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PERSPECTIVE

# STRATEGIES FOR IMPROVING WATER USE EFFICIENCY IN DRYLAND AGROECOSYSTEMS

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## 1 INTRODUCTION

Rainfed cultivation is under pressure in dryland agroecosystems in developing countries and is a major concern for subsistence farmers. Alternate crop management and efficient water use practices may help improve water use efficiencies (WUE) in the dryland farming systems. Here, we summarize dryland ecosystem challenges and strategies to overcome the adversities of high WUE, including rainwater harvesting, precision water management, cconservation agriculture, crop diversification, use of mulches, promotion of agroforestry, mixed crop-livestock systems, policy options and ecosystem approach (Fig. 1).

## 2 CHALLENGES FOR DRYLAND AGROECOSYSTEMS

### 2.1 Water deficit

Water deficit conditions often determine the productivity of agricultural systems. However, many of the assumptions about drylands turn out to be unfounded. For example, some drylands in equatorial Africa receive more than 1000 mm of rainfall per year, but often suffer from prolonged dry seasons and high mean temperatures, leading to high rates of water loss through transpiration and evapotranspiration[1]. Low soil moisture and high atmospheric water demand are the two main driving forces threatening agroecosystems. Variable rainfall patterns and increased drought may alter the capacity to provide ecosystem services, such as biomass production and clean water provision[2].

### 2.2 Weather variability

Aggregated data from different weather stations for rainfall, facilities to adopt new strategies to contextualize erratic local and historical weather conditions, relative to previous rainfall patterns. Rainfall patterns, erosive winds and high temperatures pose the greatest risks to dryland agroecosystems. Most dryland agroecosystems face climatic uncertainty, and annual precipitation can vary from well above and to well below the 50% mean throughout the year, which can cause hydrological imbalance[1]. Rainfall intensity and the number of dry days increased from 1974 to 2017 in tropical drylands of Iguatu, Brazil, aggravating the already dry characteristics of the region and contributing to more extreme runoff events[2].

### 2.3 Erosion

Many soils in arid and semiarid agricultural areas are prone to wind erosion due to human activities, such as grazing and extensive agricultural practices, resulting in substantial losses of fertile soil layers and increasing risk of environmental pollution.

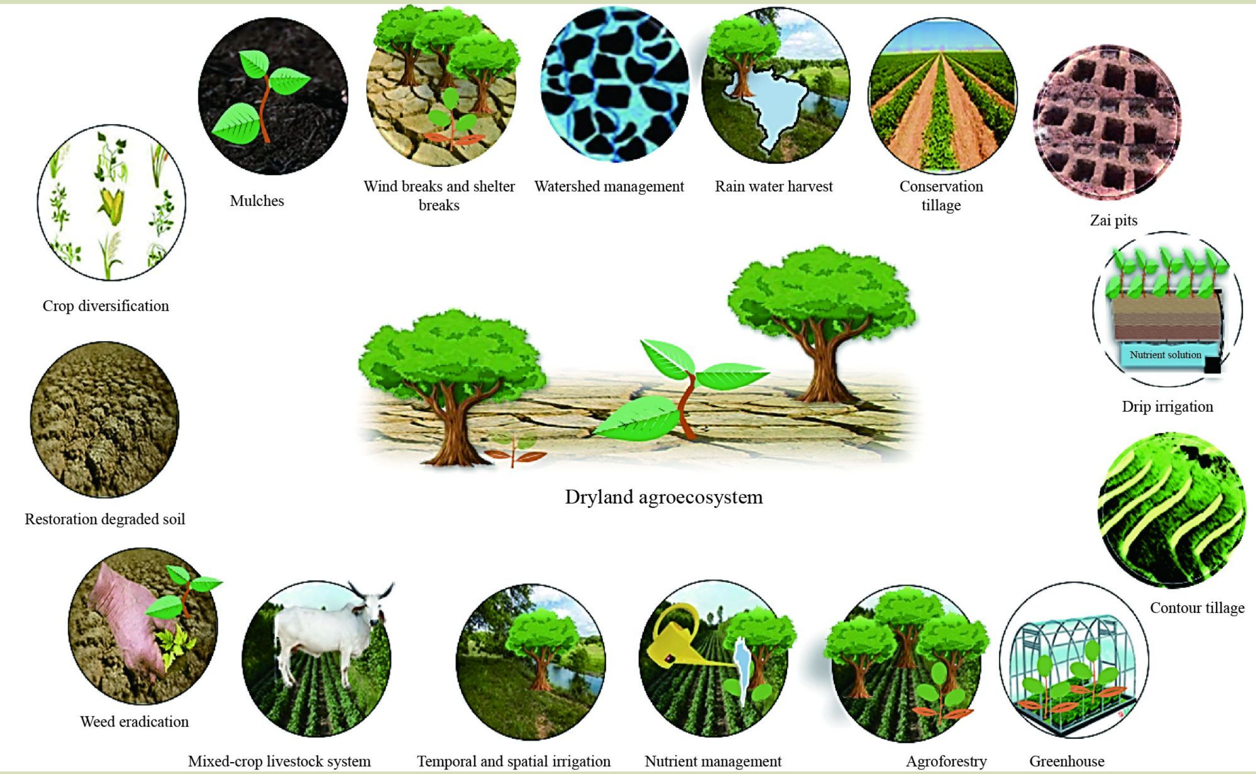


**Fig. 1** Major strategies to improve water use efficiency in dryland agroecosystem.

### 2.4 Nutrient mining

Continuous cropping, without an adequate supply of nutrients reapplied as fertilizers or manure, removes soil nutrients. Nutrient mining from the soil is a major challenge for developing countries in dryland areas, and is often associated with soil degradation, threatening long-term food production[3]. Localized root proliferation was seen in nutrient-rich dry soils, which indirectly affecting the nutrient uptake. Yan et al.[3] reported that rhizosphere wetting, efficient root systems and nocturnal soil rewetting (hydraulic redistribution) of nutrient-rich dry soil are effective for intensive dryland ecosystems. but not in nutrient-poor dry zones[3].

### 2.5 Institutional role

In many countries with dryland agroecosystems, lack of adequate institutional support is one of the main hurdle for the sustainability of agroecosystems[4]. System gaps within weak institutions hamper efforts to mitigate drought, climate change, and water scarcity. Moreover, many research institutions are poorly funded, such that research outputs rarely succeed in fulfilling the needs for sustainable agriculture[4]. Weak partnerships between the whole value chain and key institutions exacerbate the situation.

## 3 STRATEGIES FOR IMPROVING WATER USE EFFICIENCY IN DRYLAND AGROECOSYSTEMS

### 3.1 Rainwater harvesting

Rainwater harvesting is a pragmatic approach for increasing crop production in dryland areas. Masaka et al.[5] reported that as much rainfall as possible should be harvested through effective tillage methods, increasing water storage and infiltration and reducing surface runoff in deep basins. Soil water storage acts as a buffer during midseason dry periods. Conservation tillage with open-ended tied ridges provides homogeneous rainwater harvesting, while closed tied ridges accumulate soil water in ridges and furrows[5].

### 3.2 Precision water management

Zai pit technology, planting in 10–20 cm deep, 20, 30 cm wide and spaced 60–80 cm small pits, is an efficient water conservation method in dryland agroecosystems, which to regenerate crusted and degraded soil by breaking the surface crust to improve water infiltration. This technology harvests water, increases soil fertility, reduces runoff rains and lessens water stress; its influence on agriculture productivity should not be underestimated[6]. Deep tillage during fallow also improves soil water storage from 0 to 300 cm depth. Low-grade water sources (brackish groundwater and wastewater) and deficit irrigation could be used to tackle water scarcity. Protected cultivation systems, such as screen houses equipped with artificial intelligence, greenhouse establishment and drip irrigation, are other sustainable options for improving water productivity.

### 3.3 Conservation agriculture

Conservation agriculture has been used to reduce soil erosion, mitigate climate change and promote ecosystem services. This technology can provide long- and short-term benefits to increase soil health, water productivity and labor costs at a small-farm scale.

### 3.4 Crop diversification

Crop diversification (including a balance of mixed legume and non-legume crops), involving annual and perennials may help overcome the effects of water scarcity. However, water use pattern and water productivity should be given the highest priority when selecting crops for dryland cropping systems. For example, chickpea had the lowest unproductive water use and was more responsive to water supply, whereas canola was less responsive water supply but had the highest unproductive water use[7].

### 3.5 Use of mulches

Mulching can be effective in responding to water scarcity by limiting soil evaporation, relegating soil temperature, preserving soil moisture, buffering soil from hot and cold environments and insulating the soil.

### 3.6 Promotion of agroforestry

The promotion of agroforestry land use system in which woody species (e.g., trees and shrub) grown using different land configurations, such as runoff water storage, contour cultivation, contour furrow, contour bunding and broad bed furrow, could enhance soil WUE in dryland agroecosystems. In addition, agroforestry practices that incorporate herbaceous species between rows of perennials could increase drought resilience by enhancing WUE in dryland areas[8].

### 3.7 Mixed crop-livestock systems

A managed crop-livestock system will improve soil WUE because intensive grazing can reduce soil hydrological properties. According to de Andrade Bonetti et al.[9], pastures with 10 and 20 cm sward height decreased water availability, whereas moderate grazing of pastures with 30 and 40 cm pasture sward height increased water availability, improved water infiltration and limited soil degradation.

### 3.8 Policy options for improvement

Region-specific groundwater policies are required for agricultural irrigation to oppose climatic change externalities and lower water tables in heavily irrigated regions. Mitter and Schmid[10] reported that efficient groundwater policies can help replenish groundwater in drylands, whereas restrictive policies lead to lower water extraction from agriculture, reducing regional net benefits for agricultural production and conserving rainfed croplands. Successful implementation of groundwater policies is challenging. Consequently, proactive management and regional expert knowledge and experience are required to fulfill the task of policy establishment. Coherent, integrated agricultural, climate and water policies, including realistic and quantitative water conservation should be established for successful policy interventions. These policies may be more likely to be implemented as intended by the key stakeholders and prioritizing the steps in a cost-effective manners during regularizing the policies.

### 3.9 The ecosystem approach: collaboration for integration

Ecosystem services refer to the ability to spatially incorporate multiple biophysical environment factors for building cooperation between policy and science when seeking a solution to climate challenges, including dryland water scarcity. To achieve long-term solutions to drought-related risks, ecosystem service-based drought adaptation and feedback mechanisms should be planned and understood with timely spatiotemporal assessment.

## 4 CONCLUSIONS

The diminishing capacity of dryland areas to support livelihoods is widespread and well demonstrated. Agricultural production in dryland areas is facing the challenges of scant water supply, so developing sustainable cropping systems is urgently required to improve soil WUE and crop productivity. This requires addressing the underlying drivers of dryland production and their management at local, regional, national and global scales using different agriculture practices and genetic techniques to offset the impact of drought stress. In addition, biological and physical factors that interact to enhance WUE in dryland agroecosystems would pay dividends in terms of advancing our knowledge and skills.

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