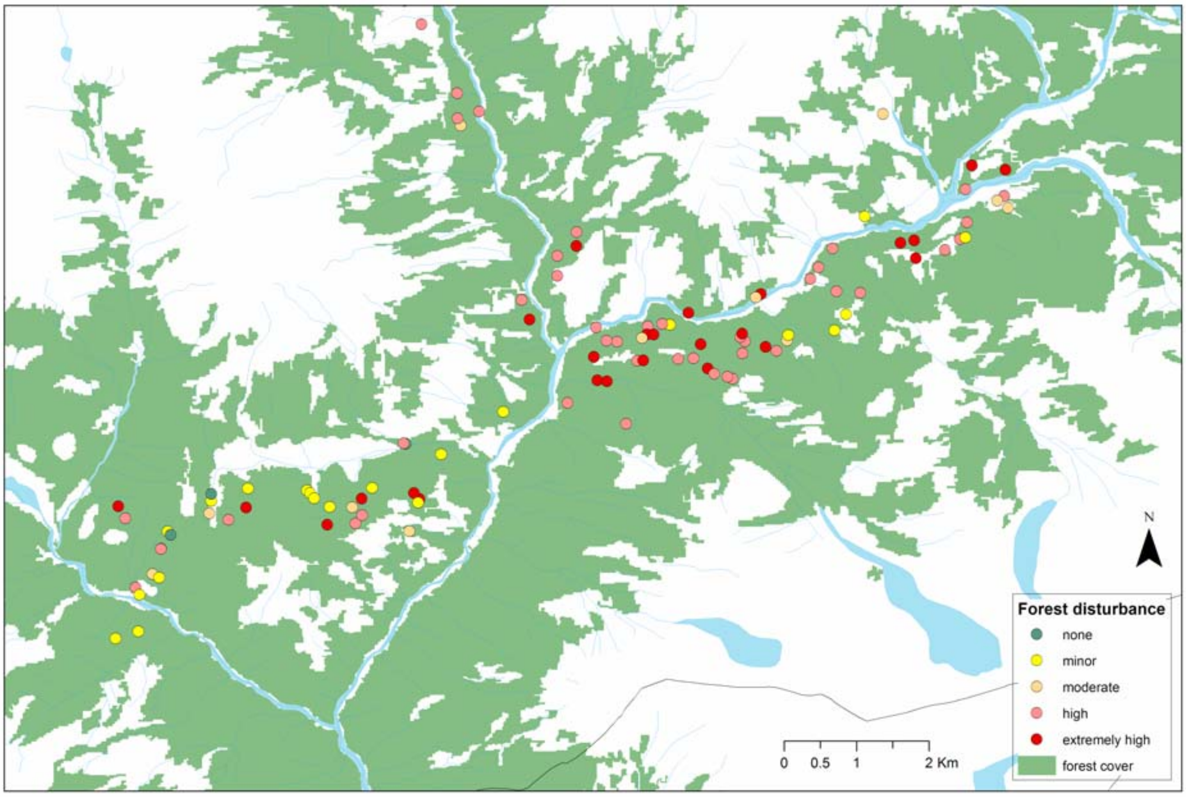

Figure 32: map-inlet showing the intensity of anthropogenic forest distubances in SNP

4.7.2 Age Structure

Overall, the recruitment and establishment of new individual trees has been very high during the last several decades. As shown in previous studies, climate can affect both tree recruitment and tree-line advance rates, however, relationships between tree-line shifts and climate change may be more complex. A tree-line ascent implies several consecutive processes: production of viable seeds, dispersal, availability of adequate regeneration sites, germination, seedling survival and the individual reaching adulthood. Climate variability affects all these sequential stages, but the same climatic variable can enhance one of these processes while inhibiting another one (Earle, 1993; Camarero & Gutiérrez, 2004). Furthermore, mature trees are affected only slightly by climatic changes as compared to seedling and saplings (Kullman, 1993). The remains of mature trees therefore are much more likely to be preserved and may be used to investigate the importance of climate in determining mortality patterns.

It has been concluded that a directional increase in temperature, as predicted by current global climate scenarios, will not result consequentially in an upslope expansion of forests growing at altitudinal tree-line (Camarero & Gutiérrez, 2004; Daniels & Veblen, 2004). Our results are very different from other studies on alpine tree-lines which have documented an altitudinal shift during the first half of the twentieth century followed by tree-density increases within the ecotone during the last decades (Rochefort *et al*., 1994; Szeicz & MacDonald, 1995; Camarero & Gutiérrez, 2004). Our results are similar to the very few studies that have shown that upward shifts in treelines have ceased since the 1950s, or earlier in certain regions, because climate stress and disturbance increasingly affect trees and ground cover (Kullman, 1996, 1998).

Some tree-line individuals can persist for decades to centuries during harsh climatic periods and respond with an accelerated vertical growth in response to improved climatic conditions (Camarero & Gutiérrez, 2004). If the climatic threshold is surpassed due to an extreme climatic event (such as severe frost or intense warming), unexpected treeline shifts could result (Kullman, 1990; Camarero & Gutiérrez, 2004).

The impact of climatic variability is imprinted on the tree rings; however, it will need more samplings from several sites for accurate confirmation and calculation. Tree-line shift is also expected due to global warming in SNP. The present study has set up permanent plots and collected data for baseline information. This will serve as reference for the future studies to analyze and calculate such shifts.

4.7.3 Biomass

Yoda (1967) carried out an ecological survey in eastern Himalaya in 1963. A destructive method (cutting of sample trees) was followed for biomass estimation and tree biomass was obtained using the allometric relations (Ogawa 1965). He found an average biomass of 330.3 t ha^{-1} for Abies forest. The biomass of *Abies spectabilis* at lower altitude (3,120m asl) was 336 t ha^{-1} and higher altitude (3,680m asl) was 111 t ha^{-1}. In another calculation by Haripriya (2000) for Indian forests, biomass totaled 142.5 Mg ha^{-1} for *Abies* species.

In the Himalayas, there is decline in species richness, tree density, basal area and primary productivity with increasing altitude (Singh & Singh, 1992; Carpenter, 2001). This attributed to harsh environmental condition of high altitudes, such freezing temperature, snow fall etc.

4.8 Management options

4.8.1 Patrolling (evaluation of this option in the model possible)

The Sherpa people have a traditional resource-management system called shiggi nawa. The nawa system is a system of forest guardians, traditionally responsible for controlling use of forest resources at settlement level. Some Sherpa settlements like -Khumjung, Phangboche, Phortse have been protecting the forest for at least 150 years by this system and some of them are still following the same tradition.

The Nawa consist of four men who are selected by the villagers at a meeting called Nuchung, which is held every April. Duties of the selected people – the "nawas" - include patrolling of forest areas, prevention of greenwood cutting, protection of plantations and reporting on wildlife poaching. Nawas are authorized to prosecute and collect limited penalties from violators of the forest protection rules, and to use the fines for community purposes.

The system was formally abandoned after 1960, when the government nationalized the forests. After the declaration of SNP, game scouts employed by SNP management were deployed for patrolling. Consequently the system and its performance is weaking.

Considering the extreme topography of the area and the limited number of game scouts available to the park, the existing patrolling activities have a limited effect, so that incidents of poaching and illegal logging are still commonplace. A unified effort for patrolling, including all stakeholders of SNPBZ would help to improve the patrolling effectiveness in SNPBZ. It is suggested that a concerted effort is made including local people and BZ committee to design effective management system for forest protection integrating the traditionally existing Nawa system in the official protected area management system. Subsequently, the nawa and game scouts would have to be trained, motivated, and equipped with facilities such as GPS, radio/mobile telephone and basic mountain gears.

4.8.2 Monitoring Forest Condition

Regarding park management the national park and the buffer zone committee are predominantly carrying out administrative tasks. No research or monitoring of management relevant parameters is being carried out independently. This also applied to the condition of forests in SNPBZ. The HKKH Partnership project has set up two permanent plots for long-term study and monitoring, however, regular monitoring of the plots by local park staff has not been institutionalized. It is suggested to include monitoring activities in park and BZ programs. Also, it is suggested to continue the current policy to include SNP and Buffer Zone staff in research activities and establishment of monitoring schemes.

4.8.3 Educational Policy and Awareness

School teachers are instrumental in bringing about positive change in attitudes toward forest conservation and natural resource management. The existing school curriculum, however, covers the matter only vaguely and not in a specific way. Local schools should be encouraged to incorporate lessons relevant to local context. The teachers could be trained and students could take take part in regional or national level activities, such as science fairs etc. It is suggested that visiting scientists or researchers provide lessons or lectures on relevant subject related to conservation in SNPBZ. This could also provide an opportunity to discuss their work with local opinion makers and members of CBOs for important feedback.

4.8.4 Regulation of Grazing Patterns

Pastoralism is a major livelihood activity of local people in SNPBZ. Especially, yaks are used for transporting goods, meat, dairy products and manure. Sheep and goats are also a traditional component of local livestock rearing. However natural pastures and sources for fodder collection and cultivation are limited. The pressure on biodiversity and forest regeneration in SNPBZ is severely affected by livestock herding in SNPBZ. Drawing on the long experience of Sherpa people with pastoralism techniques, such as village- and valley-based agro-pastoral management systems aimed at protecting crops and pastoral resources through controlling grazing, new knowledge about grassland management should be synthesized with thess indigenous techniques.

4.8.5 Regulation for extraction of timber and fuelwood (evaluation of this option in the model possible)

Less than 5% of the Park and 15% of the Buffer Zone is forested area. The low percentage of forest cover, slow growth rates at high altitudes and high firewood and timber demand due to an extensive tourism industry and harsh winters as well as a lack of alternative energy sources, render forests in SNPBZ a priority ecosystem for conservation efforts. Most probably the demand for fuelwood and timber exceeds the productive capacity of the forests by far.

Tourism’s most serious environmental impacts are associated with the degradation of forests and alpine shrub land due to heightened demand for timber for lodge construction and fuel wood for cooking and heating. The suitability for construction and as fuel differs between different types of wood. Consequently, not all forest types are subject to the same amount of pressure through harvesting. From the main types - juniper, birch and rhododendrons forests - juniper shrubs at high altitude are particularly endangered, due to their slow reproductive rate and suitability as fuelwood.

A long-term goal of SNP forest-management is to intensify the production of timber and fuelwood in the Buffer Zone in order to initiate an export of surplus forest resources to meet the park population’s need to prevent over-exploitation of forest resources within the park boundaries. the idea is that the park people will "buy" the products or harvesting rights from the Buffer Zone rather than harvesting resources themselves in the park.

In practice, there is still a long way to go for this goal to be achieved. Although this exchange is happening to a limited amount, no actual "permit-system" is in place in SNPBZ, that would clealy determine amounts for fuelwood and timber to be legally harvested in the park per time unit, based on solid data about forest production and biodiversity or condition of the forests.

Currently the forest area in the Park falls under the management responsibility of SNP, whereas different legislations apply to the forests of SNPBZ. Areas declared as “Buffer Zone forest” are directly managed by the park. “Buffer private forests” can be managed by the owner without limitations as long as products are not sold outside the Buffer Zone or park. “Buffer religious forests” are managed by religious communities and resources are restricted to be used for religious purposes. “Buffer community forests” are managed by forest user groups under the supervision of the park.

The regulation currently in place and supervised by the forest user groups and park allows every households in the park and Buffer Zone to collect fuelwood twice a year for a period of 15 days through maximum 2 people per household (An exception of this rule is the settlement Phakding, where the bi-annual fuelwood collection periods are 30 days). This way a maximum amount of 60 “Baris” (summing up to 1200kg at 50kg per Bari) can be collected per household in the overall thirty day-long collection period per year. The amount corresponds to a daily collection amount per household of 100kg (50 kg per person) during the collection period or a daily average of 3.3 kg per day per household. The forest areas in park and Buffer Zone designated for fuelwood collection are defined by the park and forest user groups according to a rotational system. Unlike timber, which is almost completely imported from outside, the amount of fuelwood imported into SNPBZ is negligible.

Depletion of forest resources is a major management problem in SNPBZ. Collection of firewood for space heating by the local people is the biggest single contribution to the problem. Solutions are ultimately based on the provision of a suitable and affordable substitute. Extending the use of imported conventional energy sources (kerosene and LPG) or extend the reach of renewable sources (electricity from hydro-, wind-, solarenergy) are substitutes, however, the former are fossil energy sources. Their combustion process emits greenhouse gases in a non-sustainable way, which is problematic with regard to climate change. However, since 1999, the use of imported fossil energy sources has increased on the account of the use of firewood by 30%, but fuel wood is still the major sources of energy for SNPBZ, followed by dung. To explore opportunities to extend the substitution of fire wood, preferably by renewable energy source is one purpose of the energy management component. The resulting higher or lower overall fuelwood demand feeds into the forestry model and requires stricter or more liberal fuelwood regulations (increasing or decreasing the overall amount that can be legally collected per year) in order to relieve pressure on forests. Vice versa, the amount of fuelwood that can be legally collected in SNPBZ per year, feeds as fuelwood supply into the energy model, whereby it increases or decreases the need for substitution of wood by other energy sources.

In practice, Illegal fuelwood collection, cutting and logging is common in SNPBZ. So besides the extraction of forest resources as per park regulations, in practice, it has to be assumed that a substantial extraction amount is a dark figure. Fuelwood and timber extraction permits and patrolling are closely connected. Effective patrolling ultimately ensures compliance with the park regulations and thus provides the transparency required for the development of meaningful and appropriate park regulations. Furthermore, the two are interdependent, the more the regulations differ from the actual needs, the higher the incentive to engage in illegal activities and the higher the need for patrolling to enforce compliance. Of course the effect is inversed if the regulations is congruent with the actual need.

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5 Solid Waste Management

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Table 35: researchers involved in solid waste research

Kathmandu University was started in 1991. The University operates from its premises at Dhulikhel, Kathmandu and Bhaktapur, through its six schools: School of Management, School of Science, School of Engineering, School of Medical Sciences, School of Arts, and School of Education. Though young, the institute has managed to become a point of reference for young Nepalese, and offers a number of modern facilities and laboratories to analyze environmental issues. The University, that strongly supports fieldwork and applied research in national parks, is actively involved in the research activities of the HKKH Partnership Project.

CEPTE/KU is an energy research unit currently being formed under the School of Engineering, Kathmandu University, Nepal. CEPTE/KU concentrates on applied R&D activities and consultancy service in all components of power generation, transportation, operation and maintenance as well as development of end-use technology covering both supply-side and demand-side energy management.

DESE fulfills the need of highly competitive, skilled and trained manpower in the areas of research, development, impact assessments, standards monitoring, management, conservation, legal measures, policy formulation, implementation and other relevant environmental field. The department also pursues research relevant to local national, regional and global significance. Focus is also given to collaborative researches with national and international organizations and academic institutions

5.2 Introduction

A growing tourism industry stimulates the import of an ever increasing amount of modern consumer goods leaving behind largely non-renewable packaging, rendering waste management one of the key challenges of SNPBZ management, especially since visible pollution through littered solid waste directly affects the visitor's experience and consequently the prosperity of the tourism industry itself. However, solid waste is a major source of environmental pollution that affects the health condition of local people by contaminating soil and water resources.

Solid waste pollution is identified as a component problem of the whole ecological and environment complex which can be by immediate actions such as creating public awareness and cooperation, and proper long-term planning for the future development of ecotourism activities (Basnet 1992, 1993). Both technical and no technical solutions are needed to tackle this problem.

Considering the far-reaching environmental and economic impacts of the solid waste problem in SNPBZ, Kathmandu University has been entrusted to analyze the extent and nature of this problem in order to formulate management recommendations The study included the quantitative and qualitative characterization of the generated waste, its spatial distribution and environmental impact, the documentation and evaluation of existing waste management schemes and practices and the identification and recommendation of appropriate management options.

5.3 Background

Although the history of tourism in SNPBZ dates back to about 50 years, publications about the solid waste problem did not appear before the 1980s. At this time all the trekking routes and the camping places between Namche (3,440m) and Everest Base Camp were littered with waste (Basnet, 1984), so that the tourist route from Lamosangu to Namche was nicknamed "garbage trail".

A few years later, in 1984, the Ministry of tourism reacted in cooperation with the Police Mountaineering and Adventure Foundation and the Trekking Agents, Association of Nepal by undertakinbg a cleaning campaign along the Sagarmatha trail and the Everest base camp area. This campaign was followed by many other national and international programs in the following years Keeping Everest clean by means of clean-up campaigns will remain an important task, however, given the extent and dynamic of the problem, the need for a more sustainable approach, a "management scheme", became clear. Following the negative news coverage in the early 1990s that defamed the park, His Holiness Rimpoche to Tengboche, Ngawang Tenzing Jangpo, took initiative of mobilizing the local people to clean up their backyards. The initiative lead to the foundation of the national non-governmental and non-profit organization „Sagarmatha Pollution Control Committee" (SPCC) (TRPAP, 2003) – which was formed with the support of WWF Nepal Program and the mandate to establish and run a solid waste management scheme, which has effectively introduced a waste collection, and partly disposal system in key settlements with limited resources. SPCC is supported by Ministry of culture, Tourism and Civil Aviation and the WWF-Nepal Programme and legally registered with the Government of Nepal under the District Administration Office in Solukhumbu and the Social Welfare Council (SPCC, 2006).

SNP provides a very special scenario as most environmental problems are excarbated due to high tourist influx in the area and the growing tourism economy. The existing management system is limited compared to the fast growing waste accumulation. A detailed scientific study to support the SNPBZ management planning process is necessary.

5.4 Methods

5.4.1 Survey

A unified standard questionnaire was for energy and solid waste developed and improvised through consultation with the stakeholders within HKKH Partnership project. These questionnaires were administered in all the households where quantification was done. All together 190 questionnaires were administered

A random 15% households were sampled for quantification and questionnaires. Households in each community were categorized into residential, institutional and commercial and sample numbers were estimated proportionately. Institutions included schools, hospitals, local offices and monasteries. The commercial installations, hotels and lodges were classified according to their size viz small, medium and large. A classified random sampling technique was applied to include all these types of households in the sampling. Rapid appraisal was also done whenever standard questionnaire was not possible to use. Any additional information important for the study was also collected.

The strategy of coverage of the study area was established based on the major settlements in the SNPBZ. Therefore major trekking routes that pass from major settlements including Everest Base Camp (EBC) were selected for the study. Altogether two field visits were conducted to cover SNPBZ area. Settlements along the route Lukla-Namche-Thame and Lukla-Namche-Pheriche-Dingboche-Chhukum were covered on the first field trip on autumn 2007. Likewise settlements along the route Lukla-Namche-Everest Base Camp-Gokyo were covered during spring 2008 second field trip. Total major 35 settlements of SNPBZ were covered during these field trips.

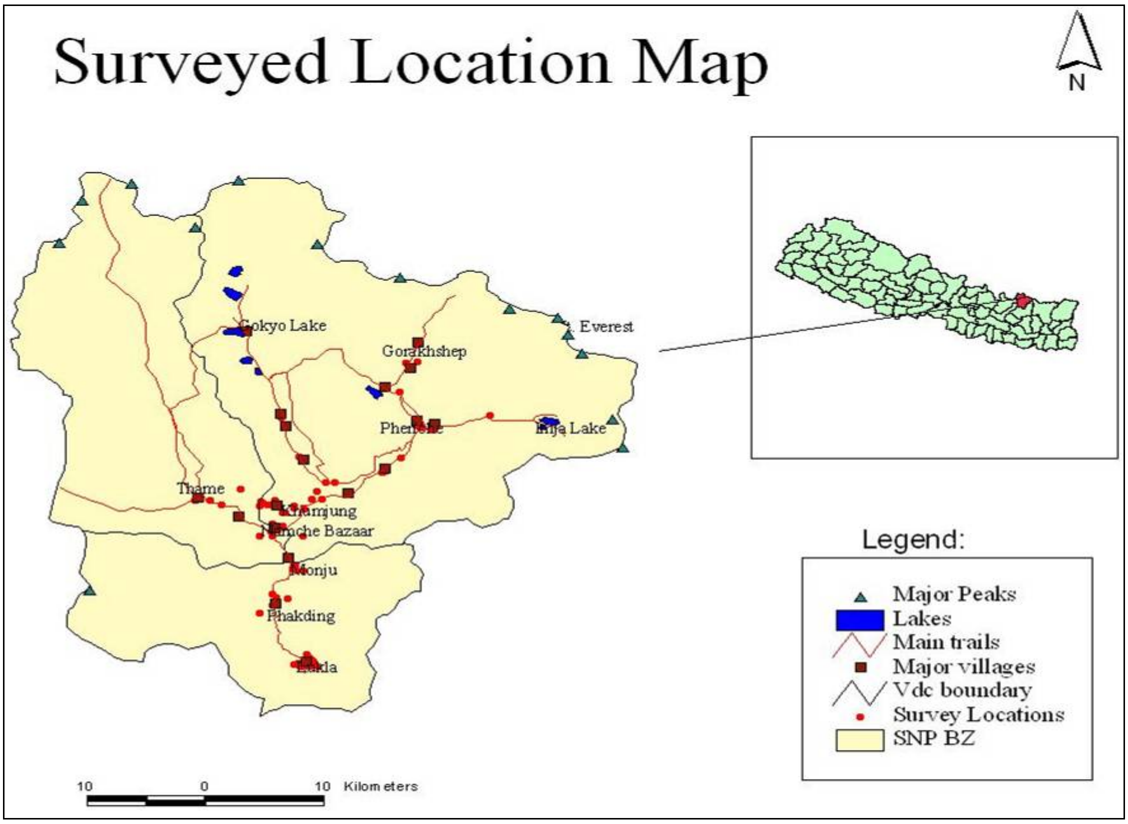

Figure 33: Study locations

Date	Activities
March, 2007	Simile training at ICIMOD
July, 2007	Contract signing
August, 2007	Conceptualization of the methods including C-map Development of questionnaires
September, 2007	First field visit
October, 2007-April, 2008	Submission of field report Data input and analysis Sample analysis Data Gap Analysis (DGA) Interaction meetings, trainings and workshops Submission of the proposal for the training/workshop Submission of proposals for environmental monitoring stations Finalization of C-map and Simile
May, 2008-June, 2008	Second field visit
July, 2008 - August, 2008	Data input and analysis Sample analysis Field report submission
November, 2008 - May, 2009	Third field visit for workshop Submission of third field report Management lever submission Decision Supporting Tool (DST) workshop Presentation in National Conference Presentation in NAST conference Final report preparation and submission

Table 36: Study duration and activities

Questionnaire

Q.No. Basic Information

GPS Point: Datum WGS84 N ……°…'……." E ….. °…….'….."
Altitude (m):
Location: Solar radiation : Wind velocity:

5. Identifying Household

Name of the Village/VDC/Ward no.	
Number	Household (HH) / Office / Institution / Business
Date of Interview	......./……./……. Time: (a.m./p.m.)
Name of interviewer	

6. Informant's background

1.	Age			
2.	Gender			
3.	Educational status			
4.	Occupation			
5.	Religion			
6.	Ethnic group			
7.	Family type (Valid only for HH)			
8.	How long your half yearly income can sustain your family expenditure (Valid only for HH)	> 12 months	> 6 months	> 3 months
9.	What is your main topic of yearly expenditure? Please rank them according to importance from 1 to 8	Topic		Rank
		Food		
		Fuel		
		Education		
		Cloths		
		If employer, salaries		
		Transport		
		Rent		
		Other		

(Gender) 1 = Male, 2 = Female	**(Educational status)** A = Illiterate B = Literate 1 – 9 = School 10 = SLC, 12= HSS, 14 = BSc, 16 =	**(Occupation)** 1 = Agriculture, 2 = Business 3 = Worker, 4 = Porter 5 = Teacher, 6 = Student 7 = Private	**(Religion)** 1=Hindus 2=Buddhist 3=Muslim 4=Christian 5=Others	**(Family type)** 1=Single

		MSc 17 = Phd		job, 8= Govt. job 9 = Tourist guide, 10 = Others		

7. **Family Size (Valid only for HH)**

Details of family members using the same kitchen			
Family member	Age/ Number		Occupation
Son	Below 16		
	Above 16		
Daughter	Below 16		
	Above 16		
	Below 30	Above 30	
Relative			
Father			
Mother			
Grandfather			
Grandmother			

8. **Information about Land**

10.	Do you have your own land?	Yes 01 No 02
11.	If "Yes" then please state your house hold and agricultural land status	

	Type of land		Hereditically owned land (valid only for HH)		Present market price of the land in NRs
	Homestead/Office/ Business				
	Agriculture				
	Garden				
	Others				
	Total owned land				

9. **Agricultural Information**

	Status of agricultural land	Increasing 01 Decreasing 02 Unchanged 03
	What are the main crops of this area? (Cropping variety)	
	Cropping intensity	Good(3 crop) 01 Moderate(2 crop) 02 Bad(1crop) 03
	Soil fertility	Increasing 01 Decreasing 02 Not yet all 03

10. **Utility Services** (Household / Office / Institution / Business)

11.

17.	Type of the toilet used by your family members	Flush type Open composting Closed composting Open pit Closed pit
18.	How far is it from the house	• In house • Outside house • Less than 50 meters • More than 50 meters
19.	Source of drinking water	River 01 Pond / Lake 02 Stream / Spring 03 Public tap 04 Private piped water 05 Other(Specify) 06
20.	How much of water in total do you use per day (in litres / Bucket / Gagri) Note: Interviewer should try to find out the breakdown the water use in percentage at later stage	Total Cooking / Drinking Washing Bathing Flushing For animal consumption For irrigation Other.....

SOLID WASTE (Household / Office / Business)

1. How many members ? If HH, how many customers, if shops, how many visitors, if office

Types	Number of member including workers	Number of visitors / customers per day / month
A. Lodge		
B. Household		
C. Shops		
D. Office		

2. Capacity: If lodge, A. Total number of rooms: ………………..
   B. Total number of beds……………………
3. What are the major environmental problems of this area?
   a. solid waste b. water pollution c .air pollution d. noise
   e. pollution e. land slide and erosion f. flood g. any other
4. Do you think the environmental image of your community is important?
   ☐ Very important ☐ Important ☐ Indifferent ☐ Not important
5. If environmental image of your community is important, why?
   a. It is important for living b. Tourist do like it c. both

6. Do you think garbage and waste management and collection are important issues in your community?

☐ Very important ☐ Important ☐ Indifferent ☐ Not important

7. How important is the waste management organization to your community?

☐ Very important ☐ Important ☐ Indifferent ☐ Not important

8. What are the organisations working in waste management in SNPBZ?

…………………………………………………………………………

9. How much solid waste normally you produce in a day?

a. < 1kg b. 1- 2 kg c. 2 – 5 kg d.5 – 10 kg e. > 10 kg

10. What you normally have in your solid waste / garbage and its quantity

Wastes	Qty	Wastes	Qty
a) Dust		b) Battery	
c) Organics		d) Clothes	
e) Plastics		f) Ceramics	
g) Glass		h) Ashes	
i) Paper		j) Rubber	
k) Aluminum		l) Cane	
m) Metal and tins		n) Any other	

11. Which kind of waste is being mostly produced at your home? Ranked them accordingly

☐ Kitchen waste ☐ Plastic ☐ Paper / burnable materials ☐ ☐

Cloths ☐ Glass materials Cane ☐ Others________________

12. Do you have idea about the reuse and recycle of solid waste?

☐ Yes ☐ No

13. How do you collect the waste generated from your house?

a. Plastic bins b. Metal bins c. Cartons d. Plastic bags

14. Do you segregate the waste generated in your house? If yes, how you do it?

☐ Yes ☐ No

15. What are the different items being used at your home?

☐ Plastic bottles and bags ☐ Papers/ Glass containers

☐ Others______________

16. How much reusable and recyclable solid waste is produced in your house in a day/ or month?

a. 5-8 kg b. 8-10 kg. c. 10-12 kg d. 12-15 e. More

17. Do someone come to purchase some of the waste? Yes ☐ No ☐
18. If yes, what and how much of waste you sold? ....
19. How do you dispose / treat the waste?
    a. Put yourself to community dump b. Compost
    c. Cattle feed c. Sell
    d. Burn e. Dump outside in the road
    f. In the container / specified place g. Bury in pit
    h. Door to door collection i. In open space
    j. In the river or river bank k. Others (specify)
20. Do you generate special waste like batteries, medical waste, etc? Yes ☐ No ☐
21. What do you do with these types of waste? ....
22. How far is the nearest disposing site?...
23. How many times do you dispose the waste?

☐ Daily ☐ In two days ☐ Three times in a Week ☐ Once a week
☐ More then a week

24. At what time do you dispose the waste?

☐ Early in the morning (4-6 AM) ☐ Morning (6-10 Am)
☐ Evening (5-7 PM) ☐ Night (After 7 PM)
☐ As and when convenient (specify time)

25. Who collects and takes the waste?

☐ Managed by Municipality, V.D.C or Ward ☐ personally managed
☐ Managed by private sector

26. How frequently is the waste collected?

☐ Daily ☐ Alternative days ☐ Twice a week
☐ Thrice a week ☐ Once a week

27. If a responsible organization fails to collect the waste in specified schedule, what do you do with waste?...
28. Do you have to pay any amount for such waste collection? If yes how much do you pay per month? If yes, how much?

☐ Yes, Rs……... ……. ☐ No

29. Are you satisfied with the fee you are paying? If no, how much fee you prefer?

☐ Yes ………………… ☐ No ……………………..

30. Do you know where does the solid waste finally get disposed off? If yes, specify the name of place. ………………………………………………………………
31. Does the order of the solid waste have affected your house?

☐ Yes ☐ No

32. Are you involved in any kind of cleaning activities? If yes, what kind of activities?

☐ Yes…………………… ☐ No

☐

33. Have you participated in any kind of solid waste management related program or training? If yes specify the name of organization.

    Yes………………… ☐ No

34. Do you have done something different on your own for solid waste management?

    ....

35. What is your suggestion for improvement of solid waste management?

    ………………………………………………………………………………

Two field visits were conducted, one in autumn 2007 and one in spring 2008. These field visits were done from 25th September till 15th October 2007 and 3rd May to 3rd June 2008, respectively. To carry out the following activities

Autumn 2007 field visit

- Household questionnaire survey from Lukla to Thame and Chhukung; total 25 settlements
- 7-days waste quantification at Namche
- 1-day waste quantification at different settlements during household questionnaire survey
- Hospital waste quantification
- Air, water and soil sampling from Namche
- Collection of dumping site information from different settlements

Spring 2008 field visit

- Household questionnaire survey from Lukla to Gokyo and the Everest Base Camp; total 32 settlements
- 7-days waste quantification at Lukla and Phakding
- 1-day waste quantification at different settlements during household questionnaire survey
- Hospital waste quantification
- Air, water and soil sampling from Lukla, Namche and Gokyo
- Collection of dumping site information from different settlements
- 7-days waste quantification

5.4.2 Waste quantification

Seven-days were devoted to waste quantification of different households within the following cateogires: residential, institutional and commercial to equal proportions. The solid waste categories for which the quantification was carried out is are: plastic, glass, metal and others. The “other”-category includes kitchen waste, paper, dust etc, essentially all waste that could not be assigned to one of the established waste categories. During the questionnaire survey, another day of waste quantification was carried out using the same as in 7-days waste quantification.

5.4.3 Dumping Site Environmental impact: Air, water and soil sampling

Air, water and soil sampling and analysis were carried out with standard techniques. Air samples were collected from waste burning sites for PM10 analysis. Water samples were collected from drinking water sources near waste dumping sites to assess the impact on dumping sites on water quality. Soil samples were also collected from the same dumping site to assess heavy metal contamination.

The water samples were taken from Namche Bazaar and analyzed for different chemical parameters. Description of locations and results of chemical analysis are shown below.

Location 1 (Water Sample 1)
GPS Location: 27^0 48' 0.86" N, 86^0 42' 48.2" E,
Altitude: 3427 ± 12 m

Location 2 (Water Sample 2)
GPS Location: 27^0 48' 0.83" N, 86^0 42' 48.2" E
Altitude: 3360 ± 20 m

These water sources (taps) are vulnerable to water contamination from solid waste since dumping pits are located and constructed above these water sources. Waste pollutants can easily mix with source of drinking waster during rainy season.

5.4.4 Dumping Site Survey: Measurement of Size and Volume

For some settlements, the number of dumping sites, along with the sites' size and volumes was collected

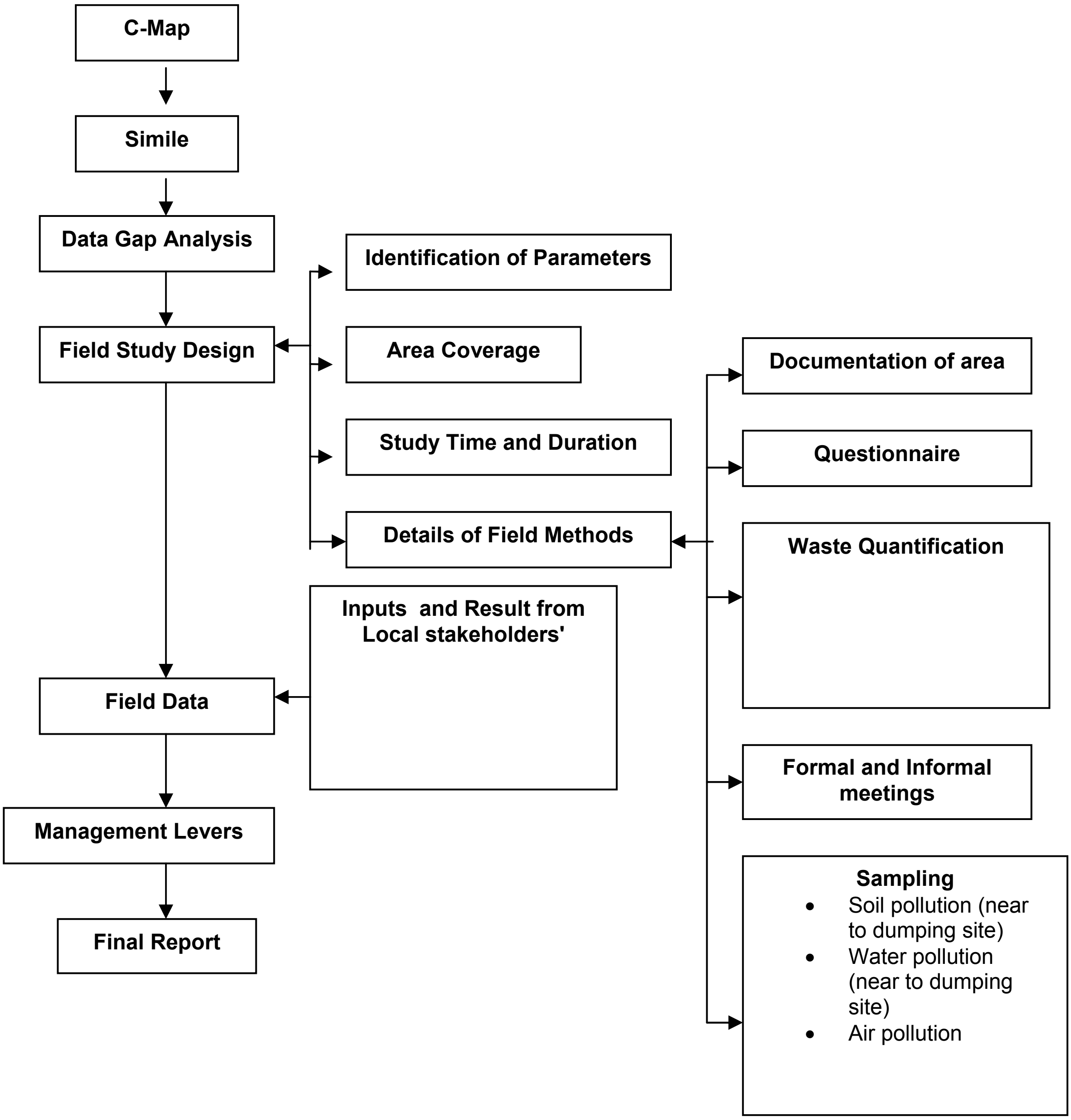

Figure 34: Diagram of study methodology

5.5 Data

Variables	Data Collected	Description
waste production data	Waste production (local)	Kgs of waste produced (divided in: plastic, glass, metal, other: "other" incorporates waste that does not fall into one of the categories) by each local person (inhabitants).
	Waste production (tourists)	Kgs of waste produced (divided in: plastic, glass, metal, other) by each tourist (trekkers and climbers).
waste treatment data	Local re-use	Percentage of waste re-used (for each type)
	Transported outside	Percentage of waste transported outside SNP (for each type)
	Burned waste	Percentage of burned waste (for each waste type)
	Buried waste	Percentage of buried waste (for each waste type)
	Incineration	Percentage of incinerated waste (for each waste type)
	Burning efficiency	Percentage of the waste mass that is lost in the burning process (for each waste type)
	Incineration efficiency	Percentage of the waste mass that is lost in the incineration process (for each waste type)
	ranking: suitability of disposal methods	rating: suitability of all disposal method ro each waste type
waste treatment coefficients	Percentage of each type of waste (glass, metal, plastic, plastic bottles) that is not disposed properly	Percentage of each type of waste that is assigned to the appropriate/optimal method (probability) according to ranking (variable SWp9a) = probability for one kg of waste to be disposed in the right way
	incineration efficiency	average incineration efficiency
	types of waste that can be incinerated	types of waste to that can (should) be burned in incinerators
	Specification of waste dumping pits	Location, volume and lifetime
Environmental assessment of disposal sites	Emissions	PM10
	Soil contamination	Heavy metal concentration
	Water contamination	Heavy metal concentration

Table 37:Overview of data collected

Settlement	Waste Composition in Percentage						
	Plastic	Glass	Metal	Others (Kitchen Waste, Paper, Dust and others)	Total HHs per settlement	Total Waste generation (kg per day)	PDPP (kg)
Lukla	4	36	2	57	153	500.98	0.16
Phakding	2	4	3	91	84	351.32	0.42
Ghat	3	11	1	85	16	24.53	0.13
Tok tok	1	7	2	90	29	51.55	0.13
Chaumo	2	3	0	95	29	65.19	0.32
Monjo	5	2	2	91	18	47.25	0.26
Namche	5	5	5	86	141	835.31	0.16
Tyangboche	11	0	2	87	11	59.52	0.09
Pangboche	7	0	1	92	44	150.57	0.49
Upper Pangboche	13	0	0	87	50	126.00	0.25
Pheriche	10	10	1	79	22	105.09	0.30
Dingboche	7	0	0	93	52	425.85	0.33
Thukla	7	0	0	93	1	9.70	0.32
Lobuche	8	0	0	91	7	32.05	0.24
Gorakhshep	7	0	1	92	6	25.98	0.17
Syangboche	4	0	0	96	5	30.00	0.40
Khunde	7	0	0	93	73	102.20	0.28
Khumjung	8	0	1	91	230	469.01	0.41
Phortse	3	0	0	97	84	303.66	0.30
Phortsethanga	7	0	0	92	6	27.63	0.42
Dole	4	0	0	96	10	60.55	0.28
Mochhermo	8	0	0	92	12	88.79	0.39
Gokyo	8	3	13	76	9	71.78	0.15
Kyangjuma	9	0	1	90	5	27.88	0.43
Sanasa	4	0	0	96	10	60.00	0.67
Lausasa	8	0	0	92	17	85.00	0.50
Phungithenga	20	0	0	80	4	6.00	0.50
Thamo	17	0	1	82	55	143.83	0.44
Thame	4	4	1	91	45	264.54	0.65
Thametenga	13	13	0	73	42	63.00	0.50
Total					1270	4614.74	

Table 38: Waste generation in different location at SNPBZ

S. No.	Name of Lodges and Restaurants	Total waste generation	Total person in seven days	Waste generation
		in seven days (kg)		/person/day in (kg)
1	Hotel Sherpa Village & Rest.	22.4	71	0.32
2	Sona Lodge & Restaurant	28.0	103	0.27
3	Sagarmatha Lodge	16.1	57	0.28
4	Jamling Guest House	56.5	179	0.32
5	Hotel Norling	45.1	170	0.27
6	Holiday Inn	29.5	84	0.35
7	Hotel Everest and Rest.	47.0	234	0.20
8	Hotel Namche & Restaurant	77.9	278	0.28
9	Hotel Sangrila	46.4	213	0.22
10	Hotel Tibet and Restaurant	42.7	115	0.37
11	Hotel Namche Inn	67.3	218	0.31
12	Hotel Moon Light	31.0	125	0.25
13	Kalapather Lodge	67.4	202	0.33
14	Himalayan Lodge	158.0	353	0.45
15	Thamserku View Lodge	53.3	174	0.31
16	Monk's Resident	3.3	19	0.17
17	Herman Bakery	12.8	21	0.61
18	Rastriya Banijya Bank	3.2	28	0.11
19	Himalayan Primary School	6.0	12	0.50
	Total waste generation	**814**	**2656**	**0.31**

Table 39: Result of seven days waste quantification at Namche Bazaar

SN	Name of lodges and others	Kitchen	Plastic	Can/Metal	Glass	Paper	Others	No. of person in seven days
1	Hotel Sherpa Village & Rest.	10.4	4.8	0.5	0.8	4.9	1.0	71
2	Sona Lodge & Rest.	19.5	3.9	1.0	0.6	2.3	0.7	103
3	Sagarmatha Lodge	9.4	1.4	1.0	0.6	0.8	0.7	57
4	Jamling Guest House	25.8	9.3	2.8	3.1	15.7		179
5	Hotel Norling	24.1	5.9	2.4	1.8	8.9	2.0	170
6	Holiday Inn	15.2	4.1	0.8	1.1	6.8	1.5	84
7	Hotel Everest and Rest.	30.0	4.8	2.5	1.1	10.8	1.5	234
8	Hotel Namche & Rest.	51.5	10.7	2.1	4.0	9.6		278
9	Hotel Sangrila	26.0	8.9	2.9	2.5	5.7	0.5	213
10	Hotel Tibet and Rest.	27.5	7.6	1.1	1.0	4.4	1.2	115
11	Hotel Namche Inn	39.5	9.1	1.5	0.6	13.0	3.6	218
12	Hotel Moon Light	16.7	6.6	0.8	0.3	6.0	1.5	125
13	Kalapather Lodge	40.0	12.0	2.0	0.5	11.4	1.5	202
14	Himalayan Lodge	81.0	42.8	8.9	21.9		3.6	353
15	Thamserku View Lodge	31.6	6.2	1.4		7.6	6.5	174
16	Monk's Resident	1.0	1.0		0.3		1.0	19

17	Herman Bakery	5.3	2.3			4.6	0.6	21
18	Rastriya Banijya Bank					3.2		28
19	Himalayan Primary School	5.0	0.2			0.8		12
	Total in seven days	**454.5**	**141.2**	**31.6**	**40.1**	**107.9**	**27.4**	**2656**
	waste per day	**64.9**	**20.2**	**4.5**	**5.7**	**15.4**	**3.9**	**114.6**
	Waste per capita per day	**0.17**	**0.05**	**0.01**	**0.02**	**0.04**	**0.01**	***0.31***

Table 40: Quantification of waste (kg) - per day per person according to different categories

Name of Place	**Status**			
	Number of pits	**Lifetime (yr)**	**Size (m)**	**Volume (m3)**
Lukla	2	1	5*4*3	60
Chaurikharka	2	1 & 13	5*4*3	60
Ghat	1	5	5*4*3	60
Phakding	2	2	5*4*3	60
Tok Tok	1	2		
Banker	1	5	5*4*3	60
Chhauma	1	2		
Monjo	1	1		
Jorsale	1	2		
Ukalo	1	1	2*2*1.5	6
Top Dara	1	1	2*2*1.5	6
Mislung(SPCC)	4		2*2*2	8
			4*4*3	48
Chor Camp Namche	2		5*4*3	60
Incinerator Namche	2		8*5*4	160
			4*2.5*1.2	12
			2*1.2*.05	0
			4*3.7*1	15
Tangboche	5	5	3*2*0.5	3
			4.5*4*1.75	32
Upper Pangboche			5*3*1.5	23
			3.5*3*0.8	8
Lower Pangboche	2	2	4.9*4.1*0.7	14
			3.5*3*1	11
Pheriche	2	3	4*4*1	16
Dingboche	5	3	3.5*3*2.5	26

			4.7*4.6*2.5	54
			3.7*3.6*2.5	33
			4.5*3.6*1.8	29
	2	2	4.6*3.4*1.5	23
Thukla	1	2	2*1*0.3	1
			3*2.3*0.5	3
			4.7*4.5*2	42
Lobhuche			4.7*4.5*2	42
			1.7*1.5*1.5	4
Gorakhshep (EBC rubbish pit)	2		10*4.7*2.6	122
			7.3*4.2*1.2	37
			4.2*2.5*1.2	13
Gorakhshep (Local Pits)	3		3.9*2.8*1	11
Phortse	1		4.7*4*1.5	28
Phortse Thangga	1		3*2*0.3	2
Mong Danda	1		5*3*1.5	23
Dole	1	2	4.5*2.5*1.4	16
Machhermo	1	1	5.2*4.2*2.8	61
Total	49	42		1292

Table 41: Size and number of existing pits in SNPBZ

5.6 Findings and Discussion

5.6.1 Waste generation in SNPBZ

The total amount of waste generated in SNPBZ per day amounts to 4614.74 kg. The per capita waste generation of tourist and local people is 0.123 kg/day and 0.109 kg/day respectively. However, since visitors spend on an average 10 days in the park per year, the actual yearly average for visitors is only 3-4 grams per day. The share of different components on the total solid waste produced are given in the Figure 3 and tabulated in Table 5 for entire SNPBZ and each settlement respectively.

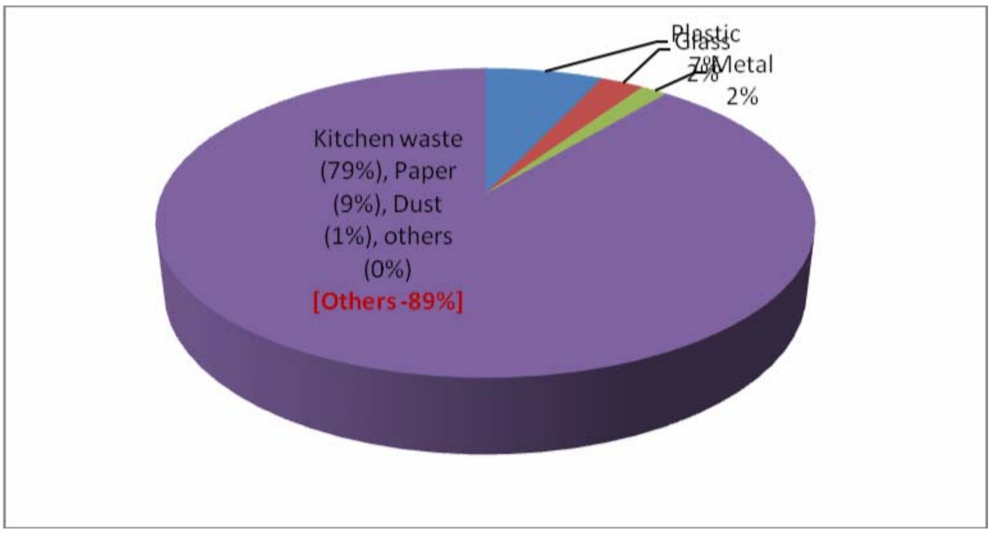

Figure 35: Different category of waste generation in SNPBZ

The by far highest amount “kitchen waste” is separated from other types of waste by people in SNPBZ to be used for cattle feeding or composting. paper accounts 9% of total waste. Kitchen waste, Paper and dust are categorized as “others”. These waste types are easily manageable. The major problem in terms of management is constituted by plastic, glass and metal, that constitue 7%, 2% and 2% of the total waste, respectively. Though the amounts generated compared to largely bio-degradable waste is low, these waste types have a high environmental and visual impact.

The waste generation in SNPBZ ranges from 0.23 to 0.62 kg per day per person (PDPP). However, in the major settlements waste generation ranges from 0.3 to 0.4 kg PDPP. Except for Mondays in Phakding, no specific temporal pattern of waste generation characteristics can be identified.

Lukla, Phakding and Namche are the major settlements of SNPBZ, located along the main route to Base camps, Gokyo and Thame. These settlements host a high number of hotels, and services enterprises. The daily per capita waste generation for all types of households in these settlements is high, particularly in the “hub” Namche Bazaar (see Table 6). Hospital waste is generated in low quantities but is highly the hazardeous. As a result, hospital waste should be subject to special treatment.

Types	Lukla	Phakding	Namche
Hotel	0.406	1.095	0.308
Bakery	0.017	-	0.098
Institute	0.002	-	0.010
Residence	0.118	0.041	0.099
Hospital	0.065	-	-
Shop	0.009	-	0.017
Restaurants		0.170	-

Table 42: Per day per person waste generation in different household in major settlements: Kg per day per person

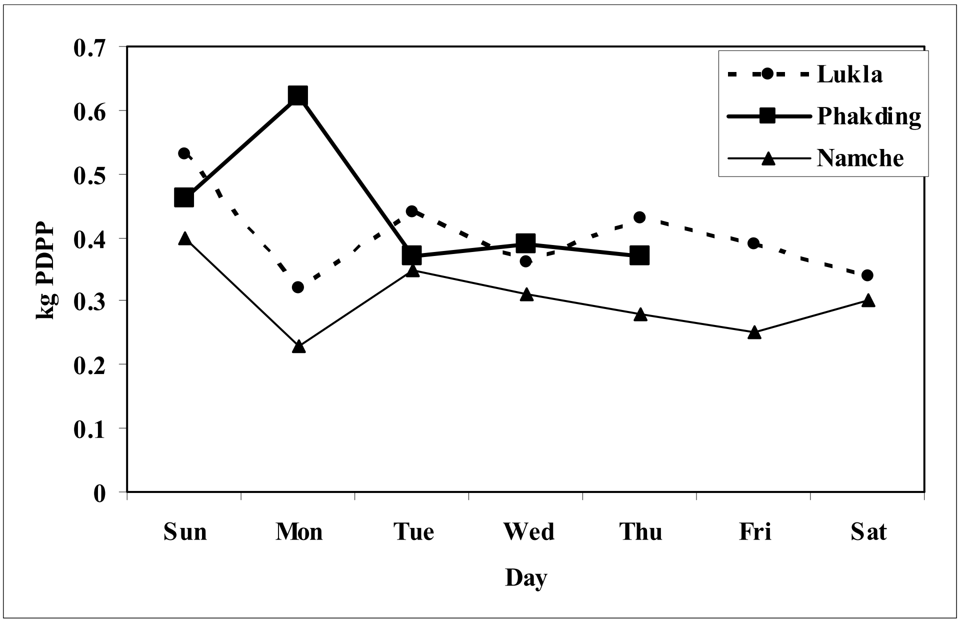

Figure 36: Daily variation of rate of waste generation (in kg PDPP) from lodges and hotels in major settlements

5.6.2 Waste Management (Collection, segregation and disposal)

The solid waste management system established by SPCC, which is currently in place in SPBZ, includes means for solid waste collection, through waste bins along trails, door-to-door waste collection and supervision and control of waste returns from expedition groups. For this work SPCC entertains a number of field staff, a field supervisor and a mountain inspector office. The office sends the collectors to the field on a daily basis for collection and disposal under the supervision of SPCCs field supervisor. The supervisor and the mountain inspection officer monitor and control the waste return from the expedition groups. The gas cylinders and batteries are shipped to Kathmandu for disposal. For this work SPCC has separate funds allocated. Annually, SPCC disposes a considerable amount of burnable and non-burnable waste produced collected in different places in entire Khumbu (SPCC, 2006)

Waste generated from the household is collected either by SPCC or managed by the households themselves. Door –to-door waste collection is carried out by SPCC staff in Lukla and Namche only. In the other settlements, the community collects the waste. Waste collection takes place along the trails by SPCC. Containers (waste bins) are maintained on the main trails, which are emtied periodically. The waste collected by SPCC is segregated in burnable and unburnable. Unburnable waste is dumped in pits whereas burnable waste is burned to reduce volume and weight in separate pits. However, the waste in these pits is often mixed. Dumping pits were constructed in all settlements of SNPBZ by SPCC.

The collected waste is segregated into burnable and non-burnable waste and subsequently openly burnt or buried in pits: ;etals, glass, batteries and inert materials are considered non burnable, whereas plastic, paper, cloth, wood and other organic matter is considered burnable. Additionally, SPCC facilitates collection and establishment of dumping pits for communities which are not part of SPCCs waste collection and disposal scheme (all settlements except Lukla and Namche). Gompas and residential areas have started to adopt the SPCCs collection practice through public waste bins. There are also some local initiatives for development of new pits

SPCCs work is supported by different regulations put in place by the government of Nepal. Glass bottles for beer and other soft drinks are banned from SNPBZ. Only cans are now permitted inside the park. Mountaineering expeditions have to take back all non-biodegradable materials. Expeditions and organized trekking groups are required to be self-sufficient regarding fuel consumption (Kerosene). Organized trekking groups, including support staff, are prohibited from using firewood inside the park boundaries. Furthermore, every expedition group has to obtain a garbage clearance certificate, issued by SPCC before entering and and leaving the park. organic waste is to be transported down to Gorakhshep it is dumped in pits.

Fiscal Year	**Burnable (all) (Kg)**	**Non-burnable (all) (Kg)**	**Expedition Team**					
			Burnable alone) (Kg)	**Bottle/Tin (Kg)**	**Empty L.P. Gas Cylinders (pcs)**	**EP-Gas bottles (pcs)**	**Empty O2 Gas Cylinder (pcs)**	**Used up batteries (pcs)**
2003/04	148886	55639	7075	NA	1	2446	773	4421
2004/05-2005/06	458051	124398	19412	4700	787	4587	833	8389
2006/07	160935	24141	10901	14193	NA	2051	1174	4359
2007/08	175718	45868	5003	45868	NA	2489	1540	3617

Table 43: Solid waste management figures from 2003/04 to 2007/08 in SNP (Source: SPCC (2003-2008))

Tourists and tourist associated activities are by far the major source of solid waste pollution in the Everest area.

Polluter	ranks	remarks
Mountaineers	1	Including porters and guides
Lodges and hotel	2	Associated with tourism
Trekker	3	Including porters and guides
Local people	4	Involved in subsistence agriculture
Other- e.g. officials	5	Small number

Table 44: Polluters and their rank (from highest to lowest) (Source: Basnet, 1984)

For every settlement tabulated in table Table 41 the number of existing dumping pits and its volume were collected. Since degradable waste is commonly used by households as fodder or for composting the waste in the pits consists predominantly of non-segregated non-degradable waste.

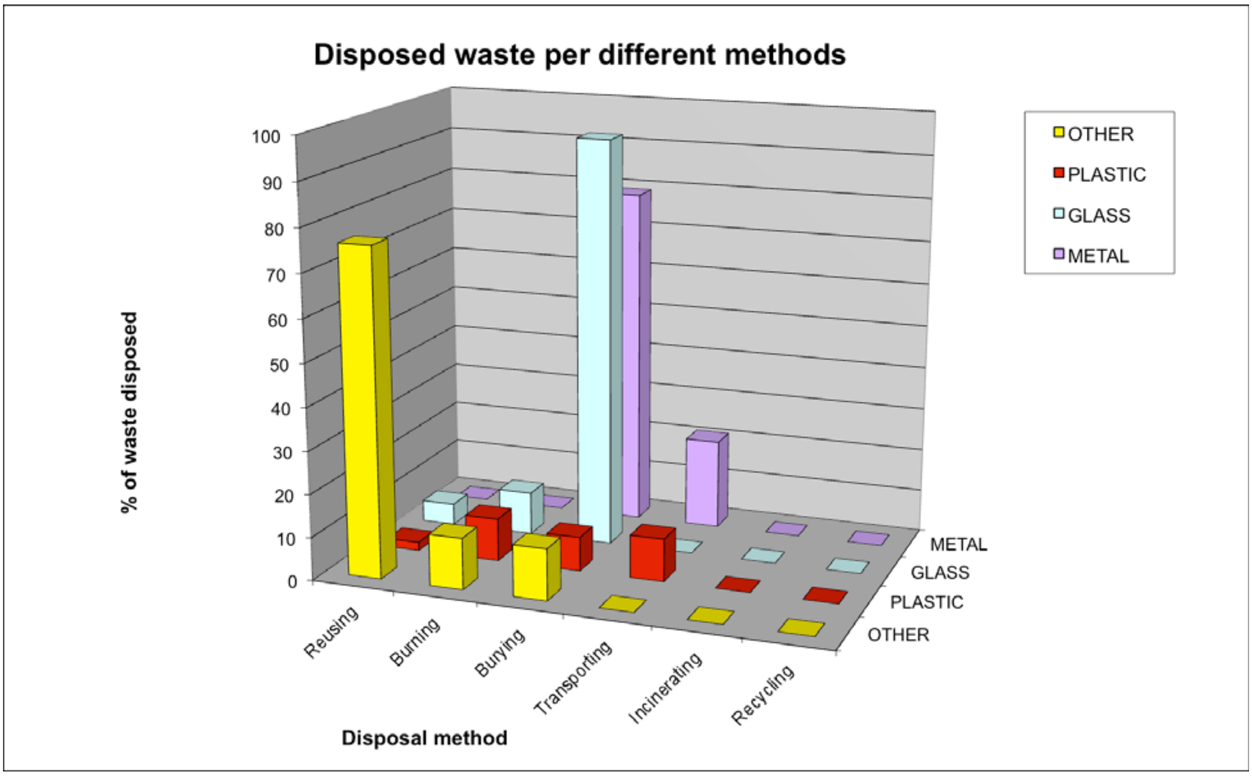

Figure 37: waste types disposed by different methods in SNPBZ according to the current practice

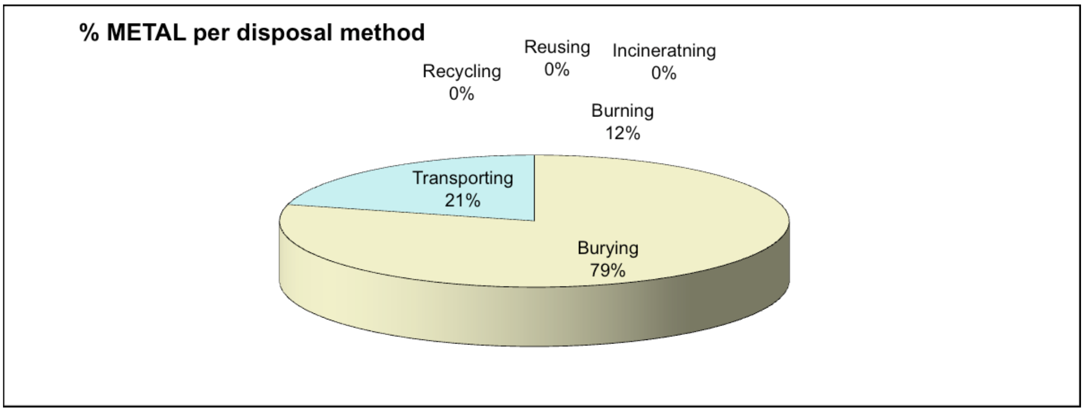

Figure 38: methods by which metal is disposed in SNPBZ according to the current practice

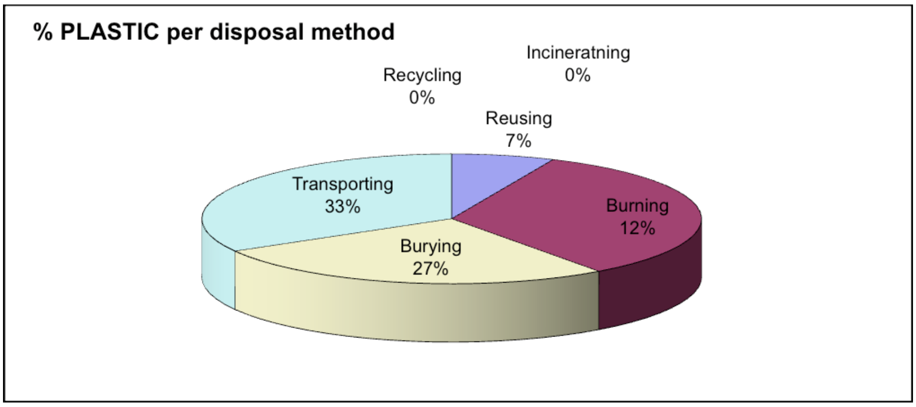

Figure 39: methods by which plastic is disposed in SNPBZ according to the current practice

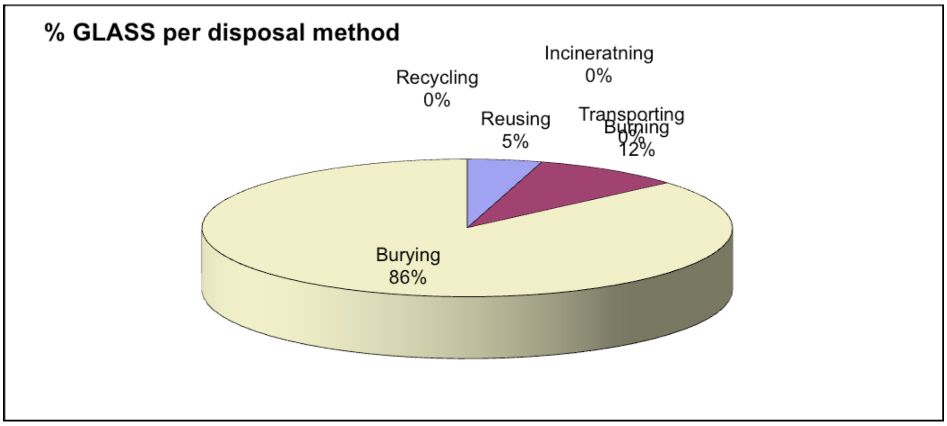

Figure 40: methods by which glass is disposed in SNPBZ according to the current practice

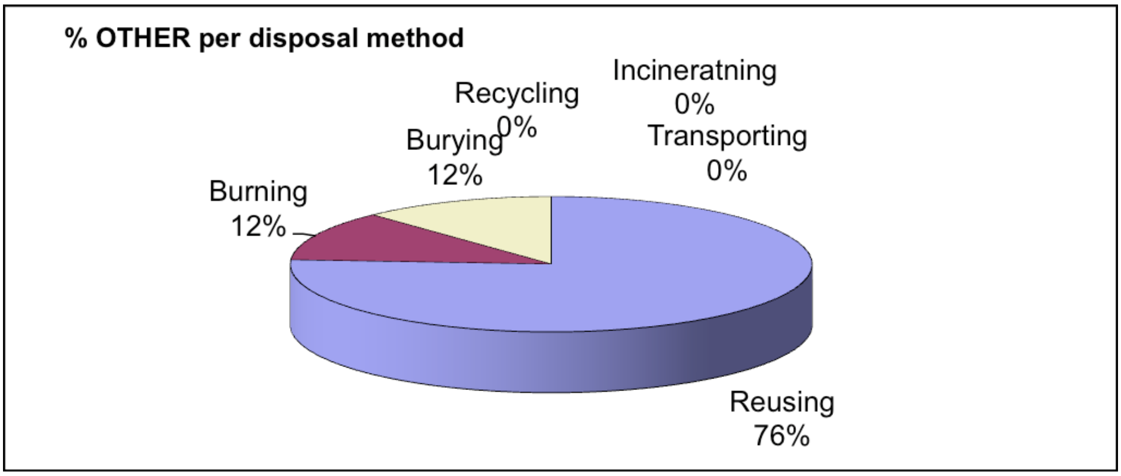

Figure 41: methods by which uncategorized waste (organic matter, paper, dust etc.) is disposed in SNPBZ according to the current practice

5.6.3 Burning/Incineration

burnable waste ccounts for around 16% of the total waste accumulated in SNPBZ. The common burning practices in SNPBZ is open burning in dumping pits, closed burning like in Namche and Khumjung and incineration in Lukla (this incinerator is not operating properly and serve currently as a closed burning system). Burning is a good option to reduce the volume and weight of waste, but has environmental impacts. The closed burning sites are not operated properly as metal and glass in burned ashes are not disposed properly; Harmful air pollutants are emitted; waste handlers are in hazardous condition etc. Lukla incinerator is the only running incinerator in the SNPBZ. Its installed incineration capacity would be about 30 kg/hr. Currently it produces 2.3 kg of ashes from 30 kg of waste.

5.6.4 Dumping

Settlements in the SNPBZ commonly feature several waste dumping sites. Some will be filled up and others are in use. Many sites are poorly managed:

- improper techniques of pit management
- waste is accessibly by and scattered through animals
- burnable, non-burnable and organic waste is mixed
- pits are prediodically set on fire iuncluding hazardous waste, such as batteries and drugs.

As a result:

- waste should be segregated before dumping
- the pits whoudl be covered to prevent access by animals
- pit construction should include proper lining to minimize the leachate
- sanitary landfill sites should be constructed for long-term disposal of medicinal waste as long as an appropriate incineration facility is unavailable

Improved construction, selections of sites and running of the pits and maintenance after filling are urgently needed. Since there is limited space around settlements, the pits are often established near trails, water bodies or agricultural fields; leachate from these pites results in contamination of soil and water.

Figure 42: A dumping pit in SNPBZ showing mixed waste and burning

5.6.5 Transportation (waste export)

A small share of the waste generated in SNPBZ is transported outside of park and Buffer Zone for disposal in other regions of Nepal or internationally. Due to a lack of facilities for recycling in SNPBZ whatsoever, recyclable waste: aluminum can, glass bottles, plastic, plastic bottles and metals should be shipped to locations that have such facilities, e.g. should be exported. However, while this is environmentally the most preferable solution for these types of waste, it is also the most expensive. At present mostly aluminum cans, but also some other economically viable items as plastics, other metals, glass etc are exported through scrap dealers on a private basis.

Beer bottles have sometimes been exported by helicopter with with support of government agencies, NGOs and INGOs. Since beer bottles are now banned, this should not be necessary anymore.

A growing tourism industry clearly leads to an increase in waste generation. Substantial amounts of noodle, chocolate and tobacco-product wrappings were found thrown by the rtrailside despite the collection campaigns of SPCC. This might be caused by an inadequate frequency of collection campaigns in other settlements (apart from Namche and Lukla) or by a lack of human resources and equipment of the waste managing organizations.

About 20 – 25% of metal and 50% of glass from Lukla and Namche are exported outside. The remaining metal and glass waste is buried in dumping pits

For example Rajendra Gurung who involved in recyclable waste transportation business sells 1 – 2.5 tons of aluminium cans and 25 tons of zinc per year. In SNPBZ, there are about 8 – 10 people involved in the recyclable waste transportation business who collect the waste from different settlements of SNPBZ and sell them outside of the area

Figure 43: Rajendra Gurung with bagage of aluminum can

5.6.6 Waste from mountaineering groups

Oxygen tanks, tents, beverage bottles, gas canisters, food packets, sleeping pads, ropes, batteries, paper and plastic are the major pollutants at the SNP base camps. To give an idea of the extent of this pollution, the mountaineering group's waste, recoreded by SPCC during two seasons is provided in Table 45.

SPCC has established regulations to manage wasete from mountaineering groups. Every expedition group must register their climbing permit and submit photocopies of their equipment and food list in the SPCC office at Namche before embarking on their expedition. After return of the expedition the groups are obliged to bring the waste according to the recorded supplied back to Namche, in separated bags. Kitchen waste is dumped in pits at Gorakhshep. Burnable waste is burned in situ and non-burnable waste has to be taken by the expedition group back to Kathmandu. Batteries and Epi gas cylinders have to be returned to the country of the group's origin.

Spring season 2007

Expedition groups	Climbing group	Paper/plastic (kg)	Ep gas (pcs.)	Battery (Pcs.)	Can/tin (Pcs.)	Bottle (Pcs.)	Human waste (kg)	Kitchen Waste (kg)
NAM peaks	490	1549	160	274	3227	272	-	-
Everest Peak and Pumari	22	153	30	117	18	9	285	145
Amadablam and others	287	947	678	852	57	32	-	-
Total	799	2649	868	1243	3302	313	285	145

Autumn season 2007								
Expendition group	Climbing group	Paper/plastic (kg)	Ep gas (pcs.)	Battery (Pcs.)	Can/tin (Pcs.)	Bottle (Pcs.)	Human waste	Kitchen Waste
NAM peaks	490	1549	160	274	3227	272	-	-
Everst Peak and Pumari	22	153	30	117	8	7	285	145
Amadablam and others	287	947	678	852	322	135	-	-
Total	799	2649	868	1243	3557	414	285	145

Table 45: Mountaineering waste generation in SNPBZ (Source: SPCC, 2007)

5.6.7 Environmental impact

Soil

Table 9 gives a brief overview of Soil quality of different locations at SNPBZ nearby dumping pits. Heavy metal residuals: Copper, Zinc, Cadmium and Nickel were analyzed and compared with the WHO standards. The concentration of Copper was found to be below the standard in all samples, but soil collected from Namche burning pit was higher than the standard value. Zinc was found to be above the standard value in most of the sampling locations, wheras the concentration of Cadmium and Nickel were everywhere below the WHO reference.

Soil environmental quality				
Sampling location	Cu(ppm)	Zn (ppm)	Cd (ppm)	Ni (ppm)
Lukla Dumping Pit	0.7948	**18.144**	0.073	9.058
Lukla Dumping Pit down	0.36	**3.42**	0.036	0.317
Lukla Incinerator	1.5416	**262.703**	0.085	0.555
Lukla near river bank	0.0674	**63.063**	0.128	0.313
Namche burning place	**5.4378**	**153.784**	1.268	0.549
Mislung	0.127	**39.573**	0.086	0.508
Monju	0.2886	**68.813**	0.097	0.994
Gorakhshep	0.0476	0.614	0.023	0.155
Gorakhshep pit local	0.0756	0.319	0.012	0.098
Tyangboche	0.007	0.719	0.006	0.271
Dingboche (lower pit)	0.064	1.151	0.024	0.351
Dingboche (Upper pit)	0.033	1.358	0.016	0.193
Lobuche	0.0502	**4.491**	0.025	0.438
Pangboche	0.058	**2.867**	0.023	0.233
Pheriche 1	0.0176	1.837	<0.003	0.123
Pheriche 2	0.0038	0.716	0.008	0.336
Thame dumping pit	0.0128	0.648	<0.003	0.202
Khumjung dumping pit	0.0694	1.231	<0.003	0.137
Mochharmo	0.0548	0.412	<0.003	<0.02
Pangboche upper	0.0716	1.164	0.004	0.342
Phortse	0.0794	**4.049**	0.008	0.255
Gokyo dumping pit	0.0224	**3.267**	0.014	<0.02
WHO Standard	0.1 - 2.5	0.2 - 2.0	20	3 - 1000

Table 46: Soil environmental quality in selected high-risk locations (locations in bold font indicate contamination by the respective heavy metals)

5.6.8 Water

Table 47 shows the overview of water quality (river) at different locations near waste dump sites at SNPBZ. Heavy metal concentrations: Lead, Nickel, Iron and Zinc were analyzed for water quality. The concentration of Lead and Iron was higher in the following sampling sites whereas Nickel and Zinc concentration were found to be below the reference value from the National Drinking Water Quality Standard for all sites

Sampling location	Lead mg/l	Nickel mg/L	Iron mg/L	Zinc mg/L
Lukla – near dumping pit near Hospital	**0.251**	0.016	0.605	0.105
Lukla- near dumping pit	**0.344**	**0.028**	0.327	0.12
Namche	**0.151**	0.014	0.339	0.06
Dole	**0.098**	0.01	0.216	0.031
Machherma	**0.074**	0.016	0.409	0.014
EBC 1 (Upstream)	**0.068**	**0.022**	**5.075**	0.054
Dingboche	**0.177**	0.013	**6.043**	0.044

Phericheche	**0.065**	0.01	1.647	0.055
Lobuche	**0.092**	0.018	**5.15**	0.037
EBC 2 (Downstream)	**0.091**	0.016	**8.922**	0.046
Gorakhshep	**0.128**	0.016	**14.431**	0.046
NDWQS*	0.01	**0.02***	0.3- 3.0	3.00

Table 47: Water quality of selected high-risk locations in SNPBZ, values in bold font are above the standard for drinking water (Source: NDWQS: National Drinking Water Quality Standard (2062)

5.6.9 Air pollution

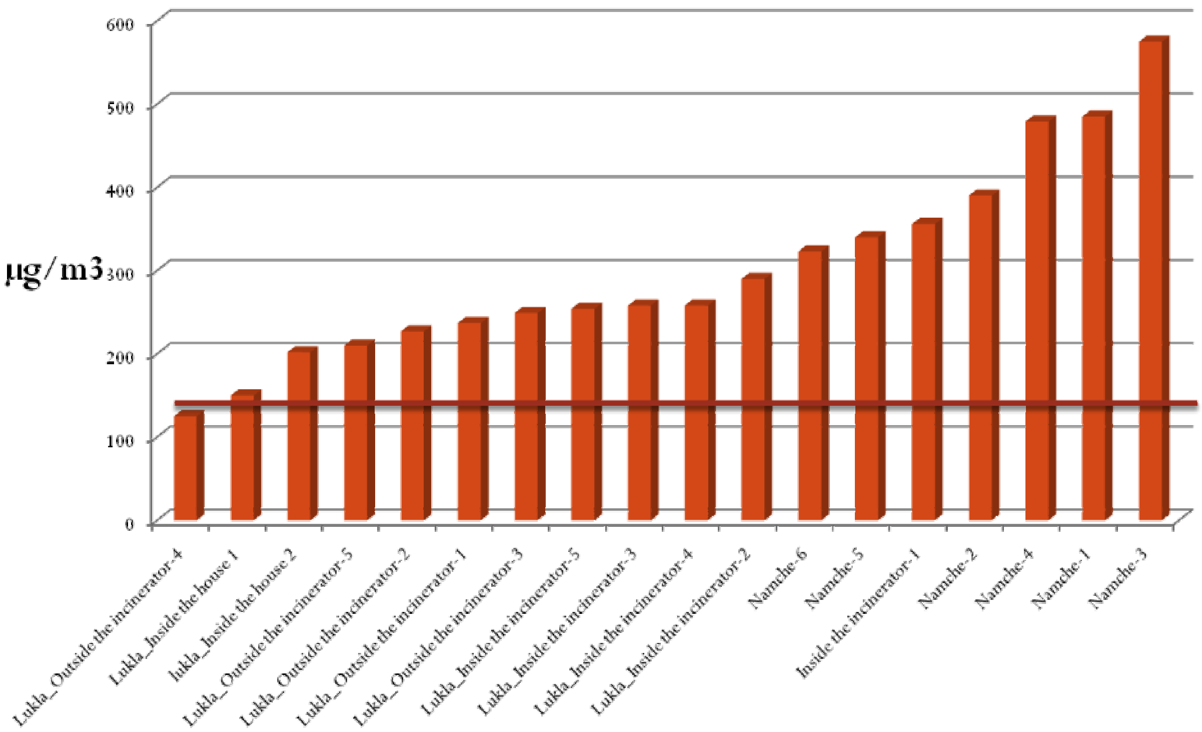

Figure 44: Concentration of PM10 at Lukla and Namche

The standard threshold concentration of PM10 in ambient air is 120 µg/m$^{3.}$ PM10 concentration near the burning place at Namche and Lukla were found to be higher - in Lukla up to 250 µg/m^3 and in Namche above the 250 µg/m^3 peaking at over 500 µg/m^3 .

5.6.10 People's perception on solid waste problem and management

The questionnaire suvey was conducted for 154 households. Solid waste above all other environmental problems is perceived as the key challenge for SNPBZ. (compare Figure 45): More than 65% of respondents considered solid waste as the major environmental problem.

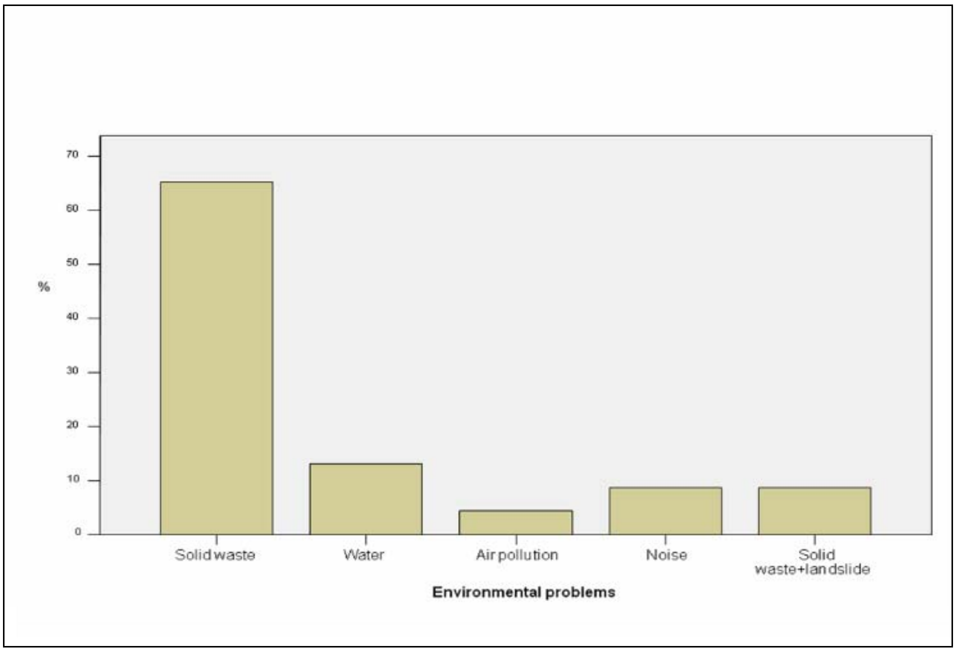

Figure 45: Perception of environmental problems in SNPBZ

97% of the respondents manage the waste themselves, which corresponds to the fact that waste management is carried out by SPCC only in Lukla and Namche. 45% of the respondents claim to dispose their waste on a daily basis, whereas 12% every other day. 17% of the respondents, twice a week, 11% once a week and 15% less often (compare Figure 46)

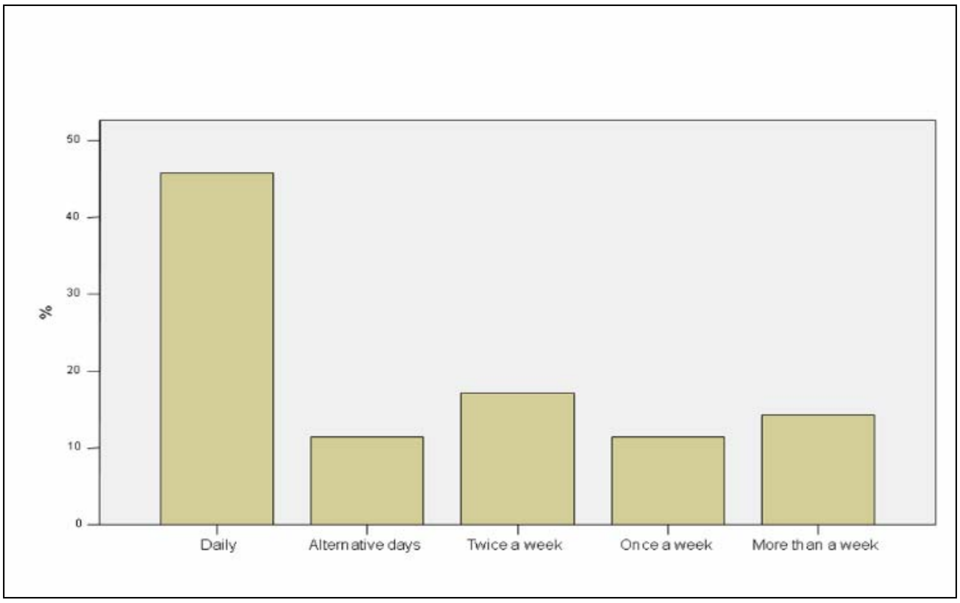

Figure 46: Disposal of waste in dumping pit

33% of the households claim to produce 2 – 5 kg of waste per day, 30% 1-2 kg and less than 20 % over 5 kg/day (compare Figure 47). The majority (72 %) of people in SNPBZ do not segregate waste except kitchen waste which is separated for cattle feeding. Plastic and glass bottle are often reused as containers to store things.

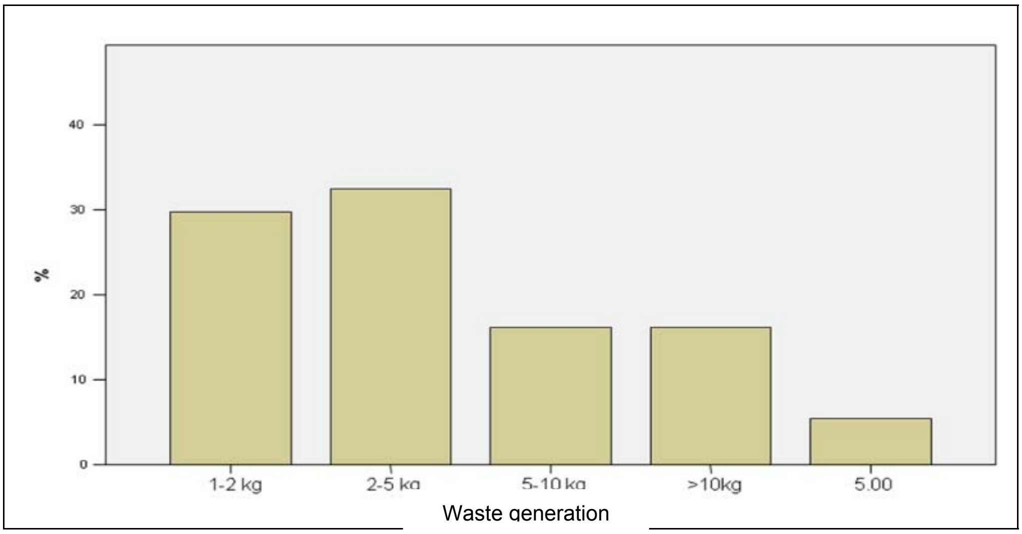

Figure 47: Average amount of solid waste generated per day

80% of the respondents do not have any knowledge about recycling waste (compare Figure 48). The majority of the people have never participated in any kind of solid waste management-related training or capacity building proram. However, most people participate in any kind of cleaning activities in the region.

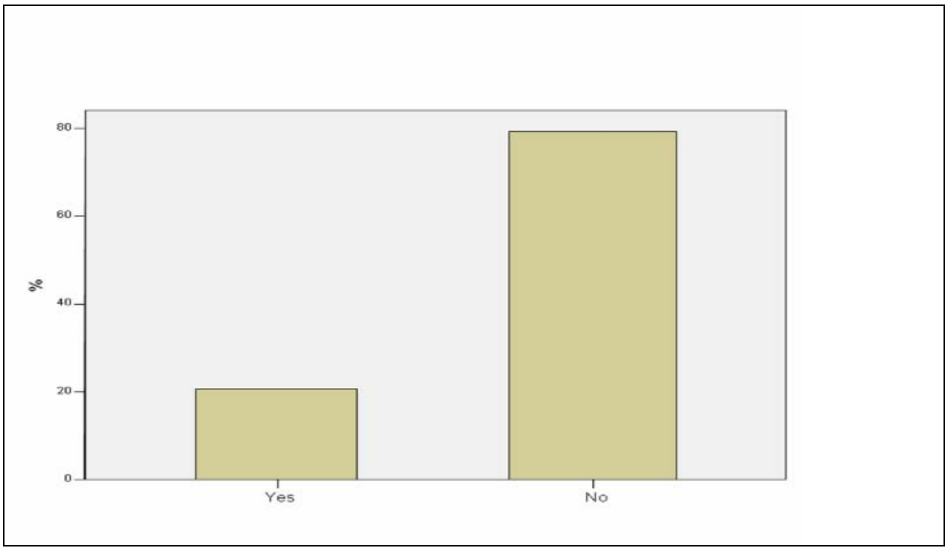

Figure 48: Idea about the reuse and recycle of solid waste

A two-day workshop was conducted in Namche on 24 and 25 November 2008 as a capacity building activity. This workshop was a good opportunity for stocktaking of existing waste collection and management systems and problems. As key suggestions to improve solid waste management in SNPBZ were raised:

- Reduce the production of solid waste by substituting
- Promotion of indigenous knowledge and practices to waste management
- Explore the possibility of a central sanitary land fill site

- Introduction of appropriate incineration technology in suitable location
- Promote better segregation and disposal of waste at different levels
- Encourage use of low waste generating materials
- Introduction/installation of waste recycling or waste reducing methods and equipments
- Improve the burning and dumping practices
- Evaluate the possibility of the export of non degradable waste along with economic consideration.
- Introduction of any other appropriate technology (briquetting, composting etc.)

5.6.11 Observations in settlements and along the trails

Lukla

Observation:	❖ **On Solid waste management:** o Production of waste = 0.85 kg per day per person o Two incinerators (local) are in operation in Lukla o After collecting burnable types of waste, segregation is done at incinerator house into three different types and burn them sequentially, i.e. light paper; wet clothes, or wastes that are not supposed to be burn easily; plastic, polythene and rubber etc. o Non-burnable waste has to be transported by local households to SPCC-suggested dumping points. o Dust bins were kept in different places along the trek o Scattered wastes were also observed in few places o Waste collection from the road side bins is the responsibilities of the SPCC in Lukla o There are two pits in the dumping site in which beer bottles are dumped in one whereas in another all the wastes even hospital wastes are dumped. o Some cattle were feeding there in dumping site o They have got one burning pit inside the hospital territory where they burn sharp wastes. o One third of the wastes are thrown to another dumping site located near hospital and bank of the river. All the wastes along with hospital waste are found mixed-type. o Rapid accumulation of non-burnable wastes (Beer bottles and tin containers). o Air purification segment of incinerator is not working and need to be repaired o Lack of Govt. land to make dumping site and private land owners are not ready to give their land for dumping purpose. o Households do not need to pay for waste management. o Quantity are supposed to be found different than that of Namche e.g. in Namche the main problem is plastic and tin while in Lukla bottles as the main problem
Impression:	o Trekking routes are largely clean o Positive attitude of people on waste management issues though some reservations and complains exists o Formulation of new policies and regulations regarding waste management is required

	○ Exporting bottle should be band or alternative solutions (reuse, recycle etc.) should be encouraged ○ Hospital waste should be managed separately because it contains sharp and infectious wastes. ○ Fee should be imposed on HH for better management of wastes. ○ Improve awareness and training among HH, business persons about relationship between waste and environment and provision of recycling opportunities. ○ Quantification of waste according to their burnable properties

Lukla-Phakding-Monju

Observation	❖ **Solid waste Management situation** ○ All lodges put wastes in pit and burn ○ SPCC collects the waste periodically from the bins in the trek. ○ Production of waste = 0.65 kg per day per person ○ Kitchen organic waste is separated and remaining are mixed and collected in same pots (Sack or Drum). ○ Once or twice a month they dispose the waste to the dumping site by themselves. ○ Once in a month SPCC person comes to burn. ○ Some HH burns the burnable types of waste inside their own garden due to long distance of dumping site. ○ Some waste bins have been provided by SPCC but local people are demanding for more bins. ○ Dumping site of Phakding which is in very critical condition. The wastes were thrown haphazardly in the dumping site and in river too. The pipelines of drinking water are passed through the dumping site and those pipelines are found to be leaked in many points.
Impression:	○ Drinking water settling tank found near dumping site. Leaking of drinking water pipe also found lined dumping site. Local people should be made aware on the effects of waste on drinking water and river which then affect the human health. ○ Wastes are not segregated and all the wastes are dumped at same dumping pit ○ Half burned wastes were found which threats for water contamination during rainy season are by leaching.

Monju-Jorsalle (28/09/2007, 14/10 – 15/10/07)

Observation	❖ **Solid waste management:** ○ Visited the dumping site of the school and clinic. Wastes from clinic were directly thrown in the same dumping site. Thus clinical waste should dump or incinerated separately. ○ Beer bottles are restricted to carry from this village. ○ Regarding solid waste, most of the HH are found their waste burring or burning in their own yard except bottles which they throw in the dump site once or twice in a month.
Impression	○ The current problem is the pure drinking water system. ○ Good waste collection system existed. ○ Unique initiative as SPCC in SNP.

Namche Bazaar (27 – 30 Sept. 2007)

Observation:	❖ **Solid waste management:** o Trekking route was largely clean (except some scattered plastics) o SPCC managing waste management in the whole trek rout ; different approaches were used for different places and routes o SPCC support local communities to waste management o Found many waste collection bins on the way from Lukla to Namche but very few waste bins were found on the way from Namche to Tengboche. o Basic strategy of SPCC – collect waste then dump or burn so that wastes are away from tourist's eye. Importing beer bottle is restricted to Namche however some wine and whisky bottles are found. o Tin containers packed food and beverages are found in most of the lodges o Scavengers collect and put up them for sale. In dumping site only paint and tuna containers are found accumulated. o One scavenger called lama has been engaged for empty containers selling business but we couldn't able to meet. o Wastes are collected based on regular and door to door system as mixed type and finally all the burnable waste are burnt in open burning place causing air pollution. o Rs. 2,000 is the fee imposed for waste management per year. o Several half degraded tin and other mixed waste were found in previous dumping pit so it can't be said as good management system. o In current waste burning place, ashes mixed with broken glass, medicine bottle and batteries are found. This dumping site is located at bank of the river's slope and all the burnt and half burnt waste finally goes to Bhote Koshi River so it is one of the major sources of environmental and water pollution. o Regarding drinking water, Namche depends on the river and spring. One drinking water source is observed near entering point of Namche bazaar. This tap's water comes from just above hill where some dumping pits were found and many wastes were found spread around the slope from the settlement of top. So, it is assumed that there must have effect on waster by leachate or by direct mixing with waste. o Environmental as well as health effect threat to the waste handlers, visitors and animals passing through this site because it is located along road and river side. It is also heard from locals that several cows have died by eating food waste of dumping site. o Burning waste along with plastic, batteries and other medical waste may produce toxic air pollution and its acute exposure may cause for headache and giddying. o Spreading broken glass is another threat for injury for people over there. o Source of river pollution since all the ashes finally goes to the river. o Potential for drinking water contamination because many waste are found spread along upper slope of the water tap. o Waste is largely dumped in pits and burned in locally made incinerator (?) o Burning is done for most kind of waste except metals, glass (though a few existed in burn too) o Burning is done every day after the collection o New dumps are dig if the old is filled. Filled dumps are covered by soil. Dumps generally not bigger than 5x3x3 meter. o Some dumps are upper side of water sources and some are in moist areas o Sewage is discharged openly after passing from settlement tank. o Weekly market waste is also collected and dumped/burned
Impression:	o Good waste collection system existed o Unique initiative as SPCC in SNP o Daily waste collection from all the lodges maintained by SPCC, though non commercial houses are yet to be fully covered o Efficient collection system, walkways are clean

	o Activities of youth club and their contribution on waste management appreciable o Public toilets, porter shelter, meat shops were excellent example of their work besides contributing to waste management in general o Good work of youth club o Some other alternatives for minimizing the plastic waste could also be thought besides the introduction of water purification units which was expected to reduce the use of bottled mineral water. One of the reasons of conflict was the operation of three mineral water factories established in Namche by some of the business persons. When personally requested for an observation visit of the factory to one of the factory owner, he flatly denied.
	o Formulation of new policy and framework that reduce the environmental contamination. o Training to the waste handler about waste and health and environmental relationship. Provision all protective clothes to them because none of them are found having protective clothes. o Provision for new incinerator having air purification system o Encourage and training for recycling opportunity so that waste can generate source of income. o Separate management system for hazardous types of waste (Batteries, medical sharp and infectious waste) o Areas around drinking water source should keep free from waste so that there should not be any mix up water contaminating agent.

Namche-Phurte-Thamo-Thame-Thameteng-Namche

Observation:	❖ **Solid waste management:** o Treks were largely clean except some scattered plastics and waste o Each HH has a waste collection practice which they dump in the pits o All kinds of waste was collectively collected and dumped in the pit, and burned in interval of time o SPCC staff visit in interval of time, trek waste dumped, waste burned o Local groups were mobilized by SPCC for waste management o SPCC also help for pit digging o All the organic waste was used for cattle feeding
Impression:	o Waste collection is largely ok. o Dumping needs some more management inputs o Hazardous waste not separated

Namche-Syangboche-Khunde-Khumjung-Namche

Observation:	❖ **Solid waste management:** o Tourists are very few in Khunde and hence there is less problem of solid waste compared to Khumjung and Namche Bazaar. ❖ **Additional observation:** o On the way to Khumjung, we saw the landslide which was occurred on July 2007 and can still viewed the property damaged by the landslide there in Khunde.
Impression:	Khunde hospital is serving local people as well as trekkers very well Hospital waste is managed by themselves

Namche-Kyangjuma-Sanasa-Lausasa-Phunki Tenga-Tengboche

Observation:	❖ **Solid waste management:** ○ We also saw mineral water bottle thrown on the way. ○ Monastery people were concerned about the waste management; The Rimpoche is also the patron of SPCC. ○ Waste management is handled by Gumba. All the burnable wastes are mixed and burned at dumping pit. ○ Some scattered dumping/throwing (on the way to main dump) was also observed ○ In Lausasa, 4 dumping sites up to intake, no any rubbish bin. ❖ **Additional observation:** ○ Problem of pure drinking water supply system in Kyangjuma. The bakery owner use 3 phase line pump for pumping the water down from river.
Impression:	○ In general OK, needs improvements and efficiency ○ Waste segregation, dump and incineration – needs improvements ○ On route cleanliness and collection of waste OK.

Tengboche-Pangboche-Debuche-Phortse-Mongla-Khumjung-Namche

Observation:	❖ **Solid waste management:** ○ Similar way and status of general waste. ○ Villagers also do campaigns in between ○ Sharps were sent to Khunde hospital for management from the other health post ○ School clubs are also working on different aspects of environments in Phortse ○ one dumping site, located near river, preliminary established by spcc and latter continued by local people. Wastes are disposed by locals twice or thrice in a month. Wastes are found haphazardly mixed with all different types of waste. SPCC supervisor comes in a month to burn. No any rubbish bin is available there.
Impression:	○ More active villagers and young

Tengboche-Pangboche-Dingboche-Imja-Pheriche-Pangboche-Tengboche-Namche

Observation:	❖ **Solid waste management:** ○ It was revealed from one of the health worker that many people came to hospital suffering from diarrhea in recent days and he said that it might be the contamination of the drinking water source with the waste disposal. ❖ **Additional observation:** ○ During monsoon for about two months all the people of Dingboche must leave that place. There was a saying that burning firewood will affect their crops. ○ Observed landforms in Imja above 5000m made by glacier and moraine deposits. ○ Imja Glacier Lake is expanding and will continue by melting dead ice in the lower part and glacier tongue in the upper part.
Impression:	○ It was a difficult day and of course a long and fruitful day. ○ So I think that wind energy might be an alternative

5.7 Management options

5.7.1 Reduction of waste production (evaluation of this option in the model possible)

It is estimated that currently around 700 tons of solid waste are being generated in SNPBZ per year. The solid waste management system is unable to cope with such large amounts. A reduction of the overall waste production is therefore the most effective and obvious solution to mitigate the solid waste problem of the park. The major types of waste that could be reduced by implementing appropriate policies are:

plastic, glass and metals are brought to SNPBZ from outside. Polythelene/ plastic bag can be substituted by paper and cotton bags as these can be used repeatedly whereby reducing the plastic waste generation. Glass and metals can be substituted by aluminum cans. Glas is difficult to managed in terms of transportation, recycle and reuse in this region, whereas aluminum cans are comparatively easy to manage

Fees could be collected for importing plastic, glass and metal containers. This would discourage excessive import of such items, also a total ban for some products could be imposed on products for which substitutes are available. For example, currently beer bottles are banned in SNPBZ, a measure, which is very effective and could be applied to other products as well. However, to render such policies effective the legitimate concerns of the present industries has to be taken into account. The implementation of such policies is facilitated by SNPBZ's geography. Virtually all products are flown in by air and reach SNPBZ through Lukla airport, a hub for SNPBZ where compliance could be supervised and enforced rather easily.

In case of plastic mineral water bottles, a pilot study carried out within the HKKH Partnership project has assessed the possibility to substitute disposable bottles entirely by providing drinking water, which is generated by means of purification devices, to visitors.

The options to achieve a reduction of waste production in SNPBZ are summarized below:

- Ban on the use of plastic bags in SNPBZ and its substitution by paper, cotton or other biodegradable materials.
- Ban on the use of beer bottles and its substitution by can beers.
- Imposition of heavy taxation on the import of plastic materials, metals and glasses.
- Regulation to take back plastics, metals, glass and can by anybody who brings in.
- Provision of improved water quality in SNPBZ through, (to reduce dependency on bottled water)
- Treatment at source and supply system
- Treatment at household level
- Awareness and training necessary for both locals and tourists about substitutes, regulations, provisions
- Collect and take back waste/throw as little as possible
- Regulation of the number of tourist flow considering socio-economic implications

5.7.2 Capacity building: training and awareness raising

Any waste management system ultimately relies on the involvement and participation of individual residential and commercial waste production units, for SNPBZ these are commonly households. The involvement requires awareness of the problem as well as the regulations in place and an intention to comply with the management recommendations and regulations. Furthermore the institutions and organizations involved in the waste management at central level need the appropriate knowledge and understanding about waste issues, management techniques and technologies.

The problem in SNPBZ concerns both aspects: a lack of awareness among the population and inadequate

technical knowledge and understanding about waste management regarding collection, storage and segregation, and disposal and treatment among the waste managing institutions. Technical trainings and awareness raising are able to overcome these shortcomings:

- Training for Waste managers: SPCC, other interested NGOs, VDC staff; focused on waste collection from household, street and trails, segregation and storage, transportation, treatment and disposal, occupational aspects, pollution aspects, operation and maintenance of equipments and treatment system etc.
- Awareness Workshops for different Stakeholders: information on general aspects of waste management and its concern, 3R principles, handling of waste etc.

5.7.3 Capacity building: equipment for collection and transportation

The key organization involved in solid waste management - SPCC – will be provided with equipment for collection, transportation of generic as well as specific solid waste. The provision would include safety and protection gear and training to waste/workers and handlers and operation, maintenance and repair of waste management equipment and system. To improve the safety, apron, proper shoes, gloves should be provided to waste handlers. For waste collection and disposal shovels are required and transportation should take place by means of Dokos and suitable bags.

5.7.4 Disposal Methods Distribution and Policy Levers

Efficiency of waste segregation (evaluation of this option in the model possible)

Waste segregation means to separate waste according to the preferable means of disposal or treatment. The status of waste segregation in SNPBZ is very poor now. Only kitchen waste (organic matter) is separated and used for composting. The dump sites consist of mixed waste, including besides paper, plastic rubber also metals, batteries etc. SPCC, the major organization currently managing waste in SNPBZ, segregates waste only at the burning site in major settlements into burnable and non-burnable waste. The latter includes metal and glass which are dumped separately, all other waste is assigned to the former category and burned in situ.

A proper waste management starts with the collection of waste. Where possible, the waste should be segregate into paper, plastic, metal, glass, batteries and hospital waste at the collection site as a precondition for applying the most appropriate disposal methods to the different waste types. Table 2 shows the appropriate treatment methods for the different types of waste in contrast to the current practice applied in SNPBZ. Table 1 shows the current segregation/disposal system in SNPBZ. Since segregation is a precondition for selective treatment and the quality of the latter is dependent on available facilities, Table 1 encompasses the entire waste management system after the collection phase, including the treatment facilities described in the following.

	Reusing	Burning	Burying	Transporting	Incinerating	Recycling
Other/Organic	86.5%	10.2%	2.8%	0%	0.5%	0%
Plastic	6.3%	50.5%	39.6%	0%	3.6%	0%
Glass	4.9%	0%	89.4%	5.7%	0%	0%
Metal	0%	0%	95.8%	4.2%	0%	0%

Table 48: current waste disposal practice in SNPBZ

Waste type	Preferable disposal method	Preferable alternative disposal method	Current disposal method	Current alternative disposal method
Plastic	Recycling	Incineration	Burning	Burying
Glass	Recycling	Incineration	Buried	Exported
Metal	Exported	Buried	Buried	Exported
Kitchen waste	Cattle feeding	Composting	Cattle feeding	Composting
Paper	Recycle	Incineration	Burned	Burying
Medical waste	Special incineration	Incineration	Dumped	Burning

Table 49: appropriate treatment methods for waste in contrast to current practice

New technologies: Installation and operation of incinerators (evaluation of this option in the model possible)

The current practice for waste management in SNPBZ consist mainly of partial burning of waste collected in open dumping pits. Burning reduces the volume and weight of waste but is extremely hazardous for the environment, not only due to the emissions released into the air. Leacheate (residual liquid released from solid waste) is caused either by the moisture content of the waste itself of by watersources that come in contact with through different hydrological process, such as precipitation, surface run off etc. Leaching may occur before or after burning. This is supported by a numbers of soil and water samples analyzed during the study.

Furthermore, the current practice does not allow a selective disposal of burnable waste (mainly plastic and paper), which constitutes around 16% of the total waste generated in SNPBZ, but invariably all types of waste are partially disposed in this way.

In some places like Namche and Khumjung, closed burning installations are found. These sites are not operated properly as metals and glasses in burns, ashes are not disposed properly; Harmful air pollutants are emitted and the health of waste handling personnel is threatened.

The only running incinerator in the SNPBZ is located in Lukla. Its incineration capacity is theoretically around 30 kg/hr producing 2.3 kg of ashes from 30 kg of waste. Leakages have been observed in the device and maintenance of the incinerator is urgently required. Furthermore, most of the supporting technical components are not operating properly, so that the system is largely functioning as a closed burning container. This, introduction of new incinerators for the disposal of plastic paper and other burnable matter in SNPBZ is a key factor of an effective and environmental-friendly waste management system.

The existing incineration system in Lukla needs to be repaired in order to increase its efficiency en environmental quality. However, repairs may not be sufficient, in which case the preferred solution would be the installation of a new incinerator with a capacity of 100 kg/hr to be in Namche, the hub of upper Khumbu, which could incinerate the waste generated from Namche and other nearby places. Lukla incinerator should be replaced with a new incinerator of a higher capacity of 100kg/hr which will incinerate waste produced from Lukla and places in lower Khumbu.

Consideration for installations of the incinerator should be based on:

- Location
- Amount of waste/ type of waste produced
- Visual Impact

- Environmental Impact
- Proper Segregation
- Trained staff – operation and maintenance
- Disposal of Ash

The cost to incinerate 1 kg of solid waste has been calculated based on examples from Malaysia and Germany. The figure includes average installation and running cost.

Other cost regarding transportation, maintenance, training, buying the land for incinerator are not included.

Capacity kg/hr	Treatment cost NRs/kg
50	224
100	153
250	93
500	63

Table 50: incineration cost related to capacity

Increase waste export (transported outside) (evaluation of this option in the model possible)

Transporting waste out of SNPBZ for recycling or proper disposal in Kathmandu is the preferable solution for some types of waste. Aluminum cans, glass bottles and plastic bottles are recyclable. Since, currently no recycling facilities are available in SNPBZ, in the medium term exporting would be the most suitable solution. There are scrap metal markets in the capital, which facilitate and motivate the export of metals. Currently, only aluminum cans are exported through scrap handlers from SNPBZ. This activity constitutes an important livelihood activity for some local people. Beer bottles have occasionally been exported using helicopter transport supported by the government, some NGOs and INGOs. Since beer bottles are now banned in SNPBZ and this regulation is enforced quite effectively, this activity will loose its relevance in the near future.

At present, a low share of waste generated in SNPBZ is exported. Increasing this share for selected waste types would support the mitigation of the solid waste problem. However, financial incentives combined with new regulations would have to be introduced to encourage an increase of waste export activities. Exporting scrap metal and unburnable waste types would support the waste management of the park most effectively.

The cost for export increases most significantly with the volume of the waste. In SNPBZ, waste has to be transported manually by porters to Lukla. The porters charge either based on the volume (irrespective of weight if large a “Bhari”) or the weight of the material. But even if the weight is less but the volume is too bulky to accommodate in a “Bhari” they charge on the basis of Bhari. In addition, many air cargo systems also charged on the basis of volume. Plastic bottles can be compressed into small cubes before exporting to reduce the volume. Also metals can be compressed in this way.

The cost of transport of 1 kg of metal outside is Rs. 50. This figure includes discounted air cargo charge and porter charge from Namche to Lukla. It does not include collection and handling charge as well as transportation charge from Kathmandu Airport to the recycling site.

New technologies: Sanitary lands fills

Existing dumping sites in SNPBZ are poorly managed and often located near trails, water bodies, agricultural fields etc. leakage and contamination of soil and water are common problems. Sanitary landfills are means to dispose unburnable waste, burned residue and inert waste material. 2 – 3 such landfills would cover be sufficient for SNPBZ. The dump sites of the settlements, which currently are the final disposal sites for most waste, would be used as temporary storage places before the waste is processed for final treatment.

The selection of sanitary landfill sites should account for geological, environmental and economical considerations. Such a site should change the geography of the surrounding area marginally when full.

The construction of sanitary landfill sites is technically feasible since it's construction does not vary a great deal from the current practice of digging pits for dumping. However, a sanitary landfill features proper lining on the bottom of the pit to prevent contamination of soil, water and air through leakage. Due to the steep topography if might be difficulty to identify proper sites and the construction cost might be higher.

5.7.5 Effectiveness of solid waste collection

It is important that the waste collection system is not confused with waste segregation and selective treatment disposal. Waste collection is the first step in the waste management process, ensuring a low rate of littered waste. Whether the collected waste is disposed and treated appropriately is a matter of waste segregation and treatment options available, which are covered by other management levers

SPCC collects waste from mountaineering groups and from households in Lukla and Namche. In other settlements SPCC supports local communities in the establishment of waste dump sites. containers have been set up along the trails, which are emptied regularly by SPCC. The effectiveness of this system - the collection of waste generated in SNPBZ - depends to a great extent on the local communities and the visitors, but also on the capacity of SPCC to carry out the three ways of collection. The system is continuously challenged by a steady increase of waste production in SNPBZ, mainly caused by an increasing number of visitors. However, overall the collection of solid waste by SPCC staff from households, trails and mountaineering groups is very effective. The problem is rather the open disposal of mixed waste and a lack of proper segregation.

5.7.6 Solid waste monitoring system

To improve a waste management system and plan it's implementation and capacity of desired treatment options, it is crucial to have accurate and up to date figures on the relevant parameters, including: quantity and composition of waste produced, effectiveness of waste collection system, condition of treatment facilities and environmental pollution caused by the waste disposal system. Specifically, the air quality and emissions near incinerators sand contamination of soil and water sources from nearby dumping sites should be monitored regularly. Amount and proportion of treated waste under different treatment systems such as landfills, incinerator, export and briquetting should also be recorded as should the quantity of substitutes used. Solid waste studies were carried out in the framework of the HKKH Partnership project, however, the effectiveness of the waste management system of entire SNPBZ has not been evaluated systematically and in detail. Such a monitoring scheme is highly recommended and should be established in collaboration with local groups.

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6 Energy Management

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Table 51: researchers involved in Energy management research

Kathmandu University was started in 1991. The University operates from its premises at Dhulikhel, Kathmandu and Bhaktapur, through its six schools: School of Management, School of Science, School of Engineering, School of Medical Sciences, School of Arts, and School of Education. Though young, the institute has managed to become a point of reference for young Nepalese, and offers a number of modern facilities and laboratories to analyze environmental issues. The University, that strongly supports fieldwork and applied research in national parks, is actively involved in the research activities of the HKKH Partnership Project.

CEPTE/KU is an energy research unit currently being formed under the School of Engineering, Kathmandu University, Nepal. CEPTE/KU concentrates on applied R&D activities and consultancy service in all components of power generation, transportation, operation and maintenance as well as development of end-use technology covering both supply-side and demand-side energy management.

DESE fulfills the need of highly competitive, skilled and trained manpower in the areas of research, development, impact assessments, standards monitoring, management, conservation, legal measures, policy formulation, implementation and other relevant environmental field. The department also pursues research relevant to local national, regional and global significance. Focus is also given to collaborative researches with national and international organizations and academic institutions

6.2 Introduction

Firewood being relatively accessible and affordable, especially at lower altitude, remains to be the predominant source of energy for the majority of people in SNPBZ for cooking, boiling and space heating (DNPWC, 2003). To meet the continuously increasing demand for energy caused by a growing local population and a booming tourism industry, over-exploitation of forest resources is omnipresent. Depending upon altitude and distance from the source of availability of modern (commercial) as well as traditional (indigenous) sources of energy, various energy sources alternative-renewable ones, firewood, dung-cakes, kerosene, LPG, hydroelectricity, solar as well as wind energy technologies have been introduced in SNPBZ.

The major settlements of Namche, Khumjung and Chaurikharka VDCs have been connected to the electric grid. This has generally led to a reduction in firewood use in the area. In Monju, Phakdin and Lukla of Chaurikharka VDC few individual households and communities are generating limited electricity from Peltric sets[2]. The energy is used mainly for lighting purpose (Household Survey, 2002). Use of solar home systems[3] is widespread in the area, again, to generate electricity for lighting. Only few hotels use solar water heating systems. Kerosene and LPG, though relatively expensive, have been recommended for higher altitudes where firewood and dung-cakes are scarcely available. However, these energy sources are currently not affordable for the majority of residents at such altitude, where rather remote communities are found and these sources are also problematic with regard to climate change (emission of Green House Gases (GHGs)). Fortunately, SNPBZ is abundant in potential for renewable, natural energy resource, such as hydropower, solar and wind Exploiting these potential would reduce dependencies on imported commercial as well as indigenous fuels, first of all firewood. In the long run there is a need to develop renewable energy sources to ensure the sustainable use of natural resources, which are vital for the existence of the park and consequently the tourism industry in the region.

Considering the environmental and economic impacts of the energy-use in SNPBZ, Kathmandu University has been entrusted to analyze the balance in energy demand and supply in order to formulate the energy management recommendations. The study includes the quantitative and qualitative patterns of energy demand and supply chain of both commercial and non-commercial/indigenous sources of energy, its spatial distribution and environmental impact, the documentation and evaluation of existing energy management schemes and practices and the identification and recommendation of appropriate management options.

Therefore, the overall objective is to analyze the environmental quality and energy scenario of SNPBZ to support the development of an energy management plan, including the suggestions for alternative energy resources. The specific objectives are:

- To study the current and potential demand of energy (data gap analysis considering the future tourism increase)
- To start preliminary hydrologic study of rivers in the park and buffer zones considering the availability of data (EV K2 CNR Meteorological stations and DHM data)
- To analyze possible and feasible alternative sources of energy

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[2] Peltric set is an electricity generating set consisting of an induction motor used as generator coupled with a tiny Pelton turbine ingenuously developed in Nepal that could generate few watts up to 5 kW.
[3] Solar Home System is a tiny electricity generating, storing and controlling system consisting of a photovoltaic panel, battery with charge control system and one or two compact fluorescent lamps with switches ranging from few watts to 40 watts.

- To provide data for a quantitative on the energy subsystem of SNPBZ as part of the model “socio-ecosystem SNBPZ) of the DST

6.3 Background

SNPBZ has been a source of inspiration for many researchers to quantify the extent of energy demand for the investigation of different problems, but eventually, to come up with sustainable energy management recommendations. This research presented in this report stands in the same tradition. However, new methodologies – qualitative system dynamics analysis involving thorough stakeholder consultations and data gap analysis in the framework of the projects modelling process.

Shepard (1970) reported that the type of stove used has a substantial effect on fuel-wood consumption. Closed topped stoves economize on fuel, but most of the world’s populations still uses very inefficient cooking facilities. Food is cooked over an open hearth, openly, under shelter or in the house, as it is practiced by most Sherpa households in Nepal. Reports about the use of stoves after this date are difficult to find. However, such a study is essential, since cooking accounts for largest share of energy consumption activities. There is a large margin with regard to efficiency of cooking stoves. A study carried out in the 90s, concerned with the cooking stoves in lodges and households in Namche Bazzar found to the efficiency to be 16 % and 12 % respectively (Sulpya and Bhadra 1991). This research has been carried out to identify both, the potential for and expansion of existing alternative energy sources at present in SNPBZ, their potential use and the development of new alternative energy sources.

Basnet (1992) conducted a firewood consumption survey in Khumjung, Sagarmatha National Park and Khumbu. He found that an average of 1.5 kg and 7.0 kg of firewood are required for an average person and family/household, respectively, per day during Monsoon season. He observed that Juniperus and Betula are the most preferred firewood species, covering 27 % and 28 % of the collected firewood, respectively. However, Abies and Rhododendron are also equally frequently used as their availability is high. The mean moisture content of the firewood varies from 19 % to 38 % indicating a semi-green and green state of the firewood people collect. The relatively low quality of firewood in use has implication for emission of GHGs.

WECS (1994/95) states that alternative fuel sources have social, environmental and economical impacts. It is able to substitute the use of fuelwood and charcoal, leading to mitigation of deforestation and protection of the environment. The study indicates that alternative sources potentially are able to substitute firewood and kerosene consumption to 82.5% and 63.1% respectively

Prasad *et al* (1998) states that existing forest cover and poor availability of commercial fuels have placed uphill people, especially the rural people, in a situation where identification, development and adoption of suitable alternative energy sources and fuel saving have become a national priority. The most suitable energy sources, in the context of SNPBZ, are related to micro-hydropower, biomass energy (biogas, briquettes), solar energy (Solar water heaters, dryers, cookers, photovoltaic) and wind energy (Rijal, 1999).

A study on energy consumption pattern in three VDCs of SNPBZ i.e Chaurikharka, Namche and Khumjung found that indigenous energy source like firewood and dung-cakes are used excessively compared to commercial energy sources, like kerosene and LPG (CEE 1999). Rijal (1999) highlighted that Nepal’s energy problem arises not from excessive reliance on non-renewable energy sources, but also from the fact that one form of energy (firewood) is being consumed at an unsustainable rate while the vast potential of other forms of renewable energy sources remain virtually unused.

6.3.1 Earlier Studies

Bajracharya T. R and Dahal Y.R. (2000) Case studies carried out in Solukhumbu and Jumla districts aimed at assessing the potential of passive heating systems in traditional buildings found that, at a particular temperature, a certain amount of heat is saved after the incorporation of solar passive technology.

Gurung T (2000) reportes that there are three kerosene depots in SNPBZ, in Syangboche, Dole and Pheriche. Syangboche depot sells about 18000 liters of kerosene every year.

World Energy Council, (2003) The energy sources of Nepal consist of a combination of traditional and commercial sources of energy including biomass, hydropower and alternative forms of energy.

Hada and Shrestha (2006) states that electrification is possible by taking advantage of wind energy technology in those scattered rural settlements where wind is abundant and connection to the grid in the near future is unlikely

Zahnd and Malla (2006) highlight the importance of High Altitude Solar Heaters for poor, remote communities to improve the hygiene of cooking conditions. Solar heater in high altitude has the great potentiality which is of the alternative energy sources and benefits both on health and environment.

Ghimire and Maharjan (2006) found out that Photovoltaic technology has been practiced in more than 80,000 households in Nepal till date and the number is growing.

Zahnd, Haddix, Komp (2006) reports that the geographical remoteness, harsh climatic conditions, low population density with minimal energy demand and low growth potential, are some of the reasons why rural electrification costs in Nepal are prohibitive and the isolated rural mountain villages in Nepal will not be reached within the foreseeable future through grid extensions alone. National grid in remote village in Nepal due to geographical remoteness, harsh climatic conditions is difficult thus alternative energy source or micro-hydro could be implemented in the region.

Nepal S (2007) A survey estimates that the ACA lodges burn about 14.1 tons of fuel-wood/day during the tourist season. When extrapolated, it results in an annual consumption for entire Annapurna Conservation Area, of about 3600 tons.

Karmacharya, N. L (2008) A study carried out on fuel-wood consumption and forest degradation in SNPBZ shows that households in the Buffer Zone consume more energy than the ones in the Park. The fuel-wood consumption is higher in winter season.

6.4 Methods

The data gap analysis within the modeling process primarily defined the data that had been collected through a the field survey:

- Primary and secondary information on demography of informants and their economic status,
- Information on migration and tourist inflow, utility services, natural disaster
- Information on energy such as fuel types, energy use pattern, availability, equipment use, Indoor pollution,
- Alternative non-conventional energy supply,
- Types of building construction design
- Electricity tariff structure and material prices.

Major trekking routes, including Everest Base Camp (EBC) were selected for the study. Altogether two field visits were conducted. Settlements along the route Lukla-Namche-Thame and Lukla-Namche-Pheriche-Dingboche-Chhukum were covered on the first field trip on autumn 2007. Settlements along the route Lukla-Namche-Everest Base Camp-Gokyo were covered during spring 2008 second field trip. Totally, 35 settlements of SNPBZ were covered during these field trips.

September 2007 Field Visit	May 2008 Field Visit
Questionnaire (Demand/Supply)	Questionnaire (Demand/Supply)
Lukla – Chhukung (25 settlements)	Lukla – Everest Base camp and Gokyo (32 settlements)
Measured of components of building like, wall thickness, material of construction, room dimension.	Measured of components of building like, wall thickness, material of construction, room dimension.
Spot measurement of solar irradiation, wind velocity	Spot measurement of wind velocity.
River discharge measurement	River discharge measurement

Table 52: Energy research: field visits and data collected

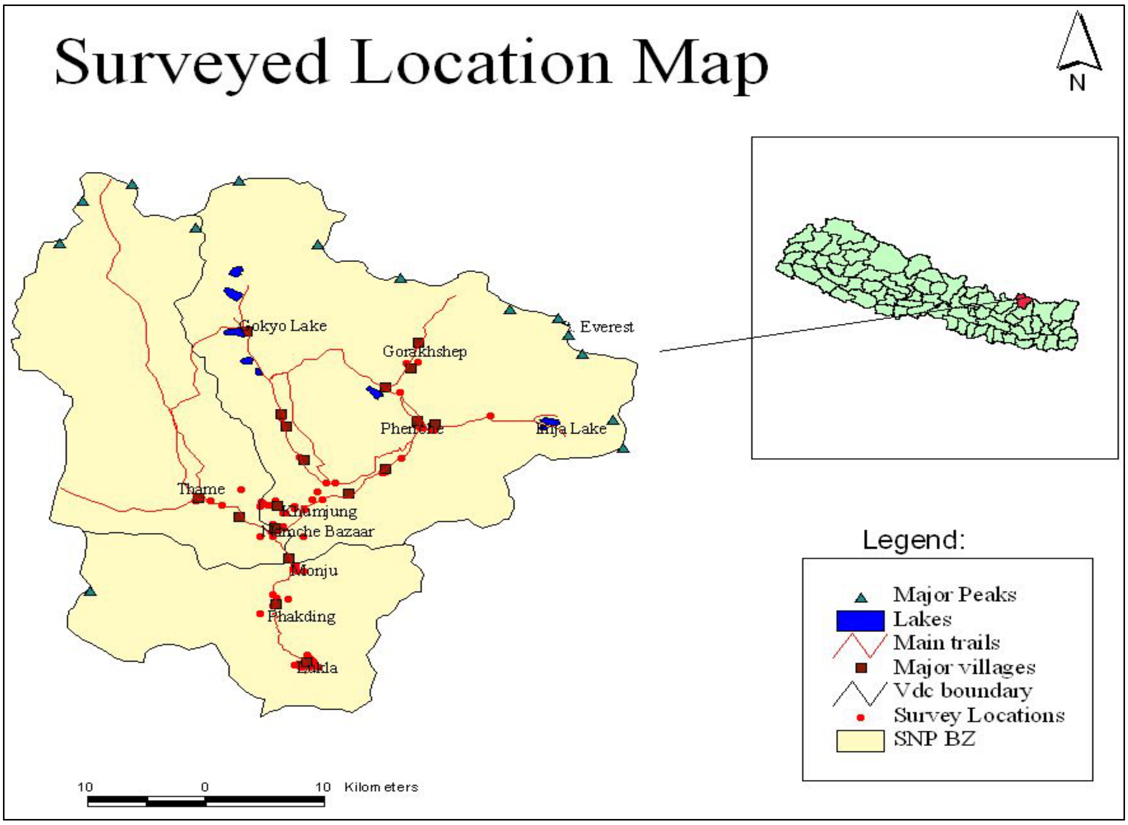


Figure 4: Energy research: study locations

6.4.1 Survey

Based on the identified data a unified standard questionnaire was developed. This questionnaire was distributed among the stakeholders within HKKH Partnership project to incorporate the comments and suggestions. The households in each community were categorized into residential, institutional and commercial and sample numbers were estimated proportionately to their relative numbers. A further differentiation of the samples household survey took place considering economic status The category “Institution” includes schools, hospitals, local offices and monasteries. The “commercial” category was subdivided according to size. A classified random sampling technique was applied to cover all these types of households, resulting in a coverage or around 15% of all households in SNPBZ

Two field visits were conducted: one in autumn 2007 and one in spring 2008. The household survey was carried out from 25th September till 15th October 2007 and 3rd May to 3rd June 2008, respectively

The households in each community were categorized into residential, institutional and commercial and sample numbers were estimated proportionately to their relative numbers. A further differentiation of the samples household survey took place considering economic status of the occupants.

Based on the architecture and construction materials used, the households have been categorized into:

Traditional type: The traditions houses follow ancestral house design, typically known as "Sherpa House" (compare Figure 49). For the construction of these houses locally available materials are abundantly used, particularly on the roof and the wall construction. Locally available material like wood is used for the roof whereas wooden planks, dry stone and mud plaster are used for walls (compare Figure 49)

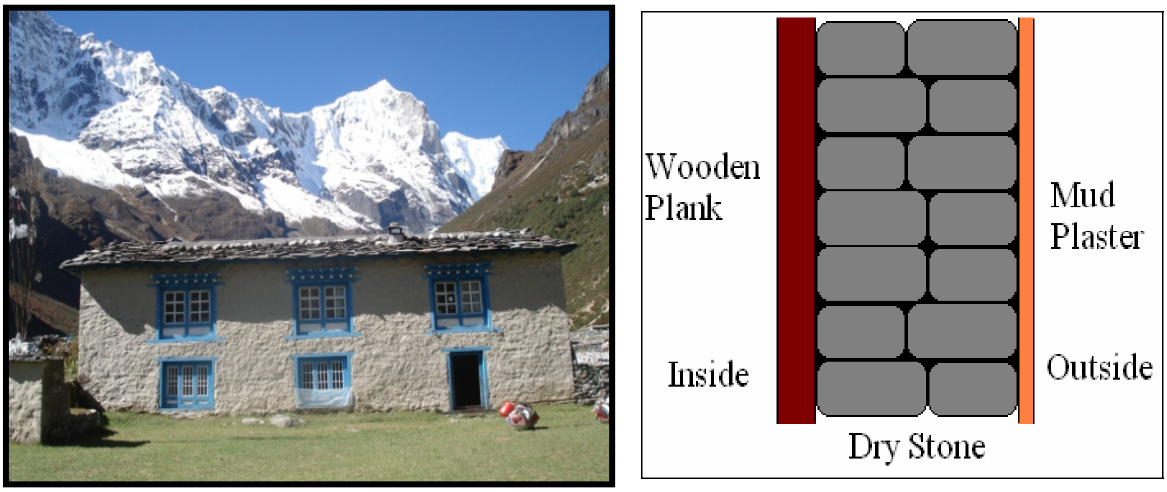


Figure 49:) Traditional type of house with cross-section of the wall

Medium/Common type: Medium or common houses are built using a combination of local and modern technologies, with limited insulation, as shown in Figure 50. Essentially, this house type is exemplary for the modification of traditional house into a modern type.

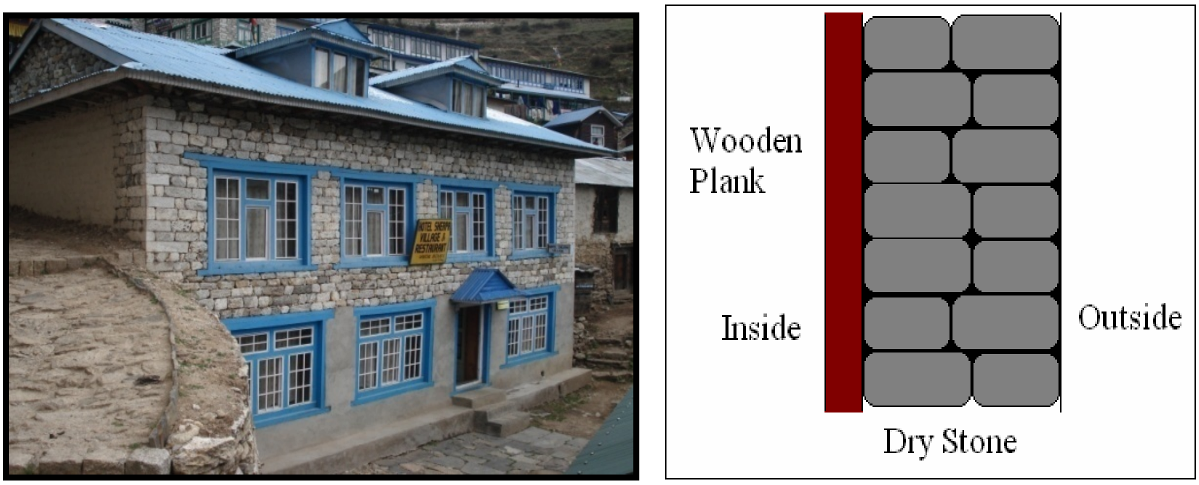


Figure 50: Medium/Common type of house with Cross-section of the wall

Modern type: To enhance the tourism in the national park area, the modern cemented houses (see Figure 51)are very well architecting which are using the imported construction materials with heavy insulation. The interesting factor is that nowadays, all modern houses (latest build) are being equipped with the latest efficient lighting arrangements.

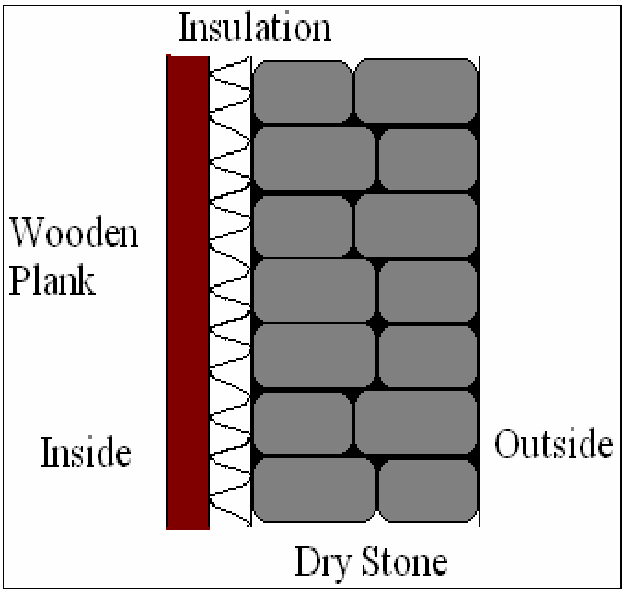


Figure 51: Modern type of house with Cross section of the wall

Based on the purpose of the household, categories considered. Category "**commercial"** includes mainly lodges, but also shops, etc. SNP is a major tourist area and thus, a high diversity of lodges (from small to large) can found. Category "**residential"** includes resident houses, only used for private accommodation. Category "**institution"** includes schools, hospital and gombas.

Survey questionnaire

HKKH Partnership
for ecosystem management

Q.No. Basic Information

GPS Point: Datum WGS84 N ……º…'……." E …... º…….'….." Altitude (m):
Location: Solar radiation : Wind velocity:

12. Identifying Household

Name of the Village/VDC/Ward no.	
Number	Household (HH) / Office / Institution / Business
Date of Interview	……./……./……. Time: (a.m./p.m.)
Name of interviewer	

13. Informant's background

1.	Age	
2.	Gender	
3.	Educational status	
4.	Occupation	
5.	Religion	

6.	Ethnic group			
7.	Family type (Valid only for HH)			
8.	How long your half yearly income can sustain your family expenditure (Valid only for HH)	> 12 months	> 6 months	> 3 months
9.	What is your main topic of yearly expenditure? Please rank them according to importance from 1 to 8	Topic		Rank
		Food		
		Fuel		
		Education		
		Cloths		
		If employer, salaries		
		Transport		
		Rent		
		Other		

(Gender)	**(Educational status)**	**(Occupation)**	**(Religion)**	**(Family type)**
1 = Male, 2 = Female	A = Illiterate B = Literate 1 – 9 = School 10 = SLC, 12= HSS, 14 = BSc, 16 = MSc 17 = Phd	1 = Agriculture, 2 = Business 3 = Worker, 4 = Porter 5 = Teacher, 6 = Student 7 = Private job, 8= Govt. job 9 = Tourist guide, 10 = Others	1=Hindus 2=Buddhist 3=Muslim 4=Christian 5=Others	1=Single 2=Joint

14. Family Size (Valid only for HH)

Details of family members using the same kitchen			
Family member	Age/ Number		Occupation
Son	Below 16		
	Above 16		
Daughter	Below 16		
	Above 16		
	Below 30	Above 30	
Relative			
Father			
Mother			
Grandfather			
Grandmother			

15. Information about Land

10.	Do you have your own land?	Yes 01	No 02
11.	If "Yes" then please state your house hold and agricultural land status		

12.	Type of land	Total land in ropani	Hereditically owned land (valid only for HH)	Owner ship by Buying	Present market price of the land in NRs
a.	Homestead/Office/Business				
b.	Agriculture				

c.	Garden				
d.	Others				
	Total owned land				

5. Agricultural Information

13.	Status of agricultural land	Increasing Decreasing Unchanged	01 02 03
14.	What are the main crops of this area? (Cropping variety)		
15.	Cropping intensity	Good(3 crop) Moderate(2 crop) Bad(1crop)	01 02 03
16.	Soil fertility	Increasing Decreasing Not yet all	01 02 03

6. Utility Services (Household / Office / Institution / Business)

17.	Type of the toilet used by your family members	Flush type Open composting Closed composting Open pit Closed pit	
18.	How far is it from the house	• In house • Outside house • Less than 50 meters • More than 50 meters	
19.	Source of drinking water	River Pond / Lake Stream / Spring Public tap Private piped water Other(Specify)	01 02 03 04 05 06
20.	How much of water in total do you use per day (in litres / Bucket / Gagri) Note: Interviewer should try to find out the breakdown the water use in percentage at later stage	Total Cooking / Drinking Washing Bathing Flushing For animal consumption For irrigation Other.....	

ENERGY

1. Fuel Types and Users (Household / Office / Business)

Using the fuel list below, what types of fuel do you use for the following purposes? (List in order of importance using numbers shown below)

Wood =1 Dung = 2 Agricultural residues = 3 Other residues = 4 Charcoal = 5	Kerosene (Paraffin) = 6 Bottled gas (LPG) = 7 Solar cooker = 8 Solar electric (solar PV) = 9 Grid electricity = 10	Batteries = 11 Wax candle = 12 Pico Hydro = 13 Water Mill (IWM/TWM) = 14 Other = 15

Purpose	Fuel Priority								
	First priority	Qty/ mth	Cost /month	**Second Priority**	Qty /mth	Cost /month	**Third priority**	Qty /mth	Cost/ mth
Cooking (including drinks)									
Lighting									
Space heating									
Heating water for Drinking/ Bathing / Bed warming / Washing									
Beer brewing									
Cooking food/drink for selling (excluding beer)									
Cooking animal feed									
Grinding grains									
If fuel is used for another type of household task, please specify task (s)	Task 1: Task 2:								

*Fuel wood in Bhari/Month, electricity in W/Month or kWh/Month, LPG in cylinder/Month, Liquid fuel in litre/Month, Grinding (in Mana/Muri/Pathi) per month

2. Getting Fuel: Buying and Gathering

How do you get fire-wood or dung?	1- all gathered 2- mostly gathered	3- mostly bought 4- all bought
Who gathers them, From where 1. SNP / SNPBZ 2. If other source specify 3. Distance from home (in hour)		
If you use the following fuels, how much do you pay for it per month? Wood Charcoal Kerosene (paraffin) Bottled gas Grid electricity Batteries Wax candles Others	Qty / month	NRs. / month
Total (in NRs.)		
What are the reasons for buying fuel? (more than one reason can be selected) 1. Scarcity of fire-wood and dung for gathering 2. Faster than gathering it 3. Cleaner for cooking 4. Other reason (please specify)		

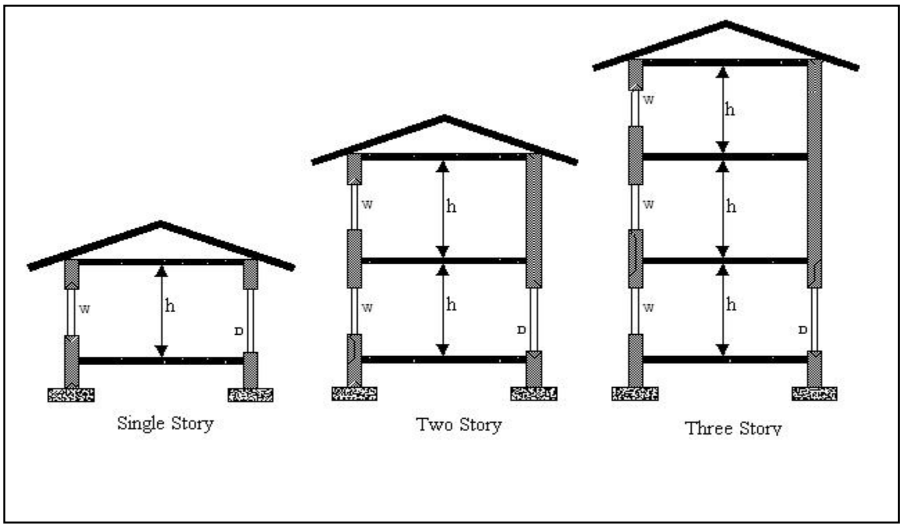
If you or your family gather fuel, how often is it gathered? 1- every week 2- every month 3- Twice in a year 4- Specific time(mention)	Qty / month in summer	Qty / month in winter
Collection Labour charge		
If you gather fuel, for how long will it be sufficient (in months)?		
If you gather fuel, for how long do you take to gather?		
If you gather fuel, do you experience any problems when gathering it? If any, write the problems?		

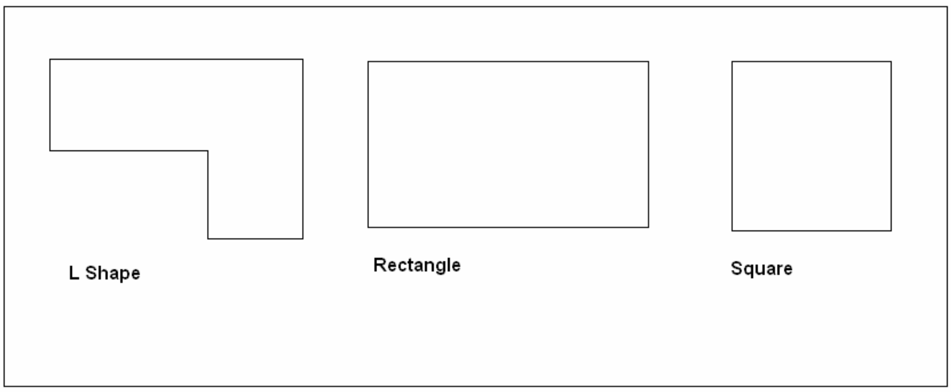
3. House Detail (for passive energy use and energy efficiency in buildings)

Sketch of house with outline plan, indicating the following (Take photo from four sides)

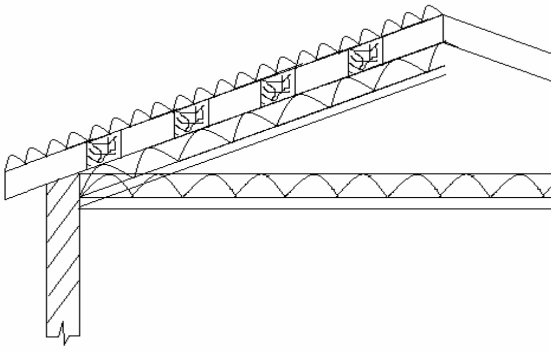
- Heated Rooms, identifying kitchen (if part of main house)
- Position of the fire/stove
- Position of door (s)
- Position of window (s)
- Exterior and Interior Walls
- Wall thickness
- Storey
- Orientation (use compass)
- Dimensions of the room L×B×H (Specifically in the room where space heating is used)
- Outer dimension of building L×B (see sketches)

Sketches please (Top View preferred in single storey otherwise 2-D View with cross-sections)





Roof

Materials of roof (If multiple roof materials are found please specify where it is)	
Roof materials 1- Thatch 3. Tiles 4- Corrugated Galvanized Iron (CGI) sheets 5. Brick Cement Concrete (BCC) 6. Reinforce Cement Concrete (RCC) 7. Wood beam Insulation materials cum false ceiling 8. Ferro-cement/plaster of Paris board 9. Wood planks/plywood board 10. Foam 11.Glass wool 12.Thermocole	

Floor and Ceiling

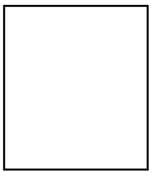
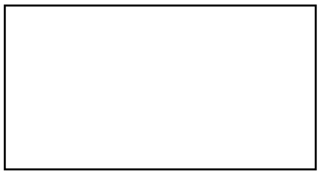
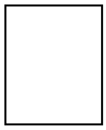
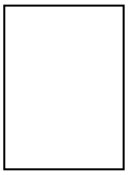
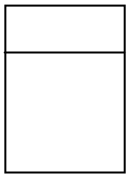
Materials for floor and ceiling (If multiple floor and ceiling materials are found please specify where it is)	
Floor made of 1. RCC 2. BCC 3. Wood beam, joist **Finishing materials** 4. Parquet (wooden, PVC 5. Cement / sand plaster (Coarse) 6. Cement punning (fine) 7. Mud 8. Tiles (Telia tile or 9. Wood planks 10. Glass wool 11. Foam 12. Plaster of Paris 13. Mattress 14. Other	

Walls

Type of materials 1. Mud or mud blocks 2. Soil/cement blocks 3. Wattle (woven sticks / reeds / bamboo) 4. Iron sheets 5. Bricks 6. Stone 7. Glass wool	

8. Foam matters 9.Thermocole 10.Wooden planks 11.Plaster a. Cement / sand b. Mud / Kamero	

Windows and Doors

Type of openings	Glazed	Unglazed	Typical elevation		
Windows	(Single / double)	(tin / metal / wood)	 Window 1	 Window 2	 Window 3
Doors			 Door 1	 Door 2	

Stoves (Chulo)

Type of stove (If multiple stoves are found to be used tick them according to priority)	For Cooking			Space Heating		
	L (m)	B (m)	H (m)	L (m)	B (m)	H (m)
1. Three-stone or two-stone fire						
2. Shielded mud fire or mud stove (including chimney stove)						
3. Ceramic stove (made of fired clay)						
4. Metal stove one pot / two pots / three pots / Nepal made or foreign made						
5. Briquette stove						
6. kerosene stove						
7.Gas stove						
8. Solar cooker						
9. Grid-powered electric stove						

10. Other type of stove						
Smoke Extraction Pipe Chimney / Hood Chimney / Pipe Chimney with water heating provision						

3. Electricity Use Pattern

List the electrical equipment and tools			**Number of equipment**	**Wattage**	**Time of the day use (period) e.g./ 6 -7 AM / PM**		
			(-)	**(W)**	**Morning**	**Day**	**Evening**
a) Light bulbs	IL	60 W					
		100 W					
	FL	20 W					
		40 W					
	CFL	< 10 W					
		> 10 W					
	WLED	1 W					
b) Toaster							
c) Bakery Oven							
d) Rice cooker							
e) Water heater							
f) Fan							
g) Room heater / air conditioning							
h) Pumping							
i) TV							
j) Audio/Video/Overhead							
k) Saw mill							
l) Grinder/coffee/wheat							
m) Mixture							
n) Coffee maker							
o) Washing machine							
p) Dish washer							
q) Refrigerator							
r) Battery charger							
s) Other specify							
Total							
Is it sufficient for them			Yes / no				
If no then what type of other energy use you want to add							
Mention any other information regarding electricity use pattern							
How much are you paying for electricity per month?							

6.4.2 Measurements

Measurement of Heat demand

Measurement of building dimensions, identification of materials used for insulation, types and pattern of energy use, listing and identifying of energy consuming equipments used by households were conducted alongside every interview. Spot measurements of global solar radiation and wind velocity were also collected along the trekking route. GPS coordinates of all surveyed households, hydropower plants and other installations were also recorded.

To calculate the thermal transmittance (U-value) of the heated rooms, measurement of room dimensions (height, length breadth), wall thickness, number of doors and windows, insulation material type, inside and outside temperature of the room were measured. For further analysis in energy requirement inside a room the temperature required was set 20 degrees Celsius as a standard that will keep a room in comfortable temperature.

Spot Measurement of Wind Velocity and Solar Irradiation

Wind and Sun are another open source for harvesting an ample amount of energy from the Mother Nature. Thus spot measurement of wind velocity and solar irradiation has been done on different sites of the region (shown in figure below).

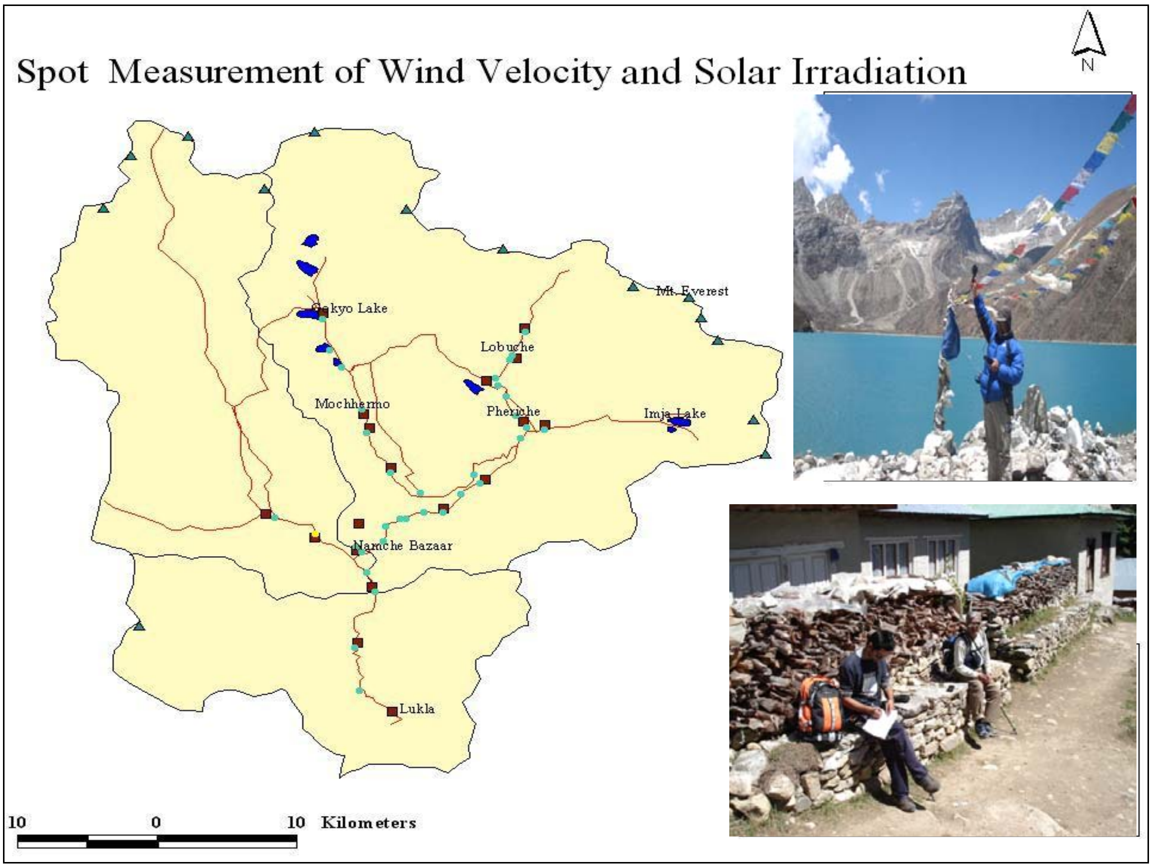


Figure 52: Spot measurement of wind velocity and solar irradiation

Study on potential sites for Micro-hydropower

To assess new potential sites for hydropower plants the discharge and gross head were measured at the site identified for preliminary study following the standard guidelines by AEPC/DOED. Existing hydropower plants were also visited and their condition were recorded

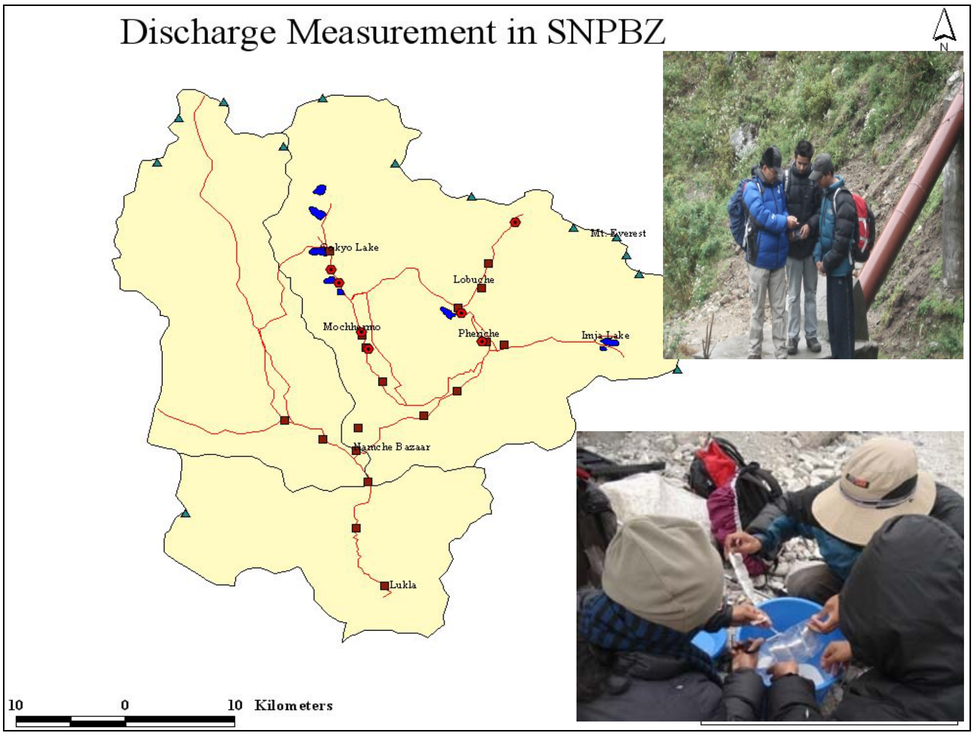


Figure 53: Discharge measurement

Other means of data collection

Rapid appraisals were carried out whenever standard questionnaires were not a suitable means of data collection, or to collect additional background information that could not be captured by the survey. Unplanned open discussions and exchanges with informants took place.

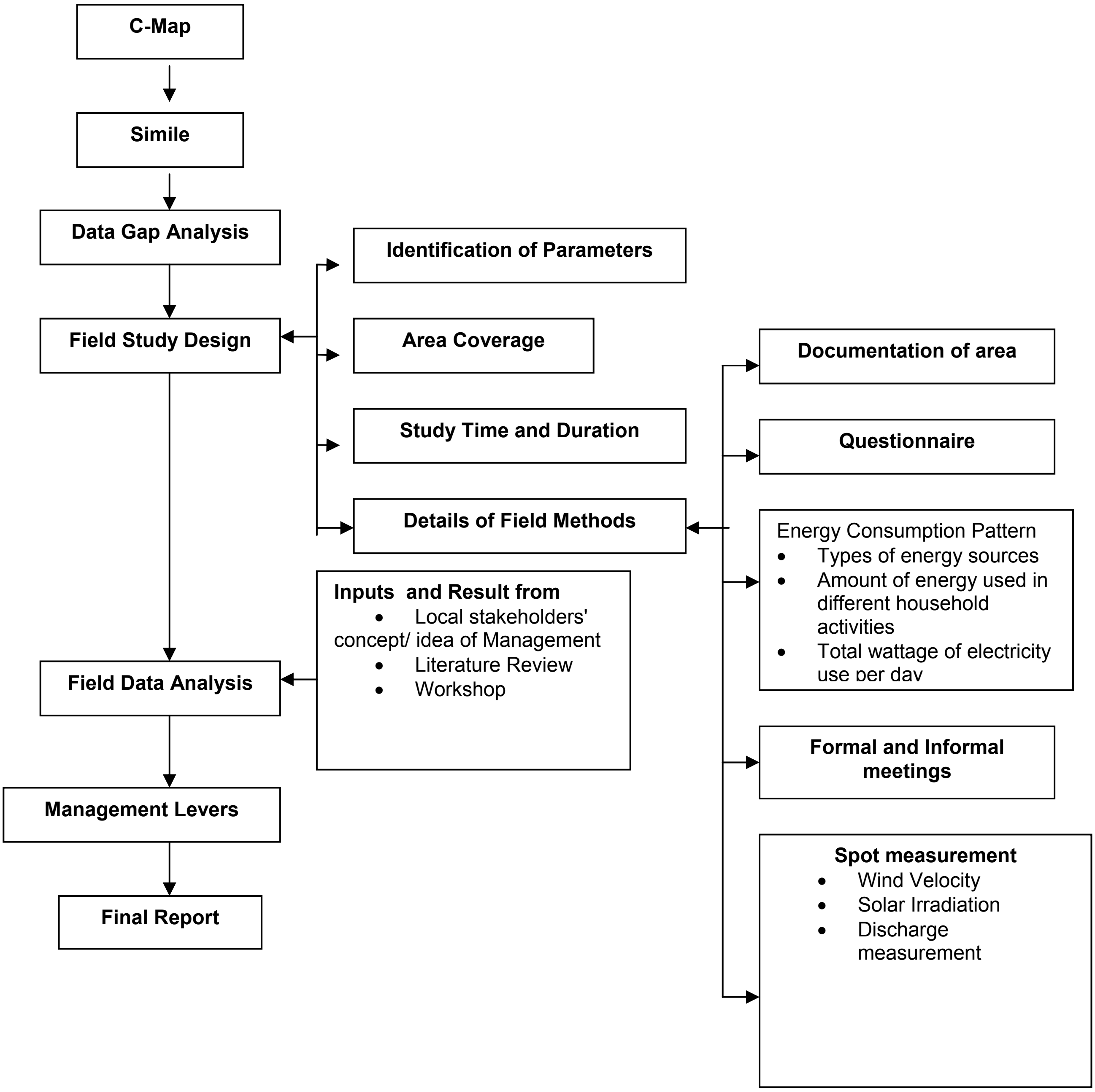


Figure 54: Flow chart of study methodology

6.5 Data

6.6.1 Secondary data

Species	**Frequency (%) occurrence**	**Weight of firewood (kg) Mean**	**Moisture percent**
Juniperus spp.	29	29	19
Betula spp.	28	28	23
Abies spp.	30	24	21
Rhododendron spp.	17	19	22
Pinus spp.	8	28	21
Acer spp.	1	4	28
Mixed species	6	28	20

Table 53:Composition of firewood by species and their moisture content (Source: Basnet, 1992))

	Fuel (kg)	**Burning Rate (gm/min)**	**Power input (kW)**	**Boil time (min)**	**Water Evaporation (kg)**	**Efficiency (%)**
Household	1.017	40.1	10.9	25.3	0.076	11.6
Lodge	1.125	48.4	12.8	23.3	0,043	16.1

Table 54: Average Water Boiling Test Result in Namche Bazaar (Source: Sulpya and Bhadra.1991))Weight of water used for the test – 5kg

	Fuel	**Moisture Content**	**Equivalent dry wood**	**Food cooked (kg)**	**Specific fuel Used**	**Time**	**Efficiency**	**Useful heat**
Household	2.88	17	23.86	5.7	0.42	46.5	11.6	5.6
Lodge	3.66	15	3.11	5.31	0.58	49.5	16.1	9.8

Table 55: Average Cooking Test Result in Namche Bazzar (Source: Sulpya and Bhadra, 1991)

Year/source	**Wood**	**Kerosene**	**Electricity**	**Dung**	**LPG**
1999	477	17	20	52	-
2007/08	239	220	50	47	49

Table 56: Total energy consumption in study region (in kWh/HH/day) (Source: CEE (1999) for 1999 data; Field Survey (2008) for 2007/08)

6.6.2 Primary data

CODE	**Variable name**	**Variable Description**	**Spatial disaggregation**	**Temporal disaggregation**	**Other disaggregations**	**Units**

E20	Amount of energy required for each person for cooking and for utilities	Amount of energy that each person, need to cook and to use other utilities.	SETTLEMENT: Tengboche, Namche			kWh per mont h
E21	Amount of energy used for entertainment per person	Amount of energy that each person, need to use entertainment system.	SETTLEMENT: Tengboche, Namche			kWh per mont h
E22	Amount of energy used for pumping per person	Amount of energy used to pump the water for each person.	SETTLEMENT: Tengboche, Namche	Month		kWh per mont h
E221	Amount of energy used to heat water per person	Amount of energy used to heat the water for each person.	SETTLEMENT: Tengboche, Namche	Month	per capita	kWh per mont h
E18	Average number of hours used for lighting		settlement	Month	building types	hours for day
Ep3a	commercial energy use	average consumption by building for each commercial energy source: Kerosine, LPG, Diesel	settlement: LUKLA, PHAKDING, CHAUMOA, MONJU, JORSALLE, TOKTOK, NAMCHE BAZZAR, SYANGBOCHE, KHUMJUNG, KHUNDE, PHURTE, THAMO, THAME, THAMETENG, KYANGJUMA, SANASA, LUSASA, TENGBOCHE, PANGBOCHE, UPPER PANGBOCHE, PHUNGITHENGA, PHORTSE, DUECHE,SOMARE, PHERICHE, DINGBOCHE, CHUKKUNG, THUKLA, LOBUCHE, GORAKHSHEP, MONGLA, DHOLE, MASHHORMO, GOKYO.	model	building type, energy source	kg
Ep4a	local energy use	average consumption by building for each local energy source: fuelwood and dung	settlement: LUKLA, PHAKDING, CHAUMOA, MONJU, JORSALLE, TOKTOK, NAMCHE BAZZAR, SYANGBOCHE, KHUMJUNG, KHUNDE, PHURTE, THAMO, THAME, THAMETENG, KYANGJUMA, SANASA, LUSASA, TENGBOCHE, PANGBOCHE, UPPER PANGBOCHE, PHUNGITHENGA, PHORTSE, DUECHE,SOMARE, PHERICHE, DINGBOCHE, CHUKKUNG, THUKLA, LOBUCHE, GORAKHSHEP, MONGLA, DHOLE, MASHHORMO, GOKYO.	model	building type, energy source	kg
Ep5a	light provided by sources	amount of light (lumen) provided per Watt of each lighting source (conventional and energy saving)		Type of brightness source	lighting source	lume n/W
Ep5b	Lux for each type of buildings	It represets the average amount of lux need to light different type of buildings.			building type, lighting source	lux
Ep5c	cost for light	Average cost of saving lanps per kW			lighting source	NRS/ KW

Ep2a	households with electricity	% of households with electricity	settlement	model		%

Table 57: Data collected about household energy use pattern

CODE	Variable name	Variable Description	Spatial disaggregation	Temporal disaggregation	Other disaggregations	Units
E46	Percentage of use of the total hydropower energy	This variable represents the percentage of the total hydropower energy provided to each settlement.	settlement			%
E45	Efficiency of hydropower plant energy production	This percentage represents the efficiency of hydropower energy production			per station	%
E391	Wind energy system power	Power of the existing energy system	SETTLEMENTS: MOCHHERMO, PHERICHE AND LOBUCHE			kW
E392	Hours of wind system activities		settlement	Month		hour
E37	Energy produced by all photovoltaic panels	Amount of energy produced by PV panels in each settlement.	SETTLEMENTS: LUKLA, UPPER PANGBOCHE, FORSTE THANGA, PHERICHE, DINGBOCHE, THUKLA, LOBUCHE, GORAKHSHEIP, DHOLE, MACHHORRMO, GOKYO, MONGLA, BASECAMP	Month		kWh per month
E38	Energy produced by all thermal panels	Amount of energy produced by thermal panels in each settlement.	settlement	Month		kWh per month
E39	Average number of hours of sun light	Amount of hours of sun in each month.	settlement	Month		hour per month
E461	Plant power	It represents the power of the hydropower station that it supplies energy to the settlement	SNPBZ		Hydropower station	kW
E48	Difference of level	DIFFERENCE OF WATER LEVEL INSISTING ON THE TURBINE: pressure head			Hydropower station	m
E49	Number of hours of energy production of the hydropower stations	Hours in each month of functioning of each hydropower station.		Month	Hydropower station: KBC, TENGBOCHE AND FORSTE	hour per month
E51	Total electric power produced	Total of montly energy produced in each hydropower station.		Month	Hydropower station: KBC, TENGBOCHE AND FORSTE	kWh per month
Ep9b	time required to build a system	average time required to build a system			system	months
Ep10b	total present system efficiency	It represents a percentage that indicates the efficiency of each hydropower station.			Hydropower station	coefficient
Ep6a	area of PV cells	area of PV cells	settlement			m2

Ep7a	area thermal systems	area of thermal systems	settlement			m2
Ep8b	number of Wind systems	number of Wind systems	settlement			numb er
Ep9a	cost per kW hydropower plant	Average cost to install a kW of a new hydropower plant			station	NPR
Ep10c	relation between cost and efficiency	average increase in efficiency per cost unit	SNPBZ			functi on
Ep10d	maximum reachable efficiency	average maximum reachable efficiency	SNPBZ			coeffi cient
Ep5a	light provided by sources	amount of light (lumen) provided per Watt of each lighting source (conventional and energy saving)		Type of brightness source	lighting source	lume n/W
Ep11a	transmission efficiency	energy efficiency of the transmission system	SNPBZ			coeffi cient
E56	Discharge	This is the montly discharge of the river section that is intercetted by the hydropower station.		Month	River section with hydropower station	m3/s

Table 58: Data collected about alternative renewable energy sources

CODE	Variable name	Variable Description	Spatial disaggregation	Temporal disaggregation	Other disaggregations	Units
E1	Average base surface of heated rooms	It represents the averege base surface of heated rooms in each settlement and for each building type.	ALL SETTLEMENTS: Lukla, Phakding, Namche Bazaar, Phortse, Phortse thanga, Tengboche, Upper Pangboche, Pheriche, Dingboche, Thukla, Lobuche, Gorakhshep, Dhole, Machhorrma, Gokyo, Mongla, Thame, Thamo, Thametyang, Pangboche, Khumjung and Khunde		building types: TRADITIONAL, SEMI MODERN AND MODERN TYPE OF BUILDING OF RESIDENTIAL, COMMERCIAL AND INSTITUTION	m2
E2	Average height of heated rooms	It represents the averege height of heated rooms in each settlement and for each building type.	ALL SETTLEMENTS: Lukla, Phakding, Namche Bazaar, Phortse, Phortse thanga, Tengboche, Upper Pangboche, Pheriche, Dingboche, Thukla, Lobuche, Gorakhshep, Dhole, Machhorrma, Gokyo, Mongla, Thame, Thamo, Thametyang, Pangboche, Khumjung and Khunde		building types: TRADITIONAL, SEMI MODERN AND MODERN TYPE OF BUILDING OF RESIDENTIAL, COMMERCIAL AND INSTITUTION	m
E4	Average surface of a heated room window	It represents the average surface of the window in a heaed room in each settlement and for each building type.	ALL SETTLEMENTS: Lukla, Phakding, Namche Bazaar, Phortse, Phortse thanga, Tengboche, Upper Pangboche, Pheriche, Dingboche, Thukla, Lobuche, Gorakhshep, Dhole, Machhorrma, Gokyo, Mongla, Thame, Thamo, Thametyang, Pangboche, Khumjung and Khunde		building types: TRADITIONAL, SEMI MODERN AND MODERN TYPE OF BUILDING OF RESIDENTIAL, COMMERCIAL AND INSTITUTION	m2
E5	Average thikness of window glass	It represents the average thikness of a window in each settlement and for each building type.	ALL SETTLEMENTS: Lukla, Phakding, Namche Bazaar, Phortse, Phortse thanga, Tengboche, Upper Pangboche, Pheriche, Dingboche, Thukla, Lobuche, Gorakhshep, Dhole, Machhorrma, Gokyo, Mongla, Thame, Thamo, Thametyang, Pangboche, Khumjung and Khunde		building types: TRADITIONAL, SEMI MODERN AND MODERN TYPE OF BUILDING OF RESIDENTIAL, COMMERCIAL AND INSTITUTION	m

E51	average thikness of walls	average thickness of walls per heated room	ALL SETTLEMENTS: Lukla, Phakding, Namche Bazaar, Phortse, Phortse thanga, Tengboche, Upper Pangboche, Pheriche, Dingboche, Thukla, Lobuche, Gorakhshep, Dhole, Machhorrma, Gokyo, Mongla, Thame, Thamo, Thametyang, Pangboche, Khumjung and Khunde		building types: TRADITIONAL, SEMI MODERN AND MODERN TYPE OF BUILDING OF RESIDENTIAL, COMMERCIAL AND INSTITUTION	m
Ep1a	thermal conductivity	thermal conductivity (U) per heated space and building type for different insulation options	settlement	model	building type, insulation options	W/m 2K
Ep1b	cost of insulation	cost for each insulation option			building types, construction material	NRS
E10	Outdoor Temperature	This represents the average enviromental temperature in each settlement and for each month.	settlement	Month		K
E12	bedroomsize volume	It represents the volume dedicated to bed room in a building in each settlement and for each building type.	SETTLEMENTS: Lukla, Pahakding and Namche		building types: TRADITIONAL, SEMI MODERN AND MODERN TYPE OF BUILDING OF RESIDENTIAL, COMMERCIAL AND INSTITUTION	%
E151	Average volume of heated rooms	Average volume for each building type.	ALL SETTLEMENTS: Lukla, Phakding, Namche Bazaar, Phortse, Phortse thanga, Tengboche, Upper Pangboche, Pheriche, Dingboche, Thukla, Lobuche, Gorakhshep, Dhole, Machhorrma, Gokyo, Mongla, Thame, Thamo, Thametyang, Pangboche, Khumjung and Khunde		building types: TRADITIONAL, SEMI MODERN AND MODERN TYPE OF BUILDING OF RESIDENTIAL, COMMERCIAL AND INSTITUTION	m3
E181	Average height of rooms	average height of heated rooms	ALL SETTLEMENTS: Lukla, Phakding, Namche Bazaar, Phortse, Phortse thanga, Tengboche, Upper Pangboche, Pheriche, Dingboche, Thukla, Lobuche, Gorakhshep, Dhole, Machhorrma, Gokyo, Mongla, Thame, Thamo, Thametyang, Pangboche, Khumjung and Khunde		building types	m

Table 59: Data collected about insulation

Alternative energy sources in SNPBZ

Settlements	area of PV Panel (m2)(Ep6a)	Hrs of sunshine (hrs/day)	Solar irradiation (W/m2)	Efficiency	Days	Energy (Wh/month)	Energy produced by photovoltaic panels (kWh/month)	No. of HH with Solar PV	Energy produced by all photovoltaic panels (kWh/month) (E37)
Lukla	0.175	6	162	0.15	30	765.450	0.765	18	13.78
Phakding	0.177	6	160	0.15	30	763.776	0.764	5	3.82
Monju	0.177	6	162	0.15	30	773.323	0.773	4	3.09
Jorsalle	0.265	6	180	0.15	30	1287.900	1.288	13	16.74
Namche	0.170	6	192	0.15	30	881.280	0.881	4	3.53

Pungitenga	0.210	6	198	0.15	30	1122.660	1.123	4	4.49
Lausasa	0.133	6	198	0.15	30	712.800	0.713	17	12.12
Pheriche	0.412	6	225.7	0.15	30	2510.687	2.511	22	55.24
Dingboche	0.338	6	225	0.15	30	2050.738	2.051	52	106.64
Thukla	0.300	6	225	0.15	30	1822.500	1.823	1	1.82
Lobuche	0.383	6	229.27	0.15	30	2370.365	2.370	7	16.59
Gorakhshep	0.425	6	232	0.15	30	2664.941	2.665	6	15.99
Upper Pangboche	0.450	6	201	0.15	30	2442.150	2.442	25	61.05
Phortsethanga	0.244	6	198	0.15	30	1306.990	1.307	6	7.84
Mongla	0.350	6	215	0.15	30	2031.750	2.032	6	12.19
Dole	0.500	6	218	0.15	30	2943.000	2.943	10	29.43
Machhermo	0.370	6	220	0.15	30	2197.800	2.198	12	26.37
Gokyo	0.273	6	235	0.15	30	1734.300	1.734	9	15.61
Basecamp	0.414	6	250	0.15	30	2794.500	2.795	45	125.75

Table 60: Energy generate from PV

Settlements	area of Thermal Panel (m2)(Ep6a)	Hrs of sunshine (hrs/day)	Solar irradiation (W/m2)	Efficiency	Days	Energy (Wh/month)	Energy prodcued by thermal panels (kWh/month)		Energy prodcued by all thermal panels (kWh/month) (E38)
Lukla	1.000	6	162	0.2	30	5832.000	5.832	41	239.11
Phakding	1.000	6	160	0.2	30	5760.000	5.760	8	46.08
Chhumoa	1.000	6	162	0.2	30	5832.000	5.832	1	5.83
Monju	1.000	6	162	0.2	30	5832.000	5.832	11	64.15
Namche	1.000	6	192	0.2	30	6912.000	6.912	31	214.27
Khunde	1.000	6	195	0.2	30	7020.000	7.020	7	49.14
Khumjung	1.000	6	195	0.2	30	7020.000	7.020	14	98.28

Table 61: Energy generated from Solar Thermal panels

Site	Altitude	Measured Wind Velocity (m/s)	Air Density (kg/m3)	C Betz	Theoretical Wind Potential / m2	Power at 2m height		
Kyanjuma	3614	14	0.848	0.59	7.009	440.358	2202	4404
Tyangboche	3853	8	0.820	0.59	3.870	243.170	1216	2432
Pheriche	4296	10.6	0.767	0.59	4.797	301.416	1507	3014
Pheriche to Dingboche	4313	16	0.765	0.59	7.222	453.763	2269	4538
Dole	4200	7	0.779	0.59	3.215	202.022	1010	2020
Dingboche to Thukla	4468	3	0.747	0.59	1.321	83.022	415	830
Pyramid (ABC station)	5079	14	0.674	0.59	5.564	349.575	1748	3496
Pyramid to Gorakhshep	5142	11.8	0.666	0.59	4.637	291.352	1457	2914

Lobuche	4898	11.2	0.695	0.59	4.594	288.633	1443	2886
Thukla	4590	9	0.732	0.59	3.887	244.207	1221	2442
Thukla to Lobuche	4640	10.2	0.726	0.59	4.369	274.511	1373	2745
Machhermo	4408	7.8	0.754	0.59	3.468	217.930	1090	2179
Gokyo	4764	3	0.711	0.59	1.259	79.092	395	791
Phrochethanga to Mongla	3675	7.5	0.841	0.59	3.722	233.881	1169	2339
Mongla	3973	8	0.806	0.59	3.803	238.921	1195	2389
Sanasa to Khumjung	3616	10	0.848	0.59	5.005	314.453	1572	3145
Monju	2849	7.6	0.940	0.59	4.214	264.786	1324	2648
Jorsalle to Namche	2940	5.6	0.929	0.59	3.069	192.850	964	1928
Ghat	2496	5.4	0.982	0.59	3.129	196.575	983	1966
Namache Ukalo	3080	5.6	0.912	0.59	3.014	189.379	947	1894
Namche to Tyanboche (Stupa)	3500	10.8	0.862	0.59	5.493	345.154	1726	3452
Way to Lobuche	4498	8	0.743	0.59	3.507	220.331	1102	2203
Thukla to Lobuche	4825	7	0.704	0.59	2.907	182.658	913	1827
Second lake of Gokyo	4740	10	0.714	0.59	4.213	264.702	1324	2647
Third lake of Gokyo	4760	9	0.712	0.59	3.779	237.435	1187	2374
Confluence of Dhudh Koshi and Gokyo	4650	10	0.725	0.59	4.276	268.685	1343	2687

Table 62: Energy generated from Wind Power

6.6 Findings and Discussion

6.7.1 <u>Energy Consumption</u>

Fuelwood remains the major energy source in SNPBZ constituting 88% which is followed by kerosene by 7% and than dung (3%) and LPG (2%) shown in figure 1.

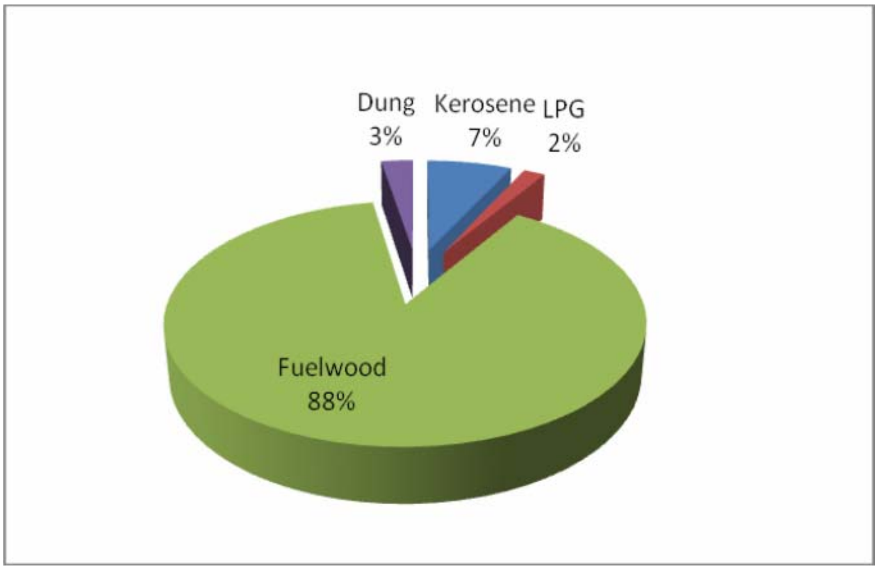


Figure 55: Percentage dependency on fuel

56%. of the energy is used for cooking. Fuelwood and electricity are the major energy sources for cooking. followed by Kerosene and LPG. Fuelwood, animal dung and electricity are the major energy source for space heating in the area with 34%. LPG, solar thermal and electric geyser are mainly used in hot showers.

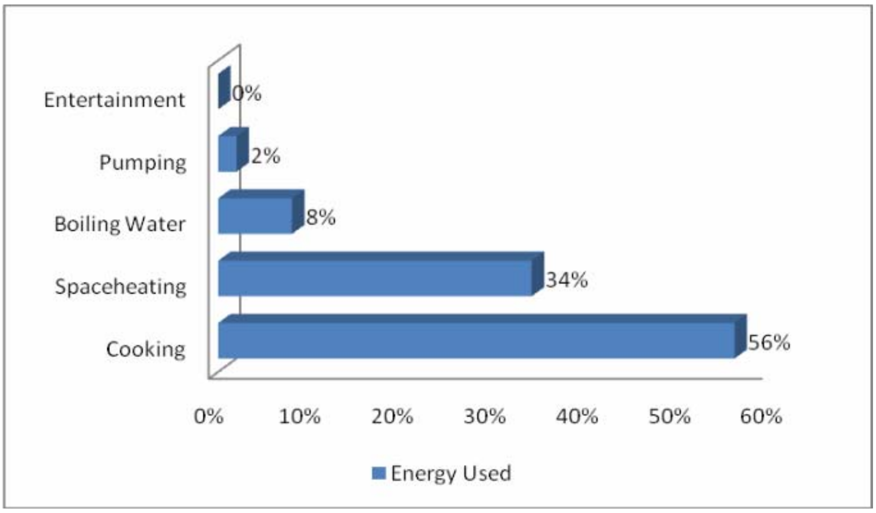


Figure 56: Energy utilization in different household activities

Renewable energy sources such as solar, wind and hydropower are abundantly available in the region. Emerging technology that generates power from these sources is being accepted as usable is recommended to reduce the fossil fuel in the region.

Factors determining energy consumption

Altitude has a profound impact on energy consumption. In a mountainous topography, the location of a lodge is an important factor in determining energy consumption levels (Nepal, 2007). With higher altitude, energy consumption for space heating and cooking increases. This is caused by low temperatures and a low atmospheric pressure, requiring more energy for water to reach its boiling point.

Nevertheless, the fuel wood consumption of households located at 2500- 3000m is higher than of households at higher altitude, due to a limited access to fuelwood in high altitude, which is substituted by kerosene and dung in high altitude altitude. The former is readily accessible due to a kerosene depot located in Dole and Dingboche. The altitude-related differences in daily fuel wood is statistically significant.

Altitudinal range (meter)	**Wood (kg)**	**Kerosene (kg)**	**LPG (kg)**	**Dung (kg)**	**Electricity (kWh)**
2500 - 3000	23.46 ± 18.55 (57)	.88 ± 1.11 (30)	6.52± 27.88 (23)	-	2.4± 2.45 (18)
3000-3500	10.93± 14.32 (24)	5.25 ±8.91 (23)	.76 ± (1)	-	23.4± 12.56 (23)
3500- 4000	13.31 ± 18.03 (34)	5.6± 5.9 (22)	1.18 ± 1.06 (11)	7.48± 5.33 (8)	11.23± 8.76 (13)
4000 – 4500	16.61± 25.90 (12)	5.77± 8.48 (16)	1.29± .88 (6)	8.62± 7.95 (5)	4.5 ±3.4 (7)
4500- 5000	-	15.66±11.00 (5)	1.52±1.14 (3)	14.03±8.23(5)	1

>5000	-	9.80 (1)	-	9.93 (1)	1

Table 2 Differences in average daily energy consumption at different elevation (Values shown are mean ± S.D (n)

One of the most determining factors of energy consumption patterns is income. Households with an income period less or equal to three months (marginalized households) depend to a greater extent on fuel wood as the small income is not sufficient to cover expenses for commercial sources. Wealthier households rely more on commercial energy sources. However, dung seems to be used by all households to similar extents, since it is likely to be related to livestock numbers.

Month of income	**Wood (kg)**	**Kerosene (kg)**	**LPG (kg)**	**Dung (kg)**
>12 months	18.56± 21.05 (91)	4.66± 7.51 (81)	3.43±18.35 (53)	9.14±7.71 (15)
>6months	14.15± 12.01 (32)	1.66±2.12 (13)	.72±.66 (7)	11.92±2.29 (3)
>3months	27.38±13.52 (4)	.16 ± .12 (2)	-	10.23 (1)

Table 3: Average daily energy consumption according to economic status

Changes in economic activities (tourism) and access to modern technologies have resulted in a change of energy consumption patterns of households in SNPBZ. Figure 3 illustrates these changes as a shift towards alternative energy sources other than fuelwood. Increasing availability of different energy sources during the period between 1999 and 2007/08 has resulted in a greater choice between different energy sources.

Due to the local airport in Syangboche facilitating the import of alternative sources and the establishment of a kerosene depot in Namche, Fuel wood consumption has decreased in 2007/08 by 63.47% as compared to 1999 in Namche. The electricity demand is 2.6 times higher in 2007/08 than in 1999. The use of LPG has considerably increased and currently accounts for about 18kWh/HH/day

Yak and Nak rearing provides another alternative energy source: dry animal dung, which accounts for 22kWh/HH/day in 2007/08. The share of this source is negligible to that of other sources (fuel wood and kerosene), but has increased by factor of 1.1 during the eight year timeframe (1999-2007/08). LPG and electricity are other major energy sources accountiong for about 17kWh/HH/day and 5kWh/HH/day respectively. The installation of Pico-hydro and Micro-hydro in the region has provided an opportunity for local people to use electricity for compensating their energy need, which accounts for about 7kWh/HH/day.

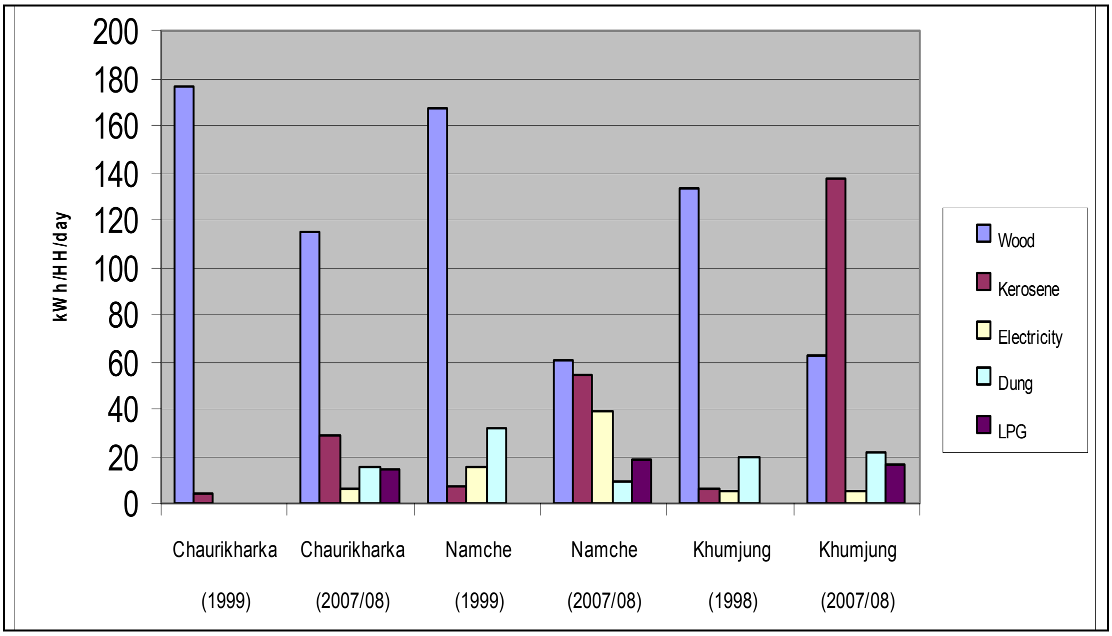


Figure 57: Comparison of household energy use in Khumbu region (Source: Bhochhibhoya et al, 2008))

SNPBZ region features very cold winters, during which more energy is used for space heating. This energy use can be decreased significantly by increasing the efficiency of house insulations or apply appropriate building materials and techniques.

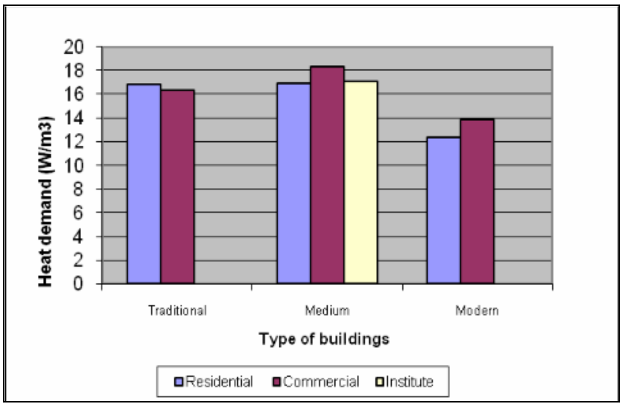


Figure 5: Comparison of Energy Use for Space heating in different types of Buildings (Source: Bhochhibhoya, S.et al (2008))

Modern buildings using imported construction materials with good insulation are more energy efficient with a requirement of 13.1 W/m^3 to maintain room temperature. Traditional buildings with ancestral house design have thick walls with mud plaster, requiring 16.6 W/m^3 to maintain a pleasant indoor climate. The “medium” or “common” houses built with a combination of local and modern technologies of limited insulation capacity need 17.44 W/m^3.

The reduction in heat demand depends on the type of insulation used. different insulating materials have their specific thermal conductivities. expensive glass wool or locally available mud plaster and thermocole, reduce the heat demand by 23% and 19.56%, respectively. Initial investment in insulation saves future expenses for energy sources.

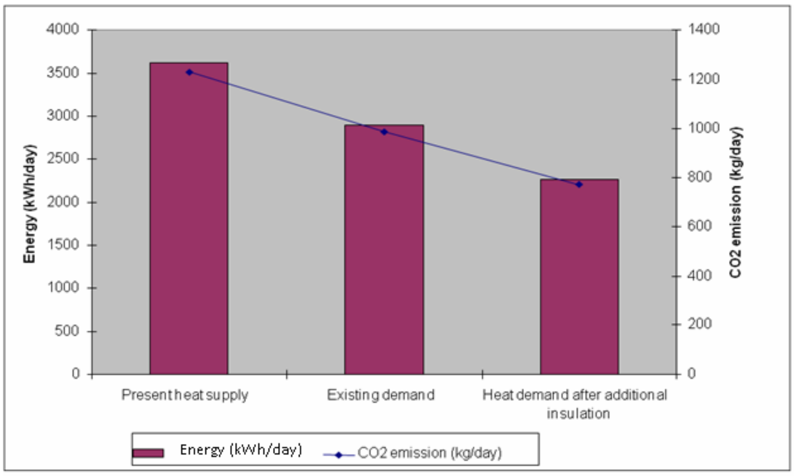


Figure 7: Reduction in CO_2 emission by use of proper insulation (Source: Bhochhibhoya, S.et al (2008))

With the advent of tourism in the region, traditional houses have been modified using dry stone masonry or concrete walls with cement plasters and large windows. Such construction materials in semi-modern and modern buildings insulate poorly. Few modern buildings are found to be better insulated than the traditional "Sherpa House" entailing high cost for construction.

6.7.2 Renewable Energy Sources

Renewable Energy Sources except fire-wood and Dung-cakes are defined here as non-conventional sources of energy. The study found that renewable energy sources such as solar, wind and hydropower are abundantly available in the region. Emerging technology that generates power from these sources is being accepted as usable is recommended to reduce the fossil fuel in the region. It has been found that tourists are more attracted in those settlements where there is better service to them with electricity and hot water. Even if there is no electricity for cooking and bathing in the settlements far from grid supply (such as from Khumbu Bijuli Company, Phortse Micro-hydropower plant, Tengboche Micro-hydropower plant, Pangboche Micro-hydropower plant in Upper Khumbu and Monju pico-hydropower plant, Phakding Micro-hydropower plant, Lukla Micro-hydropower plant, Ghat pico-hydropower plant in Lower Khumbu), households tend to use small-scale photovoltaic and wind power systems to attract tourists thus increase their livelihood. On the other hand, lack of electricity supply for cooking and space heating in upper Khumbu increases the use of indigenous sources of energy such as firewood and dung-cakes as well as commercial energy sources such as kerosene and LPG. This will have negative impact on climate and economy. Thus new hydropower plants' installation in the region is emphasized.

6.7.3 Hydropower

Hydropower plants are capable to produce a substantial amount of electrical energy that could be advantageously used for substituting conventional sources of energy (commercial and traditional sources of energy) in SNPZ. Several hydropower sites could be developed to address the energy need in SNPBZ. SNPBZ already hosts hydropower plants with a capacity ranging from a few kW to 630 kW. Local peoples' aspiration in Namche is to build larger scale hydropower plants, however, SNPBZ regulations restrict such large scale projects.

Currently, four hydropower stations supply electricity to Upper Khumbu region namely; Khumbu Bijuli Company (630 kW), Tengboche Micro-hydropower Plant (22 kW), Pangboche Micro-hydropower Plant (15 kW) and Phortse Micro-hydropower Plant (60 kW). Lower Khumbu, has Ghatte Khola Micro-hydropower Plant and several pico-hydropower plants. The efficiency of existing hydropower systems can be improved through partial or complete rehabilitation – installing better turbines, alternators and controllers as well as by improving civil work components. Some of the micro-hydropower plants in

SNPBZ - in Tyangboche and Pangboche - are in a critical condition and would require urgent rehabilitation.

Thame Small Hydropower Project (Khumbu Bijuli Company, KBC)

Thame Small Hydropower Project is located in Namche VDC. The plant was developed with financial assistance from the Austrian Government and the Government of Nepal. The power station supplies power to 18 villages of Khumjung and Namche VDC of Khumbu Valley in Solukhumbu district.T he main source of water for the power generation is Thame Khola which has the capacity to generated 600 kW of electricity.

Project	Thame Small Hydropower Project
Source stream	Thame Khola
Location	Namche VDC, Sagarmatha National Park, Solukhumbu district, Eastern Development Region, Nepal
Power demand	High in lodges whereas residential and institute subscribe nominal power only.
Present beneficiary	18 villages of Khumjung and Namche VDC
Generating voltage	400 volt
Transmission line	11000 volt
Distribution	400 volt
11 kV high voltage grid system	20 km
Powerhouse site	Easting: 86°44'00" Northing: 27° 49'46" Altitude: 3500
Design flow	380 l/s
Head	128 m
Canal length	305 m
Capacity	600 kW
Turbine type	Pelton
Average Estimated cost	4285714 US$
Annual Energy generation	~ 2 GWh

Table 63:Salient features of the Thame Small Hydropower Project

The current capacity of Khumbu Bijuli Company (KBC) could be increased by installing an additional 300 kW unit. This would be the most feasible option, expressed by stakeholders of KBC in a meeting in Kathmandu. The specific cost of adding one more unit at KBC is estimated to be round 3111 US$/kW.

Tyangboche Micro-hydropower Plant (TMHP)

The generator of this plant was out of order due to a recent flood for some period and has been repaired recently. However, there is also a need for river bank protection near the powerhouse and slope protection along the headrace pipe.

Pangboche Micro-hydropower Plant (PMHP)

During the field visit to Pangboche MHP in summer 2008, parts of the intake, water ways and power generating unit were repaired and maintained by technicians from Khumbu Bijuli Company. The plant has increased its power generating capacity from 7 kW (as observed in Autumn 2007) to 11 kW in Summer 2008. However, the river bank near powerhouse, the slope protection along the headrace pipe and load controlling device (IGC with ballast) are urgently needed to be maintained.

Phortse Micro Hydropower Project

Phortse MHP is located in Khumjung VDC. The power station supplies power to 80 households, gomba, schools and gompa medical center of Phortse village. The main source of water for the power generation is Khonar Khola which has the capacity to generated 60 kW of electricity.

Project	Phortse MHP
Source stream	Khonar river
Location	Khumjung VDC, Sagarmatha National Park, Solukhumbu district, Eastern Development Region, Nepal
Power demand	High in lodges whereas residential and institute subscribe nominal power only.
Present beneficiary	80 houses, gomba, schools and gompa medical center of Phortse village
Transmission line	11000 volt
Powerhouse site	Easting: 86°48'00" Northing: 27° 51' Altitude: 3540
Design flow	60 l/s
Head	135 m
Penstoke	390 m
Capacity	60 kW
Average Estimated cost	93592 US$

Table 64: Salient features of Phortse Micro Hydropower Project

Cost for rehabilitation of existing MHPs

Table 66 shows the complete rehabilitation cost (civil, mechanical and electrical components) for all existing hydropower plants in Upper Khumbu. The cost range from 55% to 23% of the total project cost. The calculations are based on literature data, as an exact estimation from field data is beyond the scope of this research. The plant's civil work structures are partly damaged or electro-mechanical components need to be repaired/replaced/rehabilitated. The cost in Table 66 does not cover the complete new addition of the aggregates to increase capacity. This has been included only for KBC (The project specific cost is about 7142 US$/kW).

Complete Rehabilitation cost (civil, mechanical, electrical)				
	Capacity of power plant(kW)	Total cost ($)	Rehabilitation cost (Higher side) $	Rehabilitation cost (Lower side) $
Khumbu Bijuli	630	4500000	1601550	1069678

Company				
Tyanboche MHP	22	55000	29607	13074
Pangboche MHP	15	30000	16212	7131
Phortse MHP	60	93592	49314	22247

Table 65: *Table 3: Rehabilitation cost for existing hydropower plants in SNPBZ*

Planned and Newly Commissioned Hydropower Plants

The current capacity of Khumbu Bijuli Company (KBC) does not cover the electricity demand at its load center (900 kW). Therefore, KBC suggests to the stakeholders to install an additional 300 kW aggregate at KBC as an immediate solution. It has also conducted a feasibility for a Namche Mini-hydropower Plant (300 kW). However, current park regulations discourage the development of new hydropower plants.

	Capacity of power plant(kW)	Total cost ($)	Implementation Status
Bom Khola I MHP	100	318744	Commissioned
Chuserma MHP	35	116124	Under construction
Monju Khola MHP	100	302803	Planned
Ghatte Khola MHP	75	232592	Commissioned
Thado-Koshi MHP	100	278900	Planned

Table 66: Cost for planned or commissioned hydropower plants in SNPBZ

Bom Khola Micro Hydropower Project

The Bom Khola Micro-hydropower Project site is located in Chaurikharka VDC of Sagarmatha National Park and Buffer Zone (SNPBZ). The main source of water for the power generation is Bom Khola which has the capacity to generated 100 kW of electricity. This power plant is recently commissioned in 2008.

Project	Bom Khola MHP
Source stream	Bom Khola
Location	Lukla, Chaurikharka VDC, Sagarmatha National Park, Solukhumbu district, Eastern Development Region, Nepal
Power demand	High in lodges whereas residential and institute subscribe nominal power only.
Present beneficiary	Lukla: Presently 147 subscribers: 36 lodges, 54 residential, 36 bhattis and 8 institute, 1 bakery, a few entertainment establishment and restaurants.
HT electrical line	11000V, 3 phase, ACSR orverhead; 600m
LT distribution line	230/400 V, PVC underground; 2100m
Powerhouse site	Easting: 86°44' Northing: 27° 43.98' Altitude: 2800
Design flow	80 l/s
Head	193 m
Canal length	12.5 m

Capacity	100 kW
Turbine type	3 Jet Pelton turbine
Average Estimated cost	318744 US$
Firewood equivalent cooking/ heating energy	~ 325 tons of firewood per annum

Table 67: Salient features of Bhom Khole Micro Hydropower

Ghatte Khola Micro Hydropower Project

Ghatte Khola Micro-hydropower Project site is located in Chaurikharka VDC of Sagarmatha National Park and Buffer Zone (SNPBZ). The main source of water for the power generation is Ghatte Khola which has the capacity to generate 70 kW of electricity. The Ghatte Khola MHP electrifies a total of present 89 households in Phaking , Thulogumila, Jhamkutte, Toktok and Nangbote villages.

Project	Ghatte Khola MHP
Source stream	Ghatte Khola
Location	Chaurikharka VDC, Sagarmatha National Park, Solukhumbu district, Eastern Development Region, Nepal
Power demand	High in lodges whereas residential and institute subscribe nominal power only.
Present beneficiary	Phakding village (North part from Kholsa), Thulo Gumila, Jhamkutte, Toktok and Nangbote villages. (Total 89 potential subscribers at present including 11 lodges, 34 Bhattis, 2 Gompas and rest are residential)
HT electrical line	0
LT distribution line	230/400 V, PVC underground; 1.63 km 230/ 400V, ACRS over head line ~ 1.3 km
Powerhouse site	Easting: 86°44' Northing: 27° 41' Altitude: 2700
Design flow	82 l/s
Head	128 m
Canal length	50 m
Capacity	70 kW
Turbine type	Multi Jet Pelton turbine
Average Estimated cost	186,258 US$
Annual Energy generation	~ 400,000 kWh

Table 68: Salient features of Ghatte Khola MHP

Proposed Micro- and Mini-hydropower Plants

It is recommended to install micro-hydropower plants at a number of places along the Khumbu base-camp route and Gokyo route as shown in table below. During the field visit, spot discharge measurements along these routes were carried out for developing a monthly pattern of river discharges using a mathematical model developed for un-gauged rivers by Medium Irrigation Project in Nepal as below:

Discharge measurement place	Route	Discharge in m^3/s												Head	Capacity
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(m)	(kW)
Pheriche	Base-camp route	0.024	0.018	0.013	0.010	0.026	0.060	0.145	0.250	0.165	0.080	0.041	0.031	75	7.5
Thukla		0.213	0.160	0.115	0.089	0.231	0.532	1.286	2.217	1.463	0.710	0.364	0.275	122	60
Dole	Gokyo route	0.080	0.055	0.041	0.029	0.055	0.092	0.398	0.735	0.613	0.306	0.147	0.110	30	4.5
Gokyo I(Between 2nd & 3rd lake)		0.118	0.088	0.064	0.049	0.128	0.295	0.712	1.228	0.810	0.393	0.201	0.152	27	4.05
Gokyo II (3rd lake) + drainage from Dudh Koshi river		0.589	0.442	0.319	0.246	0.638	1.473	3.560	6.137	4.051	1.964	1.007	0.761	154	192

Table 69: Discharge measurement and installed capacity

Installation of new micro-hydro plants in this area will provide an opportunity for local people to use electricity for their energy needs. Gokyo-II and Thukla have a potential for high power generation to meet the demand for a range of household activities like lighting, cooking, space heating and boiling water. Power generation in Pheriche, Dole and Gokyo-I is less and can be utilized for lighting purpose only. The reason for limited amount of power generation is primarily the low discharge. A short description and salient features of identified micro-hydropower projects along the route to Everest Base Camp and Gokyo follows:

Pheriche Khola Micro Hydropower Project (Proposed)

The proposed Pheriche Khola Micro-hydropower Project site is located in Khumjung VDC of Sagarmatha National Park and Buffer Zone (SNPBZ). It is a run-of-river type project, which will have the capacity to generated 7.5 kW of electricity. The main source of water for the power generation is Pheriche Khola which is located at the elevation of 4296 ± 7m near by Pheriche village. The project site is about 3 days walking from Syangboche airport which is at the elevation of 3760 ± 10 m at SNP. The proposed 7.5 kW Pheriche Khola Micro Hydropower Project may electrify 22 households for lighting purpose only. The reason for limited amount of power generation is primarily the available hydrological potential.

Project	Pheriche Khola MHP
Source stream	Pheriche Khola
Location	Khumjung VDC, Sagarmatha National Park, Solukhumbu district, Eastern Development Region, Nepal
Power demand	High in lodges whereas residential and institute subscribe nominal power only.
Load Centre	Pheriche: 22 HH: 14 lodges, 1 institute and 7 residential
Distance from powerhouse	To Pheriche village: km
Intake site	Easting: 86.81648º Northing: 27.90116º Altitude: 4296 ± 7m
Powerhouse site	Easting: 86.81648º Northing: 27.90112º Altitude: 4221 ± 11m
Design flow	10 l/s
Head	75 m
Capacity	7.5 kW
Average Estimated cost	30000US$
Annual energy generation	139973.2 kWh
Remarks	Good site for Powerhouse, Intake should be selected at geologically stable site

Table 70: Salient features of Pheriche Khole MHP

Thukla Khola Micro-hydropower Project (Proposed)

The proposed Thukla Khola Micro-hydropower Project site is located in Khumjung VDC of Sagarmatha National Park and Buffer Zone (SNPBZ). It is a run-of-river type project, which will have the capacity to generated 60 kW of electricity.

To meet the larger demand of Thukla Pheriche and Dingboche, water could be drawn from Thukla Khola on the main trail to Lobuche nearby Thukla village, a few kilometers away from the powerhouse site located near Pheriche village. It has a potentiality to generate 60 kW of electricity. The project site is about 3 days walking from Syangboche airport which is at the elevation of 3760 ± 10 m at SNP. The proposed 60 kW Thukla Khola Micro Hydropower Project may electrify three villages for lighting, cooking, entertainment purpose.

Project	Thukla Khola MHP
Source stream	Thukla Khola
Location	Khumjung VDC, Sagarmatha National Park, Solukhumbu district, Eastern Development Region, Nepal
Power demand	High in lodges whereas residential and institute subscribe nominal power only.
Load Centre	Pheriche: 22 HH: 14 lodges, 1 institute and 7 residential Thukla:1 HH: 1 lodge Dengboche: 52 HH: 22 lodges, 30 residential
Distance from powerhouse	To Pheriche village: 3.9 km To Thukla village: 1.26 km To Dengboche village:5.9 km
Intake site	Easting: 86.80699º Northing: 27.92401º Altitude: 4616 ± 10.8 m
Powerhouse site	Easting: 86.80673º Northing: 27.91478º Altitude: 4432 ± 18.9 m
Design flow	100 l/s
Head	122 m
Capacity	60 kW
Average Estimated cost	240000 US$
Annual energy generation	2019651 kWh
Remarks	Good site for Powerhouse, Intake should be selected at geologically stable site

Table 71: Salient feature of Thukla Khola MHP

Dole Khola Micro Hydropower Project (Proposed)

The proposed Dole Khola Micro-hydropower Project site is located in Khumjung VDC of Sagarmatha National Park and Buffer Zone (SNPBZ). It is a run-of-river type project, which will have the capacity to generated 4.5 kW of electricity. The main source of water for the power generation is Dole Khola which is located at the elevation of 4030 ± 8m nearby Pheriche village. The proposed 4.5 kW Dole Khola Micro Hydropower Project is able to connect 10 households to the grid for lighting purpose only. The reason for limited amount of power generation is primarily the available hydrological potential.

Project	Dole Khola MHP
Source stream	Dole Khola
Location	Khumjung VDC, Sagarmatha National Park, Solukhumbu district, Eastern Development Region, Nepal
Power demand	High in lodges whereas residential and institute subscribe nominal power only.
Load Centre	Dole: 10 HH: 5 lodges and 5 residential
Distance from powerhouse	To Dole village: 0.52 km
Intake site	Easting: 86.72829º Northing: 27.86737º Altitude: 4030 ± 8m
Powerhouse site	Easting: 86.73091º Northing: 27.86771º Altitude: 4000 ± 12m
Design flow	30 l/s
Head	30 m
Capacity	4.5 kW
Average Estimated cost	180000 US$
Annual energy generation	172578.7 kWh
Remarks	Good site for Powerhouse, Intake should be selected at geologically stable site

Table 72: Salient features of Dole Khola MHP

Gokyo lake-I Micro Hydropower Project (Proposed)

The proposed Gokyo lake Micro-hydropower Project site is located in Khumjung VDC of Sagarmatha National Park and Buffer Zone (SNPBZ). It is a reservoir type project: the water would be drawn from the third lake to the second lake. This will have the capacity to generated 4.05 kW of electricity. The main source of water for the power generation is the lake which is located at the elevation of 4742 ± 7.6m nearby Gokyo village. The proposed 4.05 kW Gokyo lake Micro Hydropower Project may electrify 8 households for lighting purpose only.

Project	Gokyo lake MHP
Source stream	Gokyo Lake
Location	Khumjung VDC, Sagarmatha National Park, Solukhumbu district, Eastern Development Region, Nepal
Power demand	High in lodges whereas residential and institute subscribe nominal power only.
Load Centre	Gokyo lake: 8 lodges
Distance from powerhouse	To Gokyo village: 1.3 km
Intake site	Easting: 86.69771º Northing: 27.94715º Altitude: 4742 ± 7.6m
Powerhouse site	Easting: 86.69765º Northing: 27.94711º Altitude: 4720 ± 6m
Design flow	18 l/s
Head	27 m
Capacity	4.05 kW
Average Estimated cost	16200 US$
Annual energy generation	247458.7 kWh
Remarks	Good site for Powerhouse, Intake should be selected at geologically stable site

Table 73: Salient features of Gokyo lake MHP

Gokyo- lake-II Micro Hydropower Project (Proposed)

The proposed Gokyo lake Micro-hydropower Project site is located in Khumjung VDC of Sagarmatha National Park and Buffer Zone (SNPBZ). The main source of water for the power generation is the confluence of Gokyo lake and Dudh Koshi which will have the capacity to generated 192 kW of electricity. The proposed 192 kW Gokyo lake Micro Hydropower Project may electrify 4 villages.

Project	Gokyo lake MHP II
Source stream	Gokyo Lake
Location	Khumjung VDC, Sagarmatha National Park, Solukhumbu district, Eastern Development Region, Nepal
Power demand	High in lodges whereas residential and institute subscribe nominal power only.
Load Centre	Gokyo: 8 HH: 8 lodges Dole: 10 HH: 5 lodges and 5 residential Machhermo:12 HH: 6 lodges, 1 institution and 5 residential
Distance from powerhouse	To Gokyo village: 3.80 km Machhermo: 5.91 km Dole:13.94 km
Intake site	Easting: 86.70796º Northing: 27.93085º Altitude: 4660 ± 10m
Powerhouse site	Easting: 86.70823º Northing: 27.92271º Altitude: 4510 ± 8.6m
Design flow	250 l/s
Head	154 m
Capacity	192 kW
Average Estimated cost	768000 US$
Annual energy generation	7056057 kWh

Table 74: Salient features of Gokyo lake MHP II

6.7.4 Solar PV

Photo Voltaic (PV) is used widely for lighting purpose in Upper Khumbu in areas without access to hydropower and other sources of electricity. But, it has also been found in the Lower Khumbu where hydropower is used widely. Lodges tend to use small-scale photovoltaic systems to meet the electricity demand for tourism-related services. Based on data from meteorological stations installed by EV-K2-CNR in the study area and on own on-the-spot measurements follows that the average global radiation is about 206 W/m^2 in 6 hr total sunshine hour. The total energy production by all photovoltaic panels in the SNPBZ is about 532 kWh/ month (details in Table 75).

Settlements	area of PV Panel (m2)	Hrs of sunshine (hrs/day)	Solar irradiation (W/m2)	Energy produced by photovoltaic panels (kWh/month)	Energy produced by all photovoltaic panels (kWh/month)
Lukla	0.175	6	162	0.765	13.78
Phakding	0.177	6	160	0.764	3.82
Monju	0.177	6	162	0.773	3.09
Jorsalle	0.265	6	180	1.288	16.74
Namche	0.170	6	192	0.881	3.53
Pungitenga	0.210	6	198	1.123	4.49
Lausasa	0.133	6	198	0.713	12.12
Pheriche	0.412	6	225.7	2.511	55.24
Dingboche	0.338	6	225	2.051	106.64
Thukla	0.300	6	225	1.823	1.82
Lobuche	0.383	6	229.27	2.370	16.59
Gorakhshep	0.425	6	232	2.665	15.99
Upper Pangboche	0.450	6	201	2.442	61.05
Phortsethanga	0.244	6	198	1.307	7.84
Mongla	0.350	6	215	2.032	12.19
Dole	0.500	6	218	2.943	29.43
Machhermo	0.370	6	220	2.198	26.37
Gokyo	0.273	6	235	1.734	15.61
Basecamp	0.414	6	250	2.795	125.75

Table 75: Summary of Solar PV electricity generation in different sites of SNPBZ

The observation regarding the use of photovoltaic system was carried out only at household level, looking at households with modest income source and without grid connection. Only small scale PV systems with 10-20 W, 6-12 V and 7-20 Ah battery capacity were found. Considering 3 hours of lighting demand for a PV system of 20W, 12V and 20Ah, the usual autonomous factor is about 3 days[4].

Since battery is an expensive component of a PV system, capacity to increase its reliability in continuous power supply it is preferable to use larger PV panels and a smaller battery. The cost for a PV system used at household level for a 20 W system is about 15-20 $/W. This figure includes a set of battery charger, PV panel and battery. If it is in the case of Institution like Pyramid with sophisticated investors, battery chargers and expensive PV panels, the cost of the system may fall between 30- 50 $/W. This cost includes material cost, transportation cost and installation cost.

[4] The autonomous factor defines the number of days the battery can supply the power without being charged continuously every day. In comparison, the autonomous factor at the Ev-K2-CNR Pyramid Laboratory is 3 days.

6.7.5 Solar Thermal

Solar thermal panel has been found widely on Lower Khumbu than in Upper Khumbu. Because of the cold weather- summers are cool too – and the type of visitor activity (trekking and climbing), hot showers are a popular item on visitor's agenda. Many lodge owners use this service as a business strategy, to generate extra income by charging around NRs. 200 for a hot shower. In lower Khumbu, hot water is generated by solar thermal panels, whereas in upper Khumbu, thermal panels are less common, since the low temperatures in winter in higher altitude cause frost which can destroy the commonly used collectors and conduits. For upper Khumbu frost proof solar thermal systems would have to be installed.

Settlements	Hrs of sunshine (hrs/day)	Solar irradiation (W/m2)	Energy prodcued by thermal panels (kWh/month)	Energy prodcued by all thermal panels (kWh/month)
Lukla	6	162	5.832	239.11
Phakding	6	160	5.760	46.08
Chhumoa	6	162	5.832	5.83
Monju	6	162	5.832	64.15
Namche	6	192	6.912	214.27
Khunde	6	195	7.020	49.14
Khumjung	6	195	7.020	98.28

Table 76: Summary of Solar thermal energy generation in different sites of SNPBZ

In upper Khumbu, people heavily rely on fuels like firewood, kerosene, and dung cakes for boiling water for drinking and bathing purpose. Some lodges in Namche and Kenjuma use solar thermal systems, also frost proof solar thermal panels (Sherpa Land Lodge, Namche Bazaar). As observed in Everest hotel in Namche Bazzar. solar thermal systems without frost proof design are damaged frequently. Lodge owners with moderate income should be encouraged to switch over the thermal panels in higher altitudes through effective mechanisms, like subsidies or incentives. Thermal panels pay off quickly, considering the substantial savings in imported fuel.

The cost for a normal black coated GI-pipe collector thermal panel (conventional) system fabricated in Nepal falls in the range of 300-400$/m2 including material, transportation and installation in Upper Khumbu region. However, the cost of a frost proof, imported vacuum tube-collector system as installed in Sherpa Land or in Ev-K2-CNR Pyramid Laboratory may go as high as 500-700 $/m2. The frost proof solar thermal panels are usually 'maintenance free' or a very little maintenance effort is required in comparison to black coated GI-pipe collector system.

6.7.6 Wind Power

Wind is another source for harvesting an ample amount of energy. The data from spot measurements in different sites of SNPBZ shows that wind power systems are a very feasible alternative. Use of wind power to reduce the use of conventional energy sources should be encouraged. Most of the investigated sites have wind velocities of more than 5 m/s (Table 77). However, air density decreases with increasing elevation which is directly affected the power generation.

Site	Measured Wind Velocity (m/s)	Power at 5 m (W/m2)	Power at 10 m (W/m2)
Kyanjuma	14	2202	4404
Tyangboche	8	1216	2432

Pheriche	10.6	1507	3014
Pheriche to Dingboche	16	2269	4538
Dole	7	1010	2020
Dingboche to Thukla	3	415	830
Pyramid (ABC station)	14	1748	3496
Pyramid to Gorakhshep	11.8	1457	2914
Lobuche	11.2	1443	2886
Thukla	9	1221	2442
Thukla to Lobuche	10.2	1373	2745
Machhermo	7.8	1090	2179
Gokyo	3	395	791
Phrochethanga to Mongla	7.5	1169	2339
Mongla	8	1195	2389
Sanasa to Khumjung	10	1572	3145
Monju	7.6	1324	2648
Jorsalle to Namche	5.6	964	1928
Ghat	5.4	983	1966
Namache Ukalo	5.6	947	1894
Namche to Tyanboche (Stupa)	10.8	1726	3452
Way to Lobuche	8	1102	2203
Thukla to Lobuche	7	913	1827
Second lake of Gokyo	10	1324	2647
Third lake of Gokyo	9	1187	2374
Confluence of Dhudh Koshi and Gokyo	10	1343	2687

Table 77: Summary of wind power generation potential in different sites in SNPBZ

Usually, wind power systems in SNPBZ are supplemented by PV systems or vice versa. Hospitals and lodges generate electric energy from either PV or fossil fuel fired small generators. Very small-scale wind power systems are in operation in Upper Khumbu. The capacity of wind power system in some areas is shown in Table 78

S.No	Location	Capacity (kW)
1	Lobuche	0.1
2	Mochhermo	0.3
3	Pheriche	0.5

Table 78: Wind power electricity generating capacity in SNPBZ

Though wind power generation is generally possible in Upper Khumbu, isolated large-scale wind power systems are not in use so far. The reason may be the thin air density, the cost of its installation in higher altitude and the value of the scenic view for the tourism industry. In case of large scale wind energy utilization through the wind farming system, there will be a visual impact on landscape or scenic beauty of the region. The construction of large size wind power systems in this region may only be possible if interconnected with the grid or installed as a decentralized wind farming system hybridized with other power supply systems such as PV, hydropower or diesel generators. Smaller stand-alone wind power systems or hybrid systems in combination with PV systems could be an option for Upper Khumbu. As observed, small wind power systems are used by those lodges who can afford it. We have not found anybody opposing this system.

6.7.7 Kerosene Depot

Kerosene is one of the major commercial energy sources in the study area. To fulfill the increasing energy demand and to reduce the pressure on in-situ natural resources (forest) three kerosene depots have been set up in SNPBZ, in Syangboche, Dole and Pheriche. The stock of kerosene in the depots is maintained at 2500 liters for the low seasons and 4500 liters for the main trekking season in Syangboche. Syangboche It sells about 18000 liters of kerosene per year. Along with kerosene, Bottled gas (LPG) is used in the study area, from Phakding to Everest Base Camp in about 1000 cylinders per year. [Mr. Lhakpa Nimbu Sherpa, businessman (LPG)].

6.7 Management Recommendations

6.8.1 Improved insulation of buildings: reduction of thermal conductivity of buildings (evaluation of this option in the model possible)

In colder regions of the earth, space heating accounts for a high share of the energy consumed by households. This share is higher for buildings with a low insulation capacity. Buildings can be made more energy efficient by reducing heat loss through better insulation, which physically corresponds to a decrease in thermal conductivity (the U-value) of building components (walls, floors, ceilings, doors and windows): The U value is a property of a material to evaluate how well a material allows heat to pass through from its confinement. The lower the U value, the lesser heat that is lost. Thus, in all aspects of housing design one should strive for the lowest U values possible.

Traditional buildings or “Sherpa houses” in SNPBZ are characterized by thick walls covered by mud plaster on both sides and feature small windows. These houses perform far better regarding insulation efficiency than the usual modern or “semi-modern” buildings found in the region. With the advent of tourism in SNPBZ, many traditional houses have been modified to incorporate facilities for the visitors and provide the required space for tourism related businesses. Dry stone masonry has been applied; concrete walls have been pulled up plastered with cement. The new house-designs also feature comparatively large windows. Such construction techniques applied in “semi-modern” and modern buildings usually exhibit a poor insulation, requiring a substantial amount of energy to maintain an acceptable room temperature. In general, traditional buildings are more energy efficient and cost effective than semi-modern buildings. Few of the modern buildings are better insulated than the traditional "Sherpa House", however, in some cases, the use of imported insulating material in wall construction and the use of modern glass technology has been successful in reducing the energy consumption in some of the modern buildings compared to traditional and medium-modified houses

Combining traditional techniques with modern (or traditional) insulation materials and technologies would preserve traditional housing design as a part of the Sherpa culture and tourist attraction and at the same time spare scare energy sources, such as fuelwood, by improving the energy efficiency and thus reducing the need for excessive energy for room heating. The high cost of insulation materials is brought forth by locals as the major factor hampering a wider promotion and application of better insulation. The materials which are locally available, such as mud plaster and stones are cheaper than high-tech materials, which have to be imported from Kathmandu. Thus, the insulation technique to be applied depends not only on the type and condition of the existing building and on the availability of materials, but also on the solvency of the proprietor. Further considerations have to be applied for the decision on the best insulation option. For example, the most effective technological insulation materials such as Thermocole, glass wool, wood planks and polyethylene are prone to fire hazard. In most cases, the locally available material will be the most cost-effective and better option in terms of investment and profit/effect.

Generally, achieving a lower U-value (better insulation) increases the cost for construction. Usually an optimum thickness and type of insulation material will be sought. The following table shows the types of insulation materials used in SNPBZ along with their property.

Types of insulating material	Conductivity (ג)	Thickness (mm)	R (m^2K/W)	Thermal conductivity (W/m2K) (Ep1a)	Unit price at site (Rs/m^2)*
Mud	0.35	50	0.286	7.0	80
Wooden plank	0.13	25	0.192	5.2	1255
	0.13	50	0.385	2.6	1520
	0.13	75	0.577	1.7	1915
Ply wood	0.17	4	0.024	42.5	515
	0.17	6	0.035	28.3	820
	0.17	8	0.047	21.3	980
	0.17	12	0.071	14.2	1169
	0.17	19	0.112	8.9	1800
Thermocole	0.02	25	1.250	0.8	465
	0.02	50	2.500	0.4	540
Glass wool	0.035	50	1.429	0.7	490

Table 79: Specification of different insulation materials (All rates include material cost, transportation cost and labor cost, overhead and contractors' profit but are without VAT)

6.8.2 Increase the number of households connected to the grid

All but the major settlements in SNPBZ are not connected to the electric grid. Households in these settlements use small-scale photovoltaic, hydropower or wind power systems to generate electricity, a key factor to provide tourism services, a major livelihood activity in SNPBZ. The lack of electricity available for cooking and space heating, especially in upper Khumbu, increases the use of traditional energy sources, such as firewood and dung cakes as well as commercial energy sources, such as kerosene and LPG, both of which are problematic, in terms of park resources and atmospheric pollution/climate, respectively. Therefore, increasing the number of households that are connected to the grid is considered a desirable undertaking

The fee to connect a building from service line is nominal, currently around Rs 500 to 1000 per household in SNPBZ. The monthly flat rates for connecting different consumers are given in Table in case of Khumbu Bijuli Company (KBC). There are Social and Commercial tariff systems developed by KBC. Level 1 and 2 are social tariff whereas 3, 4 and 5 are the commercial tariff. It is assumed that other hydropower plants in SNPBZ follow the same tariff pattern as devised by KBC as follows:

KBC, Thame			
Level	Power Watts	Flat rate (Rs/month)	Unit rate, Rs/kWh
1	100	70	-
2	1260	700	-
3	4000	300	7.75
4	12000	800	7.75
5	30000	3000	7.75

Table 80: Cost to connect buildings to the electricity grid in SNPBZ

6.8.3 Reduction of combustive energy source: discourage usd of kerosene, LPG and dung (evaluation of this option in the model possible)

Wide access to modern technologies, also for remote regions and a growing tourism industry has resulted in increased energy consumption of households in SNPBZ. The versatility of use and cleanliness of these sources have rendered kerosene and LPG highly popular in the tourism sector and for tourism-related service provisions. Meanwhile, these energy sources are used abundantly in SNPBZ, despite their high price and frequent supply shortages. Despite their popularity, these energy sources have their disadvantages and risks. Kerosene and LPG are imported from Kathmandu where already a deficit is rampant, additionally, this combustion process of energy sources emits greenhouse gases, especially in high altitude, CO_2 emission from combustion of fossil energy sources is comparatively high. Nevertheless, it is observed that LPG and kerosene were successful in substituting fue-wood as energy source, whereby counteracting the depletion of forests in the park.

It has to be noted that opportunities to exploit renewable energy sources, such as solar, wind and hydropower are readily available in the region. Emerging technologies that allow exploiting these sources on a large scale is preferable over either, traditional sources, such as dung and fossil sources, LPG and kerosene

6.8.4 Increase of households substituting conventional through energy saving lamps (evaluation of this option in the model possible)

In some of the settlements of SNPBZ, the energy demand matches the maximum capacity of the hydropower plants supplying the local grid, although still many households in SNPBZ are without electricity. The energy situation in SNPBZ is characterized by a problem to meet the peak energy demand. The energy supply during off-peak hours is mostly sufficient. The load is predominantly fed by the local demand for lighting. In rare cases, electricity is used for heating or cooking, A reduction of the overall energy demand could most effectively achieved through the promotion of energy-saving lighting technologies. Many settlements drawing predominantly on micro-hydropower, use Incandescent lamps, a technology which demands a high lighting power. Supporting the households in substituting traditional (filament/fluorescent lamps) through mainstream energy saving lamps, such as Compact Fluorescent Lamp (CFL) or White Light Emitting Diode (WLED).

Compared to traditional light bulbs, energy saving lamps produces high lumen (brightness) with less energy. While the lifespan of these bulbs is much longer then the one of traditional bulbs, they are also more expensive. In the long run, the additional cost will be compensated by regular saving on the energy bill through the lower demand of these solutions. To start mainstreaming the new technologies, energy saving lamp could be sold in villages for a subsidized price, demonstrating the benefit of the new technologies to the local people through own experiences.

Types	light provided by sources (Ep5a)	cost for light (EP5c)
Incandescent Lamp	15W, 25W, 40W, 60W,100W	Rs25, Rs35, Rs45, Rs50, Rs75
Fluorescent Lamp	40W	Rs 800
Compact Fluorescent Lamp	5W,7W, 9W,11W,18W	Rs 200, Rs300, Rs700, Rs800, Rs900
White Light Emitting Diod	1.2W	Rs 1000

Table 81: cost for energy saving lamps (These costs include only material cost without transport to the site)

6.8.5 Install new photovoltaic (PV) systems (evaluation of this option in the model possible)

Photovoltaic (PV) devices produce electric power from sunlight. PV has been used widely for lighting purpose in Upper Khumbu and in areas without access to the electric grid or hydro-power systems, but it has also been found in Lower Khumbu, where hydropower is available. Small-scale PV are not able to supply enough electricity for high-demand activities, such as cooking or heating, but it is a means to provide energy for lighting to household without access to the grid. Households in settlement which for some reason cannot be connected to the grid should be encouraged to use PV.

The observation regarding the use of photovoltaic system was carried out looking at households with modest income source and without connection to the grid. Only small scale PV systems of 10-20 W, 6-12 V and 7-20 Ah battery capacity were found among these households. Considering 3 hours of lighting demand for a PV system of 20W, 12V and 20Ah, the average autonomous factor (the number of days the battery of the PV system can supply power without having to be charged) is about 3 days. To achieve its reliability as a continuous power supply, it is preferable to use a larger PV area and a smaller battery capacity in remote areas, since the battery is the expensive component of a PV system.

The cost for a PV system used at household level for a 20 W system is about 15-20 $/W. This figure includes a set of battery charger, PV panel and battery. For a larger, more sophisticated system (which is not part of this management lever), including invertors, battery chargers and expensive PV panels, the cost of the system may fall between 30- 50 $/W. This cost includes material cost, transportation cost and installation cost.

6.8.6 Install solar thermal (ST) systems (evaluation of this option in the model possible)

Solar thermal energy system is a renewable energy technology for harnessing solar energy to generate hot water. It is an alternative to using fossil energy sources such as gas and kerosene or fuel wood and dung cakes to boil water. Visitors to SNPBZ consider the possibility to take a hot shower an important asset, thus many lodge owners provide this facility and use it for an additional incomes. On an average NRs. 200 is charged per shower. In lower Khumbu hot water is generated by solar thermal panels, whereas in upper Khumbu, thermal panels are less common. In this area people heavily rely on fuels like firewood, kerosene, and dung cakes for boiling water both for drinking and bathing. Some lodges in Namche and Kenjuma are also found to use solar thermal system as well as frost proof solar thermal (Sherpa Land lodge for example) to heat water for bathing purpose. Solar thermal systems without frost proof are frequently damaged in winter as it observed in Everest hotel in Namche. Lodge owners with moderate income should be encouraged to switch to thermal panels in higher altitudes. Subsidies or low-interest credits would be a possible incentive, as the debt would pay off quickly considering the substantial cost saving on imported fuel

The cost for a normal black coated GI-pipe collector thermal panel (conventional) system fabricated in Nepal falls in the range of 300-400$/m^2 including material, transportation and installation in Upper Khumbu region. The cost of a frost proof, imported vacuum tube-collector system as installed in Sherpa Land for example may go as high as 500-700 $/m^2. The frost proof solar thermal panels are usually 'maintenance free' or a very little maintenance effort is required in comparison to black coated GI-pipe collector system.

6.8.7 Install wind energy systems (evaluation of this option in the model possible)

Wind energy systems convert wind energy into electricity by means of rotors and turbines. Wind is also a renewable energy source. Three wind power systems are operating in SNPBZ in Lobuche, Machhermo and Pheriche. The wind power system at Lobuche is used by a lodge. The latter two are used to supply energy for hospitals when they are in operation. During off tourist seasons, these wind power systems are not put into operation. Usually, the wind power systems in SNPBZ are supplemented by PV systems or vice versa. The hospitals and lodges produce electricity from either PV or fossil fuel fired small generators. Very small-scale wind power systems are in operation in Upper Khumbu. The capacity of wind power systems in these area is 0.1-0.5 kW

Though wind power generation is generally possible in Upper Khumbu, isolated large-scale wind power systems are not in use so far. The reason may be the thin air density and the cost of its installation in higher altitude. The construction of large size wind power systems in this region may only be possible if interconnected with the grid or installed as a decentralized wind farming system hybridized with other power supply systems such as PV, hydropower or diesel generators. Smaller stand-alone wind power systems or hybrid systems in combination with PV systems could be some options for Upper Khumbu. As observed, small wind power systems are used by those lodges who can afford it. We have not found anybody opposing this system.

There is a question as to whether wind turbines disturb the scenic view, one of the key attractions of SNPBZ. Small-scale wind power systems are relatively unproblematic, as they are neither high, nor large. However, large scale wind farming system might have a clear visual impact on landscape or scenic beauty of the region. It is important that for such a project the site selection criteria include the scenic view of the mountains.

The cost of a small-scale wind power system is, in an average, 10-15$/W. This figure includes the material, transportation and installation costs.

6.8.8 Install new hydropower plants (evaluation of this option in the model possible)

Hydropower is a renewable energy source and has a great potential to substitute fossil energy sources and fuelwood use in SNPBZ.

Apart from areas with hydropower plants in the range of few kW to 630 kW capacity in both lower and upper Khumbu the electricity in the region is not sufficient for cooking, boiling and space heating. Settlements located away from these plants rely on the use of traditional sources of energy such as firewood and dung cakes as well as commercial energy sources such as kerosene and LPG. This practice has clearly a negative impact on climate and economy. The installation of new hydropower plants would be able to overcome these problems.

Suitable locations for new hydropower plants are available or could be developed. Local peoples' aspiration in Namche is to build a larger scale hydropower plant. The Khumbu Bijuli Company studied the pre-feasibility of Namche Mini-hydropower Plant (300 kW). However, The Park regulations discourage the development of new hydropower plants at larger scale. Alternatively, it is recommended to install micro-hydropower plants at a number of places along the Khumbu base-camp route and Gokyo route as assessed in this report.

The cost for different micro -hydro powers existing in SNPBZ are given in Table 66 as indication for new plants. Material, transportation and construction cost are included in this cost.

6.8.9 Improve and rehabilitate existing hydropower plants (evaluation of this option in the model possible)

The efficiency of existing hydropower systems can be improved through partial or complete rehabilitation. Rehabilitation is the option with the best cost-benefit ratio. Some of the micro-hydropower plants in SNPBZ - in Tyangboche and Pangboche - are in a critical condition and would require urgent rehabilitation. The efficiency of these systems could be increased by installing better turbines and alternators.

For Pangboche MHP, in summer 2008, some part of intake, water ways and power generating unit were repaired and maintained by technicians from Khumbu Bijuli Company. This masure has increased the power generating capacity from 7 kW as observed in Autumn 2007 to 11 kW in Summer 2008. However, the river bank near the powerhouse, the slope protection along the headrace pipe and maintenance of load controlling device (IGC with ballast) need urgent maintenance and repair

Tyangboche MHP's generator has been out of order due to a recent flood for some period, however it has been repaired recently. Again, there is a need for the river bank protection near the powerhouse and slope protection along the headrace pipe.

The current capacity of Khumbu Bijuli Company (KBC) could be increased by installing an additional 300 kW unit as the most feasible option discussed with the stakeholders of KBC in a stakeholders' meeting in Kathmandu. The specific cost of adding one more unit at KBC is estimated as, an order of magnitude, 3111 US$/kW.

The cost for rehabilitation depends on the condition of the hydropower components. Currently, the cost of a complete rehabilitation (civil, mechanical and electrical component) is given in table below. The figure includes the cost of material, transportation and installation at site.

The table below shows the complete rehabilitation cost (civil, mechanical and electrical components) for all existing hydropower plants in SNPBZ. The cost ranges between 55% to 23% of the total project cost. Repairs are likely due regarding civil structures or electro-mechanical components. The cost in the table below does not cover the addition of a new aggregate needed to increase the capacity as in the case of KBC (The project specific cost is about 7142 US$/kW.

Complete Rehabilitation cost (civil, mechanical, electrical)				
	Capacity of power plant(kW)	Total cost ($)	Rehabilitation cost (Higher side) $	Rehabilitation cost (Lower side) $
*Bom Khola I MHP	100	318744	164121	75766
Chuserma MHP	35	116124	62057	27603
*Monju Khola MHP	100	302803	155913	71977
*Ghatte Khola MHP	75	232592	121506	55287
ThadoKoshi MHP	100	278900	143606	66295
Khumbu Bijuli Company	630	4500000	1601550	1069678
Tyanboche MHP	22	55000	29607	13074
Pangboche MHP	15	30000	16212	7131
Phortse MHP	60	93592	49314	22247

Table 82: Rehabilitation cost for existing hydropower plants in SNPBZ

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