Modelling Soil Erosion by Water in the Drâa Catchment (South Morocco) with PESERA

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Summary
Due to high relief energy and low vegetation coverage the Drâa catchment is very vulnerable to soil erosion. This is shown by bathymetric survey data from the reservoir El Mansour Eddabhi situated in the catchment, which has lost 11% of its capacity in 16 years. Thus the identification of high erosion risk areas is crucial for planning efficient measures for the protection of soil and the prevention of off-site effects like the sedimentation of the reservoir. In this study, soil erosion is simulated with the PESERA-model, which has been developed for erosion risk assessment in Europe. A first validation via a model-model-comparison indicates the suitability of PESERA for the Drâa catchment. In a first intervention scenario, areas of high erosion risk where reforested. The results show a significant reduction of soil erosion from 9.5 t/ha/year to 7.4 t/ha/year mean erosion rate in the catchment.

Résumé
Le bassin versant du Drâa est très vulnérable à l'érosion à cause d'énergie du relief forte et la faible couverture végétale. La quantité de la sédimentation du barrage El Mansour Eddabhi , lequel est situé dans le bassin, explicite cet effet : le barrage a perdu 11 % de sa capacité pendant 16 années, comme des recherches bathymétrique ont montré. Donc l'identification des zone à risque d'érosion élevée est cruciale pour la planification des mesures efficientes de la protection du sol et l'évitement des effets off-site, comme la sédimentation du barrage. Dans cette étude, l'érosion du sol est simulé avec PESERA, un modèle développé pour l'estimation des risques d'érosion en Europe. Une première validation par la comparaison avec un autre modèle d'érosion indique l'applicabilité du modèle pour le bassin versant du Drâa. Un premier scénario d'intervention considère la reforestation des zones avec un grand risque d'érosion. Les résultats montrent une réduction signifiante de l' érosion moyenne de 9.5 t/ha/a à 7.4 t/ha/a dans le bassin versant.

Introduction:

This work is part of the GLOWA-IMPETUS-project, an integrated project for the efficient management of scarce water resources in West Africa funded by the German Ministry of Education and Research. IMPETUS investigates the different components of the hydrological cycle and their interactions with an interdisciplinary approach in two river catchments in West Africa: the Ouémé River in Benin and the Oued Drâa in Morocco. In the first phase, investigations of all essential aspects of the hydrological cycle have been carried out and form now the basis to develop long-term prospective scenarios. The aim of the second phase (2003-2006) is to forecast the likely changes in water resources and soil degradation up to the year 2020 considering these different scenarios and driving forces.
In this context, soil erosion in the Drâa catchment is investigated. The basin (30.000 km²) reaches from the High Atlas Mountains in the north with a maximum altitude of 4070 m.a.s.l. to the edge of the Sahara in the south with an altitude of 450 m.a.s.l. Great parts of the catchment are covered by semi-natural steppes suffering from overgrazing, while the agriculturally used oasis cover approximately 2% of the area. Due to high relief energy, low vegetation coverage and a heterogeneous geological situation, the catchment is very vulnerable to erosion. In the central part of the Drâa basin, the reservoir "El Mansour Eddahbi" is located. Bathymetric surveys have shown a loss of capacity due to sedimentation

of 11% in 16 years (LAHLOU, 1996). Using a simple regression equation developed on the basis of data from Moroccan, Tunesian and Algerian reservoirs (MEDDI ET AL., 1998), the calculated capacity of the reservoir will be reduced to 75% in the year 2020 and 50% in the year 2065.
In view of these figures, it is of great importance to identify areas of high erosion risk in order to plan efficient measures against soil erosion. Unfortunately, there are no data on the amount and distribution of erosion apart from the sedimentation data of the reservoir. So the application of a physically based model is the only possibility to assess the erosion risk in the catchment and to calculate scenarios of land use and climate. Thus in this study, erosion by water is modelled with PESERA (**P**an **E**uropean **S**oil **E**rosion **R**isk **A**ssessment), a model developed in the framework of the PESERA – project. Validation will be qualitative with the help of remote sensing data. Model results are used to support decision making processes with regard to measurements of soil conservation and protection against off-site effects such as the sedimentation of reservoirs.

Materials and Methods:
The choice of the PESERA model is funded on the definition of conditions, which a model must satisfy in the given situation, i.e. the Drâa catchment. A suitable model has to be physically based and spatially distributed. It has to offer the possibility to model long time scales and large catchments in semi-arid regions. Further more it has to request few easily available input parameters and provide the potential for scenario-analysis. PESERA is a physically based raster-model developed to assess the erosion risk in entire Europe. It was developed to use input data which are available on a small scale (<= 1:100.000), such as the CORINE land cover classification. It includes a plant growth model, which accounts for the possibility to model scenarios by dynamically adjusting vegetation to the given climatic conditions. The model is adapted to semi-arid conditions as it uses a storm size threshold for the generation of overland flow. This threshold does not take into account the antecedent soil moisture, which is an appropriate simplification for a semi-arid region where Hortonian overland flow is the dominating process (GOBIN & GOVERS, 2003; IRVINE & KIRKBY, 2003). PESERA combines the factors climate, soils, vegetation and topography to an overall sediment yield for each raster cell in t/ha/year, as figure 1 shows.

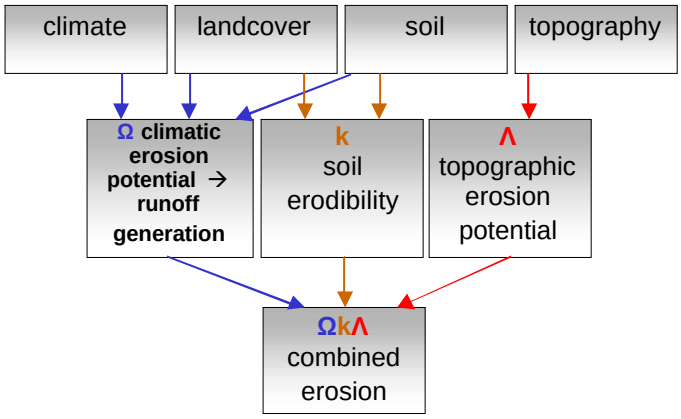

Fig. 1: Schema of the PESERA approach (modified according to IRVINE & COSMAS, 2003)

The model was parametrised for the Drâa catchment using widely available input data. These data are the FAO world soil map, CORINE landcover classification, Digital Terrain Model (DTM) produced by the SRTM-mission and the results of the IMPETUS meteorological models.

For validation, nearly no data is available, as no erosion studies are carried out in the catchment. The only available data is the sedimentation data of the reservoir El Mansour Eddahbi, but this cannot be used directly, as PESERA does not include sediment routing in channels. Furthermore, the most important aspect in terms of management options is the spatial distribution of erosion in the catchment. Thus, the spatial distribution modelled by PESERA has to be validated. As a first step, a model-model-validation is carried out. The PESERA results are compared to the results of a model developed by YASSIN et al. (1996). This approach combines geology, slope, vegetation and landuse attributes to classify areas of different erosion risk, as figure 2 describes. As this model was already applied successfully to other catchments in Morocco, its applicability for the Drâa catchment is assumed.

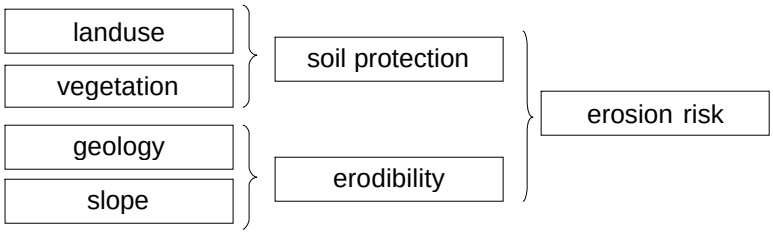

Fig. 2: Flowchart of the erosion risk assessment methodology proposed by YASSIN et al. (1996)

The two models are compared using the *weighted Kappa coefficient* as proposed by COHEN (1968).

Results

The first PESERA run was carried out using the modelled meteorological data for the year 2002 and the above mentioned data sets. The erosion risk assessment following the approach of YASSIN et al. (1996) was carried out using the 1:500.000 geological map, the SRTM – DTM and the CORINE landcover classification.

The mean erosion in the catchment of the reservoir (~15.000 km²) is calculated as 9.8 t/ha/year by PESERA. From the bathymetric survey, a mean erosion rate of 4 t/ha/year was computed. Thus the PESERA result seems to be quite high, but it has to be taken into account that PESERA does not consider the transport of sediments in the channel.

As PESERA produces continuous output data and the YASSIN model discrete classes, the PESERA outputs had to be classified first. As a first attempt, the class limits given by MARKS et al. (1992) were used. The *kappa coefficient* accounted for -0.469, which is not acceptable. This bad results may be due to a significant difference in the spatial pattern in erosion rates or due to the classes defined for comparison. For calibration and validation of the class used for comparison the erosion maps were splitted into a western and an eastern part. For the calibration data set, a *kappa coefficient* of 0.655 was obtained, for the validation data set it was even better (0.765).

As a first intervention scenario, a reforestation in the areas of the highest erosion risk (> 30 t/ha/year) was assumed. Comparing the “Status Quo” run and the reforestation scenario, 2361 cells from high erosion classes were reduced to significantly lower erosion rates (< 10 t/ha/year). The mean erosion for the whole catchment was reduced from 9.5 t/ha/year to 7.4 t/ha/year.

Discussion and conclusions

The first results indicate the applicability of the model for the Drâa catchment. The comparison of PESERA and the YASSIN-approach shows a good agreement and the processes typical for semi-arid regions, such as Hortonian overland flow, are represented by the model.

Up to now, the data sources especially for vegetation and soils are not satisfying. In the next steps, they have to be replaced by data of higher resolution. From the IMPETUS vegetation

subproject, a Landsat TM vegetation classification exists, which will be integrated into PESERA. Unfortunately, there is no soil information for the regions outside the oasis. In the framework of the IMPETUS project, approximately 200 soil profiles were studied all over the Drâa basin. These profiles form the basis for a soil map of the catchment, which is currently being prepared and will in the future be integrated in PESERA.
At the moment, a remote sensing approach is tested to validate the spatial erosion patterns computed by the model. The aim is to get information about the real distribution of erosion in the catchment. This will be a qualitative validation via the distribution of differently intensive eroded areas. To test the applicability of the remote sensing approach, linear erosion forms where mapped using a simple field estimation method. The results of the field campaign will be compared to the results of the remote sensing investigation.

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