Regional erosion assessment: an example of using local knowledge

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Introduction

After several decades of soil erosion modelling and a wealth of newly developed models, a general agreement exists among scientists worldwide that erosion modelling and mapping is not an easy task. This is partly due to the many processes involved and the different scales at which these processes act, but also to considerations such as data availability and quality. There is not, nor will there be one single model that performs best in all cases.

At the regional scale (several tens to thousands of km^2) it is virtually impossible to accurately describe the parameters used in most process-based models. If we take for example relief, a 30-m DEM is often the best data option available at this scale. However, at this resolution micro-relief cannot be represented, thus sedimentation within a grid cell will be ignored, thereby overestimating run-off and erosion. Hence, another approach should be used taking into account the actual data availability and the regional important processes causing soil erosion.

We argue that local knowledge can contribute to such an approach, especially when assessing erosion in a region where the cartographer does not have much experience. Local informants can assist in the identification of the important erosion-controlling factors as well as their interactions. These informants can be scientists who have worked in the considered region, but also experienced extension workers and local farmers. However, it is crucial to identify key persons that have a good knowledge on the area in terms of erosion. For example, farmers' knowledge can assist in regions where farmers have long-term attachment to the land, but not in areas where farm managers generally only stay for a few years.

This paper presents an example for the qualitative mapping of soil erosion risk, called Qualitative Erosion Risk Mapping – QUERIM (Vrieling et al., 2002). The methodology has the flexibility to adapt to changes in data availability and to regional characteristics. Local knowledge is used to select and combine the relevant attributes from the available data. QUERIM is applied to the Puerto López municipality in the Eastern Plains of Colombia.

Methods and materials

QUERIM is based on the concept of the morphogenic-pedogenic balance (Tricart and KiewietdeJonge, 1992) and on the derived erosion mapping methodology developed at the Brazilian National Institute for Space Research (INPE). The INPE methodology gives a rating between 1.0 and 3.0 to the erosion-controlling factors being geology, soil, relief, vegetation, and climate. The average of these values results in the erosion risk map. To analyse erosion within the whole of Brazil, standard values are assigned to the factors (Crepani et al., 1999). Although this is a valid approach for comparison at the country scale, it cannot account for regionally important processes and process-interactions, nor does it give insight in the characteristics that determine erosion risks within a particular area. Therefore the approach needs to be adapted for the regional scale, where most of the planning of erosion control and mitigation strategies takes place.

QUERIM evaluates five erosion-controlling factors: geology, soil, relief, management, and climate. Unlike the INPE approach, each factor is composed of sub-factors reflecting physical parameters that can be derived from the available spatial data. The sub-factors are assigned a qualitative rating and are subsequently combined using decision trees that evaluate the occurring combinations of sub-factor ratings based on a comprehension of their interrelation. This results in a value of each of the five factors between 1.0 (low erosion) and 3.0 (high erosion). The average of the geology, soil, relief and climate factors at each location results in the potential erosion risk map, whereas the average of all five factors (including management) gives the actual risk map. However, also a weighted average or other combination methods may be applied.

The relevant sub-factors and the decision trees can be different for various regions, both depending on the regional characteristics and the data availability. For the definition and selection of the sub-factors and their combination in decision trees, QUERIM uses local knowledge. This can be acquired through either interviews, or jointly selecting sub-factors and defining decision trees. As stated before, it is crucial to identify local informants that know the area well in terms of erosion. QUERIM can thus be considered as a translation of local knowledge into a formal structure that allows utilizing available spatial data to create erosion risk maps.

In principle, QUERIM can be used through zoning, dividing the area in individual zones that have the same characteristics and a high degree of internal uniformity. In this case, erosion-controlling factors have to be evaluated for each individual zone. But it can also be used in a raster environment to better account for the high spatial variability of erosion. Then factors are analysed per pixel. This choice will also depend on the data availability.

Study area

QUERIM was applied to the Puerto López municipality (6907 km^2) in the Colombian Eastern Plains to assist in land use and conservation planning. The region has an average temperature of 27 ºC and an annual rainfall of 2800 mm. Rain falls mainly between April and November in high intensity rainstorms. On an annual basis rainfall amount is distributed evenly over the municipality. Terrain elevations vary from 180 to 300 meters above mean sea level. The area consists of low-lying alluvial plains, where floods occur and a higher elevation that is called the “altillanura” (high plains). These high plains can be divided in a non-dissected and a dissected region. Analysis of Landsat Thematic Mapper (TM) data shows that pastures constitute 50% of the area, forest covers 20% and transitional vegetation makes up for another 25%. The remainder consists mainly of agricultural crops of which lowland rice is the most important. Farm sizes are mostly large (>5.000 ha) with absentee landowners and managers taking care of the cattle.

Soils in the municipality generally have a low infiltration capacity, which results from a low organic matter content, poor soil structure and surface crusting. Rainfall with intensities of more than 20 mm h^{-1} causes Hortonian runoff and erosion (Amézquita and Londoño 1997). Given the present rainfall regime, this causes a high erosion risk in the area and stresses the fact that a good vegetation cover is essential to prevent the soil from being eroded.

Data

To apply QUERIM to the Puerto López municipality, we interviewed four soil experts that have worked in the region. Three of them have performed soil erosion studies within the study region or in its vicinity. The interviews permitted the application of QUERIM through revealing the important sub-factors to be selected and extracted from the available spatial data, and the relationships needed for the construction of decision trees. Farmers' knowledge was judged not to be very useful as generally managers that only stayed for a few years were in charge of the farms.

Data on the sub-factors could be extracted from three different data sources. The first is a soil survey done by the Colombian Geographical Institute, IGAC (IGAC, 1978), which resulted in a soil map on a scale 1:100.000. The survey is well documented and for each cartographic unit the constituting soil profiles are described in terms of their physical and chemical properties. The second data source is a Digital Elevation Model (DEM) that was interpolated from contour lines and point elevation data. The third data source is a Landsat TM image of August 10^{th} 1998. The soil map was rasterised and the image resampled to obtain the same 25-m grid as the DEM, which allowed a pixel-based evaluation of erosion risk within a GIS.

In July 1999, field data on land use and vegetative ground cover (VGC) was gathered, using a Global Positioning System (GPS). Border coordinates of parcels or homogeneous vegetation areas were measured which resulted in a collection of polygons. For every polygon land use and average VGC were determined through visual estimation. Validation data was recorded after construction of the erosion risk map at seven places distributed over the study area where the map showed high erosion risk. At these locations erosion signs were observed and topsoil, geology, topography, and vegetation characteristics were determined.

Results and discussion

The five factors used in QUERIM were divided into sub-factors by the local soil experts. Each sub-factor was given a qualitative rating that is subsequently used in the decision trees. In this case study, the climate factor was not used because annual rainfall can be assumed homogeneous in the study area and therefore this factor would not contribute to the spatial distribution of the erosion risk. In this paper we only present the ratings, criteria, and decision trees of the soil factor, whereas the sub-factors of the other factors are merely mentioned. Vrieling et al. (2002) give the full description of sub-factor ratings and decision trees.

The sub-factors for the geology and soil factor are selected from the attributes contained in the soil survey. For geology only one attribute was used, which is the degree of weathering. The sub-factors for the soil factor are listed in Table 1. For relief, the sub-factors dissection grade and slope gradients were used, which were derived from the DEM. For the management factor the sub-factors land use and VGC were used. A maximum likelihood classification was performed to obtain a land use map, using the Landsat TM image and field data. The overall accuracy of this map was 84 %. The VGC has been determined for the total area by relating the field estimates to the normalized difference vegetation index (NDVI), extracted from the image. Erosion measures or conservation tillage practices were not present in the area, and therefore these were not included in this study.

Table 1. Selected sub-factors for the soil factor with used ratings, description and criteria, for the Puerto López municipality. Sub-factors and criteria were derived from the soil survey executed by IGAC.

Sub-factor	Rating	Description	Criteria
Effective depth	1	Moderately deep	> 50 cm
	2	Superficial	25 - 50 cm
	3	Very superficial	10 - 25 cm
	4	Excessively superficial	0 - 10 cm
Topsoil texture	1	Fine	
	2	Medium	
	3	Coarse	
Organic matter content (topsoil)	1	Very high	> 6.0 %
	2	High	2.5 - 6.0 %
	3	Medium	1.5 - 2.5 %
	4	Low	1.0 – 1.5 %
	5	Very low	< 1.0 %
Structure	1	Strong	
	2	Moderate	
	3	Weak	
	4	Structureless - massive	

The sub-factors were combined to obtain the factor values with the decision trees. Here, a value between 1.0 and 3.0 was assigned to each factor by the local experts through evaluation of the occurring combinations of sub-factors. Table 2 shows the decision tree for the soil factor.

Subsequently a map was constructed for each factor, giving the resulting numerical index for every pixel. Evaluating the factors per pixel, the average of the geology, soil, relief and management factor resulted in the actual erosion risk map (Fig. 1). The 5 classes mentioned in Fig. 1 are the result from a reclassification of the values ranging from 1.0 to 3.0.

Table 2. Decision tree for soil factor, which shows the combinations of ratings for the sub-factors. These ratings correspond with Table 1. Only the 17 occurring combinations in the study area are shown.

Effective depth	Topsoil texture	Organic matter content	Structure	Soil Factor

1	1	4	3	1.4
1	2	2	3	1.3
1	2	3	1	1.3
1	2	3	2	1.4
1	2	4	2	1.5
1	2	4	4	2.3
2	2	1	2	1.7
2	2	2	2	1.9
2	2	4	1	2.2
2	2	5	3	2.4
2	3	3	2	2.3
2	3	5	4	2.8
3	1	1	3	2.0
3	2	3	2	2.5
3	2	3	3	2.6
3	2	4	3	2.7
4	3	5	4	3.0

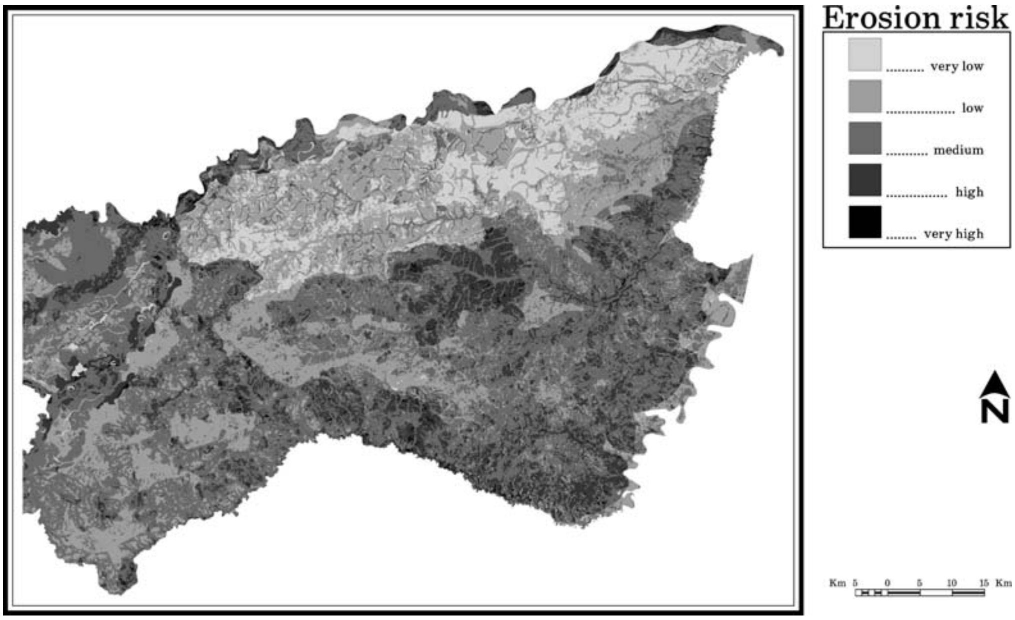

Fig. 1 Actual erosion risk map of Puerto López municipality, developed with QUERIM.

The actual erosion risk map (Fig. 1) shows a high risk for the dissected high plains and in the low-lying areas, which consist of young unstable alluvial sediments. A low risk is found on the non-dissected high plains. Comparison with the erosion risk verification data resulted in a good correspondence between areas in the field that showed advanced signs of erosion processes or high erosion risk, and areas on the map indicating a high erosion risk at all of the seven locations visited. At four locations advanced signs of sheet erosion and gully formation could be observed, whereas at the remaining three locations favourable conditions for erosion (steep slopes, bare soil, etc.) were present. In spite of this good agreement between high erosion risk areas on the map and in the field, the study could benefit from a more thorough ground check.

Conclusions

This paper presented one way of incorporating local knowledge into soil erosion mapping. QUERIM is a relatively simple qualitative approach, which gave adequate results for the study area in the Colombian Eastern Plains. To apply the methodology to other regions, the selection of local informants is very important. The main advantage of QUERIM is its flexibility to adapt to different regional characteristics and to data availability. A disadvantage of QUERIM is its inability to quantify soil losses, unless through upscaling of erosion measurements. However, resulting soil loss values of quantitative models should also be taken with care, and at the regional scale they are generally used in a qualitative way.

Other ways of utilizing local knowledge for soil erosion mapping can be envisaged. QUERIM is just one possible framework, which may be refined. However, we strongly believe that local knowledge can greatly contribute to proper erosion assessment. At least its incorporation may provide a good way to work around limitations that most erosion models experience, considering data limitations in many regions of the world, and invalid assumptions outside the region for which the specific model was developed. In this way we may obtain more sensible results that correspond better to the local logic.

References

Amézquita, C.E., and H. Londoño. 1997. La infiltración del agua en algunos suelos de los Llanos Orientales y sus implicaciones en su uso y manejo. Revista Suelos Ecuatoriales 27:163-168.

Crepani, E., J.S. de Medeiros, P. Hernandez F., T. Galloti F., V. Duarte and C.C. Faria B. 1999. Sensoriamento remoto e geoprocessamento aplicados ao Zoneamento Ecológico-Econômico e ao ordenamento territorial. Instituto Nacional de Pesquisas Espaciais (INPE), Brasil.

IGAC. 1978. Estudio general de suelos de los municipios de Cabuyaro, Fuento de Oro, Puerto López, San Carlos de Guaroa y la Inspección de Barranca de Upia (Departamento del Meta). Instituto Geográfico "Agustín Codazzi", Bogotá, Colombia.

Tricart, J., and C. KiewietdeJonge. 1992. Ecogeography and rural management - A contribution to the international Geosphere-Biosphere Programme. Longman Group, UK.

Vrieling, A., G. Sterk and N. Beaulieu. 2002. Erosion risk mapping: a methodological case study in the Colombian Eastern Plains. Journal of Soil and Water Conservation 57:158-163.