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Mountain Peaks of Nepal Himalaya

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Abstract

Nepal is a mountainous country with numerous peaks and pinnacles. It is shaped by tectonic movement, the action of gravity, and erosion. It is a gradual transition process from plain to mountain terrain. The present study explores the peaks of the Nepal Himalaya and visualizes the peaks as open sources for mountaineering. The height of Nepal Himalaya is derived from 'Nepal Himalaya Inventory' Gurung (1994), 'Inventory of Nepal Himalaya' (CDG, 2002), and 'Spot Height Shapefile' (DOS, 1998). The total number of peaks opened and mountaineering royalty are derived from the Department of Tourism. The spot height and administrative boundary are derived from the Department of Survey (DOS, 1998 & 2020). Shapefiles and Google Earth are used to map the distribution of the Himalayan peaks of Nepal, and the height categories are based on mountaineering royalty reports. This study also discusses some essential aspects of royalty generation and seeks a better understanding in exploring and identifying peaks for further mountaineering activities.

Keywords: Himalaya, Himalaya ranges, mountain peak, mountaineering, royalty

Introduction

The Himalaya uplifted when the Indian subcontinent started pushing northward against the Eurasian plate for the past 40 million years (Molnar & Tapponnier, 1977), whereas USGS claims that it has been uplifted since 50 million years ago (USGS, 1990). The tectonic movement, gravity, and erosive forces shaped the mountain peak feature on the Earth's surface (Brondon & Printer, 2005). It is a gradual transition process from plain to mountain terrain. Mountain peak regions consist of rugged terrain, a low-temperature climate regime, steep slopes, and remoteness. Kapos has used (as cited by Vivirol, Du¨rr, Messerli, Meybeck, & Weingartner, 2007) criteria based on altitude and slope in combination to represent the world's mountain environments. Kapos Goudie (1985) defines mountains as ''substantial elevations of the Earth's crust above sea level resulting in localized disruptions to climate, drainage, soils, plants and animals (Vivirol, Du¨rr, Messerli, Meybeck, & Weingartner, 2007). The word 'Himalaya' is derived from two Sanskrit words,- "Hi-ma' snow, and "a-la-ya," abode; and it means abode of snow. The Himalayan range is in the south and east of Asia, separating the plains of the Indian subcontinent from the Tibetan plateau, which is 2400 km long and 200 to 300 km wide (Yang & Zheng, 2004). According to geographical location, the Nepal Himalaya lies on the Eastern Himalaya (WWF, 2021) of the Asian continent,

which separates the Tibetan plateau and Ganga plain. Apollo (2017) classified the Nepal Himalaya as central Himalaya based on the longitudinal division of Himalayas. Similarly, based on climate-ecology and phytogeographical division, the Nepal Himalaya lies on the eastern part of the Kumaun Himalaya (Kumaun to Kali Gandaki) and the western part of eastern Himalaya (Kaligandaki to Satlaj River) (Gurung, 2004).

Nepal is a mountainous country with numerous peaks and pinnacles. Its surface configuration consists mainly of mountains, hills, plateaus, basins, valleys, and plain/Terai of varying altitude and magnitude. It is home to the world's highest peak, Sagarmatha (Mt. Everest) 8848.86 m asl (MoCTCA, 2020), as well as a number of 8000 meters exceeding snow-capped mountains. Other highest eight-thousanders also lie within Nepal's territory: Kanchenjunga, Lhotse, Makalu, Cho-Oyu, Dhaulagiri, Manaslu and Annapurna exist in Nepal. These mountains are often called nature's water towers so that these are sources of freshwater. About half of all humankind directly depends on mountain resources, primarily water (Sharma, Molden, Rahman, Khatiwada, Zhang, Singh, Yao, & Wester, 2019).

The Nepal Himalaya is home to 26.5 million people (CBS, 2014), and it serves the downstream large population of the world because the ecosystem of the region depends on the Himalaya system. Its scenic beauty and adventurous attractions magnetize the world's tourists and mountaineers/ mountain enthusiasts (Howard, 2016). According to Pomfret and Hales (cited by Musa, James, & Anna, 2015), mountaineering is mountain-based adventure tourism. It has gained immense worldwide popularity. The high water towers (Himalayan water reserves) attract many people for cultural reasons as well. Mountaineers devotedly offer prayers and prayer flags at the top. According to Buddhism and Hinduism, the mountains are considered sacred places of the divine presence.

In 1590, Antonio Monserrate accurately sketched the Himalaya ranges, and in 1733 a French geographer, Jean-Baptiste Bourguignon d'Arville, compiled the first map of Tibet and the Himalayan range based on systematic exploration (Britanica, 2021). In the mid 19th century, Nepal and Indian mountains were measured by the systematic trigonometric survey, and during this time, the highest peak of the world was named Sagarmatha (Mt. Everest) after Sir George Everest in 1865. In Nepal, the first efforts were carried out to mapping peaks in the Nepal Himalaya in 1994 (Gurung, 1994) based on available topographic maps. Central Department of Geography (CDG) of TU prepared an inventory of mountain peaks of Nepal Himalaya in support of Nepal Tourism Board (CDG, 2002) and Survey Department, Government of Nepal, publishing spot heights including Himalaya peaks of Nepal (DOS, 1998). The total number of Himalayan peaks varies with different studies. So, the present study explores the peaks of the Nepal Himalaya as open spots for mountaineering.

Method and materials

The distribution of the Himalayan peaks of Nepal is presented based on secondary data. The heights of Nepal Himalaya are derived from 'Nepal Himalaya Inventory' (Gurung, 1994), 'Inventory of Nepal Himalaya' (CDG, 2002), and spot height shapefile (DOS, 1998). The study of Gurung is based on Indian topo-sheet and the scale is 1:50000. The study of CDG is based on a topo-sheet of the eastern part to the Annapurna range. Rest of the database is based on an Indian topo sheet, boundary map between Nepal and China. The spot height is based on a 1:50000 map scale. The total number of peaks opened and mountaineering royalty in 2015 are derived from the Department of Tourism. The spot height and administrative

boundary is derived from the Department of Survey (DOS, 1998 & 2020). Shapefiles and Google Earth are used to map the distribution of the Himalayan peaks of Nepal. The Himalayan peaks' height categories are based on mountaineering royalty report (DOT, 2015). The Himalaya ranges and peaks are visualized using Geographic Information System (GIS).

Table 1: Sources of Nepal Himalayan peaks

S.No.	Publication	Types of Data	Source
1	Nepal Himalaya Inventory	Hard Copy	Gurung, 1994
2	Inventory of Nepal Himalaya	Hard Copy & Digital Shapefile	CDG, 2002
3	Spot Height	Topographic map & Digital Shapefile	Dos, 1998

Result

Origin of Nepal Himalaya

According to USGS (1999), 3 billion years ago, all the present continents were in one place called Pangaea. Extreme heat from lava and magma inside the Earth flowed in and out of the earth, causing continental reclamation. In the course of continuous flow, the Asian and Indian plates collided with each other (the Tethys Sea between the Asian and Indian plates, (See Fig 1) and the Himalayas first raised about 650 million years ago, the Mahabharata (mountainous terrain) and the Chure mountains about 600 and 250 million years ago respectively. The movement of continental plates of the Earth's surface follows the thermodynamic principle. This sequence is still continuous, and thus the present Himal, Mid Hill, Mahabharat, and Chure originated (See Fig 2).

The mountains and hills of Nepal occupy 77 percent, and single high mountains occupy 25 percent (Gurung, 2004).

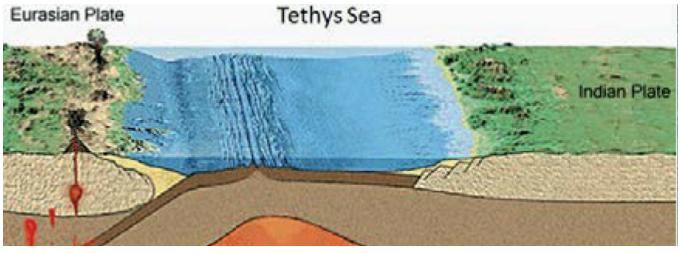

Figure 1: *Tectonic plate*
Source: After USGS, 1999

Figure 2: *Himalaya ranges*
Source: Google earth, 2020

Nepal Himalaya ranges

The erosive power of perennial snow-fed rivers dissected the Himalayas and formed the Himalaya ranges. Gurung (1994) has listed 28 Himalaya ranges with native names and sub-ranges of some main ranges. The highest peak, Sagarmatha, lies on Mahalangur Himalayan range. The above 8000-meter height peaks lay on Kanchanjunga, Manaslu, Annapurna, and Dhaulagiri Himalayan ranges.

Table 2: Himalayan ranges

S. N.	Himalayan ranges	Highest peak	S. N.	Himalayan ranges	Highest peak
1	Kanchenjunga	8586 m	15	Damodar	6701 m
2	Janak	7462 m	16	Nilgiri	7063 m
3	Umbek	6430 m	17	Annapurna	8093 m
4	Mahalangur	8848.86 m	18	Dhaulagiri	8169 m
5	Rolwaling	7140 m	19	Mustang	6372 m
6	Pamari	6160 m	20	Gauttam	6142 m
7	Jugal	7462 m	21	Palchung	6160 m
8	Langtang	7227 m	22	Kanjiroba	6885 m
9	Ganesh	7422 m	23	Kanti	6817 m
10	Sringi	7187 m	24	Gorakh	6258 m
11	Kutang	6498 m	25	Changla	6721 m
12	Manaslu	8163 m	26	Chandi	6249 m
13	Peri	7140 m	27	Nalakanker	6369 m
14	Lugula	7035 m	28	Gurans	7132 m

Source: After Gurung, 1994

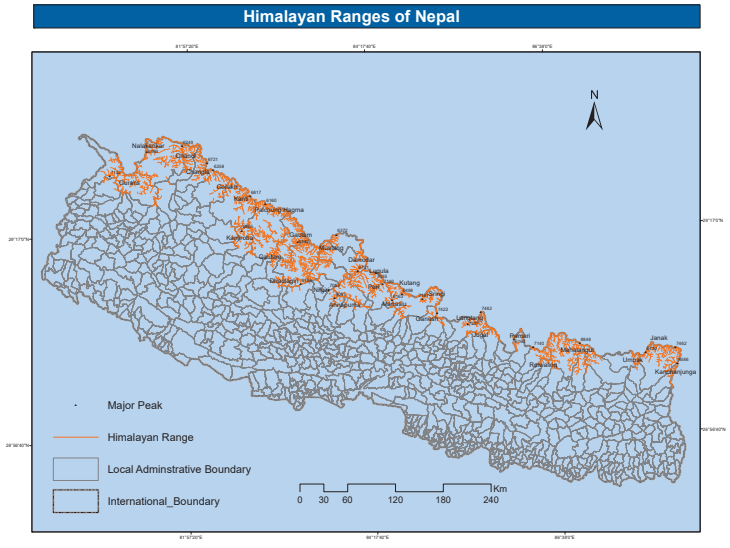

Figure 3: *Himalaya ranges of Nepal*
Source: CDG, 2002

The Highest peak of Jank, Umbek, Rolwaling, Pamari, Jugal Langtang, Ganesh, Sringi, Kutang, Peri, Lugula, Damodar, Nilgiri, Mustang, Gauttam, Palchung, Kanjiroba, Kanti, Gorkha, Changla, Chandi Nalakankar, and Gurans are 7462 m., 6430 m., 7140 m., 6160 m., 7462 m., 7227 m., 7422 m., 7187 m., 6498 m., 7140 m., 7035 m., 6701 m., 7063 m., 6372 m., 6142 m., 6160 m., 6885 m., 6817 m., 6258 m., 6721 m., 6249 m., 6369 m., and 7132 m. asl respectively.

Distribution of mountain peaks of Nepal Himalaya

Gurung (1994) lists out a total of 1310 mountain peaks of Nepal above 6000 meters based on a survey of India topographic sheets at a scale of one inch to a mile (1:63360) and maps prepared for the Sino-Nepal Boundary Agreement of 1979. There are 17 peaks above 8000 m height, including the Sagarmatha (Mt. Everest, 8848.86 m), the highest peak of the world (MoCTCA, 2020). The mountain ranges from 7501 to below 8000 meters and ranges from 7000 to 7500 meters constitute 40 and 87 number peaks respectively. There are 301 (23 percent) and 865 (about 66 percent) peaks that range from 6500 to 7000 meter and 6000 to 6500 meter, respectively (see table 1). About 20 percent of the peaks are identified with specific names.

Table 3: Inventory of Nepal Himalaya

S. No.	Categories	No. of Peaks	Percent
1	>= 8000	17	1.3
2	7501 - 7999	40	3.05
3	7000 - 7500	87	6.64
4	6501 - 6999	301	22.98
5	6000 - 6500	865	66.03
	Total	1310	100

Source: Gurung, 1994

CDG (2002) listed 1792 mountain peaks of Nepal above 5000 meters based on the topographic map prepared by the Department of Survey from Kanchanjunga to Annapurna range and Nepal, and the Sino-Nepal Border map was used for the rest of the western Himalayan ranges. The study finds out there are 15 peaks above 8000 meters, including Sagarmatha (Mt. Everest). The peaks below 6500 meters occupy 82.48 percent. Above 7500 to 8000, 7000 to 7500, 6500 to 7000, and below 6500 meters heights peaks are 29, 73, 197 and percent share 1.62, 4.17, 11 and 82.48 percent respectively (See Table 3).

Table 4: Inventory of Nepal Himalaya

S. No.	Peak Categories	No. of Peaks	Percent
1	>=8000	15	0.84
2	7501 - 7999	29	1.62
3	7000 - 7500	73	4.07
4	6501 - 6999	197	10.99
5	<=6500	1478	82.48
	Total	**1792**	**100.00**

Source: CDG, 2002

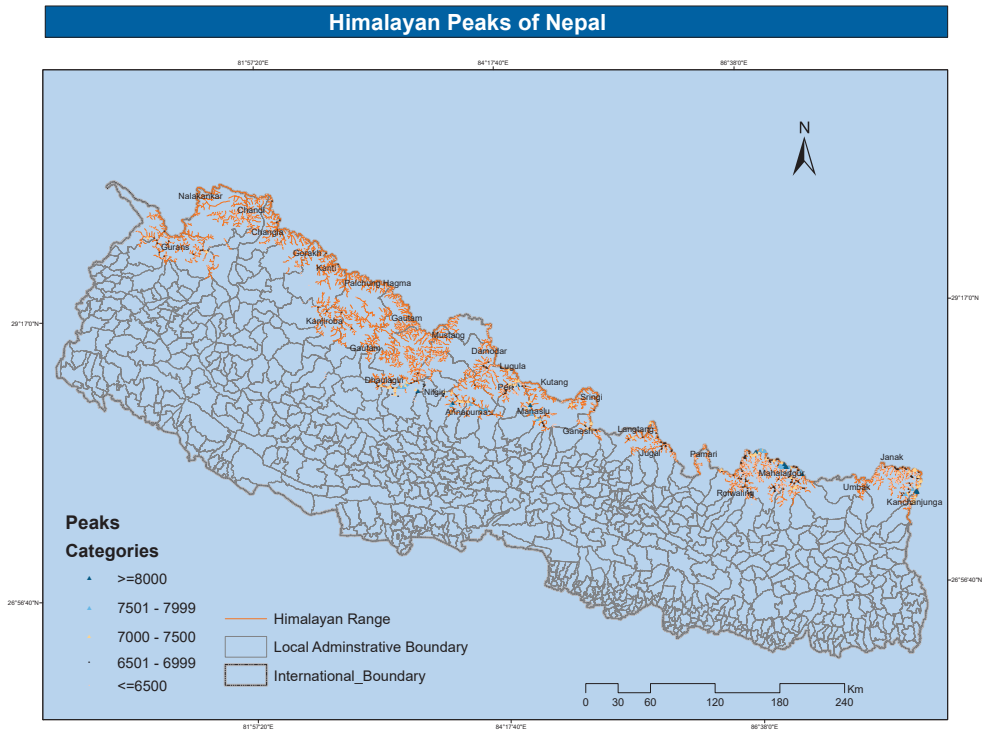

Figure 4: *Himalaya peaks of Nepal*
Source: CDG, 2002

The spot height and peaks' height of Nepal are published from the Survey Department of Nepal in the form of hardcopy and digital shapefile (DOS, 1998). There are 9321 spots and heights mapped in the topographic map of Nepal. There are 23 places greater than 8000 meter, and 57 places are more than 7500 meters to 8000 meters which share 0.25 percent and 0.61 percent, respectively. There are also 7000 m to 7500, 6500 m to 7000 and less than 6500 m ranges; peaks and spot heights comprise 115, 364 and 8762 numbers respectively and 1023, 3.91 and 94 percent share respectively (See table 4).

Table 5: Spot heights

S. No.	Peaks categories	No. of Peaks	Percent
1	>=8000	23	0.25
2	7501 - 7999	57	0.61
3	7000 - 7500	115	1.23
4	6501 - 6999	364	3.91
5	<=6500	8762	94.00
	Total	**9321**	**100.00**

Source: DOS, 1998

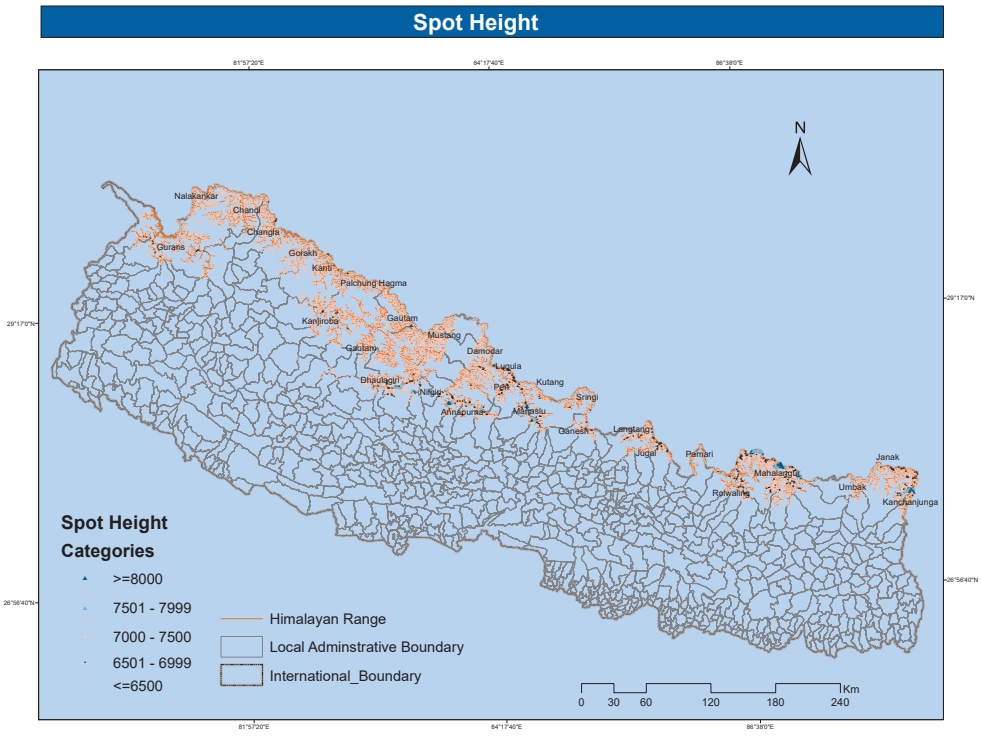

Figure 5: *Himalaya peaks of Nepal*
Source: DOS, 2002

Peaks open for mountaineering

Department of Tourism (2015) opened altogether 411 peaks for mountaineering where 14 peaks are greater than 8000 meters asl, including Sagarmatha. Out of the total, 24 peaks range from 7500 m to 8000 m asl. Similarly, 7000 m to 7500 m, 6500 to 7000 m, and less than 6500 m range peaks are 47, 138, and 188 in number, respectively. 45.74 percent peaks are up to 6500 m for mountaineering. 33.58 percent peaks are open in ranges from 6500 m to 7000 m asl.

Table 6: Mountain peaks open for mountaineering

S. N.	Peak Categories	No. of Peaks	Percent
1	>=8000	14	3.41
2	7501 - 7999	24	5.84
3	7000 - 7500	47	11.44
4	6501 - 6999	138	33.58
5	<=6500	188	45.74
	Total	**411**	**100.00**

Source: DOT, 2020

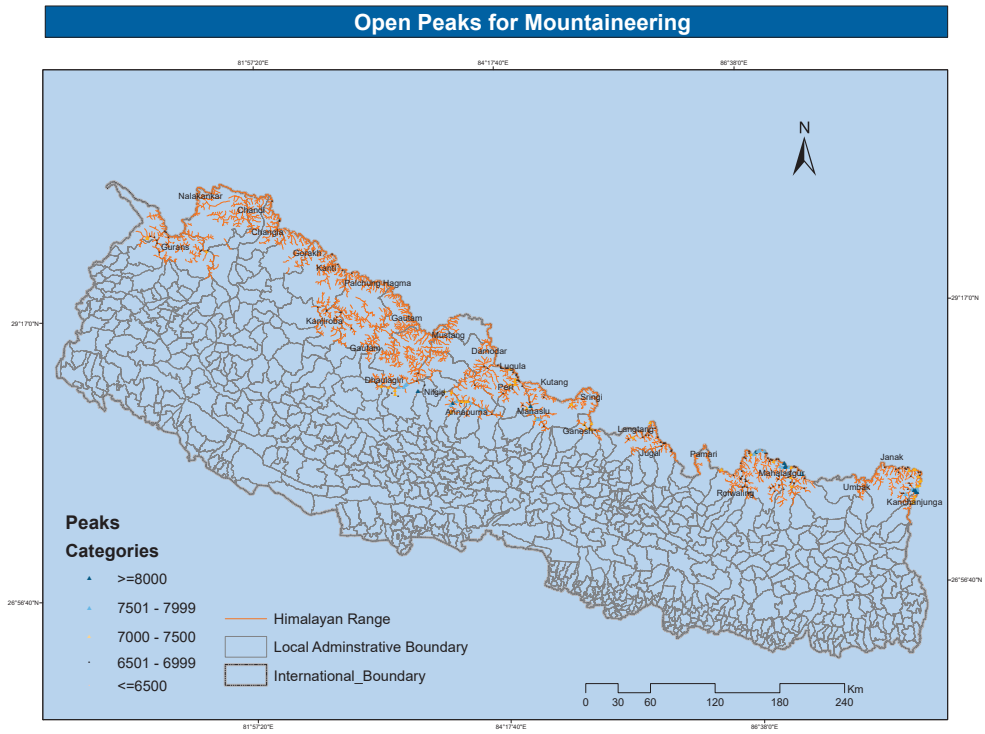

Figure 6: *Himalaya peaks of Nepal*
Source: DOT, 2002

The Department of Tourism, Government of Nepal, fixed the mountaineering royalty for foreign climbers under the height of peak, season, and route. The Sagarmatha regular route's (South Col route) royalty for spring season is 11000 US$ and autumn season is 5500 US$. The royalty for another route of Sagarmatha for the spring season is 10000 US$ and the autumn season is 5000 US$. The other eight-thousander peaks' royalties are 1800 US$ for spring and 900 US$ for autumn season. The mountain peaks ranging from 7500 m to 8000, 7000 m to 7500 m, and 6500 m to 7000 m height's royalty for spring season are 600 US$, 500 US$ and 400$ respectively and for autumn season's royalty are 300 US$, 250% and 200 US$ respectively. In the case of Amadablam, the royalty for spring and autumn season is 400 US$. The mountain peaks range below 6500 m height's royalty is 250 US$ for spring and 125 US$ for autumn season.

Table 7: Mountaineering royalty for foreign climber per person in American Dollar (US$)

S. N.	Peak Categories	Spring Season	Autumn Season
1	Everest Normal route	11000	5500
2	Everest Other route	10000	5000
3	Other Mountain Peaks >=8000	1800	900
4	7501 - 7999	600	300
5	7000 - 7500	500	250

6	6501 - 6999	400	200
7	Mt. Amadablam (6812M)	400	400
8	<=6500	250	125

Source: DOT, 2020

The mountaineering royalty in Nepali rupees for Nepali climbers also varies with the height of peaks, seasons, and routes (See table 6).

Table 8: Mountaineering royalty for Nepali climber per person in NRP

S. N.	Peak Categories	Spring Season	Autumn Season
1	Everest Normal route	75000	37500
2	Everest Other route	600000	30000
3	Other Mountain Peaks >=8000	10000	5000
4	7501 - 7999	8000	4000
5	7000 - 7500	6000	3000
6	6501 - 6999	5000	2500
7	Mt. Amadablam (6812M)	8000	8000
8	<=6500	4000	2000

Source: DOT, 2020

Discussion

Traditionally trigonometric land survey was an effective tool for measuring and mapping height of mountains (Punmiya, 1995). Before that, travelers used to sketch the mountain ranges pretty accurately. Sir George Everest scientifically measured the Himalayan peaks, including Sagarmatha (Mt. Everest), the highest peak (8848.86 m) of the world, from 1830 to 1843 (Smith, 1999), and in 1961, this region was mapped by the Royal Geographical Society (Ward, 2013) based on stereo photogrammetric expeditions. Gurung (1994), DOS (1998) and CDG (2002) mapped Himalayan peaks of Nepal based on the aerial photo using the stereo-photogrammetric method. Gurung (1994) listed out Himalaya peaks based on topographic maps (Nepal west sheet 1967 and Nepal east sheet 1969) by the UK Ministry of Defense and Sino Nepal border Map 1962. DOS (1998) worked on a topo map of Nepal with spot heights, including Himalaya peaks and place heights. CDG (2002) mapped Nepal Himalaya peaks based on a topographic map published by DOS for the eastern part of Nepal and rest of the peaks were done using the Sino-Nepal Border Map 1962.

The table shows the list of peaks opened for mountaineering. Out of the total peaks greater or equal to 8000 meters asl, 14 (88 percent) peaks are opened for mountaineering. Similarly, the peaks range from 7501 m to 7999 m, 7000 m to 7500 m, 6501 m to 6999 m, and 6000 m to 6500 m are open 70, 59, 58, and 17 percent respectively. There are the highest peaks opened for mountaineering in highest percent.

Table 9: Nepal Himalaya peaks and open peaks for mountaineering

S.N.	Categories	No. of Peaks			Peaks Open for Mountaineering
		Gurung 1994	DOS 1998 (Including spots height)	CDG 2002	
1	>= 8000	17	23	15	14
2	7501 - 7999	40	57	29	24
3	7000 - 7500	87	115	73	47
4	6501 - 6999	301	364	197	138
5	6000 - 6500	865	8762	1478	188
	Total	**1310**	**9321**	**1792**	**411**

Source: Gurung, 1994, DOS, 1998, CDG, 2002 & DOT, 2015

Advancement of space science and technology, Digital Elevation Model (DEM) data and technique automatically detect the mountain peaks and terrain features (Graff & Usery, 1993). Global Navigation Satellite System (GNSS) is also a recent advanced space technology for mapping Himalayas and mountains. Recently, the Department of Survey, Government of Nepal, measured Sagarmatha's height using GNSS (DOS, 2020). DEM and GNSS techniques will be the supportive tools for detecting Himalaya peaks and terrains in detail.

Conclusion

Nepal is a mountainous country with numerous peaks and pinnacles. There are different facts and figures about the number of Himalayan peaks with height and name. Although there is an inverse relationship between the number and height of peaks, the Department of Survey has digitized more peaks and pinnacles but needs more detailed work to separate peaks and spot heights. The Nepal Himalaya peaks opened for mountaineering are concentrated in the eastern part of the country. This study concludes that the needed amount of detailed study lacks appropriately due to the shortage of technical expertise and sources. So, detailed research activities are requuired to explore unidentified and unnamed mountains and potential mountaineering using DEM and GNSS space technology. These methods also support exploring physical characteristics of Himalaya like rock type, slope, aspect, slope and height which help to find alternative routes to promote mountaineering in all seasons and all parts of the Nepal Himalaya and develop mountaineering sustainably. It also supports the determined scientific mountaineering royalty based on mountaineering techniques.

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