Water Conservation Techniques for Sustainable Agriculture

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ABSTRACT

Water scarcity necessitates innovative conservation techniques for sustainable agriculture. This article highlights water-saving strategies such as Direct Seeded Rice (DSR), drip and sprinkler irrigation, rainwater harvesting, mulching, and conservation tillage. These methods enhance water use efficiency, reduce groundwater depletion, and improve crop yields. Implementing these methods not only conserves water but also enhances soil health and reduces environmental impact. By integrating such practices, agriculture can become more resilient to climate variability, ensuring food security for future generations.

INTRODUCTION

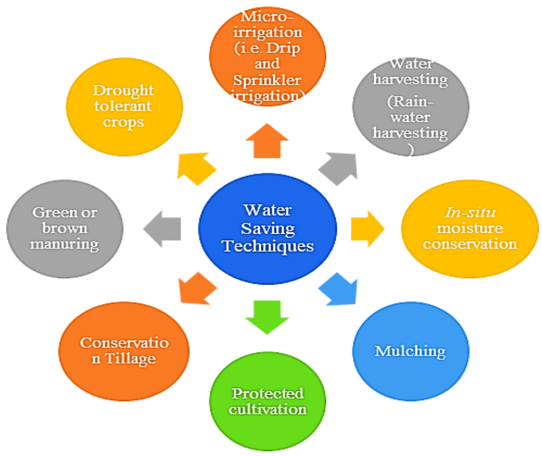
In an era of growing water scarcity and escalating climate challenges, the adoption of innovative water conservation techniques has become a global necessity. As water resources continue to dwindle, the need for solutions to optimize water use efficiency has never been more urgent. Innovative techniques such as precision irrigation, rainwater harvesting, and advanced water recycling technologies are emerging as transformative solutions to address this challenge.

In different regions, location-specific technologies play a pivotal role. For instance, Direct Seeded Rice (DSR) has proven effective in the plains, while rainwater harvesting techniques have been tailored for hilly areas. The Indian farmers are using 25 times more water than what agricultural scientists deem necessary for paddy cultivation, leading to a drastic decline in the groundwater table in North Indian states. Around 20% of the overall irrigation demand for paddy is allocated to puddling before transplanting. However, through the adoption of direct sowing techniques, approximately 20 to 25% of water can be conserved by eliminating the necessity of flooding the field for puddling and then transplanting.

In Punjab, the situation is becoming increasingly concerning. According to data from the Central Ground Water Board (CGWB) for November 2021, compared to the average levels from November 2011 to 2020, a significant decline in groundwater levels was observed. Of the 176 wells surveyed, water levels declined in 69.31% of the wells, while only 30.68% showed an increase. Given this concerning trend, addressing the issue of injudicious water use in agriculture has become critical. The development and adoption of water-saving techniques are essential not only for conserving valuable water resources but also for ensuring sustainable agricultural production. As the global population continues to rise, it is crucial to find solutions that balance water conservation with the ever-growing demand for food production.

Water saving techniques

Surface irrigation methods are utilized in more than 80% of the world's irrigated lands, yet their efficiency is often 40-50% (Westrap *et al* 2004). However, this issue can be resolved by introducing the micro irrigation techniques including drip irrigation and sprinkler irrigation. The drip irrigation has the maximum water use efficiency among all the irrigation methods available.



Drip irrigation: Also known as trickle or micro-irrigation, represents an advanced and efficient approach to water and nutrient management. This method significantly reduces water consumption by delivering a precise, slow supply of water directly to the plant's root zone through a network of valves, pipes, tubing, and emitters. Compared to traditional surface irrigation, drip irrigation can save up to 50-80% of water, minimizing evaporation losses (Spaldon *et al* 2015). Additionally, it can increase crop yield per unit of water consumed by 10-50% through enhanced plant evapotranspiration (Spaldon *et al* 2015). This system is especially beneficial for high-value horticultural crops like grapes, bananas, pomegranates, citrus, tomatoes, chillies, capsicum, cabbage, and onions, as well as cash crops such as sugarcane and cotton, making it an ideal solution for sustainable agriculture.

Table 1: Response of different crops to the Drip Irrigation System

Crops	Water saving (%)	Increase in yield (%)
Banana	45	52
Cauliflower	68	70
Chilly	68	28
Cucumber	56	48
Grapes	48	23
Groundnut	40	152
Pomegranate	45	45
Sugarcane	50	99

Sweet lime	61	50
Tomato	42	60
Watermelon	66	19

Sprinkler irrigation: It is a highly effective method of water delivery, where water is applied under high pressure with the assistance of a pump, mimicking the natural process of rainfall. This is achieved through a network of pipes with small-diameter nozzles that ensure a uniform distribution of water, even in uneven terrain, thereby reducing water wastage (Shankar *et al* 2015). It saves up to 30-50% of water compared to other methods, offers flexibility in watering schedules, and can cover large areas with minimal labour. Adaptable to most soil types, it contributes to increased crop yield through efficient water application.

Table 2: Response of different crops to the Sprinkler Irrigation System

Crops	Water saving (%)	Increase in yield (%)
Chilli	33	24
Cotton	36	50
Fenugreek	29	35
Gram	69	57
Jowar	55	34
Maize	41	36
Onion	33	23
Sunflower	33	20
Wheat	35	24

Water harvesting: In arid and semi-arid regions of the country, water harvesting is a major concern to ease future water scarcity. The term ‘water harvesting’ generally refers to the collection of rainstorm-generated runoff from a particular area (a catchment) to supply water for agricultural purposes. The water collected through this technique can either be utilized immediately for irrigation or stored in aboveground ponds or subsurface reservoirs for subsequent utilization. Rainwater harvesting holds the potential to enhance arable land productivity by raising yield and decreasing the vulnerability to crop failure amid changing climatic conditions.

Rainwater harvesting (RWH): It involves gathering and storing rainwater instead of letting it flow away. Rainwater is typically collected from a roof-like surface and channelled into a receptacle such as a tank, cistern, deep pit (such as a well, shaft, or borehole), aquifer, or reservoir equipped with percolation mechanisms. This process enables the rainwater to infiltrate the ground, reduces the impact of runoff and flooding, and replenishes groundwater levels.

The hilly areas, blessed with heavy rainfall, rainwater harvesting is popularly practiced to store ample water for future use, mitigating the impact of climatic variability on water availability and contributing to efforts combating climate change while enhancing food and water security.

***In-situ* moisture conservation measures practices:** In-situ soil moisture conservation involves agronomical methods like contour cultivation, tillage, mulching, and strip cropping, supplemented by mechanical techniques such as contour bunding, graded bunding, sub-soiling, and bench terracing. These measures enhance water infiltration, retain moisture, and improve soil porosity, supporting crop resilience in fluctuating rainfall. Practices like contour bunding have increased crop yields by 12–22% (Rao *et al*. 2016).

Mulching: Mulching is the technique of covering the soil surface with organic or synthetic mulch around the plants to create favourable conditions for plant growth and proficient crop production. This technique helps to conserve soil moisture, prevent soil degradation, reduce evaporation, moderate the soil temperature and reduce soil run-off and erosion. Mulching protects crops from adverse weather conditions like heavy rains, extreme heat, and flooding, potentially saving 20-25% of irrigation water (Spaldon *et al* 2015). Rice residue can be incorporated into the soil at 10-20 days before sowing of following wheat using appropriate machinery without any detrimental effect on crop productivity. Recent advancements in machinery such as Happy Seeder, Super Seeder and Smart Seeder allow zero-till sowing of wheat with rice residue as surface mulch. Plastic mulch with different thicknesses is also used in various vegetables and other crops. Dark plastic mulch prevents sunlight from reaching the soil surface and the rice straw insulates the plastic from direct sunlight thereby preventing the soil temperature from rising too high by conserving moisture during the day.

Protected cultivation: Protected structures such as polyhouses, shade nets, and greenhouses play a crucial role in conserving soil moisture by creating a controlled environment that minimizes evaporation and optimizes water use. These structures shield the soil from direct sunlight and wind, reducing water loss while maintaining humidity levels that lower plant transpiration. Additionally, they prevent excessive rainwater runoff, ensuring better infiltration and retention of moisture in the soil. By providing a stable microclimate, protected structures enhance water efficiency, reduce irrigation needs, and support sustainable crop production, making them essential for water conservation in agriculture. Among these structures, polytunnels are widely utilized for raising vegetable seedlings during the rainy season. Seedling rising in pro-trays and crop production inside agro-shade net also gaining popularity among the farmers.

Conservation tillage: Conservation tillage includes zero tillage, minimum tillage, mulch tillage, ridge tillage, and contour tillage, all aimed at minimizing soil disturbance while enhancing water retention and soil health. No-till planting, as with the Happy Seeder, improves organic matter retention and can save up to 12 cm of water per hectare, reducing water use by 30% (Mooventhan *et al*. 2018). Mulch tillage maximizes soil cover, ridge tillage involves planting on raised rows, and contour tillage aligns with slopes to reduce erosion. These practices boost water infiltration, nutrient cycling, and soil resilience.

Green and brown manuring: The supply of organic matter to the soil through the incorporation of green manure enhances the soil fertility. Green manuring of rice with leguminous annual crops, such as dhaincha (*Sesbania aculeata*), sunn hemp (*Crotalaria juncea*) and cowpea (*Vigna unguiculata*) or with twigs and leaves of perennial trees, such as *Glyricidia sepium* has been recommended to improve soil fertility and crop productivity. Brown manuring, which involves retaining crop residues on the field, forms a protective layer that minimizes evaporation, suppresses weeds, and prevents soil erosion. Both practices enhance soil organic matter, improving infiltration and reducing the need for frequent irrigation, ultimately promoting sustainable water management in agriculture.

Drought-Tolerant Crops: Drought resistant crops, also known as drought-tolerant or water-efficient crops, are crops that can withstand prolonged periods of water scarcity or limited irrigation. These crops, such as millets, sorghum, and drought-resistant wheat and pulses, have deep root system that access water from deeper soil layers, reducing the need for frequent irrigation. Their efficient water-use mechanisms, like reduced transpiration and enhanced drought resistance traits, help conserve soil moisture and sustain yield in dry conditions.

Similarly, drought-tolerant varieties of wheat (PBW 826 and DBW 187), rice (Sahbhagi Dhan, DRR Dhan 42 and CR Dhan 801), and maize (DHM 117 and PMH 1) have been developed to withstand moisture stress without compromising yield. Pulses like **pigeon peas (ICPL 88039, Pusa Arhar 16)** and chickpeas **(JG 11, JAKI 9218)** perform well in dry conditions, enriching the soil with nitrogen while using minimal water. Additionally, oilseed crops such as **drought-tolerant mustard (Pusa Vijay) and groundnut (ICGV 91114)** ensure productivity in water-limited environments.

CONCLUSION

By reducing dependency on excessive irrigation and making better use of available water, drought-tolerant crops and their varieties support sustainable agriculture and water conservation, especially in arid and semi-arid regions. Farmers can enhance their crop productivity per unit of water by cultivating crops that are well-suited to the local climate. Drought-resistant crops are particularly advantageous, as they can reduce the risk of crop failure during periods of water scarcity, improve overall yields, and enhance economic stability for farmers.

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