

Chapter 19

Climate Scenario in Cold Arid Region and its Future Prediction



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Abstract Ladakh region of Jammu and Kashmir State is characterized by excessive aridity and severe moisture deficit throughout the year. On one side of the region are the Karakoram ranges while on the other side lie the mighty Greater Himalayas and Zaskar ranges. Together these impart a rain shadow effect to the region resulting in very low annual precipitation. With scarce water resources, such regions show high sensitivity and vulnerability to the change in climate and need urgent attention. The objective of this study is to understand the climate scenario in the cold arid region of Ladakh region and to characterize its changing climate. The climate over Leh has shown a warming trend with reduced precipitation. The reduced average seasonal precipitation may be associated with some indications of reducing number of days with higher precipitation amounts over the region.

Keywords Climate · Cold-arid · Climate change · Ladakh

19.1 Introduction

Ladakh is a cold-arid region which lies between 32°15' to 36°0' N and 75°15' to 80°15' E. It is the northern-most territory of Jammu and Kashmir province of India. Ladakh lies in the Trans-Himalayan Area and is limited in the north-upper east by Tibet, in the northwest by Baltistan and in the west by Himachal Pradesh. Ladakh is

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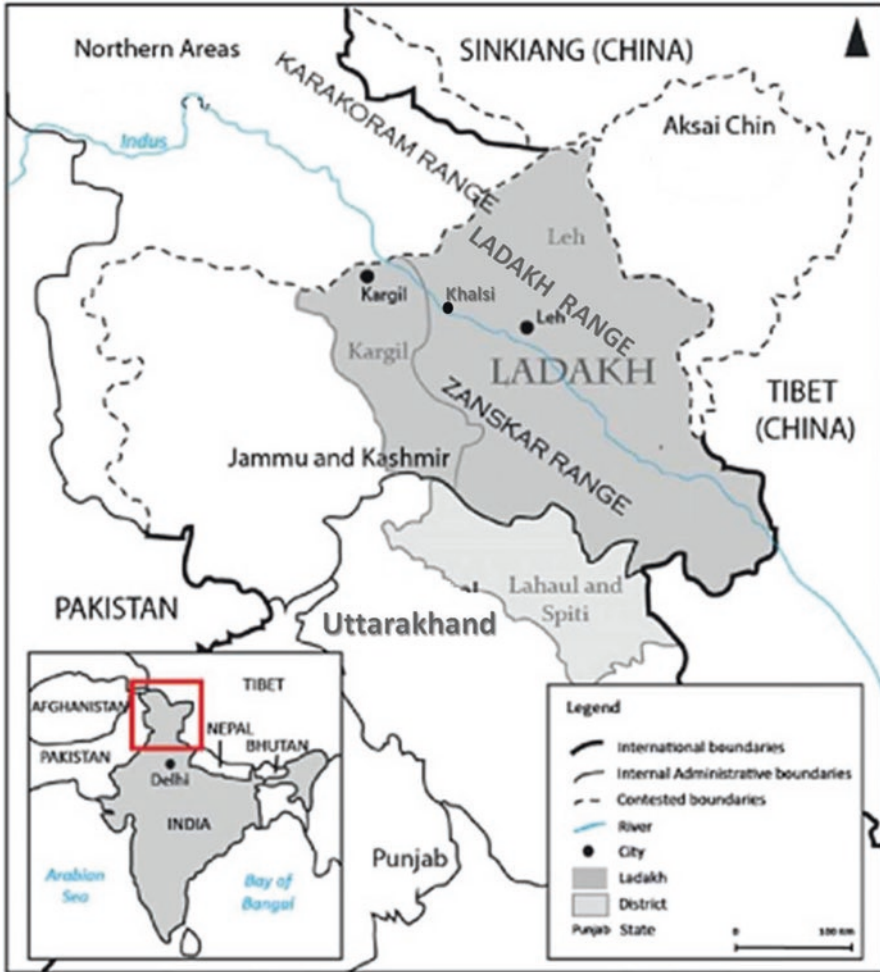


Fig. 19.1 Map of Jammu and Kashmir showing the Ladakh region (Le Masson and Nair 2012)

the biggest zone of Jammu and Kashmir state and involves a territory of 58,321 km² which is almost 42% of the aggregate region of the state. The height ranges from more than 2400 m with peaks extending from 7200 to 8400 m. The zone is one of the most astounding occupied places on the planet. The map of Jammu Kashmir State demonstrating Ladakh area is given in Fig. 19.1.

Ladakh consists of two districts Leh and Kargil. Leh with an area of 45,110 km² makes it largest district in the country in terms of area. The topography is mostly mountainous and bare. Except for few places, the area is mostly devoid of vegetation. The cold arid zone experiences severe cold and dry winter and moderately hot and dry summer. The zone receives about 80–90 mm rainfalls in Leh to about

Table 19.1 Land Utilization Pattern of Leh (Area in Hectares)

Year		2003–04	2014–15
Reporting area		45,167	45,167
Forest area		–	0
Area not available for cultivation	Land put to non-agricultural uses	2908	2978
	Barren and uncultivable land	25,163	27,474
Other uncultivable excluding fallow	Permanent pastures and other grazing lands	1092	NA
	Land under misc. tree, crop, grooves not including net area sown	1148	1732
	Culturable wasteland	4412	2567
Fallow land	Fallow other than current fallows	143	37
	Current fallows	190	376
	Net area sown	10,111	9982
Area sown more than once		313	632
Total cropped area		10,424	10,614

300 mm in Kargil. Severe aridity with very cold thermal index is a characteristic of the zone. Soils of this zone have a high permeability and low water holding capacity.

The state of Jammu and Kashmir has been divided into three main regions on the basis of physiography. The Outer Himalayas consisting of Jammu province, the Lesser Himalayas consisting of Kashmir province and the Inner Himalayas consisting of Ladakh province. Ladakh lies in the cold-arid agro-climatic zone of Jammu and Kashmir and is divided into three agro-ecological zones (Ahmad and Kanth 2014):

1. Upper Agricultural Zone (UAZ) 3597–4420 m. (a.m.s.l)
2. Central Agricultural Zone (CAZ) 3048–3597 m. (a.m.s.l)
3. Lower Agricultural Zone (LAZ) < 3048 m. (a.m.s.l)

The physiography of the region is divided into hilly and valley lands. About 85% of the area comes under hills and only 15% area is under valley. The population density of the region is very low being only 4.6 per km². The land use statistics of Leh district is presented in Table 19.1 (LAHDC 2015). The region has no forest cover. Most of the land in the region is barren or uncovered. The total cultivated land forms less than 25% of the total area of Ladakh.

The district Leh has a location of 34° 17' N and 77° 58' E. Besides being the district head quarter, it is also the capital of Ladakh Autonomous Hill Council in the state of Jammu and Kashmir, India. The city is located in the foothills of the Ladakh range. It lies in the Indus River catchment with an average altitude of 3500 m amsl. The Indus valley is bound by the Ladakh range in the north and Zaskar range in the south.

19.2 Agriculture

Ladakh region possesses a wide range of flora and fauna. The forest vegetation mostly comprises of few trees species and few shrubs like poplar, willow, sea-buck thorn etc. The major crops grown in the region are barley and wheat. Grasses like alfalfa are also grown in the region. Horticulture is a major part of livelihood of people. Varieties of Grapes (Resin type), prunes and drying varieties of apricots, sea-buck thorn are grown widely in the region. Cultivation of apple, walnut and currants is also practiced in certain areas of the region. Ladakh region is the major producer of apricot crop in Jammu and Kashmir. The major share of the fruit (almost 40%) alone comes from Kargil district of the Ladakh region.

Agriculture in Ladakh is mainly subsistent in nature yet one of a kind and a typical of Tibetan plateau farming system. The people of Ladakh until recently followed an integrated farming system. They produced and consumed their own grains, cereals and vegetables. The manure, seeds and other agricultural inputs were produced by the people themselves. They also raised their own animals and arranged their own farms in an integrated and adjusted way in order to confront the harsh climate and hostile environment of Ladakh.

Nonetheless, many factors like cropping intensity at a low level, lesser productivity and a brief agriculture season has brought about the reliance of its developing populace on import of food grains, vegetables and spices. Moreover, as Ladakh opens to the world, its conventional agricultural framework and produces confront serious interruptions. Agriculture has now occupied a secondary position to the fast development of tourism in the region. Nevertheless, the potential for agricultural development in the region is still immense in spite of its high elevation and arid climate. Both agricultural and horticultural crops are grown in Ladakh especially niche or specialty crops. These crops if properly marketed after value addition can bring about its very own green in this region.

Besides, as Ladakh opens to the world, its traditional system and crops face severe disruptions. Nonetheless, there is a huge back seat to the rapid growth of tourism in the region. Nonetheless, there is a huge potential for agriculture in Ladakh, despite its high altitude and arid climate. Ladakh grows niche crops, both agricultural and horticultural, which with an appropriate value added and proper marketing can herald a green revolution of its own sort in this region. Aiming at production of vegetables in winters, market in the prolonged winter season can prove to be very beneficial to local farmers. The area under cultivation of different crops is given in Table 19.2 (LAHDC 2015).

Table 19.2 Area (in hectares) sown under different crops in Ladakh, J&K

Year	Rice	Maize	Wheat	Grim	Other Millets	Pulses	Fruits	Vegetables	Spices	Other food crops	Total food crops	Oil seeds	Fodder	Total non-food crops	Total Area sown
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2001–02	–	–	2604	4734	436	270	98	240	–	–	8382	73	2068	2141	10,523
2002–03	–	–	2653	4702	377	272	85	246	–	–	8335	73	2070	2143	10,478
2003–04	–	–	2894	4504	349	349	85	245	–	–	8327	73	2024	2097	10,424
2004–05	–	–	2894	4480	384	249	35	299	–	–	8341	67	2020	2087	10,428
2005–06	–	–	2973	4463	375	272	38	310	–	–	8431	65	2089	2154	10,585
2006–07	–	–	2973	4463	375	272	38	310	–	–	8431	65	2089	2154	10,585
2007–08	–	–	2968	4452	359	286	39	313	–	–	8436	74	2089	2163	10,599
2008–09	–	–	2634	4639	379	306	91	348	–	–	8402	86	2028	2114	10,516
2009–10	–	–	2690	4646	342	297	90	358	–	–	8427	86	2095	2181	10,608

(continued)

Table 19.2 (continued)

Year	Rice	Maize	Wheat	Grim	Other	Pulses	Fruits	Vegetables	Spices	Other food crops	Total food crops	Oil seeds	Fodder	Total non-food crops	Total Area sown
2010–11	–	–	2579	4421	–	192	131	229	–	–	7552	86	1947	–	11,692
2011–12	–	–	2595	4488	97	243	40	280	–	–	7743	90	1991	2081	9824
2012–13	0	0	1092	2869	556	258	88	321	3	1	5188	86	2093	2179	7367
2013–14	0	0	1077	3934	622	251	134	393	3	1	6415	80	2100	2180	8595
2014–15	0	0	2776	4288	564	258	104	388	5	1	8364	89	2161	2250	10,614

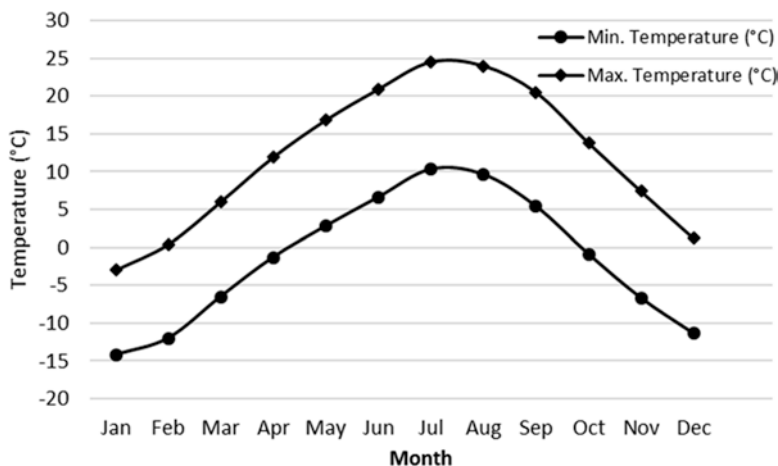


Fig. 19.2 Monthly variation on Maximum and minimum temperatures in Ladakh

19.3 Climate Scenario

19.3.1 Temperature

Ladakh is located on the rain shadow region of the Himalayas. The monsoon winds after losing their moisture in the Himalayan Mountain and the plains make their way to Leh. The district brings together the elements of both arctic and desert climate, thus attributing it the title of “Cold Desert. It has unique attributes as wide diurnal and seasonal fluctuations in temperature with -40°C in winter and 35°C in summer. The average monthly variation of Maximum and minimum temperatures in Ladakh (2000–2016) is presented in Fig. 19.2.

January, February and December are the coldest months of the year. The temperature seldom goes above the subzero condition beginning from December. The night-time is chilling and temperatures float around -20°C . Days are warmer with 2°C as average temperature. January also witnesses maximum snowfall and thick ice sheet formations over rivers and lakes are common. Manali - Leh and Srinagar - Leh Highway are closed and Ladakh remains practically inaccessible by road during these months. Frostbites are common and most locals develop scales and cracks on their skins.

March and April are warmer than January, February and December. During March, temperatures hover between 6°C in the day and -5°C in the night. April is still better and day temperatures go up as much as 12°C . Occasional snowfall during these months can result in lower temperatures.

During May to August, life begins to move towards normal in Ladakh. The Highways open up the last week of April or the first week of May. The weather

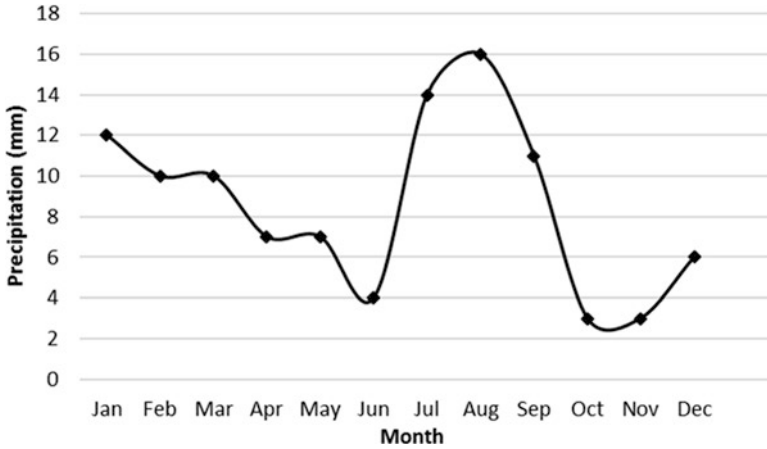


Fig. 19.3 Monthly variation of precipitation in Ladakh region

starts clearing during May. Temperatures are a pleasant 16 °C during the day and a barely manageable 3 °C in the night. Even during May, the breeze carries the winter chill. June is when the mercury really kicks up and temperatures soar up to 21 °C (day). The night temperatures are still low being about 7 °C. July is arguably the warmest month of the year. The day and night temperatures are 25 °C and 10 °C respectively. This is when Ladakh receives the odd rain, otherwise, the weather remains pleasant and inviting all through the month. The weather starts to get chilly once again in August. The breeze is a lot gustier and carries a lot of bite.

The weather is again cold during September to November. All through September, the weather is somewhat similar to that in May. The days are a lovely 20–22 °C. The nights are back to being bitterly cold. However, it's amid the periods of October and November that Ladakh backpedals to its miserable self. Since temperatures begin dipping under 0 °C on significantly more standard premise by and by, all interstate roads and passes are closed again for 5–6 months.

19.3.2 Precipitation

Precipitation is very low with annual precipitation of 10 cm mainly in the form of snow. Roughly one-third of the total annual precipitation is associated with westerly disturbances and occurs between December and February. Another third falls from July to August, so the summer monsoon is only of minor importance in Ladakh. Air is extremely dry and relative humidity ranges from 6–24%. Because of high elevation and low humidity the radiation level is very high. The value of global solar radiation is one of the highest in the world being 6–7 KW-hmm⁻¹. It is very usual to experience dust storms in the afternoon. The soil in the region is thin, sandy and

porous. The entire area completely deprived of any natural vegetation. The water for irrigation is chiefly obtained from the glacier-melted snow.

The region has inherent constraints like pro-longed winter, scanty rainfall, rugged terrain's and consequently limited availability of productive land and there exists possibility for expansion of economic activity through various scientific methods.

The average monthly variation of precipitation (2000–2016) in Ladakh region is shown in Fig. 19.3 The monthly analysis of rainfall shows that summer months of have shown an average precipitation of nearly 40 mm with August (16 mm) being the rainiest month followed by July and then June. The precipitation in the summer is usually in the form of rainfall.

During winter, January is the most precipitous month with average 11 mm precipitation followed by February, December and November. Precipitation during winter is mostly in the form of snow.

19.4 Climate Change and Future Trends

Climate change has turned out to be one of the essential worldwide issues of discussion on the globe today. Additionally, it is presently broadly perceived and acknowledged by established researchers that there are different types of environmental change in various parts of the world. A consensus has emerged that the mountain regions are more vulnerable to the adverse impacts from climate change due to its fragile environment. Ladakh is one such area which has witnessed changes in the trends of extreme weather and climatic events. Climate change in the region has also been indicated by recent research and historical data analysis. There has also been a significant change in the pattern of rainfall and snowfall in the region.

An overall significant warming trend over the last 100 years has been observed in Ladakh (Chevuturi et al. 2016). It has been observed that from 1901 to 1979 there was a warm period over Leh followed by lowering temperature during 1979–1991, after which from 1991 onwards, the temperature again increased rapidly. The precipitation records show that after a low precipitation period before 1970, there was a period of increasing precipitation trend from 1970 to 1995, but after 1995 onwards, there is again a decreasing trend in the precipitation.

In addition to this, the variation in temperature and precipitation trends in Leh indicate that is to some degree an inverse relationship between temperature and precipitation. A warm period was observed in Leh before the 1970s, which was accompanied by lower precipitation over the region. The temperature was low between the 1970s to mid-1990s, when the region received higher precipitation. During the last two decades, the precipitation has witnessed a decreasing trend while the temperature is on a rising trend. Moreover some sign of diminishing number of days having high precipitation has also been observed.

The winter precipitation has been on a slight rise during last century (1901–2000). The rise is of the order of nearly 0.04 mm per year which accounts to 0.40 mm per decade (Shafiq et al. 2016).

The precipitation in the summer is usually in the form of rainfall with linear trend and has shown an overall decline during past century (1901–2000) with recent decades showing some positive trend in summer season rainfall. A reduction of 0.127 mm per year in the summer precipitation has been observed over the time period 1901–2000 in Leh.

In the past 20 to 25 years there has been a trend towards greater precipitation, but the pattern remains highly irregular. For instance, in 2002, a large amount of snow was recorded but the rainfall recorded for the region was very low. However in 2006 out of the total precipitation recorded, 150 mm was rain and 232 mm was snow. This was much more than the average over 1995 to 2007 of being 32 mm rain and 215 mm of snow (Paul 2010).

The climate change projection models have indicated an increase in the maximum and minimum temperature of Ladakh region. Precipitation would increase but with an uneven distribution. Furthermore, the changes in maximum and minimum temperature during the next few decades would not be significant whereas precipitation variation would be quite significant.

19.5 Impact of Climate Change on Agriculture

Agriculture is one of most delicate areas to effects of climate change due its high reliance on atmosphere and climate. Over hundreds of years, agriculturists in Ladakh have developed self-supported cultivating frameworks not withstanding in the midst of a climatically difficult condition. In fact, it has been the pillar of economy and gives nourishment and occupation security to the general population of Ladakh.

However, recent environmental changes are harmful for the fabric of sustainability for the general population of Ladakh. The effect of environmental change in the course of the most recent couple of years has unfavorably influenced farming in this district in various ways. Snow and water from glaciers is the chief source of irrigation for nine-tenths of the farming community. Thus, glacial melt determines the productivity in the region to a large extent. Besides glaciers are the primary sources of water for the farmers in the region. Excessive glacial melt has now become a cause of floods in the region, putting the lives of more than 80% farmers to risk.

Continuous retreating of glaciers in the region will have an adverse effect on t agriculture. The economy and food security of the region will be threatened due to changes in agricultural produce. It is supposed that increase in temperature could modify agricultural produce. The change may be either positive or negative. The impact on agriculture and its outcomes on the general public are probably going to

differ locally contingent upon the kind of environmental change that has occurred here and the choices accessible to farmers. It could cut down the yield of wheat.

However, higher temperature may enhance the productivity of wheat in the high altitude areas. Warmer temperatures may influence many crops to develop all the more rapidly, however hotter temperatures could likewise diminish yields. Crops have a tendency to grow quickly in warmer conditions. Nonetheless, for a few crops, (for example, grains), speedier development decreases the measure of time that seeds need for growth and maturity. Throughout the years, agriculturists have brought new plants into their farmlands.

Crops tend to grow faster in warmer conditions. However, for some crops (such as grains), faster growth reduces the amount of time that seeds have to grow and mature. Over the years, farmers have introduced plants into their farmlands. Looking at the brighter side of the impact of climate change, it merits saying that farmers in Ladakh have profited from the current global warming as they can develop number of new vegetable products.

Climate change is likewise connected with an increase in the incidence of extreme climatic events, for example drought, cloudburst and floods. The nomads known as the Changpas living in the Changthang region intensely feel environmental change. These individuals are reliant on the raising of animals, the pashmina goats for their fleece. As of late, the migration paths of the Changpas have changed because of decline in pasture land. Further, indeterminate snowfall has led loss of numerous domesticated animals in the district. In future, environmental change in Ladakh is probably going to influence agriculture and increment the danger of water for irrigation. The villagers could confront serious water shortage which is credited to overwhelming runoff from rapid snow melt. Besides, an expansion in the occurrence of pest attacks and weeds could also make destruction in the district.

19.6 Leh Cloudburst 2010

A cloudburst occurred near Leh in Jammu and Kashmir on August 6, 2010 at around 0130–0200 hours IST (Indian Standard Time) as per the report given by India Meteorological Department (IMD 2010). The National Disaster Management (NDM) cell under the Ministry of Home Affairs (MHA) gave the report on the situation dated 6th August 2010. According to the report, this cloudburst hit the Leh region at around 0100–0200 hrs after torrential rains in the interceding night of 5 and 6 August, 2010. The report also notes that this cloudburst triggered flash floods in Choglumsar and Pathar Sahib Villages and the surrounding areas of Leh Township. As of 25th Aug 2010 the figure of human deaths reached 196 (including six foreigners) and the normalcy in basic civic amenities, like water supply, electricity, communication, health, transport, aviation and tourism was restored only by end of August.

According to the India Meteorological Department (IMD), “a cloudburst features very heavy rainfall over a localized area at a very high rate of the order of

100mm per hour featuring strong winds and lightning. It is a remarkably localized phenomenon affecting an area not exceeding 20–30 km². A cloudburst occurs during monsoon season over the regions dominated by orography like Himalayan region, northeastern states and the Western Ghats”.

The IMD report following the Leh cloudburst, in light of the satellite images presented that “a convective system developed in the easterly current associated with monsoon conditions over the region. The convective cloud band extending from southeast to northwest developed over Nepal and adjoining India in the afternoon of 5th August. It gradually intensified and moved west-northwestward towards Jammu & Kashmir. An intense convective cloud cluster developed to the east of Leh by 2130 hours IST of 5th August which resulted in a cloudburst event between 0130-0200 IST of 6th Aug 2010”.

Ladakh experienced a substantial and ill-timed rainfall, followed by the terrific flash floods resulted from cloudburst in August 2010. This resulted in flooding of agricultural fields along with mudslides consisting of rock and sand. This resulted in further deterioration of agricultural fields and reduction of area available for cultivation. Also numerous agricultural fields and roads were washed away due to consistently happening floods in the course of the most recent couple of years, prompting decrease in net farming area.

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