



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; SP-9(8): 396-399
Received: 25-05-2026
Accepted: 29-06-2026

Dr. Kunal narwal
School of Agriculture, Sanskaram
University, Jhajjar, Haryana,
India

Dr. Dharmender
School of Agriculture, Sanskaram
University, Jhajjar, Haryana,
India

Dr Akanksha Sharma
School of Agriculture, Sanskaram
University, Jhajjar, Haryana,
India

Dr. Akanksha
School of Agriculture, Sanskaram
University, Jhajjar, Haryana,
India

Vicky Yadav
School of Agriculture, Sanskaram
University, Jhajjar, Haryana,
India

Usman Shuaibu Majikumna
School of Agriculture, Sanskaram
University, Jhajjar, Haryana,
India

Iliya Hassan Abubakar
School of Agriculture, Sanskaram
University, Jhajjar, Haryana,
India

Adamu Inusa Daya
School of Agriculture, Sanskaram
University, Jhajjar, Haryana,
India

Corresponding Author:
Dr. Dharmender
School of Agriculture, Sanskaram
University, Jhajjar, Haryana,
India

Climate change effects on rice–wheat cropping systems in Haryana: A review

**Kunal Narwal, Dharmender, Akanksha Sharma, Akanksha, Vicky Yadav,
Usman Shuaibu Majikumna, Iliya Hassan Abubakar and Adamu Inusa
Daya**

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i8Se.6419>

Abstract

The rice-wheat cropping system underpins food security and farm income across Haryana, one of the most intensively cultivated states in India's north-western Indo-Gangetic Plains. This review synthesises recent literature on how a warming, increasingly erratic climate is affecting this system, and on the agronomic responses being tested and adopted in the region. Observed trends include faster warming of minimum than maximum temperatures, more erratic monsoon onset and distribution, episodes of untimely and excessive late-season rainfall during the wheat season, and rapid groundwater depletion across the wider Punjab-Haryana-Rajasthan belt. These pressures interact with the twin-crop calendar: heat and moisture stress at rice transplanting and grain filling, terminal heat and lodging risk during wheat grain filling, and a compressed inter-crop turnaround window that has historically encouraged residue burning. The review then examines the evidence base for major adaptation and mitigation responses being scaled in the region, including direct-seeded rice, zero-tillage wheat, conservation agriculture, laser land levelling, adjusted sowing dates, climate-resilient cultivars, and crop diversification. Evidence suggests these practices can improve water-use efficiency, soil carbon retention, and resilience to specific climate extremes, but adoption remains constrained by procurement policy, subsidised groundwater pumping incentives, and uneven access to machinery and extension support. The review concludes that climate resilience in Haryana's rice-wheat system will depend on packaging agronomic, water, and policy interventions together rather than promoting individual technologies in isolation.

Keywords: Climate change, rice-wheat cropping system, Haryana, Indo-Gangetic Plains, groundwater depletion, conservation agriculture, direct-seeded rice, climate-smart agriculture

1. Introduction

Haryana, together with neighbouring Punjab, forms the core of India's post-Green Revolution rice-wheat belt. After the mid-1960s, the area under rice and wheat expanded substantially in this semi-arid to sub-humid region, supported by assured irrigation, subsidised power, and minimum support price procurement, turning the state into a major contributor to India's central food grain reserves. The rice-wheat cropping system (RWCS) here is agronomically intensive: a single field typically carries irrigated, puddled-transplanted rice in the kharif (monsoon) season followed immediately by irrigated wheat in the rabi (winter) season, with only a narrow turnaround window between the two crops.

This intensity has made the system productive but also climate-exposed. Rising atmospheric CO₂ concentrations can benefit the C3 photosynthetic pathway used by wheat, but associated warming shortens crop duration, raises respiration and evapotranspiration, and can reduce fertiliser-use efficiency, effects that are especially consequential in a region already facing scarce and depleting water resources. Haryana's climate is semi-arid subtropical, with historical annual rainfall ranging widely from roughly 350 to 1400 mm across years and about three-quarters of it concentrated in the June-September monsoon window, leaving the winter wheat crop dependent on stored soil moisture, canal water, and groundwater.

This review synthesises recent evidence on (i) observed and projected climate trends relevant to the state, (ii) the specific climate sensitivities of rice and wheat at different growth stages within

the regional cropping calendar, (iii) the resulting productivity, water, and emissions pressures on the system, and (iv) the adaptation and mitigation technologies being tested or scaled to address them.

2. Materials and Methods

This is a narrative review rather than a formal systematic review with meta-analytic pooling, given the heterogeneity of study designs, timeframes, and outcome metrics in the underlying literature. Sources were identified through structured searches of peer-reviewed journals, institutional and government climate and agriculture reports, and long-term field-trial publications associated with research stations in Haryana and the wider north-western Indo-Gangetic Plains, including Central Soil Salinity Research Institute (Karnal), CCS Haryana Agricultural University (Hisar), and multi-country CGIAR-linked

programmes such as the former Rice-Wheat Consortium and the Cereal Systems Initiative for South Asia. Priority was given to state- and district-level studies from Haryana and Punjab, supplemented by regional Indo-Gangetic Plains and South Asian modelling studies where state-specific data were unavailable. Sources were screened for relevance to climate trends, crop-climate sensitivity, or adaptation/mitigation practice within irrigated rice-wheat systems, and findings were synthesised thematically.

3. Observed and Projected Climate Trends in Haryana

Table 1 summarises the principal climate and water-resource trends documented for Haryana and the surrounding region over the period roughly 2000-2023, together with longer-range projections referenced in state-level agro-climatic assessments.

Table 1: Observed climate and water-resource trends relevant to Haryana's rice-wheat system

Climate variable	Observed change (approx. 2000-2023)	Notes / source basis
Maximum temperature	Warming of roughly +0.5 °C across the state over the period	State-level agro-climatic assessment
Minimum temperature	Warming of roughly +1.0 °C, faster than the maximum-temperature trend	Night-time warming narrows the diurnal range relevant to grain filling
Monsoon (kharif) rainfall	Increasingly erratic onset and distribution; recurring drought years (e.g., 2002, 2009, 2019)	Affects rice transplanting windows and canal supply
Winter (rabi) rainfall / heat	Episodes of untimely, excess late-season rainfall (e.g., 2014-15) and terminal heat spells	Both extremes damaged standing wheat in documented seasons
Groundwater storage	Depletion of about 17.7 ± 4.5 km ³ per year across the Punjab-Haryana-Rajasthan belt in the 2000s	Identified via satellite gravimetry as a global depletion hotspot

A consistent feature across sources is that night-time (minimum) temperatures are rising faster than daytime (maximum) temperatures, narrowing the diurnal temperature range. This pattern is agronomically significant because both rice grain filling and wheat grain filling are sensitive to elevated night-time temperature independent of daytime heat. State-level assessments also describe recurring drought years and an increasing frequency of climate extremes at both ends of the calendar: erratic monsoon onset affecting rice establishment, and untimely excess rainfall or terminal heat spells affecting the standing wheat crop. Longer-range agro-climatic projections for the wider region suggest further mean warming and some increase in mean monsoon and winter rainfall by mid- to late-century, but this is expected to be accompanied by greater year-to-year variability and a higher probability of both floods and droughts, rather than a smooth or uniformly beneficial shift. Superimposed on these atmospheric trends is a well-documented groundwater crisis. Satellite gravimetric measurements have

identified the Punjab-Haryana-Rajasthan belt as one of the most significant groundwater depletion hotspots globally, with losses estimated at roughly 17.7 ± 4.5 cubic kilometres per year during the 2000s, driven substantially by pumping for paddy irrigation under subsidised electricity. This depletion interacts with climate change rather than operating independently of it: more erratic monsoon rainfall increases reliance on groundwater-fed supplemental irrigation for both crops, while a warmer atmosphere raises evapotranspirative demand.

4. Crop-Level Climate Sensitivities Within the Cropping Calendar

Because rice and wheat occupy the same field in immediate succession, climate stress at any point in the annual cycle can affect both the current crop and the timing of the next. Table 2 summarises the principal stage-specific sensitivities documented in the reviewed literature.

Table 2: Stage-specific climate sensitivities of rice and wheat in the Haryana cropping calendar

Crop / stage	Primary climate sensitivity	Documented or modelled consequence
Kharif rice - transplanting and vegetative stage	Delayed or erratic monsoon onset; heat during nursery and transplanting	Shifts optimum transplanting windows and increases dependence on groundwater-fed pre-monsoon irrigation
Rice - flowering and grain filling	Night-time (minimum) temperature rise	Elevated minimum temperatures are linked to spikelet sterility and reduced grain filling in irrigated rice systems
Rabi wheat - reproductive to grain-filling stage	Terminal heat stress in February-March	Multi-model crop-simulation work indicates each additional 1 °C of growing-season warming can materially reduce wheat yield without adaptation
Wheat - grain filling	Untimely, excess late-season rainfall and associated lodging/disease	Documented severe production losses in Haryana wheat during an anomalously wet 2014-15 season
Whole system - inter-crop turnaround	Compressed window between rice harvest and wheat sowing	Encourages residue burning under time pressure, itself a source of regional air-quality and greenhouse-gas impact

Wheat is particularly exposed to terminal heat because its reproductive and grain-filling period falls in February-March, when temperatures in north-western India can rise sharply within a short window; multi-model crop-simulation research

spanning many production environments indicates that each additional degree of growing-season warming can meaningfully depress wheat yield in the absence of adaptive management, a relationship widely cited in Haryana-focused assessments.

Wheat is simultaneously vulnerable to the opposite extreme: an anomalously wet 2014-15 rabi season caused substantial documented production losses in Haryana through lodging and disease pressure associated with untimely, excessive rainfall near maturity, illustrating that the state's wheat crop faces climate risk from both heat and unseasonal moisture, sometimes within the same decade.

On the rice side, the key constraint is less about mean temperature and more about the reliability of monsoon-linked water supply for transplanting and the vulnerability of flowering-stage rice to elevated night-time temperature, which is associated with spikelet sterility and reduced grain filling in irrigated systems across South Asia. The system-level consequence is a compressed and increasingly unpredictable turnaround window between rice harvest and wheat sowing, which has historically pushed farmers toward burning rice residue to clear fields quickly, a practice that both emits greenhouse gases and degrades regional air quality.

5. Productivity, Water, and Emissions Pressures on the System

Regional crop-modelling studies that combine global climate models with crop simulation models (such as DSSAT and APSIM) project material mid-century yield reductions for both rice and wheat in comparable rice-wheat systems of the broader region under unmitigated management, with reported reductions in the range of roughly 12-17 percent for wheat and 15-17 percent for rice depending on the model and scenario used; these

ranges come from studies conducted in adjoining rice-wheat systems of the region and are presented here as indicative rather than Haryana-specific point estimates. Other basin-scale hydrological modelling exercises in different parts of the Indo-Gangetic Plains project net yield gains for irrigated rice and wheat once CO₂ fertilisation and adjusted irrigation allocation are factored in, illustrating that outcomes are highly sensitive to model assumptions about adaptation, irrigation reliability, and CO₂ response — a reminder that climate-impact estimates for this system should be read as scenario-dependent rather than as a single deterministic forecast.

On the water side, groundwater depletion functions as both a cause and a consequence of climate stress on the system: farmers pump more heavily to buffer against erratic monsoon timing, which accelerates depletion, which in turn increases the system's vulnerability to any future dry spell. On the emissions side, conventional puddled-transplanted rice is a recognised source of methane, while conventional tillage combined with residue burning contributes both greenhouse gases and particulate air pollution across the wider Punjab-Haryana airshed during the October-November rice-to-wheat transition.

6. Adaptation and Mitigation Responses

A cluster of resource-conservation technologies, developed and tested substantially within Haryana and neighbouring Punjab through research-station and farmer-field trials, has emerged as the primary agronomic response to these pressures. Table 3 summarises the main practices and their reported effects.

Table 3: Reported effects of major adaptation and mitigation practices in the regional rice-wheat system

Practice	Reported effect in rice-wheat systems of the region	Primary CSA pillar addressed
Direct-seeded rice (DSR)	Avoids puddling and transplanting; field-level studies report water savings on the order of 30% and yield changes ranging from modest gains to parity depending on weed and nematode management	Adaptation (water) and mitigation
Zero-tillage (ZT) wheat / Happy Seeder	Sowing directly into rice residue shortens the turnaround window and reduces the incentive to burn stubble; long-term tillage-residue trials report gains in soil organic carbon and lower net greenhouse-gas emissions	Mitigation and adaptation
Conservation agriculture (combined CA package)	Case evidence from Karnal district shows CA-based wheat coped better with an extreme untimely-rainfall event than conventional tillage-based wheat in the same season	Adaptation (climate-extreme resilience)
Residue retention with reduced/zero tillage	Seventeen-year assessments in the western Indo-Gangetic Plains report improved soil organic carbon stability and reduced net greenhouse-gas emissions relative to conventional residue burning and tillage	Mitigation
Laser land levelling and micro-irrigation	Improves irrigation-water application efficiency across both crops, partially offsetting groundwater decline	Adaptation (water)
Adjusted sowing dates / short-duration and heat- or climate-resilient cultivars	Crop-modelling studies across the wider rice-wheat belt project that shifting sowing windows and cultivar choice can partly offset simulated mid-century yield losses	Adaptation
Crop diversification away from paddy	Reviews of the north-western Indo-Gangetic Plains identify diversification toward less water-intensive crops as a strategic option, though adoption is constrained by assured procurement and subsidised power for groundwater pumping	Adaptation and resource sustainability

Long-running, multi-year field experimentation at CCS Haryana Agricultural University's Karnal research station has directly compared direct-seeded rice (DSR) with conventional puddled-transplanted rice (PTR) followed by zero-tillage wheat over a seven-year period, finding that while DSR reduces water and labour input, it can intensify weed pressure, including species that carry over into the following wheat crop, underscoring that individual technologies bring trade-offs that require integrated weed and residue management rather than simple substitution. Separately, district-level case evidence from Karnal found that wheat grown under a conservation-agriculture package coped better with an untimely, extreme excess-rainfall event in 2014-15 than wheat grown under conventional tillage, offering a concrete regional example of climate-resilience benefits from

conservation agriculture under a real extreme-weather event rather than only in simulation.

Longer-duration soil studies in the western Indo-Gangetic Plains, assessing seventeen years of tillage and residue management, report that reduced or zero tillage combined with residue retention increases soil organic carbon stability and lowers net greenhouse-gas emissions relative to conventional tillage with residue removal or burning, positioning residue retention as a practice that serves both the adaptation and mitigation pillars simultaneously. At the same time, regional reviews of the rice-wheat system note that structural policy settings, including assured procurement at minimum support prices for paddy and heavily subsidised electricity for groundwater pumping, continue to favour continuation of water-

intensive paddy cultivation over diversification toward less water-demanding crops, even where diversification would reduce climate and groundwater exposure.

7. Challenges and Knowledge Gaps

- State-specific, long-term climate-impact projections for Haryana remain less abundant than for the wider Indo-Gangetic Plains or for neighbouring Punjab, so many quantitative yield-loss estimates cited in state-level assessments are extrapolated from regional or basin-scale modelling rather than Haryana-specific field trials.
- Adaptation technologies such as DSR and zero-tillage wheat show trade-offs (notably weed and nematode pressure) that are agronomically manageable but require sustained extension support, herbicide access, and machinery availability that are unevenly distributed across farm sizes.
- Policy incentives, particularly assured procurement of paddy and subsidised groundwater pumping, work against several of the water-saving and diversification options that the climate evidence base supports, creating a gap between technically available solutions and farmer-level economic incentives.
- Most greenhouse-gas mitigation evidence for the region addresses individual practices (tillage, residue management) in isolation; system-level, farm-scale carbon and water accounting that combines DSR, zero tillage, and diversification together is comparatively scarce.
- Climate-extreme case evidence (such as the 2014-15 wet rabi season) is valuable but limited to a small number of documented events, so confidence in how conservation agriculture performs across a wider range of extreme-weather types remains an open research question.

8. Future Directions

Three priorities follow from this synthesis. First, downscaled, Haryana-specific climate projections combined with locally calibrated crop models would sharpen yield-risk estimates currently drawn largely from regional or basin-scale studies, improving the precision of extension advice on sowing windows and cultivar choice. Second, integrated system trials that combine DSR, zero-tillage wheat, residue retention, and diversified rotations within the same experimental design would help quantify whole-system water, carbon, and profitability outcomes, rather than assessing each practice in isolation. Third, research on policy instruments, such as adjusted procurement incentives, groundwater pricing reform, or targeted subsidy redesign, that could align farmer incentives with the water-saving and emissions-reducing practices already validated agronomically deserves the same level of attention as the agronomic research itself.

9. Conclusion

Haryana's rice-wheat cropping system faces a layered set of climate pressures: faster night-time than daytime warming, increasingly erratic monsoon timing, episodes of both terminal heat and untimely excess rainfall during the wheat season, and rapid, climate-interacting groundwater depletion across the wider region. These pressures act at specific, agronomically critical points in the twin-crop calendar, from rice transplanting and flowering through wheat grain filling, and are compounded by the narrow turnaround window between the two crops. The evidence reviewed here indicates that resource-conservation technologies, including direct-seeded rice, zero-tillage wheat,

conservation agriculture, and residue retention, offer genuine and in some cases directly demonstrated resilience and mitigation benefits, but none functions as a complete solution in isolation, and their benefits are partly constrained by policy settings that continue to favour water-intensive conventional practice. Building durable climate resilience into this system will likely depend on combining agronomic innovation with water-policy and procurement reform, rather than relying on either track alone.

References

1. Asseng S, Ewert F, Martre P, Rötter RP, Lobell DB, Cammarano D, *et al.* Rising temperatures reduce global wheat production. *Nature Climate Change*. 2015;5(2):143-147.
2. Central Soil Salinity Research Institute (CSSRI), Karnal. Long-term rainfall and agro-climatic data for the rice-wheat growing area of Haryana. Karnal: CSSRI.
3. Conservation agriculture-based wheat production better copes with extreme climate events than conventional tillage-based systems than conventional tillage-based systems: a case of untimely excess rainfall in Haryana, India. *Agricultural Systems*.
4. Direct seeded rice in sequence with zero-tillage wheat in north-western India: addressing system-based sustainability issues. *Discover Applied Sciences*. 2021.
5. Assessing the soil organic carbon stability and greenhouse gases mitigation in rice-wheat system: seventeen-years assessment of tillage and residue management. 2025.
6. Challenges and technological interventions in rice-wheat system for resilient food-water-energy-environment nexus in North-western Indo-Gangetic Plains: a review. 2023.
7. Climate change and agricultural sustainability in Haryana. *The Economics Journal*. 2024/2025.
8. Climate change impact assessment for wheat and rice productivity, Haryana, India. *AGU Fall Meeting*. 2017.
9. Climate change impacts on irrigated rice and wheat production in Gomti River basin of India: a case study. 2016.
10. Direct seeded rice in Haryana: a review of drivers of adoption. *CGIAR CGSpace*.
11. Impact of climate change on agricultural production: issues, challenges, and opportunities in Asia. 2022.
12. Modeling adaptation strategies against climate change impacts in integrated rice-wheat agricultural production system of Pakistan. 2020.
13. Productivity and sustainability of the rice-wheat cropping system in the Indo-Gangetic Plains of the Indian subcontinent: problems, opportunities, and strategies. *Advances in Agronomy*.
14. Rodell M, Velicogna I, Famiglietti JS. Satellite-based estimates of groundwater depletion in India. *Nature*. 2009;460:999-1002.
15. Zero tillage to reduce air pollution in India. *CGIAR System Rice-Wheat Consortium retrospective*.