

Quenching Punjab's Thirst: A Roadmap to Sustainable Water Management

*Ruchi Goyal and Mohit Goyal

Punjab Agricultural University, Ludhiana, Punjab, India

*Corresponding Author's email: ruchigoyal068@gmail.com

Punjab, widely recognized as the “Food Basket of India,” is currently confronting a gradual yet serious environmental crisis. Although Punjab occupies only about 1.5% of India’s total land area, it has contributed nearly 25-30% of rice and 35-40% of wheat to the central pool over the past decade (PAU, 2022). Under the current scenario of free electricity for agriculture and assured procurement of paddy, making it the most profitable kharif crop in the state, the farmers are reluctant to move towards crop diversification. However, this productivity comes at a steep price: groundwater extraction in Punjab has reached an alarming rate of 156.8% of its annual recharge. With levels declining by an average of 0.49 to 0.70 meters annually, the central districts are now categorized as critically over-exploited. Out of the 153 blocks in Punjab assessed in the study, 115 blocks (75.16%) fall under the “over-exploited” category, while 4 blocks (2.61%) are classified as “critical,” 12 blocks (7.84%) as “semi-critical,” and the remaining 22 blocks (14.37%) are considered “safe” as shown in Fig 1 and 2.

Groundwater depths ranging from 20-30 m below ground level (mbgl) have been recorded at nearly 20% of the monitoring sites, mainly across selected blocks of districts such as Amritsar, Barnala, Bathinda, Faridkot, Fatehgarh Sahib, Firozpur, Hoshiarpur, Ludhiana, Mansa, Moga, Patiala, S. B. S. Nagar, Sangrur, Tarn Taran, Jalandhar, and S. A. S. Nagar. Furthermore, even deeper water levels exceeding 30 m have been observed at about 24% of the sites, covering parts of districts including Barnala, Bathinda, Hoshiarpur, Kapurthala, Ludhiana, Moga, Patiala, S. B. S. Nagar, Sangrur, Jalandhar, and Malerkotla (Fig 3).

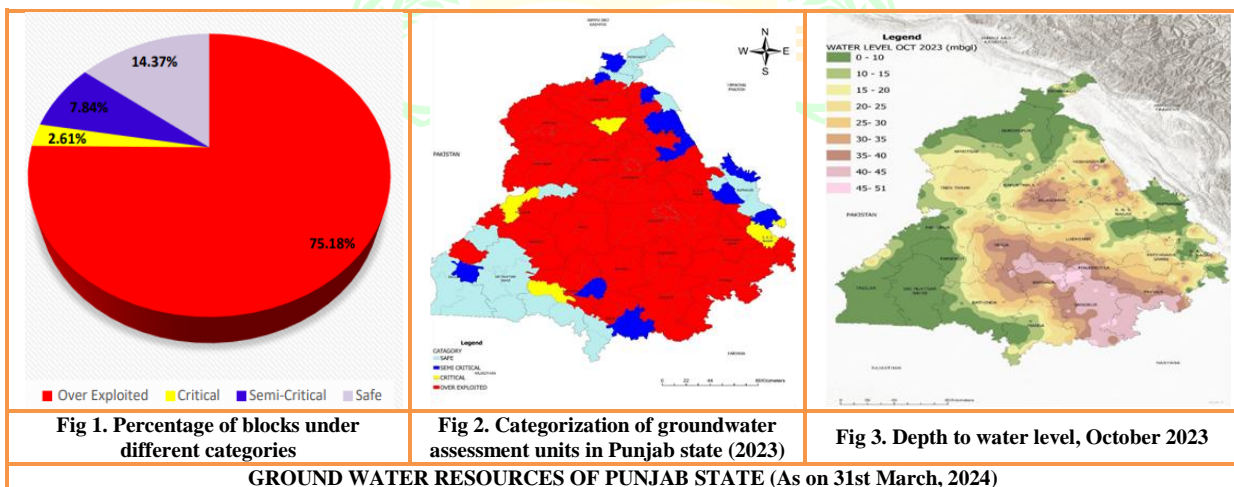


Fig 1. Percentage of blocks under different categories

Fig 2. Categorization of groundwater assessment units in Punjab state (2023)

Fig 3. Depth to water level, October 2023

GROUND WATER RESOURCES OF PUNJAB STATE (As on 31st March, 2024)

The net annual groundwater availability during 2014-23 has been estimated at 17.63 BCM, whereas the total groundwater draft for all uses stands at 28.95 BCM. It has been noted that there is no scope for additional groundwater development in over-exploited blocks of the state. However, in safe, semi-critical, critical, and waterlogged areas, the potential availability for future irrigation has been assessed at 1.18 BCM. Overall, groundwater extraction in

Punjab has reached a critical level, amounting to 156.8% of its annual recharge as shown in Table 1, as per the REPORT OF GROUND WATER RESOURCES OF PUNJAB STATE (As on 31st March, 2024).

Table 1. Groundwater Resource Assessment

Net Annual Ground Water Availability	17.63 BCM
Existing GW Draft for Irrigation	26.24 BCM
Existing GW Draft for Domestic and Industrial Use	1.42 BCM
Existing GW Draft for all uses	28.95 BCM
Net GW availability for future irrigation development in Safe, Semi-critical and potential resources in water logged areas	1.18 BCM
Average stage of GW Extraction of state	156.87%

The escalating groundwater crisis in Punjab necessitates a paradigm shift from conventional, resource-intensive practices toward efficient, climate-resilient agricultural systems. A combination of improved agronomic practices, technological interventions, and policy support can substantially enhance water productivity while sustaining crop yields.

Direct Seeding of Rice (DSR): A Transformative Approach

Conventional puddled transplanted rice (PTR) systems are highly water-intensive, requiring approximately 2000-5000 L of water per kg of grain produced. In contrast, Direct Seeding of Rice (DSR) eliminates the need for nursery raising and puddling operations.

- **Water-saving potential:** DSR reduces irrigation water use by nearly 20-40% due to the absence of standing water conditions.
- **Environmental benefits:** The shift from anaerobic puddled systems to aerobic soil conditions significantly lowers methane emissions, resulting in a ~16.6% reduction in global warming potential (GWP).
- **Economic gains:** Reduced labour and irrigation requirements can lead to savings of approximately ₹3000 ha⁻¹, while maintaining comparable productivity under optimal management.

Thus, DSR represents a viable strategy for improving water use efficiency (WUE) and reducing environmental footprints.

Strategic Crop and Variety Selection

Crop genotype plays a crucial role in determining water demand and system sustainability.

- **Short-duration cultivars:** Replacement of long-duration, water-intensive varieties such as Pusa-44 with early-maturing cultivars like PR 121, PR 126, and PR 132 enables reduced irrigation frequency and shorter field occupancy periods.
- **Resource optimization:** Early maturity helps in minimizing terminal water stress and reduces the narrow harvesting window, thereby mitigating residue burning risks.
- **Crop diversification:** Simulation and field-based evidence suggest that diversifying even 10% of paddy area toward maize, pulses, or oilseeds can significantly stabilize groundwater levels.

Precision Land and Water Management Technologies

Technological interventions enable precise control over spatial and temporal water application.

- **Laser Land Levelling:** Uniform land grading ensures equitable water distribution, reducing runoff, deep percolation losses, and irrigation time, thereby enhancing water productivity and crop yields.

- Micro-irrigation systems: Adoption of drip or sprinkler irrigation improves application efficiency. Studies indicate that converting even 1% of wheat area to drip irrigation can reduce groundwater decline by ~3 cm annually.
- Improved conveyance systems: Replacing open channels with underground PVC.

Policy Interventions: Regulatory Support for Conservation

The Punjab Preservation of Subsoil Water Act (2009) plays a pivotal role in groundwater conservation by regulating transplanting dates.

- By restricting paddy transplantation before mid-June, the policy aligns crop establishment with the onset of monsoon rainfall.
- This synchronization reduces pre-monsoon irrigation demand and evaporation losses, thereby conserving groundwater resources.

Conservation Agronomic Practices

A suite of field-level practices can further enhance irrigation efficiency:

- **Permanent Raised Beds:** Facilitate furrow irrigation, reducing water use by up to 25% compared to conventional flood irrigation, while improving root aeration and yield.
- **Soil moisture-based irrigation:** Use of tensiometers or sensors helps optimize irrigation scheduling, correcting the misconception that continuous ponding is essential for rice productivity.
- **Delayed transplanting:** Aligning nursery transplanting with monsoon onset (July) significantly reduces irrigation requirements.
- **Zero Tillage:** Minimizes soil disturbance, conserves soil moisture, reduces cultivation costs, and improves soil structure.
- **Crop diversification:** Transitioning from rice–wheat monoculture to less water-intensive crops (maize, pulses, oilseeds, potato) reduces groundwater exploitation.
- **Micro-irrigation expansion:** Wider adoption of drip and sprinkler systems is essential for long-term sustainability of irrigated agriculture.

Key Challenges in Adoption of Sustainable Water Management Practices in Punjab

Despite the availability of advanced water-saving technologies and conservation strategies, their large-scale adoption in Punjab remains constrained by several socio-economic, institutional, and policy-related challenges.

1. High Capital Investment Requirements

The adoption of modern technologies such as micro-irrigation systems, underground pipeline networks, and protected cultivation (polyhouses) involves substantial initial investment. Given that the average landholding size in Punjab is approximately 2.5 acres, the majority of farmers fall under the smallholder category. These farmers often lack the financial capacity and risk-bearing ability to invest in capital-intensive technologies, thereby limiting their adoption despite long-term benefits.

2. Limited Access to Advanced Farm Machinery

Access to precision agricultural machinery, including zero-till, laser land levellers, and residue management equipment, remains inadequate. Small and marginal farmers, in particular, face difficulties in procuring or hiring such equipment due to high costs, limited availability, and weak custom hiring infrastructure. This restricts the implementation of resource-conserving technologies at the field level.

3. Insufficient Funding for Research and Innovation

The research community working on critical issues such as water conservation, irrigation efficiency, and sustainable cropping systems faces constraints due to inadequate financial support. Limited funding hampers long-term experimental studies, technological innovation, and the development of region-specific solutions, thereby slowing progress toward sustainable agriculture.

4. Policy and Institutional Constraints

Although efforts have been made to promote crop diversification, the absence of a comprehensive and supportive policy framework continues to be a major barrier. In particular:

- Lack of assured Minimum Support Price (MSP) and procurement systems for alternative crops (e.g., pulses, oilseeds, maize) discourages farmers from shifting away from the rice–wheat system.
- Existing policies heavily favour water-intensive crops, creating an economic imbalance.
- Farmers are unlikely to diversify unless alternative crops offer comparable or higher economic returns per unit area.

5. Additional Emerging Challenges

- **Groundwater depletion pressure:** Continuous over-extraction has created a dependency trap, making transition to low-water systems difficult.
- **Awareness and knowledge gaps:** Many farmers are not fully aware of the long-term benefits of conservation technologies or lack technical guidance for their implementation.
- **Fragmented landholdings:** Small and scattered fields reduce the feasibility of adopting large-scale precision technologies.
- **Energy-water nexus issues:** Free or subsidized electricity encourages excessive groundwater pumping, undermining conservation efforts.

Conclusion

At last, these challenges highlight that the transition toward sustainable water management in Punjab is not merely a technological issue but a multi-dimensional problem involving economics, policy, infrastructure, and farmer behaviour. Addressing these constraints requires coordinated efforts in terms of financial incentives, institutional support, technological access, and policy reforms. The sustainability of Punjab’s agriculture hinges on a strategic transition from “maximizing production” to “maximizing resource use efficiency.” Integration of DSR, precision irrigation technologies, improved crop choices, and supportive policy measures can significantly reduce groundwater depletion. Adoption of these interventions not only enhances water and nutrient use efficiency but also ensures long-term agricultural resilience, economic viability, and environmental sustainability.

References

1. PAU (2022) Package of Practices for Cultivation of Khairf Crops. Pp. 1-21. Punjab Agricultural University, Ludhiana.
2. REPORT OF GROUND WATER RESOURCES OF PUNJAB STATE (As on 31st March, 2024)