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Increasing farmer's income and reducing soil erosion using intercropping in rainfed maize-wheat rotation of Himalaya, India

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ABSTRACT

Humankind faces the need to achieve sustainable agriculture production, meanwhile increasing crop yields and reducing soil and water losses. Soil conservation through intercropping or crop canopy management is widely accepted as one of the ways of diversifying crop yields in rainfed agriculture in sloping landscapes. Field experiments were conducted between 2009 and 2014 to evaluate the effects of one or two rows of cowpea/okra intercropped with maize (planted either in 90 or 150 cm row spacing) on productivity, profitability, and resource conservation on 4% sloping crop land in the Himalayas. During five years of experimentation, a total of 110 runoff events were observed in the maize crop grown in rainy months of June to September. The results showed that by growing one row of cowpea in between two rows of maize (90 × 20 cm), no effect was observed on the productivity of rainfed maize. Productivity of the succeeding wheat crop was enhanced by 13% which resulted in a higher net return (117 US$ ha^{-1}) than in a maize-wheat system. This system also reduced runoff and soil loss by 26% and 43%, respectively, compared to only a maize cropping system. Regression analysis revealed as runoff in maize crop increases, grain yield of succeeding rainfed wheat crop decreases due to the less availability of soil moisture.

1. Introduction

Realizing the importance of soils, the United Nations declared 2015 the "International Year of Soils" and mentioned that the soils (a non-renewable resource over the lifespan of a human being) are in danger because of widespread soil degradation which threatens the capacity of the soil functions to meet the needs of future generations for ecosystem services (Food and Agricultural Organization, 2015). Soils around the world are affected by land degradation processes as a consequence of the abuse of grazing, fire, mining or agriculture (Pereira et al., 2017; Rodrigo Comino et al., 2016a, 2016b). The growing world population needs an increase in food production, and therefore it is needed to increase crop yields to avoid famines and malnutrition. Furthermore, the expansion of cropland can have negative consequences for the sustainable use of land. The shrinking area of forest soils and increased soil erosion on steep slopes that were previously not cultivated and protected from soil erosion by forest cover are of major concern (Mwango et al., 2016; Singh et al., 2016). This is especially relevant in developing countries where the population growth is often higher than the increase in food production due to agricultural innovation; which means a large risk for food insecurity (Nyssen et al., 2015; Muluneh et al., 2016).

The mountains of the world are an important source of water and food; however the mountain ecosystems are more vulnerable to soil erosion because of their steep slopes. The Himalayan Mountains have fragile and diverse ecosystems which cover parts or fully eight countries of south Asia viz., Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan. It is home to over 51 million people who practice hill-slope agriculture for their livelihood. The Indian Himalayan region (IHR) due to steep slopes, fragile geology and intense storms is intrinsically prone to soil erosion (Sharma et al., 2014). Recent estimates indicate that nearly 39% area of the Indian Himalayas has a potential soil erosion rate of more than 40 Mg ha^{-1} yr^{-1}, which is much higher than the specified soil loss tolerance limit of 10 Mg ha^{-1} y^{-1} (Mandal and Sharda, 2011). Erosion due to runoff on sloping land causes loss of soil, water and nutrients, leading to low agricultural productivity and threatens agricultural and environmental sustainability (Singh et al., 2016). The findings in the Himalayan context can be seen as a study case that represents other mountain regions of the world (Nadal-Romero et al., 2016; Egarter-Vigl et al., 2017; Romero-Diaz et al., 2017). Recent estimates made by Sharda et al. (2010)

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