

# RAINFED AGRICULTURE AND WATERSHED MANAGEMENT: Integrating Sustainable Practices for Environmental Resilience

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**EDITION: VOLUME 02, ISSUE 02 , - FEBRUARY 2026**

**ISSN 3107-9903**

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## Abstract

Agriculture and watershed management are intricately linked, as agricultural activities significantly influence water resources, soil health, and ecosystem stability. This article explores the interplay between these domains, emphasizing the need for integrated approaches to mitigate environmental degradation. Key topics include the impacts of conventional farming on watersheds, such as soil erosion, nutrient runoff, and water pollution, alongside sustainable strategies like conservation tillage, agro-forestry, and riparian buffer zones. The article highlights successful implementations and challenges posed by climate change and urbanization. By adopting watershed-based management, agriculture can enhance productivity, ensure water security, and promote biodiversity. The discussion underscores policy recommendations and technological innovations, advocating for collaborative efforts among farmers, policymakers, and scientists. Ultimately, sustainable agriculture within watersheds is essential for global food security and environmental sustainability.

**Keywords-** Agriculture, watershed management, sustainable farming, soil erosion and nutrient runoff.

## Introduction

Agriculture forms the backbone of human civilization, providing food, fibre and livelihoods

for billions. However, its expansion and intensification have often come at the expense of natural resources, particularly watersheds areas that drain into a common waterway, encompassing rivers, lakes, and groundwater systems. Watershed management involves the coordinated planning and implementation of practices to protect and restore these vital ecosystems, ensuring sustainable water flow, soil retention, and biodiversity. The relationship between agriculture and watersheds is symbiotic yet fraught with challenges. On one hand, watersheds supply irrigation water, nutrients, and fertile soils essential for crop production. On the other, agricultural practices like deforestation, excessive tillage, and chemical fertilizer use can lead to soil erosion, sedimentation of waterways, and pollution from pesticides and nutrients, resulting in eutrophication and degraded water quality. These issues are exacerbated by climate change, which alters precipitation patterns and increases the frequency of droughts and floods. This article aims to delve into the dynamics of agriculture and watershed management, highlighting their interconnections, challenges, and solutions. It begins by examining the environmental impacts of agriculture on watersheds, followed by sustainable management strategies, case studies, and future prospects. By integrating watershed principles into agricultural systems, we can foster resilience, enhance productivity, and safeguard ecosystems for future generations.

## The Interplay Between Agriculture and Watersheds

Watersheds are dynamic systems where land use directly affects water quantity and quality. Agriculture occupies about 38% of the Earth's land surface making it a dominant force in watershed dynamics. Conventional farming practices, such as monoculture cropping and heavy machinery use, disrupt soil structure, leading to erosion rates that can exceed 10 tons per hectare annually in vulnerable areas. This eroded sediment clogs rivers, reduces reservoir capacity, and harms aquatic habitats. Nutrient runoff from fertilizers is another critical issue. Excess nitrogen and phosphorus from agricultural fields contribute to algal blooms in water bodies, as seen in the Gulf of Mexico's "dead zone," where hypoxic conditions kill marine life over thousands of square kilometres. Pesticides further contaminate groundwater, posing risks to human health and wildlife. Deforestation for farmland expansion reduces evapotranspiration, altering stream flows and increasing flood risks. Conversely, watersheds provide essential services to agriculture. They regulate water cycles, recharge aquifers, and deliver nutrients through natural processes. Effective management can



enhance these benefits, promoting sustainable intensification where yields increase without compromising environmental integrity.

**Rainfed Agriculture:** Growing of crops entirely under rainfed conditions by using rain water is called as rainfed agriculture.

## Types of Rainfed Agriculture:

**Dry farming:** The cultivation of crops in regions with annual rainfall less than 750mm. Crop failure is most common due to prolonged dry spell during the crop period. These are arid regions with a growing season less than 75 days. Moisture conservation practices are necessary for crop production.

**Dryland farming** – cultivation of crops in the regions with annual rainfall more than 750 mm. In spite of prolonged dry spell crop failure is relatively less frequent. These are semi-arid tracts with a growing period between 75 to 120 days. Moisture conservation practices are necessary for crop production. However, adequate drainage is required especially for Vertisols.

**Rainfed farming** – Crop production in the regions with annual rainfall more than 1150 mm. Crops are not subjected to soil moisture stress during the crop period. These are humid regions with growing period more than 120 days.

## Importance of Rainfed agriculture in India:

- About 70% of rural population lives in dry farming areas and their lives depends on success or failure of crop.
- Rainfed agriculture plays a distinct role in Indian agriculture occupying 49% of net cultivation area and supports 40% of human population and 60 % of livestock population.
- The contribution of rainfed agriculture in India is about 42% of total food grains,

75% of oilseeds, 90% of pulses and 70% of cotton.

- Drylands offer good scope for development of agroforestry, social forestry, horti-silvi-pasture and such other similar systems which will not only supply food, fuel to the village people and fodder to the cattle but forms a suitable vegetative cover for ecological maintenance.

## Problems of dryland agriculture:

- Inadequate and uncertainty of rainfall and its erratic distribution. Expected rainfall in the year is 650mm but 80% of it is received in 75-90 days of the monsoon season.
- Late onset and early cessation of monsoon.
- Prolonged dry spells during the crop period.
- Low moisture retention capacity.
- Poor soil fertility conditions.
- Socio-economic constraints particularly because of predominance of small and marginal farmers, 54% of the holdings are less than 1 ha.
- Limited infrastructure development and improper and untimely availability of credits and agricultural inputs.

## Challenges in Integrating Agriculture and Watershed Management

Several factors complicate the integration of agriculture with watershed management. Climate change intensifies these challenges by causing erratic rainfall, prolonged droughts, and extreme weather events. For instance, rising temperatures accelerate evaporation, reducing water availability for irrigation, while intensified storms heighten erosion and flooding (IPCC, 2021). Urbanization and industrialization encroach on agricultural lands, fragmenting watersheds and increasing impervious surfaces that exacerbate runoff. In developing regions, smallholder farmers often lack access to resources, leading to unsustainable practices like slash-and-burn agriculture, which degrades watersheds in tropical areas. Policy and institutional barriers also hinder progress. Fragmented governance, where agricultural and water management fall under different agencies, leads to uncoordinated efforts. Economic pressures prioritize short-



term yields over long-term sustainability, with subsidies for chemical inputs discouraging eco-friendly alternatives.

## Sustainable Strategies for Watershed Management in Agriculture

To address these challenges, integrated watershed management emphasizes holistic approaches that align agricultural practices with ecosystem health. Key strategies include:

- **Conservation Tillage and Soil Management:** Reducing tillage minimizes soil disturbance, preserving organic matter and reducing erosion. Practices like no-till farming, combined with cover cropping, enhance soil infiltration and water retention. In the United States, conservation tillage has reduced soil loss by up to 50% on croplands.
- **Agro-forestry and Diversified Cropping:** Integrating trees and shrubs into farming systems, such as alley cropping or windbreaks, stabilizes soils and improves water cycling. Agro-forestry can increase biodiversity and provide additional income from timber or fruits, as demonstrated in Kenya's Mau Forest Complex, where

it has restored degraded watersheds (Nair, 2012).

- **Riparian Buffer Zones:** Planting vegetation along waterways filters runoff, traps sediments, and absorbs nutrients. Buffers of 10-30 m wide can reduce nitrogen runoff by 60-90% (Lowrance et al., 1997). In Europe, the EU's Common Agricultural Policy mandates such zones to protect rivers.
- **Precision Agriculture and Technology:** Using GPS, sensors, and drones enables targeted application of inputs, minimizing waste and pollution. Remote sensing helps monitor watershed health, while models like SWAT (Soil and Water Assessment Tool) simulate impacts and guide decisions (Arnold et al., 1998).
- **Water Conservation Techniques:** Rainwater harvesting, drip irrigation, and constructed wetlands manage water efficiently. In arid regions, these methods have boosted crop yields while conserving

watersheds (Pimentel et al., 1995).

- **Policy and Community Engagement:** Incentives like payments for ecosystem services encourage farmers to adopt sustainable practices. Participatory approaches, involving local communities in watershed planning, foster ownership and compliance.

## Future Prospects and Innovations

Advancing technology, such as AI-driven predictive analytics for drought forecasting will enhance watershed resilience. Climate-smart agriculture, combining adaptation and mitigation, is crucial. Global initiatives like the UN's Sustainable Development Goals (SDGs) target zero hunger (Goal 2) and clean water (Goal 6), urging integrated approaches. Collaboration across sectors farmers, governments, NGOs, and researchers is essential. Education and capacity-building can empower communities, while international funding supports developing nations.

## Conclusion

Agriculture and watershed management are interdependent pillars of sustainability. While conventional practices have degraded watersheds through erosion, pollution, and resource depletion, integrated strategies offer pathways to harmony. By embracing conservation tillage, agroforestry, and technological innovations, agriculture can thrive without compromising water quality, biodiversity, or resilience to climate change. Case studies from the Mississippi, Indo-Gangetic Plain, and Chesapeake Bay affirm that with policy support and community involvement, positive outcomes are achievable. Moving forward, prioritizing watershed-centric agriculture is imperative for global food security and environmental health. Policymakers must incentivize sustainable practices, researchers should innovate adaptable solutions, and farmers should adopt them for long-term prosperity. Ultimately, nurturing watersheds ensures a bountiful legacy for future generations.



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