SOIL EROSION ON AGRICULTURAL LAND

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Abstract

Maintaining the productivity, the filter and buffer capacity of our soils is a major interest of our society. Heavy rainstorm producing runoff and soil loss decrease amount of organic substance, clay particles and nutrients in our soils. Transport and deposition of eroded material as well as substances dissolved in runoff and attached to soil particles lead to negative impacts on agricultural land and adjacent water bodies. Decreased fertility and increased production costs of agricultural commodities do have an impact on land values. The off site damages caused by erosion affect not only land owners but also the public at large. Without future protection measures large portions of our land used for agriculture will turn into economic and ecological burdens. We have to keep in mind that soil and water quality are inherently linked. Conserving or enhancing soil quality is a fundamental step to improve water quality.

Keywords agricultural ecosystem, contour farming, land use, nutrient loss, process-oriented models, soil erosion, soil fertility, soil protection, suspended sediments, topographic conditions
INTRODUCTION

The adjustments and modernization of agriculture in the last three decades led to considerable changes of the agricultural landscape. To increase economic efficiency changes were made mainly in land use, crop production, crop rotation, fertilizer management and pest control. These human impacts affected the stability of agricultural ecosystems. Beside others, soil erosion potential by water and wind increased in many parts of the world resulting in negative changes of soil and water resources.

EFFECTS OF SOIL EROSION

Main soil erosion processes can be divided into detachment, transport and deposition of soil particles. Soil, land use and topographic conditions determine which process is dominating. Within a watershed all processes occur. Their magnitude can vary greatly. Although high erosion rates can be reached in a watershed, not all sediments may reach nearby water bodies due to deposition.

Soil erosion by wind and water has many negative economic and ecological effects. These effects can occur directly on the affected field (on site effects) as well as on nearby fields, water bodies or landscapes (off site effects). On site effects include impacts on soil, on crops, on soil organisms, while off site effects include effects on aquatic ecosystems, damages on buildings, structures and landscape.

Soil loss reduces the depth of the root zone and therefore changes considerably the water and air balance of the soil. As the bulk of nutrients and organic matter (soil microorganisms) is stored in the top soil most of it is lost when erosion occurs (Liu et al., 2000). This loss of active soil surfaces (organic carbon and clay particles) reduce the filter and buffer capacity of the soil, diminish soil fertility and increase potential of soil and groundwater contamination by pollutants.

1 mm of soil loss correspond to appr. 15 t soil per hectare. On average, 1 ton eroded soil contains 14.1 kg organic carbon, 1.6 kg total nitrogen and 0.7 kg total phosphorus. Even relatively small amounts of eroded material which have, in place, very little detrimental impact on soil quality, can have very negative effects on ecology of aquatic ecosystems because of high concentrations of nutrients and pollutants in solution and adsorbed on soil solids.
In Austria, since 1994 field experiments were performed to study effects of different tillage systems on runoff, soil loss, nutrient and pesticide transport. Treatments consisted of 1) conventional tillage (CV), 2) conservation tillage with cover crop (CS), and 3) no-till with cover crop (NT). No significant differences in total runoff during growing season were measured between the three tillage practices (Figure 1). Overall average annual soil loss ranged from 2.4 to 8.7 t ha\(^{-1}\) with highest amount for conventional tilled and lowest for no-till plots (Figure 1). Nutrient losses from April to October were 13.0 kg ha\(^{-1}\) a\(^{-1}\) for CV, 8.4 kg ha\(^{-1}\) a\(^{-1}\) for CS, and 4.2 kg ha\(^{-1}\) a\(^{-1}\) for NT (Figure 2). Corresponding values for phosphorus were 6.4, 3.0, and 1.6 kg ha\(^{-1}\) a\(^{-1}\) (Figure 2). Beside N and P, another main soil quality parameter, organic carbon (OC) was transported off the field. All sediment samples contained up to 1.2% higher OC-contents than in situ soil. In total between 35 and 110 kg OC were lost by erosion from fields (Figure 3). Conservation tillage and no-till management were able to reduce pesticide losses between 23 and 99 % (Figure 4). Investigations show that beside pesticide characteristics, timing of erosive rainfall influences amount of pesticide losses from the field.

Fig. 1. Runoff and soil loss from different tilled plots

Fig. 2. Nitrogen and phosphorus losses from different tilled plots

Fig. 3. Organic carbon losses from different tilled plots

Fig. 4. Pesticide losses from different tilled plots
Long-term measurements in Zhifanggou watershed, Shaanxi Province, PR. China, showed that average long-term annual soil loss was appr. 140 t ha\(^{-1}\) which equals appr. 1 cm soil loss per year. To reduce soil erosion they started an initiative to change land use. Fields planted with corn and small grains were converted to grassland and apple orchards. Additionally grazing by sheep and goats was reduced because of the negative impact on soil structure (compaction). They also introduced glasshouses where they grew vegetables in a very efficient way. All this resulted in a reduction of soil loss by 74% to 36 t ha\(^{-1}\) while overall yield increased by 370% (Table 1).

Table 1. Land use, average yield and average soil loss in the Zhifanggou watershed, Shaanxi Province, P.R. China

<table>
<thead>
<tr>
<th>Year</th>
<th>Agricultural use</th>
<th>Grassland</th>
<th>Trees</th>
<th>Average Yield kg ha(^{-1})</th>
<th>Average soil loss t ha(^{-1}) a(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>1</td>
<td>0.1</td>
<td>0.1</td>
<td>444</td>
<td>140</td>
</tr>
<tr>
<td>1997</td>
<td>1</td>
<td>1.6</td>
<td>2.1</td>
<td>2100</td>
<td>36</td>
</tr>
</tbody>
</table>

Input of sediments, nutrients and pesticides in water bodies have negative impact on the quality of aquatic ecosystems. High concentration of suspended sediments in streams diminish their recreational uses because pathogens and toxic substances commonly associated with suspended sediments are threats to public health. Suspended sediment is also harmful to stream biota; it inhibits respiration, diminishes the transmission of light needed for plant photosynthesis, and promotes infections. In the Chinese Loess Plateau, total soil loss in recent years is estimated to be about 2 200 million tons annually. Three-quarters of the total soil loss is transported to the lower reaches of the Yellow River (Wen Dazongh, 1993). Therefore average sediment concentration of Yellow River is 38 kg m\(^{-3}\), 20 times higher than of the Nile River in Egypt and 38 times higher than of the Mississippi River. During periods of floods, silt content in the Yellow River can rise to more than 650 kg m\(^{-3}\). Sediment depositions in stream channels, reservoirs, estuaries, and water conveyances reduces the capacity of the water bodies and structures to perform their prime functions and often require costly repairs and treatments.

Investigations in an agricultural used watershed in Lower Austria showed that nutrient input in surface water caused by soil erosion was appr. 5 – 15 kg N and 0.1 – 0.5 kg P per hectare and year (Strauss et al., 1994 a,b). As phosphorus is usually minimum factor in surface water
bodies, each increase on P concentration leads to increased growth of undesirable algae and aquatic weeds, oxygen shortages, and subsequently to problems with fisheries, and water for recreation, industry and drinking.

**SOIL PROTECTION MEASURES AND PREDICTION TOOLS**

Soil loss leads to a long-term decrease of soil fertility and soil quality. Therefore soil and water quality are inherently linked; improving or enhancing soil quality is a fundamental step toward improving water quality. Many different soil protection measures are available to reach this goal.

Soil erosion, in many cases, is not controlled by a single practice but by a system, composed of a number of components. Each component performs one or several functions. The functions a system must perform are 1) control rill and interrill erosion, 2) deposit eroded material, and 3) convey runoff water in a nonerodible manner.

Beside agricultural and management practices soil conservation measures include contour farming, terracing, grassed waterways, water and sediment control basins and many more. Some alternatives maintain the soil resource better than others in specific instances. In every case, however, a satisfactory system of maintaining the soil resource should be designed so that erosion is reduced to an acceptable level, runoff water is delivered to an outlet in a non erosive manner, and structures that induce sediment deposition are located where needed.

With advancement of high-speed computers, numerous hydrologic computer models have been developed and are being used for watershed planning and assessment. Process-oriented, physically based models are able mathematically to mimic the spatial behavior of hillslopes and watersheds, and are therefore tools to identify site-specific practices to reduce non-point source pollution from agricultural fields. To apply these models, necessary input data about climatic, pedologic, topographic, and management conditions must be available. However, the reliability of these models needs to be validated by comparing their predictions with observed data.

**REFERENCES**


