More Crop per Drop: Agronomic Innovations for Water Conservation

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ABSTRACT

Water scarcity is a major challenge to sustainable agriculture, making improved water-use efficiency (WUE) essential for ensuring food security. The "More Crop per Drop" approach aims to maximize crop productivity per unit of water through efficient irrigation and improved agronomic practices. This review highlights key strategies, including precision irrigation, laser land levelling, mulching, conservation agriculture, integrated nutrient management, rainwater harvesting, climate-resilient crop varieties, digital agriculture, and watershed management. It also discusses the challenges limiting adoption, such as high investment costs, limited technical knowledge, and climate variability. The review concludes that integrating innovative technologies with sustainable water management practices can significantly enhance crop water productivity and support climate-resilient agriculture.

INTRODUCTION:

Water is the most critical natural resource for agricultural production, directly influencing crop growth, productivity, and global food security. Agriculture accounts for approximately 70% of global freshwater withdrawals, making it the largest user of freshwater resources worldwide (Food and Agriculture Organization [FAO], 2021). However, population growth, climate change, declining groundwater reserves, irregular rainfall patterns, and increasing competition for water from industrial and domestic sectors have intensified pressure on agricultural water resources (Intergovernmental Panel on Climate Change [IPCC], 2022). Therefore, improving water-use efficiency (WUE) has become a major priority for sustainable agricultural development.

The concept of "More Crop per Drop" emphasizes increasing agricultural productivity per unit of water consumed rather than simply increasing irrigation inputs. This approach, promoted by organizations such as the International Water Management Institute (IWMI) and FAO, focuses on improving crop water productivity (CWP), defined as the amount of crop yield produced per unit of water used through evapotranspiration or irrigation. Achieving higher water productivity requires integration of efficient irrigation technologies, improved agronomic practices, soil-water management, climate-resilient crops, and precision agriculture approaches (Molden *et al*., 2010).

Understanding the "More Crop per Drop" Concept:

The principle of "More Crop per Drop" is based on improving water-use efficiency, defined as the amount of crop yield produced per unit of water used. Higher water-use efficiency means that crops produce greater yields using the same or even less water. This can be achieved through efficient irrigation systems, improved soil management, drought-tolerant crop varieties, balanced nutrient application, and the adoption of digital technologies that support precision farming.

The concept extends beyond irrigation management. It encompasses integrated agricultural practices that minimize water losses, improve soil moisture retention, and increase the efficiency with which crops convert water into biomass and grain yield. Consequently, the "More Crop per Drop" approach is recognized as a cornerstone of climate-smart agriculture and sustainable water resource management (Hatfield & Dold, 2019).

Why Water Conservation Matters:

Agriculture consumes nearly 70% of the world's freshwater resources, making it the largest water-using sector. Unfortunately, much of this water is wasted through inefficient irrigation, evaporation, runoff, and poor field management.

Several factors are intensifying the water crisis:

- Declining groundwater levels due to excessive pumping.
- Irregular and erratic rainfall caused by climate change.
- Frequent droughts and heat waves.
- Increasing demand for water from industries and urban areas.
- Soil degradation, reducing the ability of land to retain moisture.

If current trends continue, water scarcity could seriously threaten global food security. Therefore, conserving every drop of water has become an agricultural necessity rather than an environmental choice.

Agronomic Strategies for Water Conservation and Enhanced Crop Water Productivity:

1. **Precision Irrigation Scheduling:** Water requirements of crops depend on crop type, growth stage, soil properties, and climate conditions. Excess irrigation causes water loss, nutrient leaching, poor aeration, and reduced root transpiration.

Precision irrigation uses soil moisture data, evapotranspiration, weather information, and crop coefficients to optimize irrigation timing and quantity. Technologies such as sensors, remote sensing, automated controllers, and IoT systems enable real-time water management (Zhang *et al.*, 2019). This improves water-use efficiency, reduces energy use, and minimizes environmental impacts.

2. **Laser Land Levelling: Enhancing Water Distribution Uniformity:** Uneven field surfaces cause poor water distribution, resulting in waterlogging and moisture stress. Laser land levelling with the help of a laser land leveller creates a uniform field gradient for efficient irrigation. This technology improves water distribution, reduces irrigation time and runoff losses, enhances crop establishment, and increases water productivity (Jat *et al*., 2006).

3. **Soil Moisture Conservation through Mulching:** Soil evaporation is a major cause of water loss in agriculture. Mulching reduces evaporation by covering the soil surface.

Organic mulches such as crop residues, straw, and compost conserve moisture, regulate soil temperature, suppress weeds, improve soil biology, and reduce erosion (Kader *et al*., 2017). These benefits support better root growth and crop performance under water stress.

4. **Conservation Agriculture and Soil Water Dynamics:** Conservation agriculture follows three principles: minimum tillage, permanent soil cover, and crop diversification (FAO, 2017).

Reduced tillage and residue retention improve soil structure, infiltration, and water storage. Crop rotations enhance organic matter and microbial activity, increasing soil water availability and drought resilience (Hobbs *et al*., 2008).

5. **Improving Soil Water Retention through Organic Matter:** Soil organic matter improves water retention by enhancing soil aggregation, porosity, and structure. Organic inputs such as manure, compost, and crop residues increase soil moisture storage capacity (Lal, 2020).

Improved soil structure enhances infiltration, reduces runoff, and increases plant-available water, contributing to higher water-use efficiency and climate resilience (Lal, 2020).

6. **Climate-Resilient Crop Varieties:** Drought-tolerant crop varieties improve water productivity through traits such as deep roots, efficient stomatal control, osmotic adjustment, and improved transpiration efficiency.

Early-maturing varieties avoid severe drought periods by completing their growth cycle earlier. These genetic improvements reduce yield losses and enhance crop stability under climate stress (Fang & Xiong, 2015).

7. **Integrated Nutrient Management and Water-Use Efficiency:** Nutrient availability influences plant growth and water uptake. Nutrient deficiencies reduce root development and limit moisture utilization.

Integrated Nutrient Management (INM) using organic inputs, biofertilizers, and mineral fertilizers improves soil fertility, microbial activity, and root growth. Efficient nutrient management increases biomass production and crop yield per unit of water used.

8. **Rainwater Harvesting and Supplemental Irrigation:** Rainwater harvesting improves water availability, especially in rainfed regions. Structures such as farm ponds, check dams, and recharge systems store runoff for agricultural use.

Supplemental irrigation during critical growth stages reduces drought effects and improves productivity (Rockstrom *et al*., 2010). It also supports groundwater recharge and sustainable water management.

9. **Water-Saving Agronomic Practices in Rice:** Rice cultivation requires high water inputs due to traditional flooding methods. Improved practices can reduce water use while maintaining yield.

Alternate Wetting and Drying (AWD) reduces irrigation demand by allowing periodic drying of fields before re-irrigation. Direct Seeded Rice (DSR) reduces water and labour requirements by eliminating puddling and transplanting (Kumar & Ladha, 2011). These methods improve water productivity and reduce greenhouse gas emissions.

10. **Digital Agriculture for Precision Water Management:** Digital technologies such as remote sensing, drones, GIS, AI, and IoT sensors enable real-time monitoring of soil moisture and crop conditions (Zhang *et al*., 2019).

These tools support site-specific irrigation decisions, reduce water wastage, lower production costs, and improve resource-use efficiency.

11. **Watershed-Based Water Resource Management:** Sustainable water management requires landscape-level approaches. Watershed management integrates soil conservation, afforestation, rainwater harvesting, groundwater recharge, and community participation (Wani *et al*., 2008).

These practices reduce erosion, improve infiltration, enhance water availability, and strengthen agricultural resilience in water-limited regions.

Table 1. Case Studies Demonstrating the "More Crop per Drop" Approach

Location	Intervention	Major Outcome	Reference
Gujarat, India	Adoption of drip irrigation in cotton	Water use reduced by approximately 40-50% while cotton yield increased by 25-30%, resulting in higher water productivity and farm income.	FAO (2021)
Punjab, India	Laser land levelling in rice-wheat system	Irrigation water savings of about 20-30%, improved field uniformity, and increased crop yield.	Jat *et al.* (2006)
Eastern India	Alternate Wetting and Drying (AWD) in rice cultivation	Irrigation water savings of 15-30% with comparable grain yield and reduced methane emissions.	(Lal, 2020)
Semi-arid Watersheds, India	Rainwater harvesting and watershed management	Improved groundwater recharge, enhanced cropping intensity, and increased farm productivity under rainfed conditions.	Wani *et al.* (2008)

Challenges in Achieving Higher Water Productivity:

Despite technological advancements, several challenges limit widespread adoption of water-efficient agricultural practices:

- High initial investment costs for irrigation technologies.
- Limited technical knowledge among farmers.
- Fragmented landholdings.

- Poor maintenance of irrigation infrastructure.
- Increasing climate variability and extreme weather events.

Addressing these challenges requires coordinated efforts among researchers, policymakers, extension agencies, and farming communities.

Future Perspectives:

Future agricultural water management strategies should focus on integrating precision agriculture, climate-smart farming, improved crop genetics, digital technologies, and ecosystem-based approaches. Research priorities should include developing crops with improved intrinsic water-use efficiency, expanding sensor-based irrigation systems, strengthening watershed programmes, and improving farmer access to efficient technologies (FAO, 2021).

Policies supporting micro-irrigation, conservation agriculture, rainwater harvesting, and sustainable groundwater management will be essential for achieving long-term agricultural sustainability.

CONCLUSION:

Water scarcity is becoming one of the greatest challenges affecting global agricultural production. Enhancing crop water productivity through scientifically based agronomic innovations is essential for ensuring food security under changing climatic conditions.

Technologies and practices such as precision irrigation, drip systems, laser land levelling, mulching, conservation agriculture, integrated nutrient management, rainwater harvesting, climate-resilient cultivars, and digital agriculture collectively improve water-use efficiency and maximize yield per unit of water consumed.

The principle of "More Crop per Drop" represents a shift from increasing water use toward maximizing water productivity. Integrating scientific innovations with farmer-centred management approaches will enable agriculture to produce more food while conserving valuable water resources. Sustainable water management is therefore fundamental for developing resilient, productive, and climate-smart agricultural systems.

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