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Himalayan glaciers, climate change and human population of Ladakh: an overview of the cold desert of India

M. N. Koul, Jammu & Kashmir

I take this opportunity to express my sincere gratitude to all the members of the Institute of Indian Geographers; particularly Professor K. R. Dikshit, the Patron of IIG, honouring me as the President of the Institute of Indian Geographers for the year 2020-2021 and giving me the privilege to address the 42nd meet of the Institute at Savitribai Phule Pune University, Poona- an eminent university with the grandeur of the natural setting and academic excellence. I am grateful to Honorable Vice-Chancellor Professor Dr. Nitin R. Karmalkar, Pro Vice-Chancellor Prof. Dr. N. S. Umarani, Convener Professor R. G. Jaybhaye, Head Department of Geography, SPPU and Secretary General IIG, Prof. Veena Joshi, Prof. Sudhakar D. Pardeshi, Prof. Amit G. Dhorde, and their colleagues, the distinguished members of the Department of Geography, for organizing this online International conference.

I take this opportunity also to express my deep gratitude to the members of the governing council of the IIG for their magnanimity in choosing me as the President of the Institute for the year 2020-2021 that was extended further due to the Covid-19 pandemic. I feel deeply honored and humbled. It is a great responsibility. I am conscious of my limitation to do justice to this office. Distinguished senior professors, well known for their scholarship and authority have graced this office previously, and contributed significantly to nurturing this association. It is the good wishes of you all and the blessings of seniors that have encouraged me to accept this onerous responsibility.

The focal theme of the IIG international conference "Geography for People, Planet Prosperity, and Peace" is most contemporary, close to the heart of geographers as it relates to the "Man-Environment relationship" based on the supremacy of human beings in shaping the global environment. With the explosion in the human population, the interference of the human population is changing the global environment of planet earth through anthro-geomorphic processes is clearly visible. At first, it was difficult to decide a topic that would be appropriate to the theme of the conference, and dwell upon my favoured specialization concerning human-nature relationships in mountain regions.

Realizing that the cold desert of Himalaya, a topographic unit, with its own separate history- defining age-old contemporaneity with other parts of the Himalayan territory through land trade and culture, is considered appropriate to the theme of the conference, encouraging me to speak on the topic "Himalayan Glaciers, Climate Change and Human Population of Ladakh: An Overview of Cold desert of India".

Presidential Address delivered at the 42nd IIG Annual Meet and International E-Conference at Department of Geography, Savitribai Phule Pune University (SPPU), Pune on 4th October 2021.

Human – Nature Relationship

The interactions between the environment and human societies have a long and complex history. Needless to re-emphasize, people not only form part of the ecosystem but also continuously alter the environment for their needs and convenience. They act as an external agent to change nature. Through this interaction, humanity has achieved incredible progress at the cost of destabilizing the natural system upon which humans rely for survival. So much so that many scientists believe that for the first time, instead of the planet shaping the humans, humans are knowingly shaping the planet. Human activities have more significantly altered the environment beginning with the industrial revolution in the latter part of the eighteenth century followed by rapid industrial and scientific innovation leading to economic growth and this is why the period is often called the Anthropogenic Age of the humans (Crutzen and Stoemer, 2000). Over the last two centuries, both the human population and economic wealth of the world have grown rapidly. These two factors have increased resource consumption significantly in agriculture and food production, industrial development, urbanization, energy production and recreational activities, in both the developed and developing parts of the world leading to the development of many other ancillary industries.

Earth: A Dynamic System

Earth is a single system within which the biosphere creates the environment that keeps the earth habitable for life processes to continue. In this system, the anthropogenic and natural landscape is co-evolving through biogeochemical processes. The global temperature and global carbon cycle, as well the locally liberated inert gases are absorbed by trace elements of the atmosphere as carbon dioxide (CO_2) and methane (CH_4) and are tightly coupled whereas the maximum and minimum temperature and atmospheric trace gases concentration follow regular pattern through time. Key indicators such as the concentration of carbon dioxide in the atmosphere are changing dramatically, and in many cases the linkages of these changes to human activities are strong.

It is increasingly clear that the earth system is being subjected to an ever-increasing diversity of new planetary-scale forces, ranging from the artificial fixation of nitrogen and emission of greenhouse gases to the conversion and fragmentation of natural vegetation and loss of biological species, largely due to increased human intervention. There is a tendency in human society to utilize all modern facilities for the comfort of human beings. The Industrialized nations such as the USA, Europe, China, Japan, Australia, etc. have recently turned into warm islands, breaking the long-standing record by emitting a large amount of carbon content to the atmosphere along with other inert gases and dust aerosols. The number of heatwaves, heavy rain events, and major hurricanes has increased manifold all over the world particularly during the last decade and the frequency has been increasing in developed countries (Fischer, 2021). Recent record-breaking weather extremes particularly during the last two years have been experienced in the developed countries like USA, European Union, Russia, China, Indonesia, and heat dome over Pacific and the northwest.

Further, the frequency of extreme weather events has resulted in the meltdown of Arctic, Antarctic, and Greenland ice sheet resulting in calving of ice shelf producing icebergs and causing the rise in Greenland landmass by one to two inches. Rapid meltdown in Greenland ice sheet has been so fast that one can see the land uplift, and is astonishing to the scientists. The same process is operating in Iceland and Svalbard. The weeklong extreme heat that broke all past records by three or more standard deviations is likely to be two to seven times more probable during 2021 -2050, and three to twenty-one times more probable during 2051-2080. Such events are estimated to occur every 6-7 years somewhere in northern mid-latitudes (Fischer, Sippel, and Knutti, 2021).

Glacier and Climate Change

The mountain glaciers, such as those that exist at higher elevations in mid-latitudes and tropics are particularly sensitive indicators of climate change. Many studies have been carried out in different parts of the world, on the response of the glacier to climate change due to global warming in the 21st century. Many glaciers experience a general state of advance with a maximum, reaching sometimes in the later part of the 19th century and steady retreat thereafter. On a global scale, studies have shown that glacier wastage has been pervasive during the last century with small glaciers disappearing in mid-latitudes whereas large ones are shrinking slowly and warming has been considerable in Polar Regions. Unfortunately, very few glaciers in the Himalayas have been studied due to their extreme ruggedness of terrain and inaccessibility. Extensive studies however have been carried out on Kolahai, Shisram (Kashmir), Machoi (Kargil), Durung Drung, Kangriz (Zanskar Ladakh), Kol (Jammu) and Naradu (Himachal Pradesh) glaciers in NW Himalaya by our team during the last three decades to assess the responses of global warming in terms of variation in length, mass balance, and the impacts of micro climatological variables on the glacier body. The studies have provided impeccable evidence to the fact that glaciers in the Himalayas, particularly in Ladakh, do not show erratic behavior in the secular movement of the snout.

The glaciers, a repository of past climate, constitute an important barometer to assess the status of present climate change. The main source of data to monitor the fluctuation in the glacier is imprinted in the flora of the climate zone. The two main subsystems of the glacier- the glacier- mass and glacier process- convincingly demonstrate positive and negative feedback processes to sustain the continuity of mass balance. The two zones' ablation and accumulation - having two different sites - adds to the mass of the glacier and vice versa. The advance and the retreat of the glacier are based upon the gain in snow through accumulation and loss of snow through ablation. Himalayan glaciers comprise nearly 30 percent of all the glaciers outside the Polar Region and cover an area that is 20 times the area of glaciers in the Alps (Wissman, 1959). According to the inventory made on Himalayan glaciers by the Geological Survey of India, there are altogether 9575 glaciers extending from Kashmir in the West to Sikkim in the East. As many as 3200 glaciers are confined to Himachal, Kashmir and Ladakh Himalaya along the major watersheds of Sutlej (926 glaciers), Beas (277 glaciers), Ravi (172 glaciers), Chenab (1278 glaciers), Jhelum (133 glaciers) and Indus (1796 glaciers) (Raina, 2015). The NW Himalayan glaciers contribute nearly 60 percent of the annual flow of meltwater while East Himalaya contributes relatively less due to higher snowline and intense monsoon melt. The volume of ice in a glacier, and correspondingly its surface area, thickness and length, is determined by the balance between inputs and outputs that are largely controlled by temperature, humidity, wind speed, slope angle and ice-albedo (Fitzharris et al., 1996).

The dynamics of the glacier are influenced by a variety of local and regional factors such as the amount of precipitation and the temperature regime. Climate change impact is manifested through rising temperature and changing precipitation. Changes in atmospheric temperature and changes in the amount and type of precipitation are bound to affect glacier health, but glaciers do not necessarily advance during colder weather or retreat during warmer conditions. The glaciers are a self-supporting system and receive snowfall during the summer season due to sublimation of glacier surface caused due to local environment leading to precipitation in higher reaches that sustains the glacier. The local environment near the glacier front (snout) may sometimes show closeness with climate parameters that may be a mere coincidence. As such, it will be prudent to come to a definite conclusion that glaciers in the Himalaya are subjected to stress due to climate change-induced global warming in the context of Alpine glaciers. The Himalayan glaciers are not co-relatable with the glaciers of the Alps as the Himalayan glaciers extend up to an altitude of 6200 m compared to the Alps which extend up to 3000 m representing a relative difference of 3200 m between the two. Also, Himalayan glaciers have much steeper slopes, and their relative relief goes up to the altitude of 2500 m. Due to high relative relief, the northwestern Himalayan peaks become "Warm Islands" and at the same time act as centres of condensation due to sublimated air mass emanating from the glacier ice to become "Moist Islands". There are two zones of high precipitation originating from two different sources of air masses: one from the local weather conditions and the other from western disturbances and monsoons. Precipitation at the higher altitude of the high Himalayas is most favourable for the maintenance of glaciers. This precipitation usually takes place during the summer season, particularly along the accumulation zone, and helps in consolidating the glacier and reducing the albedo effect.

The glaciers in Karakorum Himalaya, due to their location in the shadow zone of Pamir and Great Himalaya, have induced a climate shift in weather condition in the last one decade resulting in a marginal shift in winter and summer season by extending the former up to May and the latter up to August/September. The High Himalayan ranges have an aerodynamic link with the air mass of the westerly airflow and the westerly disturbances (originating from the Mediterranean and Caspian Ocean) that move aloft the Pamir Range. The air mass develops cold high air pressure at a higher altitude that ultimately sinks lower giving rise to cold anticyclonic circulation leading to the production of thermal gradient during the winter season (October to May) responsible for anchoring southeasterly Jet Stream in atmospheric conditions. Sometimes these air masses extend to late winter and further rejuvenate during late summer with the influence of El Niño, Southern Oscillation helping the glacier to remain stable and grow.

Cold Desert Region of India

The cold desert of India is situated in the rain shadow zone of the Himalayan and the Trans Himalayan. The cold desert is confined along the protracted zone of the Higher Himalayas extending from Ladakh in the North to parts of Lahul-Spiti- Kinnaur (Himachal Pradesh) in the South. It covers an area of 61,000 km^2, out of which the Ladakh cold desert covers an area of 59,146 km^2 (96.7%), and is confined to Leh and Kargil districts. The cold desert region, also called the high-altitude desert, is girdled on three sides by higher Himalayan ranges that house 5355 glaciers as per glacier inventory prepared by the Geological Survey of India (Kaul et al 1990, Sangewar et al 2009). More than 5221 (97.5%) glaciers are situated in Ladakh- Karakorum region alone (Raina et al 2015). Ladakh is cut diagonally by the Indus forming a huge basin. The upper half of the basin constitutes Leh district, the Western portion of the Skardu, and the southern half of the Kargil-Zanskar district. Indus basin houses 1796 glaciers and the Shyok basin hosts 2667 glaciers (Sangewar et al 2009). The glaciers in the Indus basin are spread over eight sub-basins, namely Kaiticho, Suru, Leh, Sanglemochu, Zanskar, Chhabe Nama, Indus, Hanle, and Drass.

Ladakh is a vast desert with rugged topography, high mountains, elevated plateau, rock gorges and sandy terrain. The nature of rocks is vulnerable to weathering process resulting in mass movement primarily due to prevailing arid conditions supplemented by the peri-glacial process (solifluction and gelifluction) leading to degradation of the Zanskar-Kargil region of Ladakh, where a detailed field study was carried out.

The preparation of Desertification Status Mapping (DSM) was carried out by IRS 1C/D-LISS III geo-coded FCC paper print followed by ground truth data. Satellite data of two cropping seasons (Rabi and Kharif) from the years 2002 to 2005 were considered for the study. Interpretation of satellite sheet formed the basis of study covering an area of 711.78 km² along with collateral data based on the topographic sheet of the Government of India at the scale of 1:50,000 in the Sod valley in Zanskar.

A fresh study on the spatial-temporal status of desertification was undertaken by the Space Applications Centre, Ahmedabad in the year 2013 in the second phase of desertification mapping. The study was based on multi-temporal digital IRS AWiFS data (2003-2005 and 2011-2013) and ancillary information supported by a detailed ground truth of cold desert covering a total area of 14,036 km² of Kargil district of Ladakh. The total area under desertification in Kargil district changed little in the intervening years between 2003-2005 (78.22%) and 2011-2013 (78.23%). The area under land degradation increased only by 0.01 percent in this period. The significant process that contributed to the land degradation/desertification was frost shattering (37.54%) during the years 2011-2013 (compared to the years 2003-2005) followed by vegetation degradation (31%) during the years 2011-2013 as against 30.95 percent during the years 2003-2005 (as per Land use/Land cover maps of Zanskar, Kargil; see Table 1). Studies carried in the first phase in Stod Valley of Zanskar reveal that the area under desertification was 80.06 percent in the period between 1965 and 2003 as against 78.23 percent at present. The difference of 1.73 percent is primarily attributed to the reduction in mass movement processes due to stabilization of slopes by extensive plantation carried by the government and the NGOs. Further, the reduction in the process of frost shattering is due to change in weather conditions particularly in the mean monthly temperature since the year 2001. This has resulted in a marginal increase in temperature during late winter and summer and wet summer during 2001-2013 in comparison to chilly cold early winter, mild late winter and dry summer during 1988-2000.

Morphology and Dynamics of the Glaciers of the Ladakh

The Himalayas encompass 9575 glaciers, covering nearly 41,000 km² of glacier area (Sangewar et.al, 2007). It is a dynamic reservoir of constantly exchanging mass with part of the hydrological system process by which glaciers, permafrost areas gain or loss of ice or snow. Ladakh Himalaya houses 4,463 glaciers in two major basins namely Indus and Shyok (Sangewar and Shukla, 2009)

Table 1: Kargil District, Ladakh Union Territory

Process of Deserification / Land Degradation	2011-13		2003-05		Change (ha)
	Area (ha)	Area (%)	Area (ha)	Area (%)	(2011-13)-(2003-05)
Vegetation Degradation	435156.87	31.00	434388.35	30.95	768.51
Wind Erosin	7179.58	0.51	7179.98	0.51	-0.40
Mass Movement	20523.93	1.46	21322.67	1.52	-798.74
Frost Heaving	9.11	0.00	9.11	0.00	0.00
Frost Shattering	526860.20	37.54	526862.73	37.54	-2.54
Barren/Rocky	107573.56	7.66	107741.18	7.68	-167.61
Settlement	**778.76**	**0.06**	**400.25**	**0.03**	**378.51**
Total Area under Desertification	**1098082.02**	**78.23**	**1097904.29**	**78.22**	**177.73**
No Apparent Degradation	**305517.98**	**21.77**	**305695.71**	**21.78**	**-177.73**
Total Geographical Area (ha)			**1403600.00**		

where a detailed study has been undertaken. Indus basin houses 1796 glaciers and the Shyok basin hosts 2667 glaciers (Sangewar et al 2009). The glaciers in the Indus basin are spread over eight sub-basins, namely Kaiticho, Suru, Leh, Sanglemochu, Zanskar, Chhabe Nama, Indus and Hanle, Drass. On the other hand, the glaciers of the Shyok basin are spread over nine sub-basins, namely Thatte, Saltoro, Sumdo, Fasten, Nubra, Rangdo, Shyok, Chumchar and Chang. Out of the total area of 43,334 km² of the Indus basin, about 2,225 km² is covered by glaciers whereas the glaciated area in the Shyok basin is 7,105 km² out of total 37,826 km² of the basin (Sangewar and Shukla, 2009). Some of the largest glaciers include Siachen (73 km long) glacier. About, 45 percent of the glaciers in the Shyok basin are less than 1 km in length and about 50 percent of the glaciers vary between 1 and 5 km in length. Similarly, about 53 percent of the total glaciers in the Indus basin including the Suru sub-basin are less than 1 km in length, and about 43 percent of the glaciers range between 1 and 5 km in length (Sangewar and Shukla 2009. Recent studies of the Suru sub- basin glaciers undertaken by the scientists of Wadia Institute of Himalayan Geology, Dehradun using temporal satellite remote sensing data reveal that the sub-basin has 252 glaciers, covering 11 percent of the basin area, and containing a large number of small (less than 1 km length) glaciers (55%) (Shukla et.al, 2019). This reflects the existence of a large percentage of small-sized glaciers in the Ladakh Himalaya, whereas the Baspa sub-basin of the Sutlej River of Kinnaur Himalaya has a comparatively large percentage of medium-sized glaciers. The region is in the convergent zone of warm moist monsoonal circulation and cold arid Westerlies between an altitude of 4300 m and 6159 m.

Study of some large glaciers representing Zanskar, Suru, Drass, Nubra sub-basins of Indus and Shyok basin and Baspa sub-basin of Sutlej basin was undertaken with a view to unraveling the cause for secular movement of the snout. The studies included both field observations and interpretation of available IRS satellite data for different points of time such as 1965 and 2001;1989 and 2001; and 2002 and 2015. The Zanskar sub-basin is represented by Drung Drung, the Suru sub-basin is represented by Kangriz glacier; the Drass sub-basin is represented by Machoi glacier; the Nubra sub-basin is represented by Siachen glacier and the Baspa sub-basin is represented by Naradu glacier.

The Case of Cold Glaciers

The study of five major glaciers of cold desert region of India provided significant insights into the complex behaviour of the glaciers.

The Siachen the largest glacier of India is a 73 km long valley glacier with a wide foot snout extending between Saltoro Mountain ridge in NW and Karakorum Mountain in the NE and covers an area of about 700 km². It is the second-longest glacier in the non-polar area of the world. The glacier is a broad-footed snout extending approximately for 10 kms. The glacier snout appears to have undergone secular retreat for over a century and a half. The glacier registered an extreme advance of 725 m between the years 1862 and 1909 followed by a retreat of 400 m between the years 1929 and 1958. Further, between the years 1958 and 1985, the snout position of the Siachen glacier remained stationary which is inexplicable by any credible, concrete scientific explanation. The glacier has completely slowed down in its retreat for almost a decade and a half. In the absence of a credible scientific explanation, one is tempted to ascribe it to its specific meteorological history. At present, the glacier's snout is showing asynchronous behavior of the feeder glaciers at its terminus.

The **Durung Drung** glacier is 23km long covering an area of 72.15 km² with an accumulation area of 45.68 km² and ablation area of 27.15 km². The glacier body is situated on the Zanskar fault that separates the Himalayan crystalline zone from the metasediments of the Tethyan Himalaya. The reactivation of the Zanskar fault has been responsible for the block movement in the West (Pensi- La) compelling the glacier to turn North and then the Northeast. The asynchronous behaviour between the feeders of the Durung Drung glacier has a partial impact on the change in the snout position of the glacier.

The Machoi is a small transverse glacier, less than 2 km long and very close to the East of Zojila pass. Monitoring the record of the glacier from 1875 AD showed continuous shrinkage till 1957 AD. In1988 the glacier showed an increase in its mass. Since 1988, the glacier is seen in a static position until the present as evident from photographs and satellite imageries. Small glaciers like Machoi and a small glacier of Nubra valley adjoining Siachen show an increase in glacier length as well as area not attributed to change in the climate.

The Kangriz glacier has shown minor changes in the position of the snout for the past one century. However, the thickness of the glacier has reduced since the year 1907 leading to a reduction in the volume of the glacier.

The study of the above-mentioned glaciers in Ladakh Himalaya has provided adequate insight into the complex behaviour of the glaciers. The field documentation confirms the change in length with respect to area, as in the case of the Kangriz glacier, whereas some glaciers show variation in the area but not in length, as in the case of Siachen and Machoi glacier. Asynchronous behaviour between the feeders of the Durung Drung glacier and its volume has resulted in the secular retreat of the East and the West feeders. The overall health of the glaciers in Ladakh Himalaya is affected by inter and intra-annual variation in weather parameters (microclimate factors), terrain morphology and tectonics. Studies on the effect of weather parameters on the health of glaciers of Suru-Zanskar and Naradu glacier (H.P) suggest the secular movement of snout and weather parameters is complex and varied (Koul, 2017 and Koul and Ganjoo,2010)

Temporal temperature change

The Karakorum is one of the most elevated (3500 m to 7000 m asl), and coldest region (-30°c to -60°c) of the world. The glaciers, housed in a protracted zone, have induced a climatic shift in weather condition since last one decade, resulting in a marginal shift in winter and summer season by extending the winter season up to May and summer to August/September due to its location in the shadow zone of Pamir and the Great Himalayas. The time series temperature data at Drass Valley Station (1987-2016) has been used to provide a regional picture of seasonal and year-to-year variation in temperature and glacier mass extent at higher altitudes. Over a record period of 30 years, there has been a little increase in annual mean temperature at Drass of -0.226°c/decade prior to 1995. However, since 1996 the rate of increase has accelerated to 0.575°c/decade. The analysis of mean monthly temperature (maximum and minimum) for a period of 30 years shows that the winters are the coolest, late winters are warm and humid, and the summers are cool, and wet during the time series between 2001 and 2016. Between 1987 and 2000 the overall weather conditions were harsh with chilly cold, early winters (November-March), mild late winters (March-May), and dry summers. As has been observed the marginal climate change has led to a decrease in mean maximum and mean minimum temperature during 2004 and 2016. The change is associated with inter-decadently, of Pacific Oscillation, as well with an increase in the frequencies of El Nino-Southern Oscillation- events that resulted in the lowering of temperature during ablation season particularly during the summers between 2004 and 2016 (Yasunari, 1987; Raina and Koul, 2011, Koul, 2017). The decrease in the trend in diurnal temperature during 2004 and 2016 further substantiate the change.

Cold Desert as Land Resource

Mountain ecosystems enrich the lives of half of the worlds' population as a source of water, energy, agriculture, etc. While the impact of climatic changes is accentuated at high altitudes, such regions are often on the edge of decision-making, partly due to their isolation, inaccessibility and relative poverty. Ladakh is primarily a mountainous terrain, having high mountain ranges that house the tallest water towers in the form of large glaciers, snowfields, confined to high-protracted zones of the High Himalayas. The Indus River system contributes a lot to the agrarian, industrial as well tourism potential of North India by providing perennial irrigation as well as generating hydropower. Snow and glacial meltwater contribute 400 to 800 km³ of water sufficient to generate 1,00,000 megawatt of hydropower (Bhadur 2000). Thus, they serve the territories with rich resource of water, energy, and areas of recreation and serve as a storehouse of biological diversity. Ladakh has the highest relative relief in the world exhibiting a component of culture and heritage territory studded with magnificent historic monuments (Gumpas) depicting fine work of art and architecture forming a component of tertiary cultural heritage with scenic and socio-economic values. Inhabitants of Spit valley in Himachal Pradesh are largely dependent on agriculture and the area is a vast reserve of wild resources such as Droh, Gandan and medicinal and aromatic plants.

Impact of Climate Change on Land use

Agriculture is the mainstay of the economy in Ladakh both in Leh as well in the Kargil district. A large section (75% - 85%) of the population in this region is engaged in an age-old agro-pastoralist form of land use. The present study was carried out in Zanskar and the Nubra, both landlocked, inhabited by Buddhists. Eighty-five percent of the population is engaged in sedentary cultivation and pastoral animal rearing. Agricultural implements such as Zho used by the farmers are crude and primitive deployed in drawing the small plough. Subsistent farming is still practiced because of unfavorable climatic conditions, steep foothills and fragmented small-land-holdings. Till recent times manure was added to agricultural fields through a pool of cooperative farming. During the last two decades, agricultural practices have changed as the villages are increasingly connected by roads. Mechanization and scientific methods have been introduced in agriculture. The region supports the cultivation of a variety of crops like wheat, grim (barley), pea, fodder and vegetables that grow in a short period. The per hectare output of these crops has increased recently due to the development of a hybrid variety of seeds that grow in a short period even under harsh climatic conditions with assured water supply. The recent changes in weather conditions have encouraged farmers to switch over to wheat from barley cultivation in areas where the soil is conducive for its growth. Further, in adjoining mountainous regions where crop cultivation is rarely feasible, livestock rearing is a natural alternative supported by a more conducive sub-arid cold climate during summer seasons. Substantial availability of free edible mass has efficiently been routed through livestock links of the food chain. Further, it has been supplemented with off-season organic vegetables through the support of government and the NGOs.

Livelihood is being reconfigured by increasing the level of market integration and external development including a preference for diversification. Vegetable gardening has become one of the economic opportunities for women farmers who are increasingly cultivating a variety of vegetables in trenches during cold arid winter. The agriculturists are also drawn towards the tourism industry in Ladakh as a lucrative option to increase cash earning. Similarly, widespread cultivation of apple, chilgoza and pea in Kinnaur District of Himachal Pradesh is also a welcome consequence of the marginal change in the climate.

Human Interface

The cold desert region has a unique synthetic culture of Indian and Tibetan confluence. It is reflected in the form of Buddhism practiced here and further manifests in its art, architecture, lifestyle, food, clothing etc. The age-old pastoralist nomads of the Ladakh, who live the harsh climatic conditions, accord them a peculiar political, social and cultural identity to the region. The modernization process unfolding in the region in recent times has improved the quality of living of the native population.

Ladakh's earliest inhabitants consisted of a mixed Indo-Aryan population of the Mons and the Dards. The faces and physique of Ladakhis, and the clothes they wear, are more akin to those of Tibet and Central Asia than the rest of India. Buddhism came to

Western Ladakh via Kashmir in the second century when much of the Eastern Ladakh and western Tibet was still practicing the Bon religion. Ladakh is sometimes called "Little Tibet" as it has been strongly influenced by Tibetan culture. In the past, Ladakh gained importance from its strategic location at the crossroads of important trade routes but since the Chinese authorities closed the borders with Tibet and Central Asia in 1960, international trade has dwindled. Since 1974, the Indian government has encouraged tourism in Ladakh that is fast emerging as a major Himalayan tourist destination. The Buddhists are predominant in Leh district and Zanskar tehsil and Shiite Muslims in Kargil district. Padum, the tehsil headquarter of Zanskar has inhabitants of both Buddhists and Muslims. Its composite population is mainly of Tibeto-Dards descent. Primarily, this is the only settlement of the Sunni population believed to be the descendants of people who came with Zorawar Singh from Kishtwar in his expedition to conquer Ladakh and Tibet. The victorious Zorawar Singh granted land in Zanskar to his followers at Padum. The low population density (less than 2 inhabitants per km^2) of Leh is considered ideal for the conservation of Himalayan biodiversity as early as 1981 when the first high-altitude national park, Hemis National Park was formed.

The Union Territory of Ladakh comprises the districts of Leh and Kargil supporting a total population of 4, 30,000 persons, (projected assessment, 2018), of which nearly 60 percent are Buddhist. Leh has a population of 2, 89,000 and the Kargil has 1, 42,000 souls. The detailed socio-economic survey of the Buddhist villages of Zanskar and Nubra households conducted during 2011-2013 reveals the superior status of women in Buddhist society. Buddhist women are given special status in the society in much contrast to their Muslim counterparts who are kept in social seclusion and girls are married at a relatively tender age. The sex ratio is largely in favour of men who constitute nearly 52 percent of the population and about 46 percent of the population is confined to the biologically reproductive, economically most vibrant and demographically highly mobile age group of 15 to 45. However, half of the villages in Zanskar and Nubra have a more favourable sex ratio of 893- 1147 females per thousand males in predominantly Buddhist villages, in sharp contrast to the highly unfavourable sex ratio of 788-1000 females per thousand males at Padum and Diskit (Nubra) villages having a composite population of both Buddhists and Muslims. The proportion of the population in 15-60 years of age is 65 percent. Society is highly vibrant and progressive in caring the livelihood and meeting the demands of the entire society. There is a great male-female disparity in education with 75 percent of the males being literate while the proportion of literates among the women being as low as a quarter of their population. Almost all the Buddhist localities have monasteries known locally as Gompas, built on a flat or atop the neighbouring hillock, depending on local factors along with paintings of Buddha. The Buddhist priests called the Lamas practice dance, sing and play on pipes and horns. The Gompas, the centers of people's cultural life, greatly influence their spiritual life for centuries. They play a dominant role in binding the society and helping farmers in managing their farming. One of the unique architectural attractions in the region is Chorten and Mani walls.

Conclusions

The Ladakh region is a well-known cold desert with its unique geological and climatic setting. The influence of westerlies in the region has played a significant role in shaping the Ladakh region to behave much differently than the rest of the Himalayas. The "Karakorum Anomaly" has been the key factor in negating the effect of global climate change in this region. Marginal increase in the mean monthly maximum temperature during the summer (June to September) causes sublimation of ice from glacier body that result in an increase in summer precipitation. The change in summer temperature has thus encouraged farmers to switch over to wheat cultivation from barley cultivation in the areas of favourable soil conditions. Cultivation of off-season organic vegetables encouraged by the Government has brought significant changes in agricultural practices in this cold desert. Incentives to women pastoralists to weave pashmina shawl on handlooms from hand-spun wool and export of Zanskari butter has been successful in increasing the earnings at the hands of the women. The focus on touristic development has helped the local agriculturists to move into the cash economy. The unique synthetic and syncretic culture of the inhabitants of the region has also contributed to the development of tourism attracting visitors from across the globe.

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Dr. M. N. Koul
Former Professor and Head,
Department of Geography,
University of Jammu,
(J&K) - 180006
E-mail: mnksahib@gmail.com