Erosion and Productivity

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INTRODUCTION

Land productivity is influenced by many factors including sunlight and precipitation, but the most productive land can be altered by a simple process like erosion. Although soil erosion is a natural process, it creates serious problems, both environmental and economical, worldwide. Soil erosion and deposition of eroded material have a detrimental effect on soil and crop production and on surface water quality. Erosion causes soil degradation by removing topsoil, which is often rich in organic matter, and by reducing the total depth of the soil profile. Additionally, erosion causes off-site water contamination by transporting agricultural chemicals, such as pesticides, fertilizers, and naturally occurring minerals or biologically derived nutrients, to rivers and lakes. Therefore, it is essential that we reduce soil erosion and understand what effects it may have, so that to the extent possible we can minimize the harm caused by erosion.

The erosional process alters important soil physical, chemical, and biological properties necessary for optimal crop production.[1] It is often agreed that the main impact of erosion on soil productivity is caused by changes in soil chemical properties (i.e., fertility); however, soil physical (i.e., water holding capacity) properties undergo significant changes that are often overlooked. Fertilizers and manures have been used with varying levels of success to restore the fertility of eroded land, and manures might restore some physical properties such as water holding capacity and structure. However, the total soil depth is irreplaceable. It is universally accepted that the long-term productivity potential of an eroded soil is lower than that of an uneroded one. Simulation models of soil erosion and changes in long-term crop productivity for various regions of western Europe estimate that productivity could drop as much as 30% for soils with a shallow profile, less than 75 cm, by 2100.[2] However, these estimates are somewhat conservative since they only take into account soil depth, and not changes in soil organic matter and nutrient losses.[3]

EROSION AND CROP PRODUCTION: SOIL PHYSICAL PROPERTIES

Erosion is defined as the detachment and movement of soil by water, wind, or ice. Many factors affect the erosional process; however, the type of soil, ground cover, and landscape are considered the most important ones. One of the most noticeable effects of soil erosion is the reduction in organic matter of the surface soil layers.[4–8] Since organic matter plays a crucial role in soil structure and in the formation of soil aggregates,[9–12] it is not surprising that researchers have found a decrease in aggregation and aggregate stability in eroded soils.[5–7] A reduction in aggregate stability can result in decreased water infiltration rates, and thus reduced water recharge of the soil profile for plant use and groundwater recharge. Additionally, a decrease in aggregation can hamper crop-seedling emergence, root growth and development, and tillage operations through the formation of soil surface crusts and increases in soil bulk density.[13–17]

Scientists have found a correlation between reduced crop yields and decline in organic matter contents in eroded soils. 20 yr after soil desurfacing, Lindstrom et al.[4] found a decrease in organic matter levels in the Ap horizon (surface soil) with increasing depth of topsoil removal. This decrease in organic matter was accompanied by a decrease in corn grain and stover yields, as well as an increase in soil bulk density of surface and subsurface horizons. Similarly, Schumacher et al.[14] found a reduction in organic carbon, in the Ap horizon, of about 10% from moderate to severe erosion areas in a study conducted to examine properties of 11 soils in the North Central Region of the United States. However, scientists have also reported an increase in organic carbon from moderate to severe erosion in 2 of the 11 soils studied. Increases in organic carbon with increasing erosion level are infrequent, but can be attributed to increased clay contents in the surface of eroded soil (from the exposure of subsoil rich in clayey materials), and consequently to an increased interaction between soil particles and organic carbon, making organic carbon more stable in the soil.[18–20] Nevertheless, reductions in corn yields on eroded areas were observed for the 11 soils in the Schumacher et al.[14] study. Lowery et al.[16] found a significant increase in bulk density of the Ap horizon, as well as an increase in clay content, decreases in plant available water, and decrease in hydraulic conductivity of saturated soil for the same 11 soils investigated by Schumacher et al.[14] Corn grain yield decreased by 30% following removal of the surface 20 cm of a silty clay loam soil to simulate erosion.[7] Since

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fertilizer was applied at twice the rate in the desurfaced areas, reduction in grain production was attributed to decreased soil organic carbon, crack formation, drought stress, and corn disease.

Crop yield is generally related to the amount of water that is available to a crop from the soil. Greater capacity to hold water because of greater clay content can result in greater crop yields on eroded land in years when rainfall is less than normal.[21,22] Since the amount and time of precipitation have great effects on crop yield, the effects of erosion are more pronounced in some years than others.[23]

Because of the impact of soil water on yield, position in the landscape has an influence on productivity.[21–25] In general, linear slopes are more eroded than foot and head slopes. This relationship between landscape position and erosion adds to the difficulty of assessing the effects of erosion on crop productivity. On sloping terrain, landscape variations contribute to the many factors determining where water infiltrates and where it flows after a rainfall event. In general, water tends to run off steep sloping areas and infiltrate in lower landscape positions. Thus, lower landscape positions tend to be more productive than steeper slopes.[8,24]

In addition to landscape position, poor plant production can be attributed to changes in soil-water holding characteristics which can be altered by erosion.[26] Water is held in the soil under greater negative pressure, making it less available for crop use, with increasing level of erosion because of increases in clay content in the exposed lower horizons. Damage to soil physical properties caused by erosion has a significant negative impact on crop production.[6,13,27]

EROSION AND CROP PRODUCTION: SOIL CHEMICAL PROPERTIES

Organic matter not only plays an important role in shaping the soil physical characteristics, but also affects soil chemical properties. It serves as a source of plant nutrients and aids in the soil pH buffering capacity. Humus, or stable soil organic matter, is one of the most chemically active components in soil and serves as a major reservoir for charged molecules, reducing the loss of nutrients and pesticides by leaching.[18–20] When organic matter is reduced by erosion, there is a greater potential for leaching of nutrients which leads to a decline in soil productivity.

Lack of phosphorus (P) has been linked to reduced crop yields in eroded soils. Delays in emergence, plant development, and yield have been recorded in eroded areas.[4,28] This has been attributed to reduced P uptake by plants grown on eroded land.[29]

Nutrient loss from erosion has been described as one of the major causes of soil fertility depletion in Kenya[30] and in the Phillippines.[8] Soil-water erosion is associated with plant nutrient removal, especially P. Sediment collected from eroded areas is usually richer in P than the original soil. Changes in soil pH, organic carbon, and total nitrogen can also be correlated to soil loss by erosion. Thus, soil erosion removes necessary plant nutrients. However, when nutrients are lost by erosion, the loss can be compensated for by fertilizer application, but loss of soil organic matter is not easily replaceable and affects soil chemical and physical properties. As previously noted, organic matter improves soil-water holding capacity and aggregate stability.

CONCLUSIONS

Since important soil properties for plant production are degraded by soil erosional processes, crop productivity is often reduced in eroded soils. Even though intensive farming practices can mask some of the effects of erosion on crop production, erosion effects are still real and detrimental to long-term soil quality and production. Soil erosion mainly impacts and changes soil chemical and physical properties. Most of these changes are caused by the removal of surface soil layers and the subsequent exposure of lower soil horizons. Major changes in soil properties include soil particle size distribution and organic matter content. Changes in soil particle size distribution depend on the existing soil conditions, but in most cases, clay content increases with increasing erosion. Since surface soil rich in organic matter is removed during the erosional process, organic matter content is reduced in eroded soils. Changes in these two soil characteristics usually create changes in other important soil properties, such as bulk density, aggregation, water retention, hydraulic conductivity, CEC, pH, and nutrient availability, among others. Changes in soil particle size distribution are difficult, if not impossible, to reverse, and can be considered more or less permanent. However, organic matter contents can potentially be increased by applying organic matter sources. One such source is animal manure. Increases in organic matter can help to ameliorate the effects of erosion on soil properties, especially soil physical properties. Therefore, cattle manure has been proposed for use on eroded soil as an amendment to ameliorate the effects of erosion. Furthermore, as already discussed, aggregate formation and stability are aided by soil organic matter. Thus, organic matter can potentially increase a soil's resistance to erosion.

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