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*Corresponding author
Murali K Darapuneni, Department of Plant and Environmental Science, Rex E Kirksey Agricultural Science Center, New Mexico State University, USA

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Opinion Article

Strategies to Improve Crop Productivity of Semi-Arid Cropping Systems for Food and Energy Security

Murali K Darapuneni*

Department of Plant and Environmental Science, Rex E Kirksey Agricultural Science Center, New Mexico State University, USA

Abstract

Semi-arid environments across the globe are low in agricultural production due to several input and management deficiencies. This article focuses on the most limiting factors of semi-arid crop production and some of the ways to address these issues with effective management decisions. Successful implementation of such suggested strategies can improve the productivity, sustainability, and economics of semi-arid agricultural production systems.

Introduction

Water is a deciding and foremost limiting factor of crop production in rain-fed semi-arid environments. The food crop choices in these environments are limited rather challenging due to the scarce soil moisture to meet the crop water demand in the growing season. The moisture limitation in coupled with high demand for evapotranspiration in the semi-arid environments makes the crop production almost impossible in approximately 40% of the arable land area around the world, including majority of the semi-arid acreage of United States, affecting the food and energy security of 700 million people (*Stewart, B.A*., Dryland Agriculture Institute). In addition to the water limitations, supplementation of nutrients in the form of expensive fertilizers is risky due to frequent crop failures triggered by unpredictable weather conditions.

Semi-arid climates in the US are found in the parts of Great Plains, parts of Texas and New Mexico, the intermountain basin of Nevada, parts of Western Washington and Oregon, and sections of neighboring states. The rainfall in most of these regions ranges from 10-20 inches.

Strategies to Improve Crop Productivity

Both crop choices and crop production capacity of semi-arid environments are often limited due to scarce input supply. Efficient utilization of limited resource capability such as land and water in those environments is untapped in most cases, leading to decreased efficiency of water and crop productivity per unit area. Improving the grain and biomass productivity per unit area with finite resources is a task in the newly emerging world for meeting the future food and energy demand of burgeoning population. This task can be achieved by: 1) modification/replacement of inefficient existing system for food security 2) Strategy for clean energy production in the semi-arid environments. Identifying the region specific and highly adoptable food and energy crop choice by addressing the issue of efficient use of water, the most limiting factor of semi-arid crop production, is critical to achieve maximum productivity in a given semi-arid cropping system.

a)Modification/replacement of existing cropping system to meet the food security

In the semi-arid environments of Southern Great Plains of US and world, most of the existing cropping systems are proven to be inefficient in using the annual precipitation. Traditionally, a fallow period (11 to 16 months in the case of traditional winter wheat cropping systems) is practiced in the current cropping systems with an objective of saving some soil moisture to the next season crop. However, during this lengthy fallow period, most of the soil moisture accumulated from the peak precipitation months is subjected to non-transpiration losses making the system more inefficient in utilizing the precipitation moisture. Moreover, in dry summers, the top soil is subjected to considerable erosion due to lack of cover on the ground, causing irreversible long-term degradation of soil physical and chemical characteristics. Nitrogen is another limiting factor of crop production in semi-arid environments. In general, the nutrient availability is dependent on soil moisture. Considering the unpredictable nature of the weather, supplementing nitrogen in the rain-fed conditions is often risky and non-profitable management decision for most of the existing cropping systems. Considering the disadvantages of existing cropping system, a new strategy is needed for efficient utilization of stored soil moisture and to conserve finite resources of soil while maintaining the production sustainability.

Finding a crop rotation choice that fit into the traditional cropping system with high water use efficiency in combination with the possible nitrogen supplemental capacity while maintaining the environmental sustainability is critical to improve overall productivity of the system in those semi-arid environments. Some ideas to address these problems are:

a) Identifying and introducing the region specific crop diversity into the existing cropping system that improves water and nitrogen use efficiency, soil conservation, and to provide dual-purpose (grain and forage) benefits for food and forage security. The crop rotations will be evaluated for their water use efficiency under both dryland and limited moisture supplementation scenarios.

b) Modelling the production capacity of various crop rotations in relation to the major limiting factors of the tested semi-arid environments.

Example: Improving the productivity of semi-arid winter wheat cropping system in the US

In the rain-fed semi-arid environments of US, the average annual rainfall is often less than 16 inches. Expanding efforts of selection of suitable crops/cropping systems to replace the fallow period in these environments are extremely limited and rather challenging due to scarce soil moisture. The moisture limitation coupled with high demand for evapotranspiration in the semi-arid environments makes the crop production almost impossible, especially during drought years. Although the majority of the production gap can be attributed to the severity of the drought, part of the problem is inefficiency in using soil and precipitation water. Most effective way of addressing this problem is modification/replacement of inefficient existing system with more relevant innovative cropping system with the introduction of water efficient rotation/cover/opportune crops (diversity) to utilize the precipitation or snow moisture received during the wet months of the year. This strategy will not only serve the local agricultural/livestock needs but also help the enhancement of the agriculture-based economy. Addressing the water issue of rain fed semiarid agriculture in through innovative solutions of cropping systems and crop selection is critical to achieve the maximum productivity and sustainability in these environments. An illustration of enhancing winter wheat cropping system productivity and sustainability with the introduction of appropriate rotation/cover crop choice is presented in Figure 1.

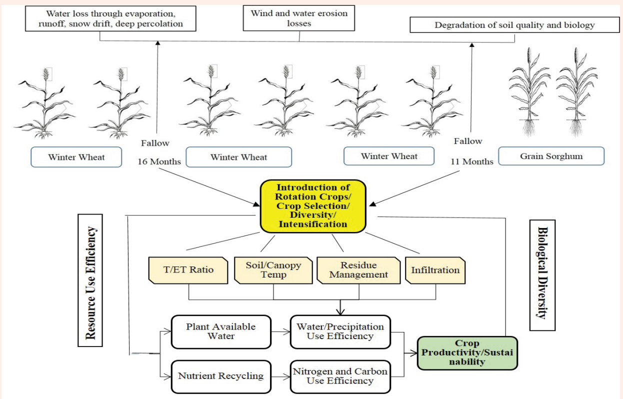

Figure 1: Illustration of strategy for improving the productivity of winter wheat cropping systems through crop selection/ innovation.

A general conception is that partial/full replacement of fallow with a crop component in existing wheat rotations affects the soil water content for the following cash crop. Although it is true to some extent, the substantial moisture loss from fallow through evaporation in the peak precipitation months in addition to the water use of weed populations in the fallow ground can be even more damaging in terms of water use efficiency under dryland conditions [1]. For example, fallow efficiency of winter wheat-fallow system in the US ranges from 15-39% [2,3]. In addition, fallow cultivation under dryland conditions can pose a considerable threat to long-term soil quality and sustainability. Therefore, an evaluation of water and nutrient use, yield potential, and rotation compatibility of cover crops should be conducted before making any final recommendations.

In recognition of synergism that exists between the sequence crops in a cropping system/rotation [4], it is critical to identify a cover/ opportune/rotation crop choices those meet specific water balance requirements of the given environment without compromising the production capability of the subsequent crop and/or overall cropping system. In a cover crop scenario, with limited available soil moisture, it is also important to know the suitable crop to grow in the previous season and extent of growth to be allowed before its termination without compromising the yield of the subsequent cash crop. In opportune and rotational cropping, the crop growth can be extended even up to the final harvestable product, given the moisture conditions are favorable. For this, estimating the amount of water consumption for achieving each growth stage i.e. early vegetative growth stage to late maturity stage is critical. Developing such water use budget for various cover/rotation/opportune crops can be extremely useful in planning the water balance of cropping system components and their expected yield levels.

b)Strategy for clean energy production in the semiarid environments.

This strategy includes:

a) Testing water use efficiency of green energy crops both bio-diesel and bio energy crops in various dryland and limited irrigation semi-arid environments across the Western US and world. Based on the region specific crop recommendation and possible expansion of bio energy acreage to underutilized marginal areas, the unit area productivity can be improved drastically

b) Modelling the production capability with respect to water use efficiency under both dryland and limited irrigation scenarios.

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