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Erosion, Hydrology, Modelling - Results from USLE-Plot Studies in South-eastern Norway

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Introduction

Soil erosion is recognized as an environmental problem in South-eastern Norwegian agriculture landscapes, especially on artificially levelled soils. The expected climate changes may aggravate the situation, and this has been simulated by an empirical erosion model -ERONOR- based on long term soil erosion experiments. The model was developed under the research program MILDRI, http://www.umb.no/forskning/mildri. The future simulations are funded by the research program EACC (Ecology and Economy in Agriculture under a Changing Climate, 2003-2007), http://www.umb.no/?avd=54.

Methods

Five USLE-plot sites located within 60 km of Oslo (south-eastern Norway) were used. They represented three soil types: A) artificially levelled silty clay loam, B) clay, and C) unlevelled loam with high aggregate stability. The slope was 13 %, with slope length of 20-80 m. Two of the tillage systems are included here: Pl-Au (ploughing autumn, harrowing spring), Pl-Sp (ploughing and harrowing spring). The plants grown were mostly small grain sown in spring, but winter wheat and grass were grown as well. Surface runoff (including sub-drainage water at two sites) was collected and measured by tilting buckets, which also allowed for volume proportional sampling. Other measurements included crop yield, plant and residue cover, surface roughness, snow storage, infiltration rates and a number of physical soil analyses.

The empirical, dynamic erosion model –ERONOR- with a resolution of one day simulates soil loss both on the surface and through tile drains, and it utilizes the following formula: daily soil loss=runoff*particle concentration. Daily runoff (surface and drain) may be simulated by the COUP model (Jansson, 2001) or internally within ERONOR. Daily particle concentration is determined by multiplying several factor values which are calculated by empirical equations. These equations take into consideration: soil type, artificial levelling, slope, slope length, necessary weather data, runoff, rainfall, snow storage, soil saturation, plant and residue cover, soil consolidation, and some structural effects.

Results

*Climate: At the University the following normal values were recorded in the period 1961-90: Precipitation 785 mm/year (monthly variation: February 35 mm, October 100 mm); Annual mean temperature 5.3 degrees (monthly variation: January and February –4.8 degrees, July 16.1 degrees). Since 1988 there have been several "mild" winters with variable or little snow cover, although the soil may still be frozen , sometimes combined with rainfall on the soil thawing on top. This increases the erosion risk.

* Runoff: Due to the distribution of rainfall, evapotranspiration and soil frost during the year most of the surface runoff occurs during winter and early spring, although a good deal of runoff also occurs in late autumn due to water saturation (mostly on soil type A). Drain runoff is most abundant during autumn and late spring when the soil is not frozen. Appreciable drain runoff in summer occurs only as a result of large amounts of rainfall. The average annual surface runoff during a seven-year period was: Soil type A 160-260 mm (3 sites), soil type B 130 mm and soil type C 115 mm. In addition to weather conditions and soil frost, the surface runoff was also affected by tillage systems (with the most surface runoff on winter wheat fields and the least usually on spring-tilled fields) and by the insulating effect of plant residues.

*Soil loss: The average losses over seven years by Pl-Au was: A) (2700-6350), B) 1043, C) 158 kg/ha/year. The large losses on soil type A were due mostly to the levelling effect. Because most of the surface runoff occurred during the winter season, soil losses were greatest by far from tillage in autumn, especially on soil type A. If soil loss by Pl-Au is set to 1, no till in autumn (Pl-Sp) showed the following relative losses: A) 0.12, B) 0.2, C) 0.66. Autumn ploughed and harrowed winter wheat was not any better on average than Pl-Au (no plant cover during winter) because the surface runoff from winter wheat was greater than from Pl-Au. Grassland reduced soil loss by 95% compared to Pl-Au on soil type A. Ploughing across slope reduced soil loss by 25% compared to ploughing along slope, provided there was no concentrated flow. Mixing the top 5-10 cm of the soil with organic material such as sewage sludge also had some positive effect. Doubling slope length increased soil loss by 1.7-1.9 on soil type A by Pl-Au.

*Soil physics and processes: Water stable aggregates were greatest by far on soil type C because of the higher content of organic C. This was the main reason for the high infiltration rates and low erodibility on soil type C. Infiltration rates were highest during summer, primarily due to cracking but they were often rather low after swelling in late autumn, even with no frost in soil. The following infiltration rates have been calculated with saturated soil in autumn and no frost in soil: Soil type A 0.6 (0.11-1.6), soil type C 1.8 (0.9-3.0) mm/hour. Such low values may result in surface runoff, even with moderate rainfall intensities. With rather shallow frost soil type A becomes impermeable, while the frost must be deeper to make soil type C impermeable. Plant residues delay frost development and thus reduces surface runoff in some cases.

*Modelling results and climate change: The ERONOR model (Lundekvam,2002) has performed rather well under Norwegian conditions. The GCM-model predictions for south-eastern Norway suggests milder and rainier winters with greatly reduced snow cover and frequent soil frost. Also, rainfall in autumn will increase. In accordance with these predictions, the ERONOR model simulated an increase in soil erosion, especially during winter but late autumn as well, which was expected. A further increase in winter temperatures may reduce soil frost, surface runoff and erosion somewhat, but surface runoff and erosion due to rainfall on water-saturated soil not protected by snow or plant residues will still occur. Thus, it will also be important in the future to avoid soil tillage in autumn in South-eastern Norway.

References

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