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Effect of Glaciers Melting on Agriculture and Horticulture Crops in Himachal Pradesh

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Introduction

Himachal Pradesh, "land snowy mountains", is located in the heart of the Himalayas in the northwestern part of India. It is a mountainous state with an elevation of approximately 350 meters (1,148 ft.) to 6000 meters (19,685 ft.) above mean sea level. The state comprises hilly topography, perennial rivers and extensive forest cover. The state provides great opportunities, given its ample water supplies, hydropower, mineral resources, horticulture, agriculture and tourism potential. However, it faces major challenges resulting from its elevation, topography and ecological vulnerability. The major population of this state lives in rural areas and is dependent on agriculture-horticulture and natural resources. Most agricultural and horticultural practices are of a subsistence nature and rely on prevailing climatic conditions for yield.

Himachal Pradesh acquires winter precipitation in the form of snow at the elevated altitudes. About one-third of the total geographical area of the state remains under thick snow cover during winters. The district Lahaul and Spiti receives scant rain because it lies in the rain shadow region. There is very little to no rainfall during the crop sowing season between April to May. Monsoon season in the cold desert largely remains dry with reduced rainfall in comparison to other regions in Himachal Pradesh. Snow melt water from the mountains and glaciers is the only major source of irrigation for farmers in the cold desert of Himachal Predesh[2].

The tendency of gradual depletion in snow cover in ecologically fragile Himachal Pradesh is proceeding to haunt the hill State. Also, the average mean of maximum and minimum temperature is on the rise in the Himalayan region. In the past few decades, Himachal Pradesh has been observing an erratic, inconsistent, and diminishing trend of

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snowfall, besides a shift in the pattern of snowfall and precipitation, triggered by climate change.

The diminishing snow cover is an expeditious concern in the mountain environment as it could have a catastrophic influence on hydropower, water sources, people, livestock, forests, farms, and infrastructure[4].

Various Case Studies on Climate Change Impact on Glaciers of Himachal Pradesh:

Given the significance of seasonal snow cover as a prime input in managing the hydrology of the river basins, seasonal snow cover assessment in terms of its spatial distribution was carried out in different river basins during the winter season of 2022-2023 from October to April. The study concluded by utilizing Advanced Wide Field Sensor (AWiFS) satellite under the title — 'Seasonal Snow Cover Variations in Himachal during 2022-23', and its relative analysis with reference to 2021-2022 revealed that during 2022-2023, there was early snowfall in the month of October and November, resulting in positive trends in some basins. However, throughout the peak winter months i.e. December to February, all four basins *viz.* Chenab, Beas, Ravi and Satluj had negative trends in contrast to the previous winter period. The total area under snow during October to April in 2022-23 slightly increased in the early half (October-November) in a few basins, whereas in the peak winter (December–February), there was an extreme depletion in the area under snow. The late snowfall, that expanded to April this year, resulted in an increase in the area under snow, but the snowfall during this spell may not be of much use as the rising temperature from April onwards may enhanced the melting rate thereby affected the discharge dependability of the major rivers that relied on the seasonal snow cover besides the glacier melt during the peak summer time, it said. The temperature trend analysis was also carried out from 2018-23, mean maximum and minimum average temperature showed an increasing trend in nearly all the river basins.

As per a study carried out jointly by Himachal Pradesh's State Centre on Climate Change (HIMCOSTE) and Geo-Sciences, Hydrology, Cryosphere Sciences and Applications Group (GHCAG) and Space Applications Centre (SAC-ISRO) it was revealed that in the 2022-23 winter period (October-April), there was an overall reduction of about 14.05 % in the total area under snow cover in Himachal Pradesh in comparison to 2021-22[4].

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Through another study, it has been indicating that around 5°Celsius rise in temperature is expected in the Himalayan region by 2050, which would have adverse impact on weather and agriculture. According to the estimate by 2030, temperature is expected to increase by one to 1.5°Celsius[7].

There are nearly 334 glaciers in the entire Satluj basin including the glaciers in Beas, Sainj, Spiti, Baspa and 457 glaciers in the Chenab basin in Himachal Himalaya. Out of 334 glaciers in the Satluj basin, 202 glaciers are situated in Himachal Pradesh[2]. The total area occupied by these glaciers in the Satluj and Chenab basins is approximately 2,175 square kilometres. In addition, there are about 1,826 permanent snow fields in these basins with a total area of 1,101,737 square kilometres. In respect of the flow of rivers in the Himachal Pradesh, the main contribution is from the snow and the glacier melt, which greatly affects the flow of the streams. In order to understand the impact of global warming on the hydrological balance, snow removal studies have been performed in the Himalayas. Initially, studies were conducted in the Beas and Baspa basins in Himachal Pradesh. The analysis of the given data therefore indicated that the effects of climate change are likely to become more severe by the next 2-3 decades, when the temperature may rise by 2-4^{0}C. There will be a strong shift in the pattern of monsoon precipitation, which could increase by 20-25%. The frequency of severe events will double. Resultantly there will be snow and glacier field loss, which will affect the flow in river system and reduce the flow in lower elevation to the maximum extent. Glacier fields can be declined by more than 50% due to temperature rise, increased melting rate, monsoon, extreme events can further rise the problems of sedimentation, significant erosion, destabilization of slopes and an increase in GLOF events etc. Glacial Lake Outburst Floods (GLOFs) are of immediate concern in the mountain environment as GLOFs can have a devastating impact on hydropower, water sources, people, livestock, forests, farms, and infrastructure. Declines in snow accumulation and glacial retreat might lead to acute water shortages in the future[4].

A government study was conducted by The Centre on Climate Change of the Himachal Pradesh Council for Science Technology and Environment (HIMCOSTE) and the Space Application Centre, Ahmedabad, to access spatial distribution of seasonal snow cover in Himachal Pradesh from October 2020 to May 2021 which revealed that, the snow cover of the Himalayas in Himachal Pradesh that feeds four major river systems is declining by 18.52% between 2019-2020 and 2020-2201, indicating climate change[6]. The study revealed that the

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area under snow cover in 2019-2020 was 23,542 sq km, which dropped to 19,183 sq km in 2020-'21, a decline of 3,404 sq km or 18.52%. Typically, in the winter season, about one-third of the geographical area of the state, which amounts to about 18,556 sq km, remains under thick snow cover. Most of the vital rivers like Baspa, Beas, Chenab, Parvati, Spiti, Sutlej, Ravi and their perennial tributaries originating from the Himalayas rely on the seasonal snow cover for their discharge dependability. Decreasing trend in four river basins of the state which put long-term implications on water availability in the river basins was observed. The report added that the snow cover in the Chenab basin cut down from 7,154 sq km in 2019-2020 to 6,516 sq km in 2020-2021, a reduction of 638 sq km or 8.92%. The Beas basin showed a decrease of about 19% with its decreased average snow cover area from 2,458 sq km to 2,002 sq km, in total having a loss of 455 sq km. The Ravi basin showed an overall reduction of 23% in the total area under snow cover. The snow cover in the Sutlej Basin, which covers 45% area of Himachal and is the longest river in the state, shrunk the most by 23.49% or 2,777 sq km. It was 11,823 sq km in 2019-2020 and 9,046 sq km this year[6]. Another study published in 2019 revealed that the Sutlej River basin glaciers are melting fast and may shrink remarkably by as soon as 2050. The research estimates that the melting would cause 33% of the glaciers to disappear by 2050 and 81% by the end of the century.

The changing climate and the rise in temperature has resulted in an average glacier loss of 20m per year in the Himachal Pradesh[7]. The Himalayan glaciers are receding like others in the world and are at the risk of melting because of increasing temperatures, erratic weather patterns and changing climate. Global warming has been a concern lately in numerous aspects because it has been in increasing trend since 1980s. Due to global warming, snowfall has reduced significantly and snow melt is very early due to which soil moisture has also reduced.

The Spiti basin is more vulnerable to climatic variations, as a higher rise in temperature has been observed in this basin than other parts of Himachal Pradesh. The overall glaciated area in this basin is 550.5 sq km with around 750 glaciers. The basin has perceived a mass loss of 8.89 Gt from 1985 to 2013. The future projection for a high emission scenario suggests 4.1^0C rise in temperature and 3.4% increase in winter precipitation by 2070 compared to 1985 to 2005 baseline period. Under this climate change scenario, the Spiti basin is likely to experience 84.8% loss in glacier stored water, 71.8% reduction in glaciated area from observed values of 2014. Around 76% of total glaciers may disappear by 2070 which will alter the village

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communities' water security status, thereby highlighting the urgency to develop an adaptation strategy for the region[3,9].

The glaciated area in Himachal Pradesh decreased at a rate of 67.84 km^2 per annum from 4020.6 km^2 in 1994–2198.5 km^2 in 2021. It was observed that from 1994 to 2021, the glacier area decreased approximately by a percentage loss of 1.678 per annum, with decreasing decadal trend from 2.31% in 1994–2001 to 1.398 in 2011–2021[8].

A study on evidences of glacier melting and expansion of glacial lake due to climate change on a moraina-dammed pro-glacial lake in Kadu Nala valley of Lahaul, Western Himalaya, Himachal Pradesh revealed that the lake has evolved in less than a few decades and continues to expand with a rapid pace since 2014. It was also observed from the analysed data that the development of this glacial-lake actually stared in 2010 and extended to nearly 0.18 km^2 during 2021[10] (Figure 1).

to * 0.18 km

2

in 2021

to * 0.18 km

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in 2021

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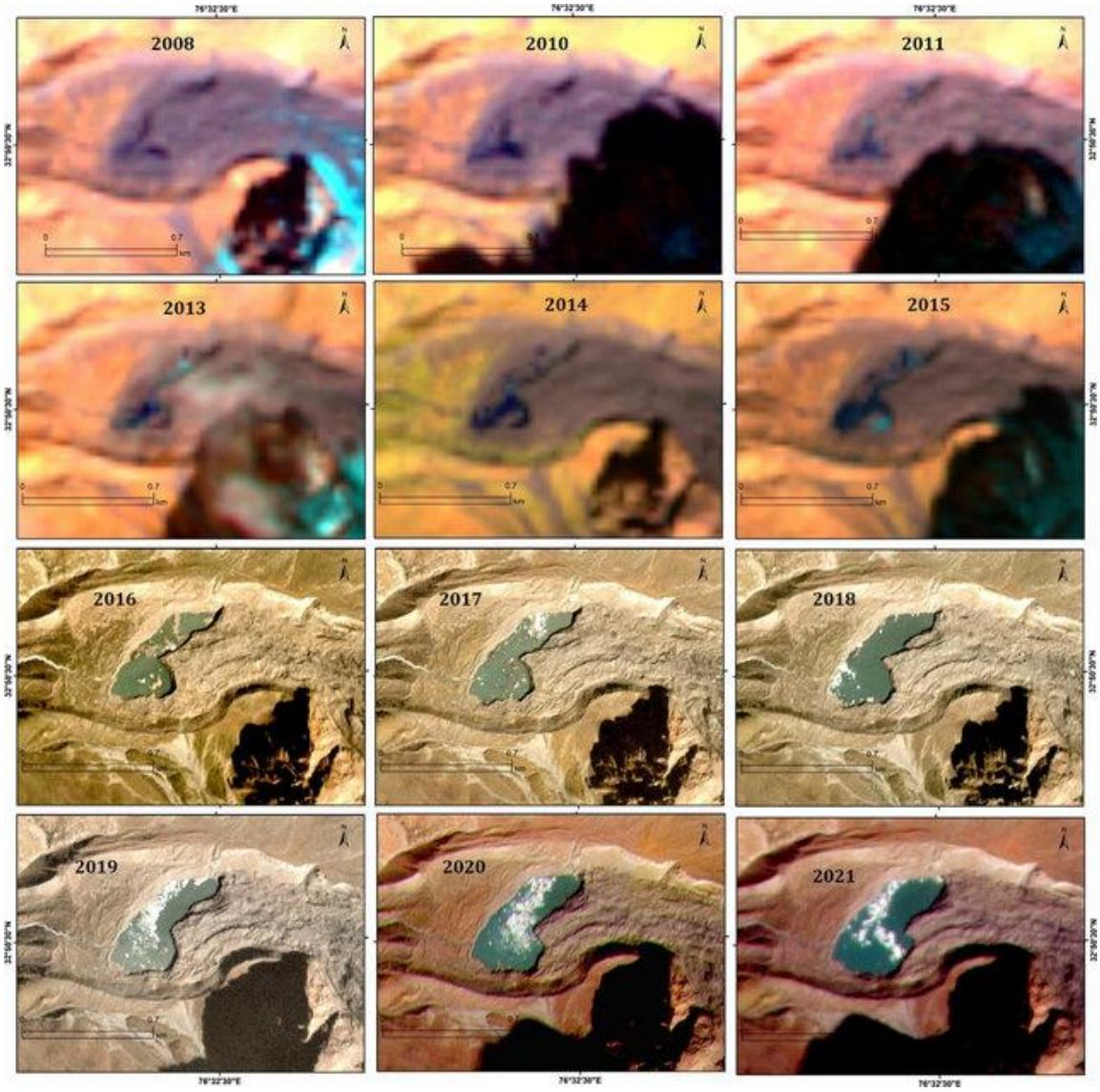

Figure 1. Evolution and expansion of Kadu Nala Lake of Lahaul valley from year 2008-2021.

Impact Of Declining Snow Cover Area and Climate Change on Agriculture and Horticulture Crops:

Climate change will affect suitability and adaptability of current cultivars by altering the growing period[1]. The broad impacts of climatic change are early melting of glaciers, warmer-extended winters precipitation and snowfall, erratic-reduced winter precipitation and snowfall, water scarcity, effect on chilling requirement, shift in apple cultivation towards

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higher altitude and cold arid areas, shift in ecological zone, incidence & resurgence of insect and diseases, and elevated requirements of irrigation etc.

The impact of climate change is much direct to the agriculture sector, especially through the change in cropping pattern due to rise in temperature and rainfall pattern in the state. The productivity of apple crop during 1985-2009 showed a recurrent pattern with an overall decreasing trend of 0.4 tonnes/ha. The total production per unit area susceptibility analysis with maximum temperature exhibited a negative rate of 3.89 every year. The farmers' perception disclosed detrimental effect on apple biodiversity due to change in the climatic conditions. The farmers also reported that the change in the snowfall pattern led to depletion and shifting of ecological niche of traditionally and commercially important apple varieties and an increase in low chilling cultivars. Apple growers particularly in lower Kullu valley diverted over to alternate crops such as pomegranates, peaches, persimmon and citrus fruits and some preferred shifting orchards to higher altitudes. Cumulative chill units showed a decrease of 9.52 in negative and 6.5 chill units every year in positive chill unit hours in Utah model in Kullu district due to increase in temperature[4].

One of the remarkable features of farming in Spiti is its snow-fed irrigation system known as Khul. Tapped from the head of a glacier, the Khul is a water channel that leads to a circular tank from which water is let out in a trickle. This unique irrigation system, nurtured the crops for hundreds of years, is now failing due to the retreat of glaciers induced by climate change. The glaciers are no longer playing their part as the main suppliers of water. They have retreated so much that in some places, they have completely disappeared and the Kuls receive very little or no water. In this valley, de-glaciation has been to the extent of 10-12% during 2001 and 2007. The unanticipated change in the weather is not only influencing the irrigation system, but is endangering the very survival of traditional livelihood crops grown in valley (barley, black peas, potatoes green peas, apples and seabuckthorn) and threatening the food security of the region. Reduction in yield and quality of crop produce and increased disease-pest incidence due to warming weather was also reported by farmers of the valley. The farmers shifted their apple orchards up the hill slopes as the snow line, once considered as "white manure" for the apple crop and forest cover necessary for conservation and recharge of natural bodies has shifted upward to higher hills, therefore, the quality apple production has shifted to higher hills and dry temperate zones of Kinnaur and Spiti areas[5].

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In vegetables, the different developmental phases like vegetative growth, flowering and fruiting are significantly influenced by the vagaries of climate. As the temperature and moisture stress increases, sun burn and cracking in tomato and capsicum affect the fruit quality and tomato fails to attain deep red colour, potato fails to form tubers and flower bud size of broccoli decreases, whereas, male flowers in cucumber and bud & flower abscission in bean increases, if temperature is high.

Stratergies For Mitigation and Adaptation:

To cope with the effect of melting of glaciers on agriculture and horticulture crops in Himachal Pardesh, the important mitigation and adaptation strategies are sowing dates adjustments, climate resilient genotype selection, to breed varieties that are more adaptive to climatic variations and improving agronomic practices such as altered crops and cropping systems to maintain soil fertility in suitable manner[11].

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