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Conventional and organic farming: Soil erosion and conservation potential for row crop cultivation

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ABSTRACT

The cultivation of row crops on mountainous farmland can generate severe soil erosion due to low ground cover, especially in the early growth stages. Organic farming, due to the absence of herbicides, can support the development of weeds and increase the ground cover compared to conventional farming. However, the benefits towards soil erosion, and the conservation potential of organic farming systems, in terms of herbicide application and weed growth, have not been investigated. Aim of this study was to identify how conventional and organic farming influence the erosion rate of soil, due to row crops cultivated on mountainous farmland in the presence or absence of agricultural chemicals. We measured multiple vegetation parameters of crops and weeds of conventional and organic farms cultivated with bean, potato, radish, and cabbage in a mountainous watershed in South Korea. We simulated the long-term soil erosion rates with the Revised Universal Soil Loss Equation (RUSLE) by using 13 years of recorded rainfall data in order to account for the temporal variability of monsoonal rainfall. We determined average annual erosion rates for the study area to be between 30.6 t ha^{-1} yr^{-1} and 54.8 t ha^{-1} yr^{-1}, with maximum values when radish was grown, due to the shorter growing period, higher soil disturbance at harvest, and low amounts of residue. Organic farming reduced soil loss for radish by 18% as a result of a high weed biomass density and cover at the end of the growing season. For potato, organic farming increased soil loss by 25% due to a reduced crop coverage, which is suspected to have been a consequence of crop–weed competition or increased herbivory associated with the absence of agricultural chemicals. Our results demonstrate that organic farming can potentially decrease the soil erosion risk for row crops because it supports weed development in the furrows, but it can also produce higher erosion rates when crop yields are reduced as a consequence, outweighing the protective effect of the weeds. However, the simulated erosion rates under both farming systems exceeded by far any tolerable soil loss. We conclude that organic farming alone cannot be used to effectively control erosion, and that both farming systems require additional conservation measures, such as winter cover crops and residue mulching, to sufficiently prevent soil loss for row crop cultivation.

1. Introduction

Intensive agriculture in mountainous landscapes can cause high soil erosion with negative impacts on farmland productivity and sustainability, as well as downstream water quality. The severity of erosion is strongly affected by the specific nature of cultivation within such areas. Vegetation above the surface protects the soil from the impact of raindrops and runoff, while the root system contributes to the internal stabilization of the soil (Morgan, 2005). Therefore, the crop type and management system applied by farmers plays a critical role in erosion control on steep agricultural land. The cultivation of row crops generally results in more serious erosion problems due to the high ratio of exposed ground, especially in the early growth stages, and due to the need for seedbed preparations (Morgan, 2005). More extensive groundcover can be provided by weeds, helping to further reduce soil erosion (Bennett, 1939), and Brock (1982) reported that weed control by the use of herbicides significantly increases soil erosion rates. Several other studies have also shown that a developed weed

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cover can effectively reduce soil loss compared to manual weeding or the application of herbicides (Afandi et al., 2002; Blavet et al., 2009; García-Orenes et al., 2009; Weil, 1982). Environmentally friendly farming systems rely on the minimization of chemical use, such as herbicides and pesticides, and can therefore play an important role in erosion control. Especially for row crops, the percentage of ground cover can be altered by weed growth, which could provide additional soil protection on organic farmland. Nevertheless, organic farming can also result in reduced crop yields due to crop–weed competition and herbivory.

Several authors have already described the potential effects of organic versus conventional farming on soil erosion control (Erhart and Hartl, 2010; Goh, 2011; Gomiero et al., 2011; Lotter et al., 2003). However, the individual studies used different methodologies to assess the erosion potential, and they observed very different impacts of the two farming systems. Lockeretz et al. (1981) calculated potential soil loss of organic and conventional farms by using the Universal Soil Loss Equation (Wischmeier and Smith, 1978) and found about one-third less erosion where organic farming was practiced, due to the different crop rotation systems in place. Reganold et al. (1987) investigated the long-term effects by comparing erosion measurements and topsoil thickness of two farms, and found an almost four times lower erosion on the organic farm as a result of different crop rotations and less tillage operations. Fleming et al. (1997) used soil samples from organic and conventional fields and calculated the soil erodibility, finding that organic farming could potentially reduce erosion for some soils. Also Siegrist et al. (1998) found, in a long-term field experiment, that organic farming increased the aggregate stability of the soil. However, organic farming did not sufficiently reduce soil erosion in their study. Also during a long-term field experiment, Eltun et al. (2002) observed lower erosion on plots with organic arable crops, but higher erosion on plots with organic forage crops. Auerswald et al. (2003) investigated the soil erosion potential also by using the Universal Soil Loss Equation, based on cropping statistics of conventional and organic farms, finding a slightly lower soil loss where organic farming was practiced, but concluding that there was no general effect, due to the large variability within both farming systems. Pacini et al. (2003) modeled soil erosion using GLEAMS (Leonard et al., 1987) on different farms, and they found that organic farming dramatically increased erosion compared to conventional farming, because of different crops and more intense tillage operations. In another study using rainfall simulations, Kuhn et al. (2012) reported lower erosion rates from organic compared to conventional soils.

Although the erosion control potential of organic farming could be identified in many of these studies, a general conclusion of the impact of the farming systems can still not be drawn. Soil stabilization might be an effect of long-term organic farming and may not apply for recently established organic farms. Large differences between both farming systems were primarily observed where farms used different crops and tillage operations. The effects of weed development associated with the two farming systems for the same crop as a specific consequence of the application or absence of agricultural chemicals has not been investigated.

The aim of this study was to identify the erosion control potential of conventional and organic farming systems on mountainous farmland in South Korea, which is highly susceptible to soil erosion due to the steep slopes and the cultivation of row crops. In the Kangwon Province in the northeast of South Korea, for instance, primarily radish and cabbage are cultivated (Kim et al., 2007), having short growing periods, thus leaving the farmland with low protection against rainfall and runoff (Y. Park et al., 2010). Conventional farmland management in South Korea is characterized by an intensive use of agricultural chemicals, including herbicides and pesticides (Kang and Kim, 2000; Kim and Kim, 2004). However, environmentally friendly farming systems (organic farming and no-chemical farming), which do not use agricultural chemicals are becoming more popular (Choo and Jamal, 2009; Kim et al., 2001). Due to governmental support, the number of organic farms in South Korea has strongly increased within recent years (Kim and Kim, 2004; Kim et al., 2012). The effect of different row crops on soil erosion in Korea has previously been studied over many years by the National Academy of Agricultural Science (NAAS) (Jung et al., 2003). Other studies investigated the effect of planting time and vegetation cover (Cho et al., 2010) or the erosion control potential of cover crop cultivation together with row crops (Kim et al., 2008; Ryu et al., 2010), but the impact of vegetation development associated with conventional and organic farming needs further investigation.

We formulated the following hypotheses: (1) organic farming increases weed coverage for row crops due to the absence of herbicides, and (2) the protective effects of weeds control soil erosion for organic farming. To test the hypotheses, we measured multiple vegetation parameters of four major row crops and the associated weeds on both conventional and organic farms in a watershed in the Kangwon Province of South Korea, and we determined the potential resultant soil loss amounts using the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997). To better understand the long-term effects of the farming systems, we considered the regional climate development, as soil loss rates associated with crops and farming systems are highly variable depending on the planting and harvest times and the occurrence of erosive rainstorm events. The majority of annual rainfall on the Korean peninsula is concentrated in the summer monsoon between June and August (J. Park et al., 2010) and hence, the annual soil erosion rate may be dependent on only a few extreme events. Choi et al. (2008) observed an intensification of extreme rainfall events in Korea, and found a strong change in temporal distribution over the years, and Kim et al. (2009) reported a large variability in precipitation during the monsoon season. Hence, the variation in rainfall patterns and intensities can therefore result in highly variable erosion rates for similar crops and farming systems between different years. The severity of erosion is also controlled by other factors, such as the level of soil disturbance during harvest and the amount of residue remaining on the field (Toy et al., 2002). Therefore, we used long-term weather station data to account for the variability of monsoonal rainstorm events, and we simulated different scenarios to include variable planting dates and harvest operations for the different row crops and farming systems.

2. Materials and methods

2.1. Study area

This study was conducted in the Haean-Myeon catchment in the Kangwon Province of South Korea (Fig. 1). The catchment is located within the watershed of the Soyang Lake, which is the largest reservoir in South Korea (Kim et al., 2000). The reservoir is affected by high amounts of nutrients from the Soyang River largely due to eroded soils from agricultural areas within the watershed (Kim and Jung, 2007; J. Park et al., 2010). The Haean catchment is a major agricultural hotspot area, which substantially affects the trophic state of the reservoir (J. Park et al., 2010). The total area of the catchment is 64 km^2, of which 58% are covered with forest and 30% by agricultural lands (22% dryland fields, 8% rice paddies). The remaining 12% consist of residential areas and seminatural areas, which include grassland, field margins, riparian areas, and farm roads. The topography of the study area is characterized by flat areas and moderately steep slopes in the center of the catchment, and high slopes at the forest edges. The terrain is highly complex with a variety of different hillslopes and flow directions. The soils of the Haean catchment are dominated by *Cambisols* formed from weathered granite. They are highly influenced by human disturbances. Especially dryland fields were modified by the replenishment of excavated material from nearby mountain slopes in order to compensate for annual erosion losses (J. Park et al., 2010). The average annual precipitation in the Haean catchment is 1599 mm (1999–2011), of which more than 65% are concentrated in July, August, and September.

For this study, 25 field sites were selected, which included the four major dryland row crops, bean (*Glycine max*), potato (*Solanum tuberosum*), radish (*Raphanus sativus*), and cabbage (*Brassica rapa* and