

Evaluation of the EUROSEM model for predicting water erosion on steeplands in the Three Gorges Reservoir areas, China

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Abstract

Because of the construction of the Three Gorges Dam in China, many farmers in the Three Gorges Reservoir areas will resettle in surrounding mountain areas and have to cultivate deep slopeland. Hence, a tool for assessing the risk of soil erosion, predicting runoff and erosion rates, and designing and evaluating the soil protection strategies in this area is needed. The European Soil Erosion Model (EUROSEM), a process-based model simulating erosion on an event basis for fields and small catchments, was tested using data from an experiment on steeplands in the Three Gorges Reservoir areas. This experiment included treatments of uncultivated slope, cultivated slope, hedgerows and fertilized-hedgerows. Results showed that EUROSEM predicted runoff reasonably well. It could be used to determine soil erosion in steeplands, especially for assessing the impact of land use change.

Introduction

Steeplands (slopes greater than 20%) are widely being used for cropping in China because of the population pressure and limited arable land. Improper steepland use has caused many problems, such as runoff, soil erosion, flood, siltation, water pollution and yield reduction. Many studies have shown that some steeplands could be used for agriculture with good control of soil erosion if proper protection practices, such as building tone ridge terrace, establishing contour hedgerows and maintaining vegetative coverage, are taken.

Many farmers in the Three Gorges Reservoir areas of China, will resettle in surrounding mountain areas and will have to cultivate more and deeper slopeland because of the construction of the Three Gorges Dam. Hence, a tool is needed for assessing the risk of soil erosion, predicting runoff and erosion rates, and designing and evaluating the soil protection strategies in this area.

The European Soil Erosion Model (EUROSEM) uses physical descriptions to describe the process of soil erosion and simulates erosion on an event basis for fields and small catchments on a minute-by-minute basis. It has been successfully used in several countries. The objective of the present study was to evaluate the EUROSEM model for predicting water erosion on steeplands in the Three Gorges Reservoir areas using data obtained through rainfall simulator experiments.

Materials and Methods

Experiments

Rainfall simulations were conducted on steep lands with slopes $>47\%$ and with different land uses at the Experiment Station, Chinese Academy of Sciences, at 293m altitude in Zigui County, the Three Gorges Reservoir areas, Hubei province. Average annual rainfall is 1013 mm. Soils were sandy clay loam (28% clay, 41% silt and 31% sand), classified as Purple soils, and were developed on residues of purple sandy shales. The parent rock is Jurassic Penglaizhen Formation which is 50-70 cm below the soil surface. Organic matter content on 20 cm surface soil was 0.7-1.8%. There were four treatments: uncultivated, cultivated, hedgerows, and fertilized-hedgerows. Native grasses (*Heteropogon contortus* and *Arthraxon hispidus*) and bushes (*Distylium Chinense* and *Sageretia thea*) on the uncultivated lands were used for goat grazing and fuel for many years. Since 1994, they were protected and natural vegetations were recovered with full land coverage. All other treatments (cultivated, hedgerows, and fertilized-hedgerows) were contour-farmed with soybean-winter wheat rotations. Soybean was seeded in June and harvested in September. Then, winter wheat was seeded in November and harvested in May of the next year. Vetiver Grass (*Vetiveria zizanioides*) plants were planted in the spring of 1993 on hedgerows and fertilized-hedgerow lands. Each hedgerow barrier was 2 rows, 0.2 m apart, with 0.2 m plant distance within the row. The distance between two neighbouring hedgerows was 2.8m, with crops grown between the hedgerows. The hedgerows were pruned each season to a height of 0.2 m. No fertilizer was used for cultivated and hedgerow plots. For fertilized-hedgerow plots 173 kg ha⁻¹ of available N (urea) and 143 kg ha⁻¹ available P (calcium superphosphate) were applied each year. Average yields for soybean and winter wheat were 1.7 t ha⁻¹ and 3.0 t ha⁻¹ for cultivated plots, 2.1 t ha⁻¹ and 4.1 t ha⁻¹ for hedgerow plots and 2.9 t ha⁻¹ and 4.7 t ha⁻¹ for fertilized hedgerow plots, respectively. Rainfall simulation experiments were conducted on 12 plots. Two portable rainfall simulators were used with a SPRACO cone jet nozzle mounted 4.8 m above the soil surface. The median volume drop size was 2.4 mm with a uniformity of 90%. Runoff was collected and measured at 2-3 min. intervals. All samples were oven-dried and weighed to determine sediment loads.

The EUROSEM model

The EUROSEM model is a dynamic distributed model, which is able to predict soil erosion by water from individual fields and small catchments. The model is based on a physical description of the erosion processes and operates for short time steps of approximately 1 min (Morgan et al., 1998). The model deals with the interception of rainfall by the plant cover, the volume and kinetic energy of the rainfall reaching the ground surface as direct throughfall and leaf drainage, the volume of stemflow, the volume of surface depression storage, the detachment of soil particles by raindrop impact and runoff, sediment deposition, and the transport capacity of the runoff. Algorithms also deal with frozen soils and stoniness.

Model calibration

EUROSEM (version 3.9) was calibrated using observed hydrographs and sedigraphs from one of the plots in each treatment. Parameters used for calibration were saturated hydraulic conductivity of the soil (FMIN), the Manning's n (MANN) and the cohesion of the soil (COH). The simulated hydrograph was first fitted to the observed hydrograph by interactively changing the input parameters followed by a fit of the sedigraphs. Parameter values were held within physically realistic limits during the calibration according to Morgan et al. (1998). The porosity of the soil (POR), the maximum moisture content of the soil (THMAX), the infiltration recession factor (RECS), the maximum interception storage of the plant cover (DINT), the roughness of the surface determined downslope (RFR), the median particle size of the soil (D50), and the detachability of the soil particles by raindrop impact (EROD) were determined according to Morgan et al. (1998). The initial volumetric moisture content of the soil (THI), the fraction of the soil occupied by rock fragments (ROC), the effective percentage canopy cover of the vegetation (COVER), and the average height of the plant canopy above the ground surface (PLANTH) were measured.

Model validation

The parameter file resulting from the calibration was used for the validation exercise using data of two of the remaining plots for each treatment. The fitness of simulated hydrographs and sedigraphs were evaluated visually. The association between simulated and measured total values was assessed by r^2 .

Results and Discussion

Uncultivated steepeland: The model simulated the accumulated runoff of the two validation rainfall simulations reasonably well, while the simulated patterns of runoff rate over time were different from the measurements. Differences in sediment concentration, soil loss rate and accumulated soil loss between simulations and measurements were similar to the results for model calibration, although the over-estimations of the model were greater.

Cultivated steepeland: Simulations were quite good for both runoff and soil loss for the first validation event. For the second event, the model simulated runoff reasonably well, but underestimated soil loss. The model failed to correctly simulate the sediment concentration, which is the main effect for the underestimation in soil loss.

Hedgerow steepeland: Validation results were reasonably good for runoff, whereas the simulated values for the soil loss accumulation were different from the observed values.

Fertilized-hedgerow steepeland: The model simulated discharge accumulation for the two validation events relatively well, but poorly simulated soil loss.

Total discharge and erosion: The application of EUROSEM for total discharge predictions looks promising with simulated total runoff values differing less than 3 mm compared to observed data (Fig. 1). This does not mean, however, that runoff simulations are satisfactory, because discharge rates were incorrectly shaped in most of the cases and timings of initiation and ending were generally not accurate. Further improvement in parameterising the model is needed. With respect to total soil loss simulations, results were not very good (Fig. 2), except for one event in the cultivated steep land, which was significantly different from another event. This indicates that the application of EUROSEM for total soil loss discharge predictions is indicative and should be further improved.

In conclusion, although there are some problems associated with event-based simulations, EUROSEM can be used for predicting runoff and soil erosion in steep lands in the Three Gorges Reservoir areas, especially for assessing the impact of land use change. Further research is necessary to improve the quality of input data. Parameters should be obtained from accurate field or laboratory measurements rather than using broad-based values.

References

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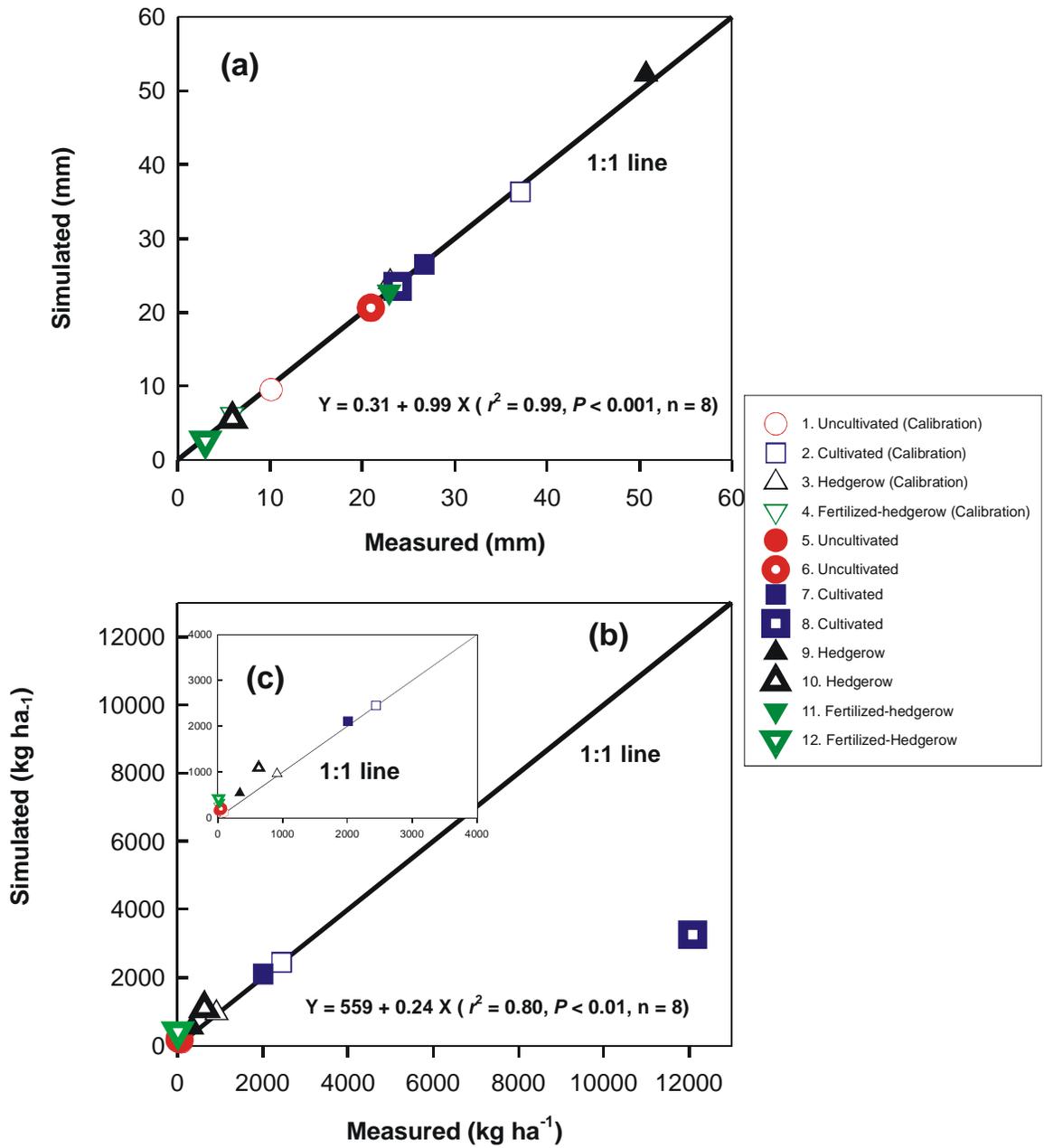


Fig. 1. Measured and simulated accumulated runoff (a) and soil loss of all plots (b) and soil loss of all plots except simulation 8 (c). Equations are calculated using validation data only.