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Potentials of Agronomic Practices in Soil Water Management for Sustainable Crop Production under Rain Fed Agriculture of Dry Lands in Sub-Sahara Africa

S Lamptey*

Department of Agronomy, University for Development Studies P. O. Box TL 1882, Tamale, Ghana

***Corresponding author:** Dr S Lamptey, Department of Agronomy, University for Development Studies P. O. Box TL 1882, Tamale, Ghana, E-mail: naalamp2009@yahoo.com

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Abstract

Water is one of the very important inputs necessary for the production of food crops. Food security and rural livelihoods are essentially linked to the accessibility of water for crop use. Eighty percent (80%) of the world's global agricultural land area is under rain-fed; this contributes to 58% of the world's staple foods. It is known that 97% of the moisture needs of crops in Sub-Saharan Africa (SSA) are fulfilled mainly by water stored in the soil through rainfall. Rainfall is the cheapest source of natural water supply for agriculture in SSA however, due to highly unpredictable and sporadic seasonal rainfalls, water stored in the soil, in most cases, cannot meet the requirements for crop growth and development resulting in lower crop yields with consequent food insecurity. It is important that water in rain-fed agriculture is used efficiently and effectively through interventions that conserve soil water. Thus, water productivity under rain-fed agriculture must be enormously improved particularly in dry climate by farming practices that conserve soil water alongside water use efficiency in crops. Implementation of crop production systems where less water is use, are the current necessity in achieving sustainable production of food. Therefore, water management through agronomic practices is a critical constituent that needs to be adopted in the current challenge of rainfall variability, climate change and expected increase demand for food. This paper highlights potentials of some agronomic practices such as crop selection, mulching, fertilization, and soil tillage in improving soil water use for sustainable crop production.

Keywords: Soil water; Drylands; Rainfed; Agronomic practices

Introduction

Majority (80%) of the world's land area for agriculture is rain-fed, accounting for 58% of the world's staple foods (SIWI 2001). Dry lands in Sub-Saharan Africa, which includes arid, semi-arid and sub-humid areas account for nearly one-half (43%) of the regions land area, three-quarters of the poor and 50% of population most of whom depend on agriculture. The number of Africans dwelling in dry land regions is anticipated to rise from 460 to almost 800 million by 2030. The economies of most Sub-Saharan African (SSA) countries rely on agriculture which is found to be five times more active in decreasing poverty than non-agriculture growth in low-income countries but 11 times more so in SSA.

About 97% of crop production in SSA is under rain-fed hence; the water needs of crop in SSA are achieved mainly by seasonal rainfall water stored in the soil [1]. Water is highly important for crop production and remains a critical input limiting global food production. Although the concept of irrigation is not new, according to Makin, about 5% of agricultural land (6 million hectares) is under irrigation. The low irrigation patronage is a result of lack of informed policies and investments that are region specific considering landscape and economy (IFPRI 2010). According to Rockstrom, rain fed agriculture in SSA will continue to play an important role in the provision of food and livelihoods. The challenge is that, rainfall is highly unpredictable and sporadic, this result to water deficit that negatively impact on crop growth and development resulting in low yield and productivity. Rainfall highly correlates with yield, especially in rainfed agriculture as illustrated in Figure 1.

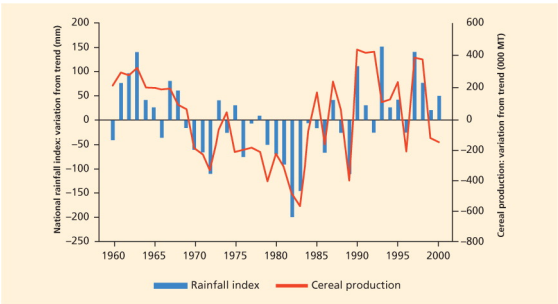

Figure 1: Dryland cereal production and rainfall in Burkina Faso, 1960-2000. Source: Ward. Note: mm=millimeters; MT=metric tons.

Water resource has an important role to play in food security challenge and the improvement in water management is critical to closing yield gaps and resulting to improved food security. Sustainability of agriculture has been hindered by water stress in all parts of the world; especially in SSA [2]. According to Borgomeo, a decrease in seasonal rainfall generally translates into a decrease in yield. Shortage of water resources and it's limitation in crop production is more compounded in SSA. According to Moyo, low use of irrigation and over-dependence on rain-fed agriculture in Africa accounts for the low agricultural productivity.

The risk of food insecurity as a result of climate change and variability is increasing among many farming communities and expected to hit harder. West Africa has already experienced a decrease of 20%-40% in annual rainfall amount in the last decade and expected

to worsen in future. A meta-analysis of 52 studies indicated yield losses of 5%, 10% and 15% in maize, pearl millet and sorghum respectively because of climate variability in Africa by 2050.

The desire to achieve food security and reduce poverty should be intensely linked to water management because it can more than double agricultural productivity in rain-fed areas with low yields. With climate change and expected increase in demand for food, more importance need to be channel on addressing management of water in rain-fed agriculture as a key determinant for agricultural production and productivity [3]. Increase crop water productivity in rain-fed agriculture will ensure crops builds resilience for water related risk and uncertainties in the future. The key to successful rain-fed agriculture is to efficiently use stored rain water in the soil and improve its productivity through improved agronomic practices.

A great deal can be done to reduce water losses and improve the efficiency of rainwater use through agronomic practices. A number of studies have shown that some agronomic practices can increase water availability to plants. For instance, according to Mary and Majule enhancing soil tillage practices, soil fertility upgrading and mixed cropping is considered important adaptation techniques towards drought.

The objective of this review was to highlight the potentials of some agronomic practices which have positive influence on soil water management for improved crop productivity.

Importance of Soil Water in Crop Production

The main source of water for crop production in SSA is rainfall. This makes seasonal rainfall variability has a deep effect on soil water availability especially for crop production. Every crop requires soil water for germination, growth and development as well as meeting its potential yield [4]. Also, the amount of water required by each crop varies with both its excess and shortage directly affecting plant growth, development and yield. The effect of long term soil moisture stress includes cell enlargement and growth reduction, cellular and metabolic activities reduction, photosynthetic inhibition, decrease in chlorophyll, turgor loss and altered carbon partitioning. This eventually leads to a decrease in yield. According to Azhar, a reduction of chlorophyll content in the crop directly or indirectly influences the photosynthetic capacity of plants. This reduction in transpiration and photosynthesis is ascribed to plant reaction to water shortage by stomata closure.

Sources of soil water

Water Footprint (WF) is the volume of freshwater required for producing goods and services. It is the consumptive use of water, and it is divided into green and blue water components. According to Rost, green water accounts for 90% of all water consumed by agriculture in a process-based crop simulation models. Green water is the rains stored in soils for crop use. Fresh water in surface and groundwater bodies available for irrigation is referred to as blue water [5,6]. The sole source of water for global rain-fed agricultural system is green water. Therefore, improvements in green water management will improve water productivity of the global food systems especially in semi-arid regions of the developing world, where water productivity may be low Figure 2.

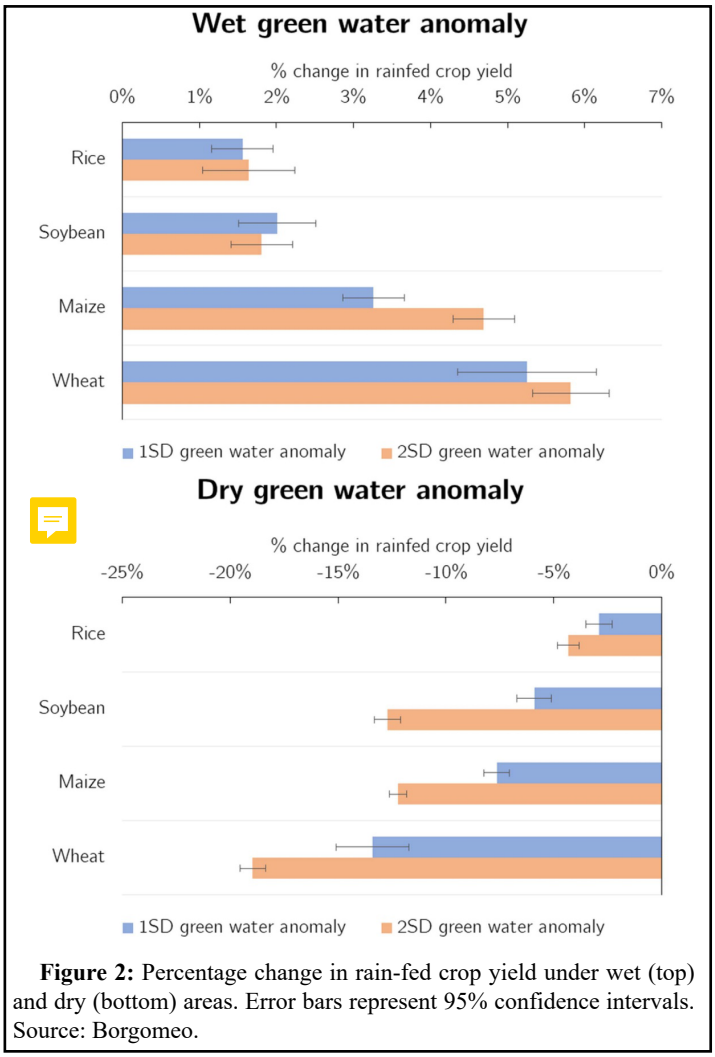

Figure 2: Percentage change in rain-fed crop yield under wet (top) and dry (bottom) areas. Error bars represent 95% confidence intervals. Source: Borgomeo.

Soil water management

Globally, the whole amounts of water kept within the soil are enormous, but at any given locality, they are comparatively small and quickly deplete through evapotranspiration. Drought, aridity, and climate variability threatens food security in many countries around the globe [7,8]. This has increased interest in various soil moisture management techniques in recent decades which can be an instrument to stabilize crop production under climate change. Countries in Africa have a relatively low ability to effectively manage with the changes that the climate brings and are thus has a great economic risk comparatively. It is of importance that water for food production is efficiently and effectively used as possible. Improving soil water management must focus on (a) increasing the productivity of water in crops, or (b) preserving crop production with reduced water use or increased efficiency through good management.

Improved water productivity in crops: Water Productivity (WP) is defined as the physical or economic output per unit of water application (World Bank, 2003). The overall water consumption of a crop is referred to as evapotranspiration which includes water loss as a result of evaporation and crop transpiration. Water productivity in crop or crop yield per unit of water consumed, is a key element in successful water resource management. Water Productivity (WP) improvement is one important approach for addressing the issue of

future water scarcity [9]. Water productivity under rain-fed agriculture, will have to extremely improve particularly in SSA to ensure food security for the teeming human population. Increased water deficits linked with overuse of surface water are threatening the sustainability of agricultural production in the region. Agronomic practices that improve water infiltration and storage capacity of the soil will improve water availability for crop use. According to Schmidt and Zemadim; Masunaga and Marques Fong, enhanced management of the soil can increase infiltration, reduce surface runoff, and additionally increase readiness of water and nutrients to plants.

Agronomic practices for improved soil water management

Recent studies have proved that cropping pattern have the potential to enhance water use efficiency, water productivity, and water footprint. According to Simpson, agronomic practices are management processes such as intercropping, contour cultivation, minimum tillage, mulching and manuring undertaken within the cropping area. Improved agronomic practices such as soil fertilization, soil cultivation, and crop selection can directly or indirectly improve infiltration, minimixe surface runoff, and additionally increase availability of water and nutrients to plants. The appropriate strategies to manage soil water must involve sustainable agronomic practices that enhance soil water while continuing to achieve improved yield [11]. There are a number of agronomic practices but concentrating on those that have the potential to improve water storage for crop use during the dry spells as well as after cessation of the rain is of great importance to dryland rain-fed agriculture especially in SSA. Some will be more appropriate than others according to local farmer preferences and local conditions. Therefore, wise area specific adoption of agronomic practices, specifically for enhanced soil water productivity such as crop selection, early planting, crop stand, different cropping systems, mulching and reduced tillage are highly important to cope-up with water shortage. Some of the agronomic practices that have the potential to improve soil water are discussed as follows:

Discussion and Conclusion

One of the suitable ways of addressing soil moisture deficit in rain-fed agriculture is through soil tillage which is also considered a soil water conservation practice. Improved water infiltration is critical for increasing water storage in semiarid and arid areas and the rate of soil infiltration is largely influenced by tillage systems. To effectively increase soil water content, proper tillage systems with minimum disturbance to the soil is essential. Conservation agriculture has been reported to increase crop productivity and conserve water. Sub-Saharan African countries have the potential to produce enough food to more than meet their own needs. Unfortunately, 95 percent of their potential cultivable land is rain-fed and most of which exists in dryland zones with highly variable rainfall. Water is critical to rain-fed agriculture and dry green water anomalies is more prevalent in dry areas such as SSA compared to wet green water anomalies in other continents. This is being compounded with climate change and its adverse effect on food security. The importance of agronomic practices such as crop selection, crop density, mulching, tillage practices and soil amendment as highlighted in this review can improve soil water use under rain-fed agriculture for increased and sustainable crop production in Sub-Saharan Africa.

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Conflicts of Interest

There is no conflict of interest.

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