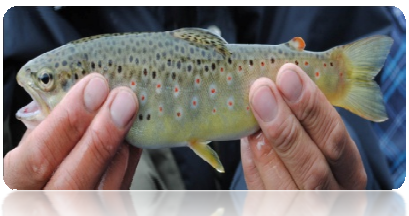
INVENTORY OF HIGH ALTITUDE WETLANDS IN BHUTAN

THE UGUEN WANGCHUCK INSTITUTE OF CONSERVATION AND ENVIRONMENT



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The Wetlands Sky High: Mapping Wetlands in Bhutan

Prologue: Fire and Water[1]

One that shines early in the east,
Is the sun that rises early in the east.

If the sun does not rise from the east,
Shall snows of the Himalayas melt?

If snows of Himalayas do not melt,
Shall fresh waters trickle down?

If melted waters do not trickle down,
Shall lakes accumulate at highlands?

If lakes do not resource at highlands,
Shall wetlands and vegetation grow?

If vegetation do not profuse to trees,
Shall cuckoos perch to sing their songs?

If cuckoos do not sing their songs,
Shall humanity hear their melodies?

If winds do not carry loads of moistures,
Shall the Himalayas have water cycle?

[1] Translated from a traditional Bhutanese song "*Shaar la ni haa lay mi shaar*."

Acknowledgement

The WWF Bhutan Program is immensely thanked for supporting this work of the high altitude wetlands inventory in Bhutan. We particularly thank and acknowledge Mr. Phurba Lhendup, Technical Director, WWF Program for his involvement in this project. The Googleearth Entrepreneurs are highly appreciated for launching free access online googleearth images, without which this baseline inventory on wetlands in Bhutan would have been of inferior quality.

Mr. Karma Wangdi, Mr. Rinchen Singye, Mr. Sangay Wangchuk, and Phurba all in UWICE, Mr. Kencho Gyeltshen in JDNP and Mr. Tashi Phuntsho in BWS are all deserves heartfelt gratitude for acquiring coordinates from field in various parts of Bhutan.

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Glossary

Alpine lake: open water lakes in alpine screes, meadows and rhododendron scrubs.

High altitude land cover: land cover or habitats above 3000 meters of elevation.

High altitude wetlands: open water lakes and marshes above 3000 meters of elevation.

Glacial lake: open water lakes on inactive, dead glacier or glaciated moraines, rocky surfaces above alpine meadows.

Supra-snow lake: open water lake floating on permanent snow cover.

Supra-glacial lake: open water lake floating on active glaciers moraines.

Sub-alpine lake: open water lakes in willows, rhododendron bushes and junipers

Marsh: wet and soggy areas mostly developed as result of slow drying up of lakes.

Terton: Terton is a Bhuddhist master who has the power to reveal or discover treasures hidden by past masters.

Tsho: open water lake.

List of Abbreviations

BWS	Bumdeling Wildlife Sanctuary
GLOF	Glacial Lake Outburst Floods
GIS	Geographic Information Systems
GPS	Global Positioning Systems
JDNP	Jigme Dorji National Park
RS	Remote Sensing
SLOF	Supra Snow Lake Outburst Floods
UWICE	Ugyen Wangchuck Institute for Conservation and Environment

Abstract

We define any land cover above 3000 meters of elevation as high altitude land. In Bhutan, approximately 43 percent (~16,610 km^2) of the total land falls within high altitude land class. Defining open water lakes and marshes in the high altitude land as high altitude wetlands, we recorded a total of 3027 wetlands inclusive of lakes and marshes. These high altitude wetlands cover about 102 square kilometers, contributing to 0.61 percent of the high altitude land area (0.26% of Bhutan's total land area), and are composed of supra-snow lakes, supra-glacial lakes, glacial lakes, lakes in alpine meadows, sub-alpine habitats and marshes. About 52 percent of total wetlands are found in the Drangme Chu Basin, primarily contributed by Mangde Chu and Chamkhar Chu river systems. Chamkhar Chu river system has the highest numbers of lakes amongst other river systems. The distribution of wetlands is concentrated within the elevation range of 3800 to 5560 meters suggesting that most wetland hydrophysical activities are operating at such heights. We believe that proper understanding of wetland hydrophysical activities is crucial for determining probable affects on downstream habitats and settlements.

Introduction

Hydrophysically, the Bhutan Himalayas are straddled in the watershed of mighty the Bhramaputra river basin. The river is religiously and faithfully believed as the blessed water of Lha Tshangpa or Goddess Tshangpa, thus called as Tshangpo in its head water sources of the Autonomous Region of the Tibetan Plateau. Bhutan has four major river basins, namely the Amo Chu (Toorsa), the Wang Chu (Raidak), the Punatshang Chu (Sunkosh) and the Drangme Chu (Manas) spread from west to east. Neyra Ama Chu, Jomotshangkha Chu and Shaar Chu form three additional small river basins that have high altitude wetlands. The river basins contain nine major river systems, which are Amo Chu, Wangchu, Punatshang Chu, Mangde Chu, Chamkhar Chu, Kuri Chu, Kulong Chu, Gongri Chu, Neyra Ama Chu, and Jomotshangkha Chu. Of the nine river systems, three rivers (Amo Chu, Kuri Chu and Drangme Chu) originate from the Autonomous Region of Tibet, while all other rivers emerge from within Bhutan.

All these river systems are either directly or indirectly fed by permanent or seasonal snows, glaciers or high altitude lakes at their sources and surface runoff water from the monsoon rainfall. The lakes above 3000 meters of elevation constitute the high altitude wetlands. The high altitude wetlands also represent the fresh waters and wetlands ecosystems in Bhutan. It is further categorized as subalpine lakes of the willow, rhododendron bushes and juniper habitat, alpine lakes of rhododendron scrubs and screes, glacial lakes on inactive or dead glaciated moraines and rocks, supraglacial lakes on active glaciers and supra-snow lakes floating on snow covers.

The primary goal of the project is to contribute towards **'ensuring the conservation of nationally and globally important wetland along with enhancing sustainability of their ecological services'.**

At the activity level, the project has achieved to make an inventory of wetlands, and use as baseline information to determine their ecological characters and ecosystem services and further develop a comprehensive database on wetlands in Bhutan. It has partially generated ecological, socio-cultural and economic (ecosystem services) information which could of use a case for protecting of wetlands in the interest of local people and biodiversity. To share the high altitude knowledge base to wider stakeholders in the country to get their views, and design conservation actions to protect wetland and freshwater biodiversity. It is hoped that this work will motivate, encourage and invigorate many other institutions in Bhutan to conduct wetland related research for the protection of wide range of species that includes aquatic and terrestrial species as well as amphibians and birds.

Through this project the priority wetland conservation sites of national and regional importance are identified to facilitate the Royal Government of Bhutan to ratify to wetland related conventions that would provide and strengthen framework for national action and international cooperation for the conservation and wise use of wetlands and their resources in Bhutan.

The project supports WWF's Global Programme Framework 2020 Biodiversity Goal – Places. Biodiversity is protected and well managed in the world's most outstanding natural places. It is specifically linked to the WWF Living Himalayas Network Initiative's Goal 2: By 2020 ecosystem contiguity and ecological connectivity of the Living Himalayas will be secured in a mosaic of ~5 million hectares of high conservation value forests, grasslands and wetlands. In terms of footprints, the project will also contribute to Goal 4 of the Living Himalayas Network Initiative: By 2020 climate change adaptation and biodiversity conservation will be mainstreamed into the management of two transboundary river systems.

The high altitude wetlands cover 0.26 percent of the total land cover of the country. The land cover of high altitude wetlands would temporarily increase from accelerated melting glaciers and snow and gradually decrease at the wake of the climate change and global warming. The high altitude wetlands are located in the northern fringes of the country which are integral components of river basin system they feed, but they are often overlooked component of mountain ecosystems. The high altitude wetlands are the main reservoirs for these basins and contribute to water storage and the hydrological cycle that are water towers for the downstream areas. Downstream they are a major component in livelihood support in mountains, especially in rain shadow areas where they provide water for pastoralists and farmers. Besides, the Royal Government of Bhutan is embarking on more mega hydropower

project in the country for which the continuous flow of water from these reservoirs is very important.

Culturally, high altitude wetlands (lakes) are considered and revered as sacred sites (abode of Gods and Deities) and their conservation is important for the myths and beliefs of traditional people. They also support high biological diversity and are important staging points for migratory birds and other animals. Quantifying such wetlands and their spatial distribution using an inventory approach, engaging remote sensing and GIS application is felt necessary not only for wildlife species conservation but also for the sustenance of hydropower-based economy. Sherub (2004), predicted 104 bird species that uses freshwater ecosystems in Bhutan and many other aquatic plant and animal species such as *Rununculus trichophyllus, Hydrilla verticillate, Potamogeton crispus, R. Tricuspis, Acorus calamus, Acorus grmineus, Shoenoplectus juncoides, Tyhus spp., Phragmites spp., Equisetum spp., Aconogonum alpinum, Carex spp., Juncus spp., Salix sp.* Similarly large predators such as *Panthera tigris, Panthera pardus, Panthera uncia,* and smaller predators like *Neofelis nebulosa, Cuon alpinus,* and *Felis bengalensis* come for water and stalk prey species at water sources. Other mammals associated with wetland ecosystems include *Platanista gangetica Lutra lutra*, *Lutrogale perspicillata*, *Bubalus arnee, Felis viverrinus, Herpestes urva, Nectogale elegans, Chimarrogale himalayica,* etc. The use and habitation by floral and faunal diversity of high altitude wetlands requires further field investigation and authentication, which is important to validate the conservation significance.

The recent developments such as rapid economic development, infrastructure projects, and opening of these areas to tourism have changed the situation. Along with the global warming, the major challenges to the high altitude wetlands in Bhutan include unplanned and unregulated tourism, grazing pressure, lack of awareness among the stakeholders, emerging threat of climate change and lack of coordination among various developmental agencies. So there is need for the intervention at each level of threats to prevent degradation of high altitude wetlands in Bhutan. So that the fragile ecosystem is conserved and protected; this is very important particularly in an era of international tourism, climate change, and megaprojects in the region.

Methodology and Analysis

Methodology

The inventory of high altitude wetlands in Bhutan was conducted using remote sensing (RS) and Geographic Information Systems (GIS) applications. Spatial data layers such as digital elevation model (DEM) and Landsat Thematic Images were acquired from available sources within Bhutan and also downloaded most recent free images from web sources. The Googleearth facilities

were downloaded free from www.googleearth.com website (May-October 2010) and installed on to computer.

From the DEM raster layer, all watersheds found in Bhutan were delineated using hydrology models built in the ArcGIS 9.3 (Figure 1). The high altitude wetlands area in Bhutan was also extracted and delineated using DEM. Initially, the landsat thematic images of all watersheds were extracted using image clipping processes of the ERDAS Imagine 9.3. However, later, freely available googleearth images were preferred over the landsat images, as manual on the screen digitization of high altitude wetlands mapping process was chosen to automated mapping approach.

In the ArcGIS environment, delineated watershed polygon shapefiles were converted to googleearth compatible format, i.e., from shapefile to kml or kmz file format. Every watershed polygons were imported and overlaid into the googleearth environment. Then, on the screen digitization of open water lakes and marshes above 3000 meters of elevation were manually performed. The googleearth images at areas of interest were magnified to best scale that enabled easy manual digitization (Figure 2).

The screen digitized polygons in kml or kmz format were then imported in ArcGIS environment transformed to shapefile format and further processed to obtain coverage and other statistical data. In the ArcGIS environment, lake or marsh wetlands polygons were merged at each watershed and national levels and projected to desired geographical datum and projection (DRUK REF).

The national level high altitude wetlands shape was again subjected through reiterated conversion processes of ArcGIS and Googleearth compatible formats. Lake types, such as supra-snow lake, supra-glacial lake, glacial lake, alpine and subalpine lakes were discriminated upon overlaying on the googleearth image. Additional data on surrounding habitats were attributed interpreting the image in the googleearth. In order to assign altitude attribute of each lake, mean centered point (centriod) of lakes were generated using conversion models of ArcTools (ArcGIS). Taking centriods of each lake as a reference, elevation of every lakes were extracted from the DEM in the ArcGIS environment. Other attributes assigned to each lake were watershed, name, area, perimeter, coordinates, type, status, characteristic and shape.

Field excursions were made to numerous high altitude areas in Bhutan to groundtruth the locations (gps coordinate, elevation, surrounding habitat) of the lakes to validate mapping, collect names of lake, photographs, information on religious and cultural significance of lakes. While most high altitude wetlands areas remain inaccessible, field expeditions to western Bhutan (Toorsa Strict Nature Reserve), Lunana (Jigme Dorji National Park), Dhur Tsha Chu are (Wangchuck Centennial Park), Singye Dzong and Pemaling (Bumdeling Wildlife Sanctuary,

Bribdungla (Thrumshingla National Park) were visited. During the groundtruth field exercise, gps point was collected from edge of the lake or at the nearest accessible lake location.

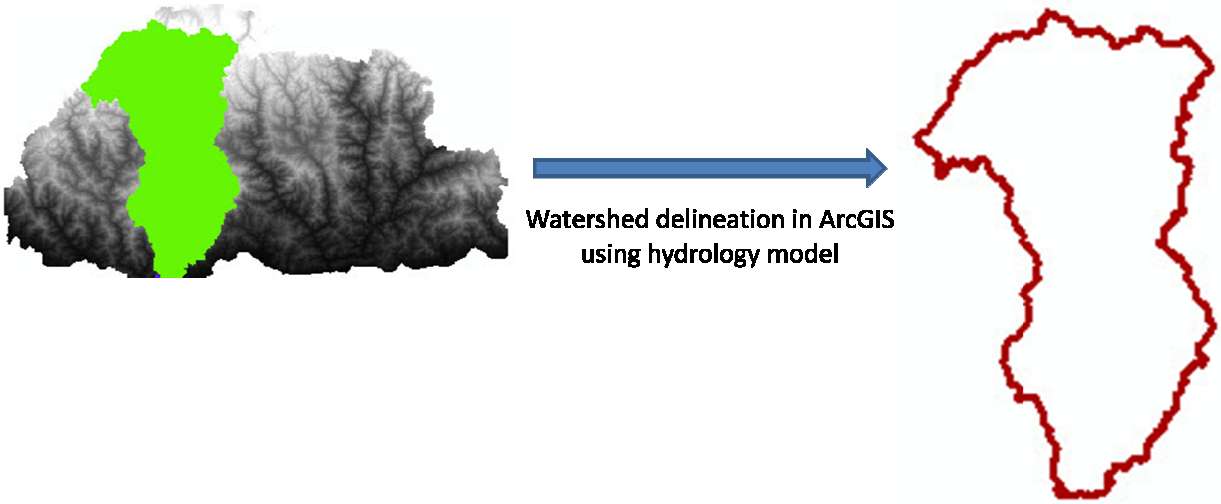


Figure 1: Delineation of watershed using DEM

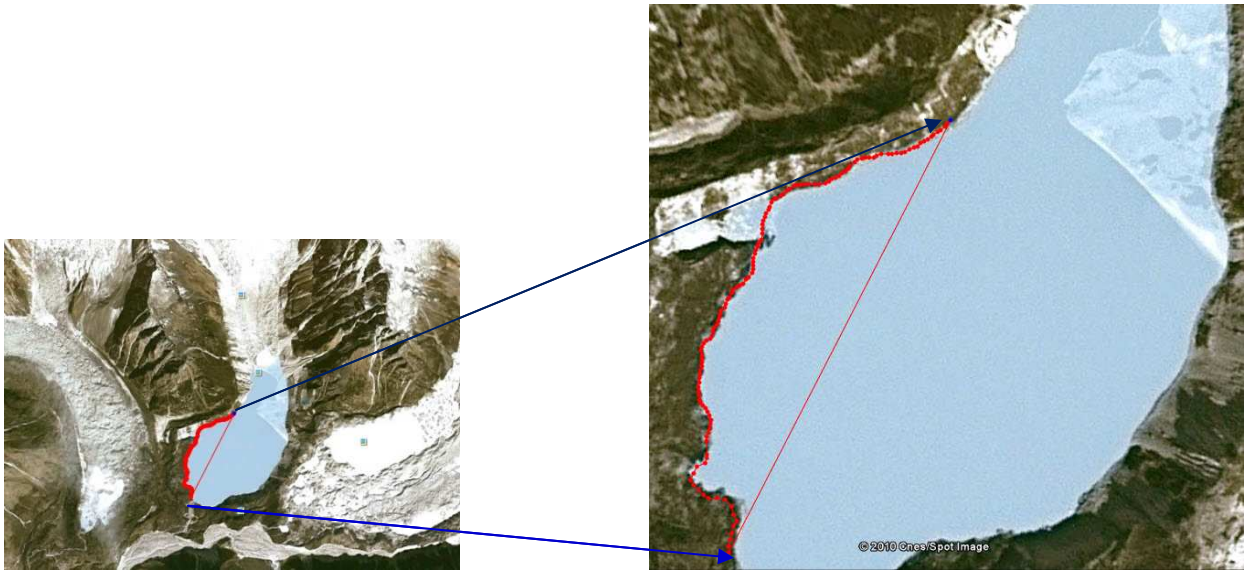


Figure 2: On screen digitization in Googleearth

Analysis

The mapped product was processed through computational and visual analysis. The computational analysis involved use of GIS and Microsoft Excel, and the visual analysis involved interpreting googleearth image. In the computational analysis, area and perimeter statistics were generated using inbuilt extensions in ArcGIS. Microsoft excel was used to process and produce relevant charts to interpret high altitude wetlands distribution along elevation gradient and amongst watersheds and coverage in each watershed. Based on attributes (status, type, shape, characteristic and surrounding habitat) assigned to each high altitude wetlands, visual analysis of interpreting googleearth image to quantify and qualify wetland status, type, shape, characteristic and surrounding habitat was made.

The gps points collected during the three main field expeditions were downloaded using MapSource and produced point shapefile. This gps point shapefile was overlaid on the high altitude wetland shapefile to validate and authenticate the mapping. A simple arithmetic was used to calculate the validity of the map produced.

Results

Wetlands: Types, Area, Size, Distribution

Total area of Bhutan is approximately 38,695 sqkm. About 16,610 sqkm of the total area is above 3000 meters of altitude. The high altitude wetlands cover about 0.61 percent of high altitude land cover. High Altitude Wetlands which include supra-snow lakes, supraglacial and glacial lakes, and marshes are the main source of freshwater in Bhutan, and it has coverage of about 0.26 percent of her total land cover. These high altitude wetlands of open water lakes forms a part of Bhutan's high water towers besides the snows and glaciers. They are crucial for biodiversity and sustainable economic growth, both locally and at the river basin and regional levels. Besides, these wetlands regulate micro-climates and have immense livelihood, cultural and spiritual significance for local communities and the country as a whole. The plants and animals that occur in and around them are often endemic and highly adapted to their locations. Many of these wetlands depend entirely on melting snow or run-off from adjacent glaciers while often having outflows comprising small streams or rivers that form the major rivers in Bhutan and finally draining to the Brahmaputra River basin which forms one of the major rivers of Asia.

With Bhutan's economy dependent highly on hydropower generation, it is crucial to protect these water towers for the sustainable generation of energy from the current and proposed hydropower plants. Besides, it will protect the ecosystems they support which are critically important from a biodiversity conservation and cultural perspective. However, these wetlands currently have received little attention so far in terms of conservation and water management,

but they are becoming increasingly important due to the possible consequences of the climate change.

Bhutan has four major river basins, namely the Amo Chu (Toorsa), the Wang Chu (Raidak), the Punatshang Chu (Sunkosh) and the Drangme Chu (Manas) spread from west to east. The three major river basins contain seven major river systems, which are Wang Chu, Punatshang Chu, Chamkhar Chu, Kuri Chu, Kulong Chu, and Drangme Chu. Of the nine river systems, three rivers (Amo Chu, Kuri Chu and Gongri Chu) originate from the Autonomous Region of Tibet, while all other rivers emerge from within Bhutan. The other independent small basins that bear high altitude wetlands are Neyra Ama Chu, Jomotshangkha Chu and Shaar Chu (head water sources of Zeminthang, Arunachal Pradesh). Downstream of the Pho Chu and Mo Chu confluence, the tributaries of Punatshang Chu, such as Dang Chu, Hara Chu, Gogona Chu and Daga Chu also have significant coverage of high altitude wetlands. All these river systems are either directly or indirectly fed by permanent or seasonal snows, glaciers or high altitude lakes at their sources and in general surface runoff water from the monsoon rainfall. The lakes above 3000 meters of elevation constitute the high altitude wetlands. The current high altitude wetland inventory reveals that Bhutan has about 3027 lakes (Map 1). These wetlands are distributed mostly in the northern fringes and clustered in central parts of the country. Lake distribution in Bhutan is correlated to height, slope, precipitation, snow cover and glacial activities.

Primary high altitude lakes in Bhutan are represented by supra-snow lakes, supra-glacial lakes, glacial lakes, lakes in alpine meadows, sub-alpine habitats and marshes (Table 1). Numerically, highest numbers of lakes are found in alpine meadows and sub-alpine habitats. The marshlands which are gradually developed from drying up of lakes and slow encroachment by vegetation accounting to 63 numbers has the lowest coverage of high altitude wetland types. A total of 110 supra-snow lakes occur in Bhutan and most of these lakes are found in head water sources of Mangde Chu watershed. 495 floating supraglacial lakes are documented in Bhutan varying from 133 sqm to the largest lake found in Bhutan, and most supraglacial lakes are found in Punatshang Chu basin.

Bhutan has 16 watersheds that have high altitude wetlands (Table 2). The watershed includes seven river systems of the four major basins, its tributaries, two small independent basins of Neyra Ama Chu and Jomotshangkha Chu, and head water sources of Shaar Chu, which flows into Arunachal Pradesh. At river basin level, the Drangme Chu basin has about 52 percent of total lakes found in Bhutan. It has 1604 lakes with an area of more than 55 sqkm. The highest number of lakes in Drangme Chu basin has been contributed by Mangde Chu and Chamkhar Chu river systems. However, the Gongri Chu river system is very poor in wetland habitat as it originates from across the international border in the north. The Punatshang Chu bas has 904 lakes with an area of around 38 sqkm. The Neyra Ama Chu has the lowest number of high

altitude. The Jomotshangkha Chu basin would have less than 10 open water lakes, however this figure has not been reflected in Table 2 owing to poor image coverage in the area.

The smallest high altitude wetland mapped in Bhutan, measures about 35 sqm., and it is located in Amo Chu basin in rhododendron scrub habitat at 4130 meters. The largest lake is found in Pho Chu river system of the Punatshang Chu basin, which measure about 1.5 sqkm. It is a glacial lake located at the terminus of Luggye glaciers, at 4506 meters. The second largest is also a glacial lake and it occurs in Mangde Chu headwater sources, with an area of 1.2 sqkm.

The high altitude wetlands habitats are distributed from 3098 to 5546 meters (Graph 1). Along the elevation gradient, distribution of lakes drastically increases from 3800 meters and decreases from 5300 meters.

Validation

The validation of high altitude wetland inventory mapping was conducted collecting groundtruth gps points. The validation results indicated that the high altitude wetlands mapping has 70 percent success.

Wetlands: The Abode of Deities

While water bodies are generally considered sacred, all lakes and marshes found in Bhutan do not get same level of reverence. Those lakes from where Buddhist Terton Masters have revealed hidden religious treasures are adorned and highly revered. Names of lakes are based on colour, shape and belief attached to its sacredness. Most revered lakes are believed as abodes of deities or local spirit. Beliefs and faiths on local deities or spirits have resulted lakes as a place of worship, thus, it has influenced conservation ethics of wetlands. The religious and cultural significance of a few selected lakes of the high altitude lakes have been described hereunder.

Drake Phangtsho: Lake Drake Phangtsho is located at 4220 meters above Shaladra, Doteng Geow, Paro. At close proximity to Drake Lake are Goratsho (courtyard-lake) on the right, and Zimpontsho on the left. Near to the lake is a cave where Mr. Karma Palbar, the Dharma Master of Shaldrago meditated. It is documented in *Lhodruk Chojung* that the 5th Dharma Master of Shaladrago, Mr. Yongdra Gyatsho, went into Drake Lake with a butter lamp on his head and remained sedentary there for a week. He returned from the lake with treasures, with his cloths dry and the butter lamp lit.

Drake Phangtsho is also a scenic point. From the lake places like Dongkarla, Mendrub Gonpa, Chidu Gonpa, Bemri and Drela Dzong could be viewed.

Nub Tshonapatra: Nub Thsonapatra is one of the most revered and renowned lakes in Bhutan. It is located in the Hala-Jula range at 3900 meters in rhododendron bushes. It is believed that

Guru Padmasambhava, hid numerous religious treasures. *Lhodruk Chojung* enumerates that Terton Sherab Mebar, from Kham, Tibet revealed numerous religious artifacts from Nub Tshonapatra, however, Terton and his attendants were able to retain only a pair of cymbals upon entrusting Chungdu (the treasure guardian) for protection. The cymbals are today kept in Paro Dzong, which is only shown to public during Paro Tshechu (annual religious festivals).

In the surroundings of Nub Tshonapatra, are Rulkhotsho, Roltsho, Dungtsho, Ngatsho and Ngetoktsho. In the oral account (Ap Sangay and Ap Phuntsho from the locality), it is documented that Terton Sherab Mebar discovered numerous religious treasures, such as cymbals, trumpets, drum and drumstick from Rulkhotsho. However, the female deity of Rulkhotsho felt that the Terton was too ambitious and pursued him in order to slain him. In the process of escape, he had to drop cymbals in the lake appeared in front of him, and has named it as Roltsho; in the second lake that appeared, he dropped trumpet, named it as Dungtsho. Subsequent lakes also appeared, where he dropped drum, and named it as Ngatsho; then dropped drumstick, named it as Ngetoktsho. Thus, these lakes appear like cymbal, trumpet, circular like drum and bent like drumstick. It is believed that an abode of the Terton at Yatokha, behind the hills near lakes Ngatsho and Ngetotsho. The waters from Nub Tshonapatra Lake complex flows into Amo Chu basin.

Bothso: Botsho, headwater source of Mochu in Sombekha, Ha, is located on a hilltop. Locally, it is adorned as Nub Tshonapatra Lake. Prior to building Paro Dzong, Terton Sherab Mebar, along with his disciples, went to Botsho to uncover gold treasure to make pillar for the Dzong. The tale describes that the Terton at lake transformed himself to a big frog and drank entire volume of water of the lake. At the same time, disciples were instructed to cut gold slab when he had taken in water and permitted them to take chips and fragments of gold, resulted from cutting by the axe. The greed of disciples forced them to produce big fragments of gold while cutting, which prompted the Terton to tell not to produce such huge fragments as the gold would not be sufficient to make pillar in the dzong. In the process of uttering not to produce big gold splinters, Terton lost a drop of water from his nose which swirled to a big lake drowning all disciples and gold. The female deity of Botsho chased the Terton in the form of peregrine falcon as the terton had transformed himself to a bird. The Terton and female deity came into terms at Tergola Pass after an agreement that both of them would not cross into their territories through the mediation of Tergola Tshen (the mountain spirit or deity).

Tsheringma Lhatsho: Tsheringma Lhatsho, which is transliterated as the spirit lake of the goddess of Long Life, is located at 4450 meters of altitude, about 40 minutes walk from Jomolhari Temple, at the base of Jomolhari, Paro. Around the lake are cliffs with caves known as sergo (golden door) and dunggo (conch door) used by great hermits. Numerous characteristic rock symbols of religious beliefs such as the Eye of Wisdom, secret path of Dakini

and Dakini Code of Script are found. On the left side of the lake is a cave believed to be a place used by Jomo (Goddess Tsheringma) to have meals. Just below the Jomo Cave is another lake called Jomo Lhatsho, a light turquoise in color.

Tshokar & Tshona: Literally translated as the White lake, Tshokar is located at 4618 meters in a rhododendron scrub habitat at Singye Dzong (Lion's Fortress), Lhuntse. Tshona or the Black Lake is located at 4518 meters. These two lakes are believed to be offerings made by the Dakini Yeshey Tshogyal to Guru Rimpoche when he was meditating in one of the caves at Singye Dzong or the Lion's Fortress.

Tshokar

Tshona

Singye Dzong or the Lion's Fortress is considered to be one of the most important sacred sites in Bhutan .There is a belief that if one ever visits the place once in one's lifetime then he /she would be born in the Zhingkham (Celestial abode) in the next life.

Singye Dzong, the Lion's Fortress

Pemaling Lakes: In the 8th century, when Guru Padmasambhava arrived to Bhutan, he also visited Pemaling, Bumdeling, Trashiyangtse. During his visit to Pemaling along with his consort Khandro Yeshey Tshogay, he discovered numerous sacred places in the area. Numerous lakes in Pemaling were identified as Lhatshos and offered them as *yoenchab* (water offered to gods and deities). These *lhatshos* are located at around 4500 meters in alpine meadows. The *lhatshos* in Pemaling area are *Dorji Phagmoi lhatsho, Chagna Dorji's Lhatsho, Pelchen Dorji Zhoenui Phurba Lhatsho, Goempoi Lhatsho, Ge Nyen Nyonkha's Lhatsho*, and a scared lake called *Jang Utsho Ngonmo*. Around these lakes are sacred caves where Guru Padmasambhava, Khandor Ysehey Tshogay and other Buddhist master have practiced meditation and hermitage. The religious sacred sites include, namely; Jetsheun Milarepa's cave, image of Karmaling Lhakhang, Khandro Sangwai Draphu, 128 crematorium of south-east Ugyenling, offerings of *Tshongpoen Norbuzangpo, Jagoed Phungpoi Ri*, the Devil Matram Rutra's intestine, *Yula Koepai Zhingkham*, cave of Khandro Jewa Bum, stone image of Jetshuen Dema, Guru's Tshechang (wine) in skull and foot print, abode of *Shingje Choki Gyalpo, Lhakarpo and Drenagchung*, and 128 crematorium of Utsho Ngonmo. The hidden future treasure sites in Pemaling areas are: inlet of '*Throo*' treasure, *Kaajur* and *Tenjur* treasure, solid rock temple treasure, and inlet of copper treasure.

Discussions

If the planet earth is being truly heated as a result of climate change and global warming, the crysoshperic and its most associated cover, habitat and biodiversity in the Himalayas will be the most affected. The number of supra-snow lakes and supraglacial lakes will numerically fluctuate in response to global warming. Thawing of snow from increased temperature and unpredictable precipitation would trigger formation of additional supra-lakes and also trigger snow-melt floods and avalanches, further triggering glacier outburst floods. Smaller glacier lakes in alpine screes would desiccate as a result of thawing of permafrost and water percolation if the underlying geophysical layer is not made of bedrocks and clay.

During the current high altitude wetlands inventory, the use of googleearth images were preferred over other image sources as result of its free access and enhanced digitization capabilities, better image resolutions as compared to other freely available images, lack of resources to procure high resolution thematic images and softwares those are enabled with faster image processing power.

Using googleearth images available in its chronological layers, natural resources can be monitored; for instance, drying or drying up of lakes could be easily monitored. The rate of drying up of lakes could be determined. Mapping of forested wetland is very difficult upon

visual reading of googleearth image, unless one is skilled with physical characteristics of such wetlands.

If the googleearth entrepreneurs biannually update their image upload, this free access resource could be used to monitor potential natural hazards causing elements, such as expanding supra-snow and glacial lakes. Highest numbers of supra-snow lakes are found in head water sources of Mangde Chu. If water is extra-potent to melt snows and glacial ice, head water sources of Mangde Chu deserves monitoring of supra-snow lakes to either prevent or mitigate downstream snow burst flood risks.

From the current inventory, it is deduced that most high altitude wetlands lakes are distributed from 3800-5560 meters elevation range. It is inferred here that this distribution pattern may be influenced by volume and extent of existing snow cover, glacial activities, geomorphology, precipitation (in form of snow above 4500 meters maintaining snow volume) and seasonality of thawing (retention of water in form of ice). There is a school of thought that water resources in the Himalayas will not be affected because of snow refueling during the summer monsoon above 4500 meters. However, it is also proven that water melt away snow, glacial ice and permafrost more efficiently and effectively than rise in air temperature. Thus, perennial potentiality of river systems is at stake.

The smallest mapped wetland measure about 35 sqm., therefore, minimal mapping unit has been purely dependent on visual discernment of wetlands above 3000 meters of altitude. It is possible that larger wetlands would have omitted from mapping as a result of poor visually identifiable wetlands characteristics. While error of omission and commission is inherent in mapping exercises, the omission-commission error gap is comparatively less in this work. Wetlands have better boundary delineation than the past mapping works. The current inventory documents 3027 numbers of high altitude wetlands, more than a double fold increment as compared to the land use and land mapping exercise conducted in 1995 using Landsat Thematic Image (LUP 1995). This success of better documentation of wetlands is attributed to availability of high resolution spatial data and advanced GIS and RS technology.

Most parts of Bhutan has good coverage of high resolution googleearth images, however, the northern frontiers of Lunana complex and eastern parts of Bhutan covering Gongri river system, and basins of Neyra Ama and Jomotshangkha Chu do not have high resolution image. Therefore, it is probable that Bhutan would have more than 3500 high altitude wetlands.

This work on high altitude wetlands inventory has only produced empirical spatial data of wetlands found in Bhutan. It does not document flora and fauna diversity, water chemistry, and numerous other aspects of wetlands and water. This inventory is one of the founding activities to lead to further investigation.

Through this work, it is hoped that level of wetlands education and awareness amongst various levels of people in Bhutan is raised to a new height. This work also has potential to influence decision makers and resource managers in making use or exploiting water resources and conservation options. It defines, describes and quantifies wetland types in Bhutan to assist to adopt policy strategies for wetlands conservation.

Way Forward Options

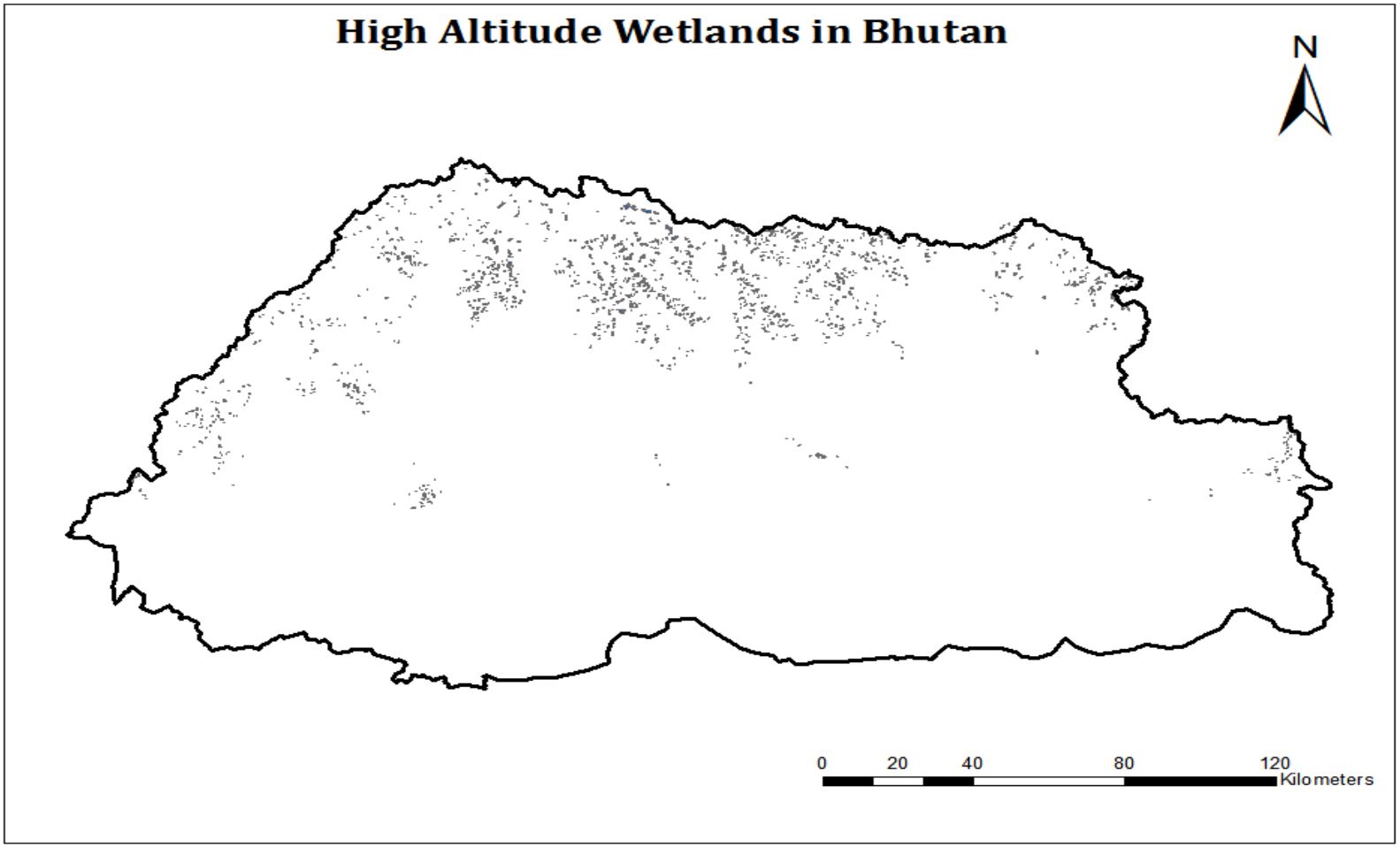
This product of high altitude wetlands inventory provide the baseline information on numbers of lake, watershed, location, wetland types, coverage and spatial distribution. Now onwards, any activities related to wetlands could be spatially connected to GIS. Therefore, it is envisaged, using this baseline spatial information numerous activities could be implemented in the field to better understand, conserve and monitor wetlands to enable people adapt to better water related livelihood options. In order to enhance better management of wetlands, the following have been suggested:

- As the earth is challenged with climate change and global warming, it has become imperative to develop long-term monitoring protocol and monitoring of wetlands. Noticing and detecting changes of the high altitude wetlands are important for downstream settlements and species.
- In order to build knowledge base and sciences of the impact of climate change in wetland ecosystems especially with respect to changes in hydrology, adaptive responses of flora and fauna has to be studied.
- To facilitate and engage people at grass root level to collect information and to identify changes in wetlands, a simple methodology has to be developed.
- Water is an important natural resource species. Chemical properties of water in wetlands in Bhutan is not at all studied. To enable people to use water wisely, it is suggested that research on water chemistry and eco-toxicology be pursued immediately.
- Wetlands in Bhutan are lost for urbanization, infrastructure, industrial and farm development. To educate people to appreciate wetlands, research on ecosystem services of wetlands ecosystem services has to be initiated. The wetlands are known to serve as water reservoir, effective natural water filter, and sequester carbon. Further, an immediate inventory of wetlands in municipal areas is required to safe guard them.
- While an attempt has been made during this inventory exercise to document cultural, religious and sacred values of wetlands, additional efforts have to be made on this front. Valuing beliefs regarded to wetlands will only enhance conservation.
- It is understood that wetlands functions as water reservoirs and contribute to maintain flow of water in our river systems. It is vital to know processes involved in natural maintenance of wetlands systems to use such knowledge base restore wetlands habitat.
- A few of the high altitude wetlands are used by waders and shorebirds to breed. The wetlands in Phobjikha, Khotokha and Bumdeling are inhabited by migratory bird species

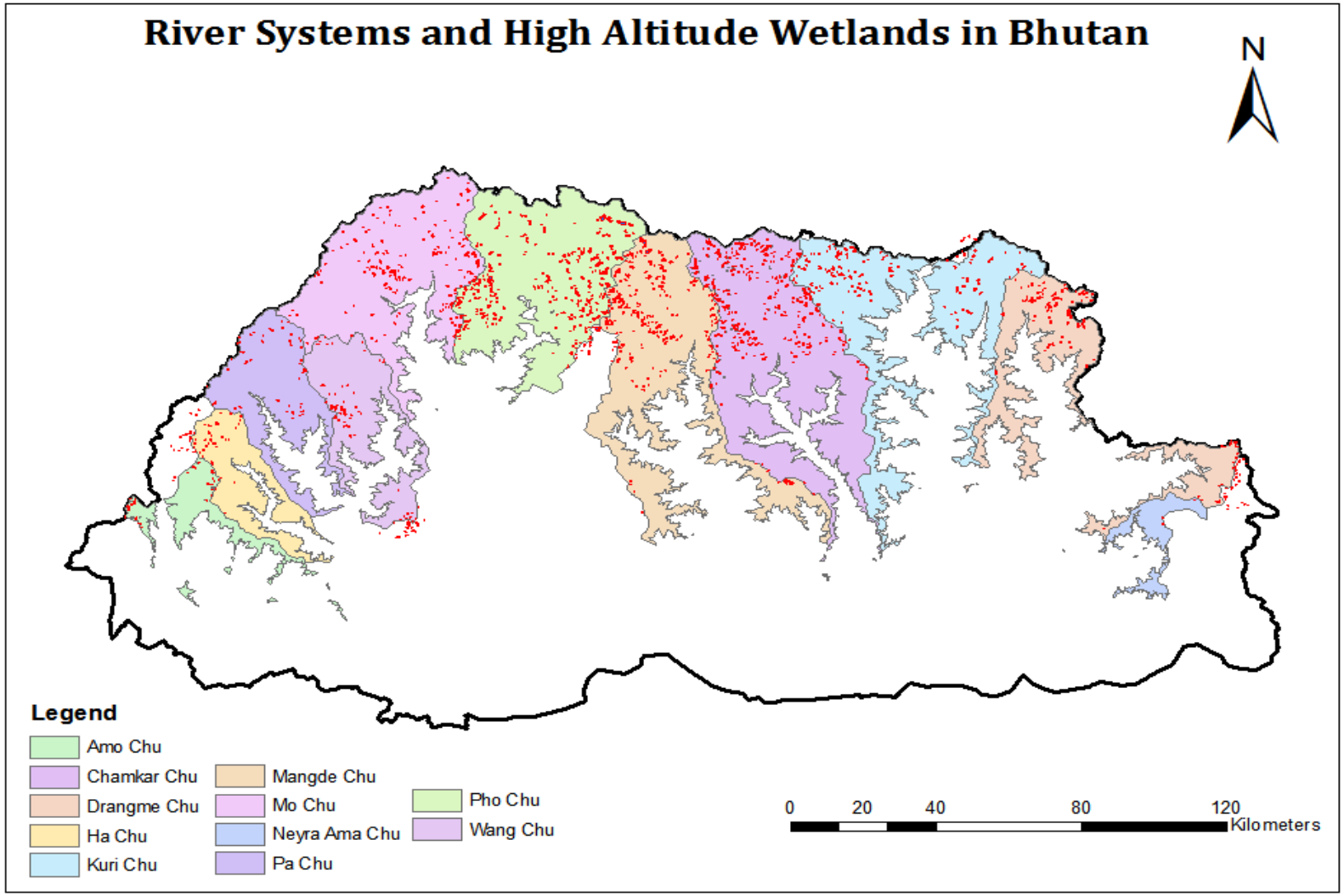
that winter in Bhutan. Populations of wintering birds have been fluctuating in different winter habitats; a study to understand and determine carrying capacity of wetlands with respect to land use and habitat use by species is necessary.

- The high altitude wetlands, besides snow and glaciers are definitely water reservoirs of river systems of Bhutan. Economically, Bhutan is more dependent on hydropower revenue to manage the country. In order to enhance proper management and conservation of high altitude wetlands, a study to evaluate contributions of wetlands in socio-economy is important. Without the high altitude wetlands reservoirs, perennial flow of water in rivers will be affected impacting revenue generation from hydropower.
- Wetlands are used by species as habitats to complete or partially complete life history. Water is also used as a medium for movement (dispersal and migration), therefore it is important to understand movement ecology of faunal and floral species to further appreciate wetlands.
- With the pace of development activities and climate change, numerous factors threatens wetlands habitat. It is of utmost importance to assess threats to wetlands to identify threats and find mitigation measures.
- Recognizing wetlands as a scarce and functionally important habitat, the global community has signed a wetland conservation convention called RAMSAR Convention. RAMSAR has played an important role around the world to safe guard wetlands for people and species. Even in Bhutan, a rapid wetland assessment to identify potential RAMSAR sites has to be initiated.
- Wetlands are inhabited by numerous life forms, from micro flora and fauna to higher forms. Aquatic biodiversity of wetlands, especially of the high altitude wetlands is the least documented. To realize the importance of wetlands and to facilitate to identify important wetlands sites, a baseline aquatic biodiversity survey is deemed necessary.
- Appreciation of wetlands or any other environmental components may not be materialized, if simple and effective communication materials are not developed on wetlands for education and awareness founded on knowledge base garnered through scientific research. Scientific findings may dissipate, unless communicated to people.
- Natural resources have to be used in a judicious manner. The river systems that generate hydropower have to be managed to maximize benefits to people and other species. Thus, a proper management plan should become a precursor to exploitation of resources. River basins in Bhutan originate from within her country and from across the border in the Tibetan Plateau. Anything that happens in upstream of basin will impact downstream habitats and settlements as upstream cause and effect are conducted downstream through river system. Therefore, Bhutan needs to initiate wetlands conservation management focus at two geographic scales, namely; at national and regional basin management scales.

Maps



Map 1: High altitude wetlands in Bhutan



Map 2: River systems and high altitude wetlands in Bhutan

Tables

Table 1: High altitude wetland type and area statistics

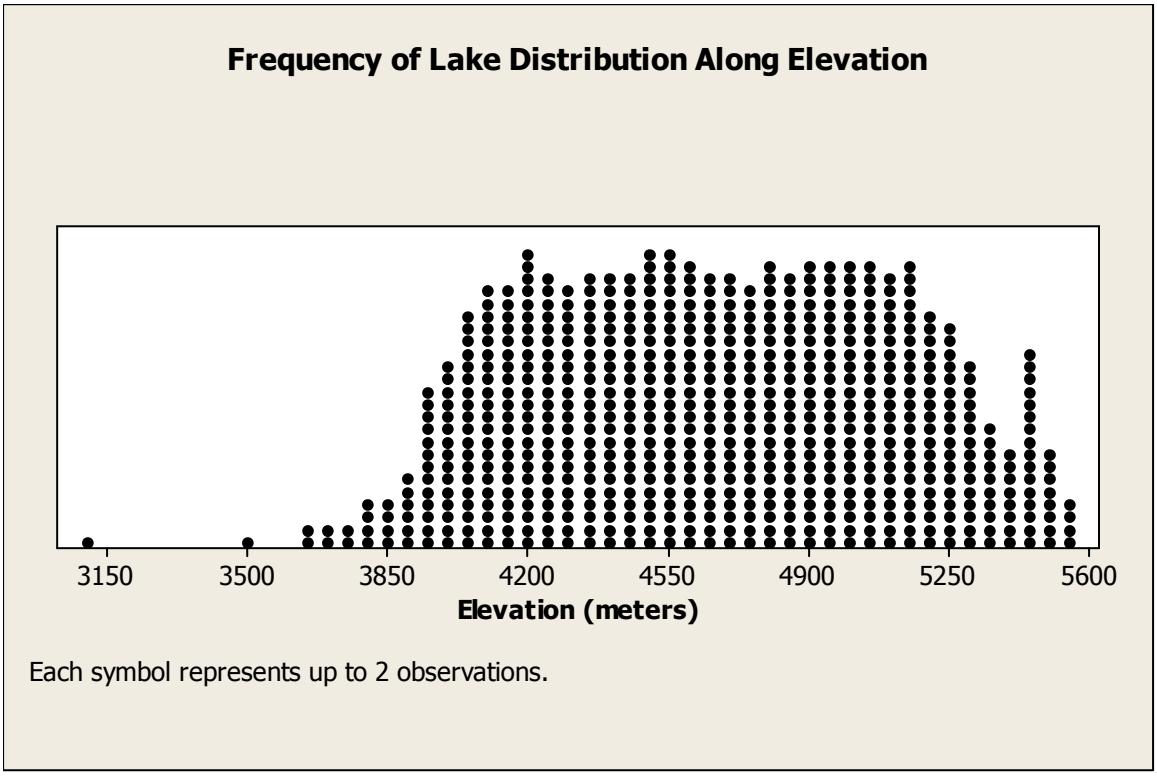
Wetland Type	# Lake	Area Subtotal (sqm)	Average Area(sqm)	Largest Lake (sqm)	Smallest Lake (sqm)
Supra-snow lake	110	52327.0	475.7	4758.8	36.2
Supraglacial lake	495	28554801.3	57686.5	1517436.4	133.6
Glacial lake	637	23230604.6	36468.8	878311.5	114.7
Lake	1722	49973272.8	29020.5	868048.9	34.6
Marsh	63	497334.4	7894.2	63811.1	126.1

Table 2: Lake distribution in river basins and river systems, and area statistics

Sl. No.	Basin	River System	# Lake	Area (Sqm)	Area (sqkm)	Average Area (Sqm)	Largest Lake (Sqm)	Smallest Lake (Sqm)
1	Drangme Chu	Chamkhar Chu	655	20008249	20.0	30546.9	1176719.2	51.5
		Gongri Chu	36	407359.9	0.4	11315.6	79128.7	529.4
		Kulong Chu	157	6081243.8	6.1	38734.0	702089.4	250.0
		Kuri Chu	238	11380505.1	11.4	47817.2	878311.5	221.8
		Mangde Chu	518	17531236.5	17.5	33844.1	1244717.3	36.2
	Basin Total		**1604**	**55408594.32**	55.4	**34544.0**	**1244717.3**	**36.2**
2	Amo Chu	Amochu	115	2044975.67	2.0	17782.4	221448.5	34.6
	Basin Total		**115**	**2044975.7**	2.0	**17782.4**	**221448.5**	**34.6**
3	Wangchu	Hachu	67	1595720.4	1.6	23816.7	269204.0	229.6
		Pachu	101	1813018.6	1.8	17950.7	221280.2	133.6
		Thim Chu	156	3105929.2	3.1	19909.8	432923.0	83.5
	Basin Total		**324**	**6514668.2**	6.5	**20107.0**	**432923.0**	**83.5**
4	Punatshang Chu	Dang Chu	28	1791793.5	1.8	63992.6	868048.9	595.7
		Hara Chu	4	58677.0	0.1	14669.3	46836.2	1183.8
		Mo Chu	355	8939309.0	8.9	25181.2	363122.4	111.4
		Pho Chu	517	26878960.1	26.9	51990.3	1517436.4	203.3
	Basin Total		**904**	**37668739.6**	37.7	**41669.0**	**1517436.4**	**111.4**
5	Nyera Ama Chu	Nyera Ama Chu	10	85374.0	0.1	8537.4	19736.3	1540.9
6	Shaar Chu	Shaar Chu	70	585988.3	0.6	8371.3	82231.5	130.1
7	Jomotshangkha Chu	Jomotshangkha Chu	0	0	0.0	0	0	0

Table 3:

Graphs



Graph 1: Distribution of high altitude wetlands along the elevation gradient.

Epilogue

Let wetlands remain wet in perpetuity;
Let water flow downstream perennially;
Let livelihoods of living forms remain unaltered;
Let happiness emanate from each living individual;
Let wetlands and waters sustain life.

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