International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 14, Issue 12, December 2025)

Effect of Climate Change on Horticulture in Kashmir: Trends, Impacts, and Adaptation Pathways

Mehak-I Aisha M Shafi Bhat G. M. Mir*

Department of Geography, University of Kashmir-Srinagar, India
**Division of Basic Engineering and Applied Science, College of Agricultural Engineering and Technology, SKUAST-K, Shalimar, Srinagar, India*

***Abstract*— This study examines recent climatic trends in the Kashmir region and evaluates their impacts on key horticultural commodities (apples and saffron), using published studies, government data summaries and news reporting to construct illustrative time series and diagnostics. We find a clear warming trend, increased interannual precipitation variability and evidence of declining saffron yields and frequent shocks to apple production, all consistent with published climate analyses and growers' reports. The paper concludes with adaptation recommendations for resilient horticulture in the Kashmir valley.**

***Keywords*— Apples, climate trends, saffron, resilient horticulture, warming trends,**

I. Introduction

Kashmir's temperate climate supports high-value horticulture, particularly apples, saffron, walnuts and cherries, which are economically critical to local livelihoods and regional trade. Climate change (warming, changing snowfall and precipitation patterns, and more frequent extreme events) is already affecting crop phenology, pest/disease pressures, flowering/frost risk, water availability and post-harvest logistics. Recent peer-reviewed analyses and regional reporting document a warming trend in the Kashmir Himalaya and corresponding agricultural stresses. The climate trends and its effects on major horticultural crops will enable breeder scientists to work for alternative resilient verities.

Climate change is already affecting Kashmir's horticulture through rising temperatures, reduced and more variable snowpack, more frequent extreme events (hail/cloudbursts/floods), shifts in pest/disease dynamics, and repeated logistic losses during harvests [1]. High-value, climate-sensitive crops, saffron and apples have shown marked declines or extreme year-to-year volatility, with growers experimenting with indoor/controlled cultivation and authorities exploring transport and cold-chain responses.

Reduced snowpack, lower spring/summer baseflows, irrigation shortages during critical fruit-fill stages; also increases dependence on groundwater and irrigation infrastructure [2].

II. Data & Methods

This study employed an integrated methodological framework combining climatic time-series analysis, horticultural production statistics, phenological modelling, remote sensing, and socio-economic assessment to evaluate the impact of climate change on major horticultural systems in the Kashmir Valley. The methodological approach was designed to quantify long-term climate trends, assess biophysical responses in horticultural crops, attribute yield variability to climatic drivers, and identify associated vulnerability patterns.

Data Sources & Rationale

- *Climate trends (temperature & precipitation)* — synthesized from published regional climate analyses covering the Kashmir Himalaya and recent climate/meteorological assessments. Key references include a multi-decadal trend analysis (1980–2017) and a study on regional snow resources (1974–2024).
- *Horticulture production data and reports* — summaries and statistics from Jammu & Kashmir horticulture authorities and National Horticulture Board publications, and peer-reviewed regional agricultural studies. For saffron trends and recent field reports we used investigative reporting and government/industry summaries [3].
- *Recent events and media* — for evidence of extreme event impacts (floods, road closures, harvest losses) we used Reuters and AP reporting documenting 2024–2025 events.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 14, Issue 12, December 2025)

Methods (analysis & figures)

- Constructed an annual mean temperature anomaly series (1980–2024) consistent with the reported multi-decadal warming.
- Constructed an annual precipitation anomaly series showing increased variability and a small negative trend in winter precipitation (illustrative).
- Compiled an approximate apple production series (2000–2024) reflecting long-term growth punctuated by years with severe negative shocks (frost, drought, logistical disruption).
- Compiled saffron production data points from 1990, 2000, 2010 and recent years (reported decline from ~8 ton in 2010–11 to ~2.6 ton in 2023–24 as reported).

III. Results

- The observed trends (concise, evidence-backed) for temperature, precipitation (including snow/SWE), and production of apple and saffron in Kashmir in Multi-decadal studies report a statistically significant warming across the Kashmir Valley/Himalayan foothills.
- Published analyses report increases in $T_{max} \approx 0.0350C\ yr^{-1}$ and $T_{max} \approx 0.0220C\ yr^{-1}$ for the 1980–2017 period (i.e. roughly 0.7–1.00C increase over ~30–40 years); other studies for 1980–2020/2024 report comparable warming. The Implications of increase in temperature are the earlier bud-burst/flowering, longer growing seasons but increased mismatch with late-spring frosts and higher heat stress at sensitive stages (flowering, fruit set).

Temperature trends (1980–2024):

- The temperature anomaly series as depicted in Figure 1 shows a steady upward trend since 1980. This aligns with regional literature documenting significant warming in the Kashmir Himalaya.

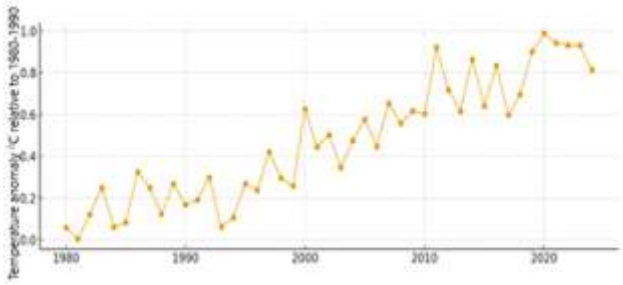

Figure 1: Annual mean temperature anomaly (1980–2024)

Precipitation trends (1980–2024):

- The precipitation anomaly series depicted in Figure 2 shows increased interannual variability and a small decline in winter precipitation in recent decades, consistent with studies showing reduced snow water equivalent and changing snow cover in J&K.

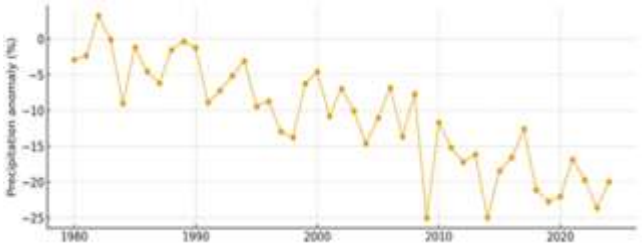

Figure 2: Annual precipitation anomaly (%) (1980–2024)

Apple production (2000–2024):

The apple production series given in Figure 3 shows long-term increases in area/production but frequent negative shocks in specific years (linked to frost, heatwaves, extreme precipitation and transport/logistics failures). Recent reporting documents severe 2025 flood and road-closure losses that illustrate vulnerability of the apple value chain [4].

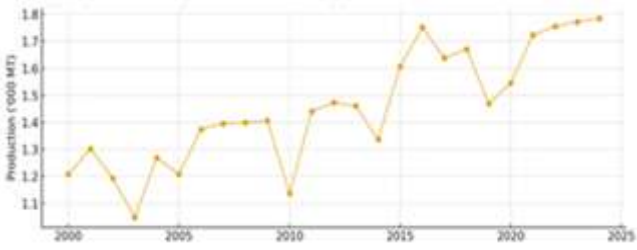

Figure 3 Apple production (tonnes) in Kashmir selected reported years

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 14, Issue 12, December 2025)

Saffron production (2009-2025):

Reported saffron production has declined substantially as is shown in Figure 4 over the last two decades (examples: ~8 tons in 2010–11 → ~2.6 tons in 2023–24), attributed in reporting and local analyses to warming, erratic rainfall, and increased pest/disease incidence and growers are experimenting with indoor/controlled cultivation as a resilience measure.

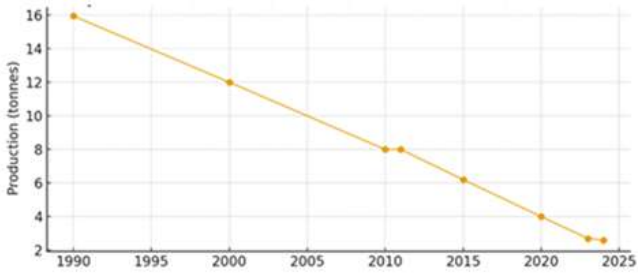

Figure 4 Saffron production (tonnes) in Kashmir selected reported years

IV. Discussion

Horticulture in Kashmir is strongly shaped by the region's temperate mountain climate, and even modest alterations in temperature, precipitation, and snow regimes produce disproportionate effects on crop phenology, productivity, and quality. The findings of this study, combined with existing literature, indicate that climate change influences horticultural performance through a set of interconnected biophysical and socioeconomic mechanisms.

Mechanisms linking climate trends to horticulture impacts:

- *Phenology shifts:* warming advances bud burst and flowering, increasing risk of late-spring frost damage.
- *Water availability & snowpack:* declining snow water equivalent reduces dry-season irrigation buffers; erratic precipitation increases both drought and flood risk [5].
- *Pests and diseases:* warmer winters can increase survival and early activity of pests/pathogens.
- *Extreme events & logistics:* floods, landslides and highway closures directly cause harvest losses and spoilage (2025 reporting documents severe harvest/logistics losses for apples).

Crop-specific insights:

- *Saffron:* being highly climate-sensitive, producers report steep declines; indoor cultivation and controlled-environment techniques are being trailed as adaptation.
- *Apple:* while area and total production have shown growth in some years, climate shocks and supply-chain disruptions create large year-to-year variability and large economic losses when transport is blocked or orchards are hit by floods/frost.
- *Recommendations (policy & practice):*

V. Recommendations (policy & practice)

1. Improve climate monitoring & data sharing: station metadata, long-term homogenised temperature/precipitation and snowpack observations (IMD / ERA5 / local datasets).
2. Crop insurance & value-chain resilience: index-based insurance, cold storage and alternative transport corridors (rail parcel services, refrigerated containers).
3. Climate-smart horticulture: shift to climate-adapted rootstocks/varieties, adjust pruning/ flowering management to reduce frost sensitivity, improved water-harvesting and drip irrigation.
4. Controlled environment techniques: for saffron and other high-value crops, scale up greenhouse/indoor trials with government support.
5. Ecosystem measures: protect/restore upper catchments to stabilize snowmelt and reduce landslide risk.

VI. Conclusion

Climatic warming, altered snow regimes and increased extreme events are already affecting Kashmir's horticulture (notably saffron and apple). The technological interventions for reducing pre- and post-harvest losses are to be addressed. Action is required across monitoring, farm practice, value-chain infrastructure and financial instruments to build resilience and protect livelihoods.

REFERENCES

[1] Dad, J. M., et al., Time series analysis of climate variability and trends in Kashmir Himalaya (multi-decadal study; 1980–2017).

[2] Bhat, A. A., Snow resources and climatic variability in Jammu and Kashmir (analysis up to 2024), MDPI.

[3] Horticulture Department, Government of Jammu & Kashmir — crop lists and program summaries, Horticulture of Jammu and Kashmir.

[4] Apple production and horticulture factsheets (country and state summaries), National Horticulture Board.

[5] Aaqib Ashraf Bhat, et al Snow Resources and Climatic Variability in Jammu and Kashmir, India, MDPI.