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1. Background, aim of the study

Changing of the vulnerable balance and dinamics of soil production is caused by the appearence of agricultural cultivation (Thyll 1992, Kerényi 1991). On global level the loss of soils from cultivated land is estimated 20 billion tons annually, the loss of agricultural production is 20 million tons, 1% of the complete harvest (Dowdeswell 1998). Loss of soil causes several decrease in quality, as humus and minerals are also lost.

If the tendency of this degradation can not be slowed down, and treated, this could cause the irreversible loss of soils, and hence a global crisis.

Remediation of the consequences of soil erosion starts at subwatersheds (10-15 km^2). Managing problems locally can solve the global situation. As there are huge differences between individual areas, solutions should be adapted to local circumstances.

Soils degradation is a serious problem for the agriculture in Hungary. Several experiments and surveys were carried out in Hungary for the measurement and modelling of soil erosion on different scales using different modells.

The main aim of my study is to elaborate a land use on cultivated subwatersheds which is more optimal than the current one.

The aims of the study are summarized below:

1. Studiing and evaluation of the Hungarian and international history of the development of watersed-level soil erosion modelling.
2. Adaptation of Erosion 3D erosion modell to the local circumstances: calibration, validation based on Hungarian soil erosion measurements;
3. determination of important parameters by sensitivity assessment of Erosion 3D;
4. Creation of parameter catalogue of the sensitive parameters, determination of the relationship between the sensitive parameters;
5. Field and laboratory measurement of the parameters infulencing soil erosion on a selected sample area, amending parameter catalogue with the divergent values, and for vineyard land use;
6. Assessment of the variation history of land use on the sample area;

7. Preparation of soil erosion scenarios for the Watershed Management Plans;
8. Determination of optimal land use;
9. Preparation of erosion hazard map;
10. Integration and definition of soil erosion and water protection priotities;

2. Materials and Methods

EROSION 3D (*Michael, 1995*) physical modell developed in Germany was used for soil erosion assessment. The modell can estimate the sediment removal after one precipitation event based on surface runoff in 10x10 m resolution for even a 30 km^2 watershed. EROSION 3D carries out the assessment with soil parameters based on precipitation data surface modell (DDM), land use and physical soil type, and defines them as net erosion (different of material in and outflow- kg/m^2) and loss of soil (kg/m^2) for each 10x10 m cells of (DDM). The modell works in GIS environment, so input data were processed with ArcView and ArcGIS softwares

Land use maps were created based on site visits, aereal photographs, and topographic maps for the period between 1998-2007.
Digitalized (vector and dot) data were converted to grid with the same resolution and extension as the DDM to ensure exact overlapping. Precipitation data after 2004 were from our observations, previous data were obtained from the regional Water Authorities. Sampling and laboratory analysis of the topsoils of the watershed and sample areas were carried out between 2004-2007. Topsoil sampling of the watershed was carried out in 2005 taking 17 sampes from the top 10 cm-s and making an average sample from the point samples.
The following soil parameters were determined: pH (H_2O, KCl), K_A, $CaCO_3$, humus content, particle size distribution, humidity, bulk density, surface coverage.

Two representative sub-catchments (1. and 2.) were selected on Cibulka watershed for sediment trapping measurements, that represent the most important parameters of the whole watershed. Area 1 is a ploughland area 2 is a vineyard.

During calibration sample quantities from the sediment traps of the two areas were compared to the erosion modelled by EROSION 3D for three precipitation events. In one case the difference was less then 10%. In the other two cases there were higher differences. As the first step of the

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Results of the simulation of the original historical land use represents the erosion rate of a catchment of an intensively cultivated vineyard and farmland.

In 9 years it gives 26681 kg removing sediment, the average net erosion is 6.31 t/year.

The result of worst case scenario is extremely bad: 646742 kg and 296 t/ha.

In the case of optimal land use water and soil protection measures were integrated into the scenario, which decreased the removing sediment to 17363.7 kg, and the average net erosion to 2.7 t/ha respectively.

3.7. As a result of simulations the erosion hazard map of the Cibulka watershed was created highlighting the most hazardous zones.

According to the erosion hazard map the 3 industrialized lots and a hill covered with meadow are highly hazardous. The average slope on the ploughland is 3,6^o on the vineyard 2,7^o on the meadow 8,9 ^{o}. Largest erosion occured on the vineyard during the 07.12.1999 precipitation event: 97872 kg.

3.8. Simulation proved that application of grassy buffer stripes on selected locations, planting wooded stripes and changes in land use can effectively reduce erosion.

Simulation runs with the Erosion 3D software proved that the software can be applied within the Hungarian environment in the 10-20 km^2 catchment with the use of the supplemental tables elaborated for the model. The model can be a useful tool to define strategic steps of erosion prevention measures within the Watershed Management Plan.

calibration the sensitive input parameters of the modell were determined with sensitivity test. During the calibration correction factors for the precipitation events were defined for 3 sensitive parameters. The correction factors proved to be applicable during validation, as the maximum difference between modell calculation and field data was 40 %.

The modell calibrated to the present land use was applied to elaborate a more optimal land use.

As a first step of modelling a background data base was created for the Cibulka watershed, based on computer processing of site measurement and laboratory results of site samples. These are supplemented with data from aereal photographs and 1:10000 topographic sections, and other land use related data. The data base contains soil related data based on soil type and mechanical composition, the type of cultivated plant of the given year and the method of cultivation for each lot between 1998-2007. Precipitation events are one of the most important part of the database and they determine the time frame of the simulations. Only precipitation higher than 3mm/h was considered. Areal limit was the 10 metre resolution of DDM.

Scenarios were used in the modelling. A series of simulations were elaborated in which a more optimal land use was tried to be reached with modifiing the land use of Cibulka watershed. First the erosion features of the original land use were defined. Net erosion (t/ha) and washed sediment (kg) were selected as indices. This was selected as reference situation. Further scenarios were compared to this one. A main goal was selected for each scenario. Changes of land use in each scenario were done to reach this goal:

Scenario 1: Historical land use 1998-2007. This is the reference situation based on detailed measurements.

Scenario 2: Worst Case Production of the crop (maize) producing the highest erosion values.

Scenario 3: Industrialized agriculture. Simulation of the typical 1998 production type

Scenario 4: Transient land use. This scenario contains both industrial and small scale farming land uses

Scenario 5 „Present situation” simulation of land use between 2005-2007

Scenario 6: Land use was changed in consideration of water and soil production, the main goal was reducing erosion

3. Summary

Studiing started with the evaluation of the Hungarian and international history of the development of watersed-level soil erosion modelling. Sample area was a catchment which was a part of the watershed of the Velencei lake. E3D modell was run for this catchment in order to determine those land use variants which are optimal for soil protection. Prior to the application of the modell calibration and validation was carried out during which the Parameter Catalogue adapted to Hungary was created. Modelling of optimal land use aimed the preparation of the erosion prevention plans of the Hungarian Watershed Management Plans.

The results are summarized int he following:

3.1. Input parameters were compared to the values of the Parameter Catalogue. Soil parameters influencing erosion are the following: The watershed is under intensive cultivation, 46,4 % ploughland, 21,5 % vineyard, 8 % meadow, 18,3 % forest, other areas are orchards. Slope of ploughland ranges between 2-6^{o} slope of vineyards ranges between 2-5^{o} Physical soil types are loam, clay loam and sandy loam. Among genetical soil types chernozem dominates, at the base of slopes alluvium, and forests soils in woodlands. average humus content is 1,7 % average value of mechanical soil type is 42 (K_A).

During the determination of parameters vineyard data were also collected which land use originally was not part of the land use types of the catalogue, and were added to the adapted catalogue as new data.

Measured values were compared to the values measured in Germany from the Parameter Catalogue, defining the difference between them. Largest differences occured between bulk density (4 %), and initial soil moisture (%) . Organic carbon content and surface cover showed similar values (less than 1 % difference).

3.2. Before calibration sensitivity test was carried out to determine those parameters that make great changes in out parameters when adjusted. During the test input parameter values were changed +- 10 % observing which parameter causes changes higher than 10 % in output parameters. Bulk density and initial soil moisture were sensitive parameters. Both produced changes greater than 100 % if modified by 10 %. Sensitive parameters give the boundaries of modell applicability, so defining them is an important issue.

3.3. During modell calibration results of sediment trap measurement (of both cathcments) of 3 years (2004-2007) were used selecting 3 precipitation events. Calibration was carried out for two representative land uses, ploughland and vineyard. Representative sampling results were used as input values. One of the 3 precipitation events was selected for the calibration of the modell for sensitive parameters, in which correlation between correction factor and initial soil moisture was determined. Function of the correlation of bulk density and initial soil moisture was determined based on calibration simulations. As bulk density and cover influences initial soil moisture, during the elaboration of final correction factor table the function of the correlation of bulk density and initial soil moisture was modified. In case of vineyard the correlation of bulk density and initial soil moisture is directly proportional, in case of ploughland relations considering power. In the final correction factor tables correction factors are given in the function of of bulk density and surface cover for initial soil moisture.

3.4. In the neighbouring cathchments (3. and 4.) of Cibulka watershed sediment trapping measurements were carried out in 1998. During validation 3 precipitation events were selected for 1998 and the tables were applied to catchments 3 and 4. Average difference between measured and modelled erosion rate was 22,4 %. Based on the validation correction factor tables were adjusted to precipitation intensity. In the correction factor tables correction factor intervals were given to the initial soil moisture values. When selecting correction factor the lower or upper value of the interval should be selected based on precipitation intensity.

3.5. As a final result a table was obtained which considers both sensitive parameters and precipitation intensity. Table should be used as a supplement of the Parameter Catalogue prepared for the catchment.

The model can be applied for clay loam and sandy loam soil types

3.6. With the help of the model land use of Cibulka watershed was changed to decrease erosion to reach TA1 and TA2 intervention levels of the Watershed Management Plan. Modeling was carried out in scenarios, considering the original land use of 1998-2007 as a reference. During simulation extreme precipitation events of the 9 years were processed. Original land use was divided to 3 periods. Each period represents a different land use type.

1. 1998-2000.
2. 2000-2005.
3. 2005-2007.