
IMPACT OF CLIMATE CHANGE IN HIMACHAL PRADESH

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ABSTRACT

Impact of climate change in Himachal Pradesh is much more pronounced because of the fragile ecology and sensitive Himalayas. So, Himalayan ranges of Himachal, serve as an indicator of climate change. The relationship between environmental changes and rainfall is complex, particularly in regions like Himachal Pradesh, which are highly susceptible to climatic and ecological shifts. Three major sectors viz., agriculture, horticulture and forestry are the backbone of the State because they are directly or indirectly linked with the economy of the people. Researchers and scientists are trying to search the factors and reasons which are responsible for the change in these sectors. Finding from different sectors revealed very significant and sharp change like shifting snowline, timberline, apple belt shifting and fluctuations in chilling units directly affects quality and quantity of apple etc. Such studies have encountered a number of findings which witnessed that climate change is happening in Himachal Pradesh. But if we talk about the observations of climate change impact on ecosystem and biodiversity, the Himalayan region (including Himachal Himalaya) is severely data deficient.

KEYWORDS: Himachal Pradesh, Environmental Changes, Rainfall Distribution, Ecology, Glacier, Biodiversity

INTRODUCTION

Himachal Pradesh is a relatively young state, having been granted full statehood in 1971. It is a relatively small state both, in terms of population and size. With a population of 6.6 million, it represents well under 1 per cent of India's total. About 90 per cent of the population resides in rural areas. Himachal Pradesh is largely mountainous with the exception of small pockets bordering Punjab and Haryana. The state comprises hilly terrain, perennial rivers, and

significant forest cover. The state offers many opportunities, given its abundant water resources, hydropower, mineral resources, horticulture, agriculture, and potential for tourism. It is however, facing significant challenges arising from its elevation, topography, and ecological vulnerability. Since the 1990s, Himachal Pradesh has grown faster than the national average and is ahead in terms of most indicators of human development. It is performing better than several more developed states on the plains in terms of social and economic progress.

CLIMATE AND ENVIRONMENTAL CONDITIONS OF HIMACHAL PRADESH

Himachal Pradesh, located in the northwestern part of India, has a diverse and complex climate system shaped by its topography, altitude, and geographical location in the Western Himalayas. The state's varied climatic zones, ranging from sub-tropical to alpine, support a rich array of flora, fauna, and agricultural practices. However, the state is also facing significant environmental challenges, including climate change, deforestation, soil erosion, and urbanization, which are impacting its climate patterns and overall ecological health.

Climate Zones of Himachal Pradesh

The climate of Himachal Pradesh is marked by significant variation due to the state's dramatic elevation differences, from the lower Shivalik hills to the towering peaks of the Himalayas. Broadly, the state can be classified into three main climatic zones: subtropical, temperate, and alpine.

1. Subtropical Climate: The lower elevations of Himachal Pradesh, including areas like Kangra, Una, and Solan, experience a subtropical climate. This region typically has hot summers with temperatures rising up to 40°C (104°F) and mild winters with temperatures dropping to around 5°C (41°F). The subtropical zone receives moderate rainfall, particularly during the monsoon season, between June and September. The rainfall in this region is crucial for supporting agriculture, particularly crops like rice, maize, and vegetables.

2. Temperate Climate: As the altitude increases, the climate shifts to a temperate zone, found in areas such as Kullu, Mandi, and Shimla. The summer temperatures in these areas are moderate, ranging from 15°C to 25°C (59°F to 77°F), while winters can be cold with temperatures often dipping below freezing, particularly at higher altitudes. This zone experiences heavy snowfall in winter and moderate rainfall during the monsoon season. The temperate climate is ideal for the cultivation of apples, pears, and other temperate fruits, as well as crops like wheat, barley, and vegetables.

3. Alpine Climate: At higher altitudes, such as in the regions of Spiti, Kinnaur, and the upper reaches of Kullu, the climate becomes alpine. In these areas, the winters are extremely cold with heavy snowfall, and summers are short and cool. The temperatures in these areas can drop to -5°C (23°F) during winter, and only a few months of the year are free from snow. Precipitation in the form of snowfall is frequent, and the summer months are relatively dry. Alpine regions support limited vegetation, with alpine meadows and forests of coniferous trees like pine, fir, and deodar.

Seasonal Variations

The seasonal variations in Himachal Pradesh are marked by distinct changes in temperature and precipitation. These seasonal cycles shape the livelihoods of the people and the ecological balance in the state:

- 1. Monsoon (June to September):** The monsoon season is a crucial period for rainfall in Himachal Pradesh, with the southwest monsoon bringing heavy rains to the state. The monsoon rains are vital for replenishing the water resources in the region, including rivers, lakes, and groundwater. However, the intensity and distribution of rainfall can vary greatly, with the lower elevations receiving more rain than the higher-altitude areas. In recent years, erratic rainfall patterns and extreme weather events like flash floods and landslides have become more frequent, often causing damage to infrastructure and agriculture.
- 2. Winter (November to February):** The winter months are characterized by cold temperatures and snowfall in the higher altitudes. The lower and mid-hills also experience cooler temperatures during this period, though snowfall is limited to the highest peaks. Snowfall is critical for replenishing glaciers and maintaining the flow of rivers throughout the year. The state's popular hill stations, like Shimla, Manali, and Dharamshala, attract tourists during the winter months due to the snow-covered landscapes.
- 3. Summer (March to June):** Summers in Himachal Pradesh are generally mild, particularly in the temperate and higher-altitude regions. The lower hills can experience hot weather, with temperatures reaching 35°C to 40°C (95°F to 104°F), making it a popular destination for those seeking respite from the heat of the plains. The summer months are also the growing season for crops in the temperate zone, where mild temperatures support the cultivation of fruits, vegetables, and grains.

Environmental Conditions and Challenges

While Himachal Pradesh boasts a rich natural environment, it is also facing several environmental challenges that are affecting its climate and ecosystems:

1. **Climate Change:** Himachal Pradesh is increasingly vulnerable to the impacts of climate change, with rising temperatures, unpredictable rainfall patterns, and shifting weather systems. The state has witnessed a significant rise in temperatures over the past few decades, leading to changes in precipitation patterns, with some areas experiencing reduced rainfall and others facing heavy rainfall events. The disruption in traditional weather patterns has implications for agriculture, water resources, and local communities who depend on stable climatic conditions for their livelihoods.
2. **Deforestation:** Deforestation is another major environmental issue in Himachal Pradesh, with large areas of forest being cleared for agriculture, development, and infrastructure projects. Forests play a critical role in regulating local climate, preventing soil erosion, and supporting biodiversity. The loss of forest cover contributes to increased soil erosion, reduced water retention, and the disruption of local weather patterns, further exacerbating the effects of climate change.
3. **Soil Erosion and Landslides:** The state's hilly terrain makes it highly susceptible to soil erosion and landslides, particularly during the monsoon season. Heavy rainfall can wash away topsoil, which is essential for agriculture, and lead to the formation of landslides that can damage infrastructure and displace communities. The combination of deforestation, agricultural expansion, and climate change has worsened these issues.
4. **Urbanization and Development:** Rapid urbanization and infrastructure development in the state have led to increased pressure on natural resources. The expansion of towns and cities has led to land-use changes, increased pollution, and greater demand for water resources, further straining the region's environmental sustainability. Unplanned development can disrupt natural ecosystems, reduce green cover, and exacerbate issues like air and water pollution.
5. **Water Scarcity:** Despite being home to many rivers and streams, Himachal Pradesh faces challenges related to water scarcity, especially in areas where rainfall has become erratic. Reduced rainfall, combined with over-extraction of water for irrigation and hydropower generation, is leading to the depletion of water resources in certain regions. This has implications for agriculture, drinking water supply, and hydropower generation.

RAINFALL PATTERNS IN HIMACHAL PRADESH

Himachal Pradesh experiences diverse rainfall patterns due to its complex topography, geographical location, and varying altitudes. Rainfall is a vital aspect of the state's climate, impacting agriculture, water resources, and ecosystems. Understanding the rainfall distribution and seasonal variations is crucial for assessing the environmental and economic conditions of the region.

Based on the climatology data from 1971 to 2020, Himachal Pradesh receives its annual rainfall in distinct seasonal patterns. Approximately 15% of the total rainfall occurs during the winter season (January-February), while the pre-monsoon season (March-May) contributes 19.3%. The southwest monsoon season (June-September) is the dominant rainy period, accounting for 59% of the state's annual rainfall. The post-monsoon season (October-December) adds another 6.7%. While the southwest monsoon is the primary source of rainfall, significant amounts of rainfall are also received during the trends.

Seasonal Rainfall Distribution

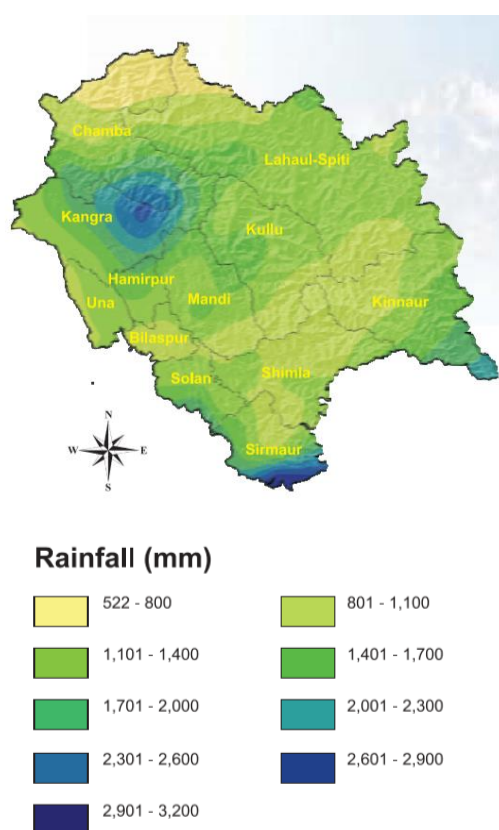
Himachal Pradesh's rainfall patterns are heavily influenced by the monsoon system, which dominates the region's weather cycle. The monsoon season, which typically lasts from June to September, brings the majority of the annual rainfall, although the intensity and distribution of rainfall can vary significantly across the state.

1. Monsoon Season (June to September): The southwest monsoon, originating from the Arabian Sea, is the primary source of rainfall for Himachal Pradesh. During the monsoon season, the state experiences heavy rainfall, particularly in the lower and mid-hill regions. These areas are exposed to the monsoon winds and receive substantial amounts of rain, which is vital for agricultural production, water supply, and the replenishment of the region's river systems.

- **Lower and Mid-Hills:** Areas like Kangra, Solan, and Mandi receive moderate to heavy rainfall, with annual precipitation ranging
- **Higher Altitudes:** In the higher reaches of the state, such as Kullu, Manali, and Shimla, rainfall is lighter but still significant. These areas often experience cooler temperatures and heavier snowfall, particularly towards the end of the monsoon season and into the winter months.

IMPACT OF CLIMATE CHANGE ON RAINFALL IN HIMACHAL PRADESH

Climate change is having a profound impact on global weather patterns, and Himachal Pradesh is no exception. The state, with its diverse topography and dependence on rainfall for agriculture, water resources, and ecosystems, is experiencing significant shifts in its climatic conditions. Changes in temperature, precipitation patterns, and the frequency of extreme weather events are altering the distribution, intensity, and predictability of rainfall, with both immediate and longterm consequences for the region.



Altered Rainfall Patterns

One of the most visible impacts of climate change on Himachal Pradesh is the alteration in the region's traditional rainfall patterns. As global temperatures rise, the monsoon dynamics are being disrupted, leading to unpredictable and shifting rainfall patterns.

1. **Delayed and Uneven Monsoon** Traditionally, the southwest monsoon arrives in Himachal Pradesh by early June and continues until September. However, studies show that monsoon rains are becoming more erratic. The onset of the monsoon is becoming increasingly delayed, and rainfall distribution during the monsoon months is more uneven. Some areas experience heavy downpours in a short period, leading to intense rainfall events, while others see

drought-like conditions. This irregularity has significant implications for agriculture, especially for crops that are dependent on consistent monsoonal rainfall.

2. **Increased Intensity of Rainfall** Climate change is linked to the intensification of rainfall events. Himachal Pradesh has witnessed an increase in the frequency of heavy rainfall episodes, particularly during the monsoon. This has resulted in flash floods, landslides, and soil erosion, particularly in hilly areas where the terrain is steep and fragile. Areas that previously received moderate rainfall are now facing rainfall events that exceed the local infrastructure's ability to manage runoff, leading to flooding, crop damage, and loss of life.

3. **Reduction in Overall Rainfall in Some Areas** While some parts of Himachal Pradesh are experiencing more intense rainfall, other areas, particularly in the rain-shadow regions like Spiti, Lahaul, and parts of Kinnaur, are seeing a decrease in overall rainfall. These regions, which were already semi-arid, are becoming drier due to a combination of reduced precipitation and changing atmospheric circulation patterns. The reduced rainfall in these areas exacerbates water scarcity, hampers agricultural activities, and threatens local ecosystems that depend on water from melting snow and seasonal rains.

4. **Shifts in Snowfall Patterns** Snowfall, which plays a crucial role in replenishing rivers and maintaining water supply in Himachal Pradesh, is being increasingly affected by climate change. The region's snow-covered peaks, such as those in Kullu, Manali, and Spiti, are experiencing reduced snowfall in some areas and earlier-than-usual melting. Warmer temperatures during the winter months lead to less snow accumulation, while the snow that does fall melts more rapidly. This disruption in snowfall patterns affects the region's water supply, as snowmelt traditionally feeds rivers throughout the year, ensuring a consistent water flow during the warmer months.

5. **Changes in Rain-to-Snow Ratio** In higher altitude regions, climate change is resulting in a shift in the ratio of rain to snow. Warmer temperatures are causing precipitation that would have once fallen as snow to now fall as rain, particularly in the pre-monsoon and post-monsoon months. This change is a cause for concern because rain runoff, unlike snowmelt, is more prone to immediate evaporation or quick runoff, which may lead to water shortages during the summer months when demand is highest.

Impact on Water Resources

Water resources in Himachal Pradesh are primarily reliant on two sources: rainfall and snowmelt. Climate change poses a direct threat to these resources, with consequences for agriculture, hydropower generation, and the daily water supply for residents.

1. **Decreased Snowpack** The decrease in snowfall and the earlier melting of snow result in a smaller snowpack in Himachal Pradesh's high-altitude regions. As the snowpack shrinks, there is less water available during the summer months, which can lead to drought conditions, especially in regions that rely on snowmelt to maintain river flow. The decreased snowmelt also affects the hydropower industry, as many of the state's power plants are fed by rivers originating from glacial meltwater.
2. **Impact on Irrigation and Agriculture** Agriculture in Himachal Pradesh is highly dependent on the timing and volume of rainfall. With climate change disrupting traditional rainfall patterns, farmers in both high-altitude and low-altitude areas are facing challenges. In regions that experience delayed rainfall or reduced monsoonal rains, crop yields may decline, especially for waterintensive crops like rice and maize. Conversely, areas that experience heavy rainfall may face flooding, which can damage crops and farmland, particularly in areas with poor drainage systems. The unpredictable water availability also complicates planning for agricultural seasons, making farmers more vulnerable to climate variability.
3. **Increased Risk of Flooding and Landslides** The increased intensity of rainfall during the monsoon, combined with deforestation and land use changes, has heightened the risk of flooding and landslides in Himachal Pradesh. The steep slopes, which are prone to erosion, become even more vulnerable to rapid runoff from heavy rainfall. The resulting floods can destroy infrastructure, wash away crops, and displace communities, particularly in the lower and mid-hill regions. Flash floods and landslides are now more frequent, causing widespread damage during intense monsoon rains.
4. **Impact on River Ecosystems** The region's river ecosystems, which rely on a mix of rainfall and snowmelt, are experiencing disruptions in their seasonal flow patterns. Reduced snowmelt, combined with unpredictable rainfall, leads to lower water levels during critical periods of the year, which can affect aquatic life. In the long term, these changes in river flow could impact biodiversity, fish populations, and the overall health of aquatic ecosystems that are vital for both the local population and wildlife.

Adaptation and Mitigation Measures

Given the impacts of climate change on rainfall and water resources, it is essential for Himachal Pradesh to adopt both adaptation and mitigation measures to address these challenges. Some strategies include:

- **Water Conservation and Management:** Implementing efficient irrigation systems and rainwater harvesting techniques can help optimize water usage for agriculture.

Additionally, protecting and restoring watersheds can improve water retention in the region.

- **Reforestation and Erosion Control:** Planting trees and controlling soil erosion can help reduce the impacts of heavy rainfall and prevent landslides. The restoration of vegetation cover can also help in maintaining the natural water cycle.
- **Climate-Resilient Agriculture:** Encouraging farmers to adopt climate-resilient agricultural practices, such as drought-resistant crops, improved water management techniques, and crop diversification, can help mitigate the adverse effects of changing rainfall patterns.
- **Early Warning Systems:** Developing early warning systems for extreme weather events like floods and landslides can help mitigate the loss of life and property, especially during heavy rainfall events.

ENVIRONMENTAL FACTORS AFFECTING RAINFALL DISTRIBUTION IN HIMACHAL PRADESH

Rainfall distribution in Himachal Pradesh is influenced by several environmental factors, including geographic features, atmospheric conditions, and global climatic patterns. These factors interact in complex ways to determine the amount, timing, and intensity of rainfall across the region. Understanding these influences is critical for comprehending how climate change and local environmental conditions affect rainfall patterns, which in turn impacts agriculture, water resources, and ecosystems in the state.

Topography and Altitude

Himachal Pradesh's diverse topography, characterized by its mountainous terrain, plays a crucial role in shaping rainfall distribution. The state consists of the lower hills, mid-hills, and higher altitudes, each of which experiences different weather patterns due to their altitude and proximity to moisture-laden winds.

- **Orographic Rainfall:** The steep mountains of Himachal Pradesh create orographic rainfall, a type of precipitation that occurs when moist air from the plains is lifted over the mountains. As the air rises, it cools and condenses, leading to rainfall on the windward slopes of the mountains. These regions, especially in the western and central parts of the state, receive significant rainfall during the monsoon. The windward slopes of the Dhauladhar, Pir Panjal, and other ranges experience heavy rainfall, while the leeward side (rain-shadow areas) receives less precipitation.

- **Rain-shadow Effect:** The areas situated on the leeward side of mountain ranges, such as parts of Lahaul, Spiti, and Kinnaur, experience significantly lower rainfall due to the rain-shadow effect. As the moist air rises over the mountains, it loses much of its moisture, resulting in drier conditions on the opposite side. These areas, particularly in the rain-shadow zone, often face semi-arid conditions and depend heavily on winter snowfall to replenish water resources.
- **Altitude and Temperature:** Higher altitudes in Himachal Pradesh, particularly in regions above 2,500 meters, generally experience colder temperatures. The colder climate results in more snowfall than rainfall. However, in lower altitudes, rainfall is more common, especially during the monsoon. Temperature also affects the rate of evaporation, which can influence the amount of rainfall that reaches the ground.

Global Climatic Phenomena

Global climate patterns, including El Niño and La Niña, also affect the rainfall distribution in Himachal Pradesh.

- **El Niño:** The El Niño phenomenon, characterized by the warming of sea surface temperatures in the Pacific Ocean, can lead to delayed or reduced rainfall during the monsoon season in Himachal Pradesh. El Niño years are often associated with a weaker monsoon, leading to drought-like conditions in parts of the state.
- **La Niña:** In contrast, La Niña, which involves cooler-than-normal sea surface temperatures in the Pacific, can lead to an enhanced monsoon, bringing above-average rainfall to the region. However, while this may increase rainfall, it can also contribute to flooding in certain areas.

Factor Responsible for climate change

In recent decades, urbanization and industrialization in some parts of Himachal Pradesh have contributed to local climate modifications.

- **Urban Heat Islands:** The development of towns and cities, particularly in the lower and mid-hill regions, leads to the formation of urban heat islands. These areas are warmer than their rural surroundings due to human activities like construction, transportation, and energy consumption. Urban heat islands can influence local atmospheric circulation patterns, which may, in turn, affect local rainfall distribution.
- **Water Management Practices:** Human interventions in water management, such as damming rivers, diverting water for irrigation, and constructing reservoirs, also affect the

natural water cycle and rainfall distribution, particularly in regions with high human intervention.

Surface Water Resources The state is drained by nine river systems.

Road-map towards achieving long term sustainable water resources management and adaptation to climate change. –

- 1) Integrated Water Resources Management (IWRM)
- 2) Environmentally Sustainable Development
- 3) Effective institutions to support integrated water resources planning and management:
- 4) Catchment and Agricultural Planning
- 5) Water Resources Data and Information Systems

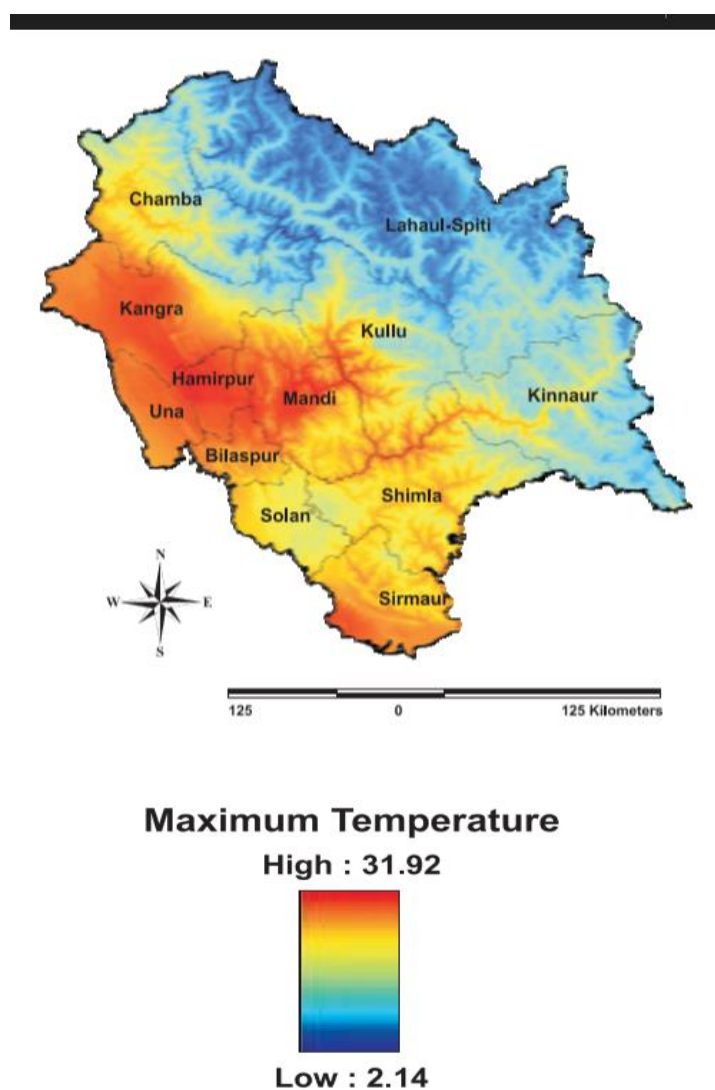


Figure 3 Maximum Temperatures

Impact of Climate Change on Himachal Pradesh

1. Rising Temperatures & Heatwaves

Himachal has warmed by 1.5°C since 1901*, with temperatures projected to rise $2\text{--}3^{\circ}\text{C}$ by 2050*. Hill stations like Shimla hit 30.5°C * and Una reached 44.3°C * in May 2026. The CM noted “temperatures are continuously rising” and heat events are increasing.

2. Glacial Retreat & Water Stress

Glaciers are retreating >50 metres per year*. Chhota Shigri Glacier lost mass at -0.46m w.e. per year since 2002*. Snow cover in 2026 was 27.8% below normal* - lowest in 20 years. Two-thirds of traditional springs have dried up, forcing some villages to depopulate.

3. Extreme Rainfall & Disasters

Days with $>100\text{mm}$ rainfall* are increasing. June-Sept 2025 saw 46% excess rainfall*, causing 366 deaths and ₹4,000+ crore damage. Over 4 years, climate disasters killed $1,700$ people* with losses of ₹46,000 crore*. Cloudbursts, flash floods, and landslides are now frequent.

4. Agriculture & Horticulture Loss

Stone fruit production dropped $60\text{--}75\%$ in 2026* due to extreme heat, hailstorms, and unseasonal rain. Apple cultivation is hit by less snow and fewer chilling hours, increasing pest attacks. Crop losses hit ₹11 crore* this year from dry spells.

5. Forest Fires & Biodiversity

Forest fires jumped from 856 in 2022-23 to 2,580 in 2024-25*. Land surface temperature now influences fires more than rainfall. Over 50% of Kangra’s forests are fire-vulnerable*.

6. Economic & Social Cost

CM Sukhvinder Singh Sukhu said HP suffered ₹15,000–20,000 crore losses in 3 years*. The Supreme Court noted climate change has a “visible and alarming impact” and the state might “vanish in thin air” if trends continue.

Statistical Data: Climate Change – Global & Himachal Pradesh

Global Status

Global Temp Rise	$+1.48^{\circ}\text{C}$	Wmo
Co2 concentration	424.9ppm in may 2026	NOAA
Sea Level Rise	4.5mm/every year	NASA
Glacier Loss	273 billion tones of ice	IPCC
Extreme Weather	Global issues disasters	Swiss Report



Indian Status

- 1) Temperature:- India warmed +0.7°C
- 2) Rainfall – extreme rainfall +76%
- 3) Economic loss – Due to climatic Disasters
- 4) Future Risk – Still Continute

Himachal Pradesh Status

- 1) Temperature- +1.5°C since 1901
- 2) Glacier Retreat - >50 meters/per yr
- 3) Snow cover – 27.8% low
- 4) Disaster loss- Very high
- 5) Forest fire , Cloud Burst = Very high
- 6) Agriculture = totally affected

What YOU Can Do - Individual Level Research*

1. ***Energy***: 1 unit saved = 0.82 kg CO₂. LED + 5-star AC cuts 1.5tonnes/year per home
2. ***Transport***: Public transport/bike 2 days/week = 0.6tonnes CO₂/year saved
3. ***Food***: Less meat 1 day/week = 0.8tonnes CO₂/year. Millet vs rice saves 3x water
4. ***Trees***: 1 tree = 22 kg CO₂/year. Plant 5 = offset 1 AC's emissions

1. **Energy**= Target: 100% green energy state by 2030. 10,000 MW hydro + 1,500 MW solar planned Hydro = 90% of HP power. Can

2. **Transport**= 3,000+ e-buses, 6 green corridors on NH. EV policy 2023 Transport = 14% of HP emissions. EVs cut 40% per vehicle

3. **Forest**= Mission-32 Percent: Forest cover 28% → 32% by 2030 1 hectare forest = 6.5tonnes CO₂/year sequestration.

4. **Waste**= Waste-to-energy plants in Shimla, Mandi Methane from landfills = 25x stronger than CO₂

7. CONCLUSION

Various studies (related to climate change) are witnessing that climate is changing in Himachal Pradesh. The studies which have been opted in Himachal Pradesh to analyze the impact of climate change in different sectors (agriculture, horticulture and forestry) are confined to particular area of the State. Therefore, there is significant need to cover those areas of the State which are also experiencing serious climate threat, with the goal that we can produce and tweak the solidified image of climate change in Himachal Pradesh. Another problem facing in assessing the impact of climate change in Himachal Pradesh is data gaps (lost sites, problem in monitoring and maintaining etc.). However, with available data and aberrations encounters, this is difficult to predict the status of climate change as it needs at least 30-40 years of continuous data to predict the status of climate change. The impact of

climate change on rainfall distribution in Himachal Pradesh presents significant challenges for the region's agriculture, water resources, and overall ecosystem...At the same time, adaptation strategies, including improved water resource management, crop diversification, disaster preparedness, and ecosystem-based approaches, enable the region to cope with the immediate impacts of changing rainfall and climatic conditions.

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