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Original Research Article

Integrated soil, water and agronomic management effects on crop productivity and selected soil properties in Western Ethiopia

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ABSTRACT

Land degradation is a major challenge limiting crop production in Ethiopia. Integrated soil and water conservation is widely applied as a means to reverse the trend and increase productivity. This study investigated the effects of such integrated approaches at two sites, Jeldu and Diga, in Western Ethiopia. A split plot design with physical soil and water conservation in the main plots and agronomic practices in the sub plots was employed. Maize (*Zea mays L.*) followed by groundnut (*Arachis hypogaea L.*) at Diga, and wheat (*Triticum aestivum*) followed by faba bean (*Vicia faba L.*) were the test crops. Surface soils were sampled before sowing and after the crop harvest, and analyzed for selected parameters. Soil moisture content during the growing period was also monitored. The use of soil bund increased soil moisture content, and significantly ($P < 0.05$) increased days to flowering and maturity, kernel weight and harvest index, grain yield of the test crops, with the exception of maize. The improved agronomic practices (intercropping, fertilization and row planting) significantly ($P < 0.05$) increased grain yield of all the test crops. The effect of the treatments on soil parameters may require longer time to be evident. Although the increase in crop yield due to soil bund and the improved agronomic practices is eminent, economic analysis is necessary before recommending the widespread use of the improved options.

1. Introduction

Human induced land degradation is a serious global threat that increases vulnerability to climate change, especially in marginal agro-ecosystems with low and variable rainfall, steep slopes and depleted soil fertility with resultant low agricultural productivity (Scherr and Yadav, 1995). In Ethiopia, agriculture is a key livelihood source for over 85% of the country's population estimated to reach 101 million by 2016 and growing at 2.5% (Beyene, 2015; UN Department for Economic and Social Affairs: Population division, 2015). Agriculture accounts for 43% of national GDP, 90% of export revenue, 70% of the country's raw materials for industries and engaging 83% of the labor force (CSA, 2014). Thus, it plays a crucial role in life and livelihoods in the country.

Growth in agricultural productivity, which is influenced by anthropogenic and natural (mainly climatic and edaphic) factors could not match that of the demand. Land degradation coupled with the limited capacity of the land users to apply amendments is recognized as a major contributor to the lower productivity (Alemayehu, 2008; Erkossa, Awlachew, & Hagos, 2009; Erkossa, Wudneh, Desalegn, & Taye, 2015; Fanuel, Kibebew, Tekalign, Karltun, & Gebrekidan, 2016; Tireza, Eyasu, & Nata, 2013; Wudneh, Erkossa, & Devi, 2014). Although a considerable increase in crop production is reported in recent decades, studies show expansion of cultivated area is a major contributor to the growth (Alemayehu & Dorosh Dand Sinafikeh, 2011; Fanuel, 2015). However, as the prime lands, especially in the settled highlands are used up, expansion of cultivation is directed towards lands with different land uses, such as forest (Bishaw, 2001) or grazing lands (Olson & Maitima, 2006). Expansion of agriculture to new lands usually involves either moving into the areas adjacent to the currently cultivated lands or migration to other areas with different agroecological settings.

Regardless of the condition of the new land acquired this way, farmers attempt to produce the same traditional crops using the techniques that are not necessarily suitable for the new site (Erkossa et al., 2015). The attendant deforestation in tandem with undulating terrain and fragile nature of the lands and the heavy seasonal rains lead to erosion and deterioration of soil quality (Erkossa et al., 2015; Fanuel et al., 2016; Schmidt

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& Zemadim, 2015). A recent study demonstrated that loss of plant nutrients with eroded sediments from the fragile ecosystems in western Ethiopia following the conversion to agricultural use resulted in a significant yield reduction with an immediate harm to the income of the farm households (USD 220 ha^{-1} and 150 ha^{-1} due to the loss of N and P, respectively) (Erkossa et al., 2015). Another study in southern Ethiopia by Fanuel et al. (2016) also indicated the decrease in soil nutrients and crop yields on steep slope cultivated lands compared to lower landscape positions that was attributed to soil erosion.

Innovative land, water and crop management practices, including the use of soil and water conservation and improved agronomic practices such as intercropping, row planting and fertilization would increase crop yields and improve soil quality and enhance ecological and economic resilience reducing the need for further expansion of agricultural land. Studies show that soil bunds reduce surface runoff, increase infiltration and improve availability of water and nutrient to plants (Schmidt & Zemadim, 2015; Tadele et al., 2013; Tireza et al., 2013) and consequently contribute to higher crop yield (Soomro, Rahman, Odhano, Gul, & Tareen, 2009; Tadele et al., 2013), especially in areas where soil moisture is a key constraint (Kassie et al., 2008). In areas where soil depth and infiltration capacity are not limiting, contour soil bunds can help store water in the soil profile for use by crops during the dry spells as well as after cessation of the rain.

After accounting for the area taken out production due to their construction, Adimassu, Mekonnen, Yirga, and Kessler (2014) reported no significant yield increase due to the use of soil bunds in the short term despite the improvement in soil quality. In addition to the offset due to reduction in the effective growing area, this may be related to the local agro-ecological settings including the extent of soil degradation, the type of crop grown, the use of complementary agronomic practices such as the choice of suitable crop varieties, cropping systems, sowing methods and soil fertility management practices. For instance, in areas where fertilizers are used, the immediate increase in crop yield due to soil bund may be related to the avoided nutrient loss with runoff (Erkossa et al., 2015). Besides, if moisture is limiting, the effect of retained soil moisture on crop yield could be immediate.

Implementation of an appropriate agronomic practices complements the physical soil and water conservation measures such as soil bund to accelerate the return to investment through increased crop yield. Intercropping which is widely practiced by smallholder farmers in developing countries of Africa, Asia and South America enables better utilization of limited resources, and improves soil quality, particularly if legumes are involved (Conant, 2009; Muoneke & Asiegbu, 1997) and increase crop yield (Woodfine, 2009). The use of suitable crop species and varieties, proper planting method and application of the right types of fertilizers complement the positive effects of physical soil and water conservation. Therefore, the use of physical soil and water conservation in tandem with appropriate agronomic practices may be a judicious and cost-effective strategy to maintain soil quality and enhance crop yield. However, research based evidences regarding the effects of physical soil and water conservation options used in conjunction with agronomic practices in the humid tropical areas in western Ethiopia is not established. This study examined the hypothesis that the integrated use of soil bund and improved agronomic practices can enhance soil quality and increase crop yield.

2. Materials and method

2.1. Description of the study area

2.1.1. Location

The study was conducted in Jeldu (9° 02' – 09° 15' N & 38° 05' – 38° 12' E) & Diga (09°10′N – 09° 00′N & 36°10′E-36°30′E) districts in western Ethiopia, located at 115 km & 346 km, respectively to the west of Addis Ababa in the Blue Nile River Basin

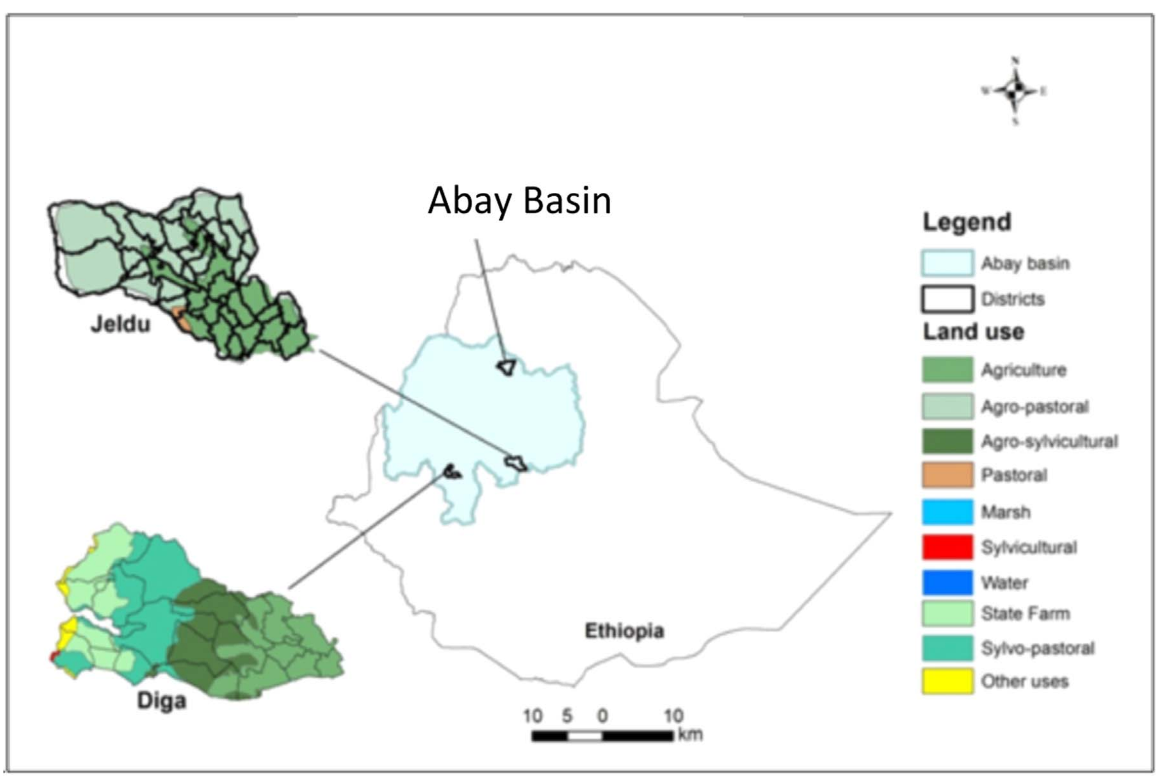

Fig. 1. Location map of the districts where the study was conducted.

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