Print

Proceedings

Regional soil erosion risk mapping in Lebanon

Olivier Cerdan[b], Rania Bou Kheir[a], Chadi Abdallah[a]
[a]Lebanese National Council for Scientific Research/Remote Sensing Center
P.O. Box: 11-8281, Beirut, Lebanon. Tel: +961-4-409845/6; fax: +961-4-409847;
E-mail address: raniabk@cnrs.edu.lb
[b]BRGM, B.P. 6009, 3 avenue Claude Guillemin, 45060 Orléans, France.
Tel: +33 2 38 64 33 92; fax: +33 2 38 64 33 99; E-mail address: o.cerdan@brgm.fr

Abstract

Soil erosion by water is one of the major causes of land degradation in Lebanon. The problem has not yet been treated in detail although it affects vast land areas. This led to elaborate a model that allows mapping soil erosion risk at a scale of 1:100,000 and supplies reliable spatial results producing derived and thematic maps. The derived maps are: 1. the runoff potential obtained by the intersection of mean annual precipitation with soil-water retention capacity plus soil and rock infiltration capacity, 2. the landscape sensitivity resulting from the combination of vegetal cover, drainage density and morphology, and 3. the erodibility of geologic and soil materials. The maps reliability depends on their precision, which can be enhanced and updated with databases through GIS. The thematic maps are: 1. the potential sensitivity to erosion obtained by combining landscape sensitivity and runoff potential, and 2. the erosion risk resulting from the combination of potential erosion with erodibility. This map consists of different classes responding to demands of different stakeholders. This map was successfully evaluated against field observations of gully occurrence. The model proves to be simple and quick. The model is applicable to other areas of the country, thus constituting a tool to help implementing a plan for soil conservation and its sustainable management.

Keywords: water-soil erosion, modelling, land degradation, GIS, risk assessment

1. Introduction

Soil erosion is affecting large areas in Lebanon, quantitative studies on erosion processes are scarce. In fact, predictions of FAO (1986) indicate that erosion is very severe in the Lebanese mountainous areas reaching 50 to 70 tons/ha/year. The values exceed by far the rate of pedogenesis under the Mediterranean climate, and reflect the importance of controlling water-soil erosion especially since areas available for cultivation have already declined. One therefore understands the need to establish soil conservation measures which can reduce land degradation and assure a sustainable management of soil resources. The implementation of effective soil conservation measures has to be preceded by a spatially distributed soil erosion risk assessment of the area in order to target and adapt appropriate policy implementation (Moussa et al., 2002; Souchère et al., 2005).

Until now, all the research done in Lebanon gives a general idea of soil-water erosion (Lamouroux, 1971; Ryan, 1982, 1983; Khawlie, 1983, 1991; Zurayk, 1994; Bou Kheir et al., 2001, 2003), but there is no focus on mapping erosion risks at a regional scale (1:100,000). Proper soil erosion mapping and the introduction of advanced information techniques including remote sensing (RS) and Geographic Information System (GIS) have come only recently (Bou Kheir, 2002). At a regional scale, the need of a large quantity of input data necessary for the description of the heterogeneity of natural systems, i.e. temporal and spatial variability of landscape characteristics, land use, topography, soil and climate makes impossible the application of complex models established from localised measurements at experimental fields (Kirkby et al., 1996; Renschler and Harbor, 2002). In Europe, empirical soil erosion models such as CORINE (1992) or more deterministic models such as PESERA (Gobin and Govers, 2001) have already been used in Mediterranean environment at a regional scale. These models are supposed to be "universal" and as such can not easily incorporate the specificity of some areas or adapt to the format and nature of available databases and available expert knowledge. All this led to the development of a "cognitive" model based on the dominant factors influencing soil-water erosion in the study area and relying on expertise work in the field. In this context, the objective of this study is to establish a soil erosion risk map of a representative region of Lebanon and to carry out a first evaluation of its accuracy.

2. Materials and methods

2.1. Description of the study area

The study area is 955 km^2 or 9% of the total area of Lebanon. It represents the diversity of Lebanon in terms of geology, soil, hydrography, land cover and climate. It extends from west to east Lebanon occupying almost its middle part, and representing three of four geomorphic units composing Lebanon (Fig. 1). These units are arranged from west to east as follows: coastal zone (< 100 m altitude), Mount Lebanon (between 100 m and more than 1500 m) and Bekaa valley (500-1500 m).

Print

Proceedings

2.2. Modelling approach

The developed "cognitive model" represents a function using qualitative decision rules, evaluations and hierarchical organization of effective parameters, based on the knowledge of experts. This type of approach which represents an interesting alternative when detailed input data are not available has already been applied successfully to model soil erosion processes at various scales (Boardman and Harris; 1990; Cerdan et al., 2002a and 2002b, Le Bissonnais et al., 2002). The model depends on the landscape map (Bou Kheir, 2002; Bou Kheir et al., 2004) established from the treatment of satellite images (Landsat TM) and base parameters, i.e. geology (Dubertret, 1945), soil (Gèze, 1956), land cover (FAO, 1990), and factorial parameters influencing water erosion in the study area. They are slope, vegetal cover, drainage density, rock infiltration, rock movement, soil infiltration, soil-water retention, soil movement and annual rainfall. The interactive effects of these parameters together on soil leads to the *formation* of homogeneous response units named "Erosion Response Units (ERU)". These parameters are coded according to their sensitivity to water erosion. Some of them, like vegetal cover and soil-water retention as well as base parameters, are validated in the field. This validation was applied on 200 sites (Fig. 1) chosen systematically in different land cover classes taking into account different lithological and soil formations.

The mapping of erosion risk is realized in several steps (Fig. 2), where essentially base maps are used to produce factorial maps, which in turn produce derived maps and finally thematic maps. As shown in Fig. 2, the two first derived maps (landscape sensitivity and runoff potential) are combined to define the first thematic map "potential sensitivity to erosion". The latter thematic map is combined with the third derived map (erodibility) to finally produce the second thematic map "erosion risk".

3. Evaluation of the erosion risk map

Soil erosion occurrence is variable both in time and space, thus erosion measurement schemes need to be implemented for relatively long periods (ca. ten years) and in various representative places to be able to obtain reliable average estimates. The validation of erosion risk map on large areas therefore poses important problems due to the cost induced by the implementation and maintenance of such monitoring systems. Because these data are not available for Lebanon, a specific field campaign to measure visible erosion signs was carried out at the two hundred locations in the study area which were also used as calibration sites for the input layers (Fig 1). The most visible erosion signs are the occurrence of rills and gullies. For each location, width, depth and length of each gully were measured and their volumes were estimated.

Five classes of erosion were distinguished with an equal range, i.e. very low (0-1.5 m3), low (1.5-3 m3), medium (3-4.5 m3), high (4.5-6 m3) and very high (> 6 m3) in order to be coherent with the erosion risk map with six classes; the sixth class is reserved to urban areas (no erosion). The interpretation of the confusion matrix indicates a good overall accuracy of 70%. The user's accuracy, which is the percentage of sites in a class derived from modelling, correctly classified vis-à-vis the reference data, is ranging between 50 and 84%, with relatively low errors of commission (excesses), varying between 16 and 50%. The producer's accuracy, corresponding to the percentage of sites of a reference class correctly classified by the model, is ranging between 23 and 100%, with similarly relatively low errors of omission (deficits) depending on the class into consideration (0-77%). Confusions are noticed between adjacent classes and the class "very low" is showing the highest confusion for the user, since a given site classified as very low erosion risk on the map can not be affected by gully erosion or can show gullies with a volume ranging between 1.5 and more than 6 m3. This evaluation procedure only takes into account observations which were carried at a given period, and would therefore not be suitable to evaluate quantitative estimates of soil erosion. However, in our case where the assessment identifies qualitative classes, it shows that the map can satisfactorily highlight areas were severe erosion is likely to occur and that the model is able to distinguish between 6 classes of erosion risk, with some limitations were erosion is low.

4. Conclusion

A soil erosion risk map was produce to inform decision-makers at the national level on the gravity of erosion process and on the necessity of implementing conservation measures. Its main purpose is to delineate priority areas at the 1:100,000 scale where to focus the implementation of conservation measures or where to carry out more detailed and specific studies.To this end, available data derived from existing maps, the interpretation of satellite images or from local expert knowledge are combined according to a function using qualitative decision rules, evaluations and hierarchical organization of effective parameters to define homogeneous response units in terms of the severity of the erosion risk. The established model can define, in a representative region, a map of erosion risk at a scale of 1:100,000. This map is the first of its type in Lebanon until now. This model can be easily extrapolated to all the country if the functional capacities of GIS are used: the model is based on nine factors issued from available on expert knowledge and data bases. It is possible to integrate with GIS new spatial data and modify codes in order to automatically analyse basic and factorial data. The elaboration of maps is quite significant: derived maps (landscape sensitivity, runoff potential and

Print

Proceedings

erodibility), and thematic maps (potential erosion and erosion risk). The two maps of landscape sensitivity and erodibility are more persistent with time than the runoff potential map: the most sensitive factor of these persistent maps, and which must be updated, is the vegetal cover: it changes with the deterioration of existing forests.

The risks are defined with a varying number of classes in order to be adequate to managers and decision makers. A comparison of the erosion map with observed signs of erosion (rills and gullies) proved the robustness of the model to adequately reproduce 6 classes of erosion. Although, the chosen scale 1:100,000 is sufficient to estimate the zones affected by water erosion control in view of a strategy of protection and targeting policy implementation, the final risk map can be improved when more detailed datasets will be available.

Acknowledgments

The research of this paper is a part of a common project (2003-06) held at the Remote Sensing Center which is a part of the Lebanese National Council for Scientific Research (LNCSR), in cooperation with “Bureau de recherches géologiques et minières (BRGM-France)” and funded by “Agence universitaire de la Francophonie (AUF)”. For that, we acknowledge all responsibles of LNCSR, in particular the General Secretary Dr. Mouin Hamzé and those of AUF.

References

Bou Kheir, R., 2002. Study of soil-water erosion risk by remote sensing and GIS: application to a representative region of Lebanon. Ph.D. Thesis, Agronomical National Institute Paris-Grignon, France.

Bou Kheir, R., Shaban, A., Girard, M-C., Khawlie, M., 2001. Impact of human activities on soil-water erosion in the mountainous coastal region of Lebanon. Sécheresse 12(3), 157-165.

Bou Kheir, R., Girard, M-C., Khawlie, M., 2004. Use of a structural classification OASIS for the mapping of landscape units in a representative region of Lebanon. Canadian Journal of Remote Sensing 30(4), 617-630.

Cerdan O., Souchère V., Lecomte V., Couturier A., Le Bissonnais Y. 2002. Incorporating soil surface crusting processes in an expert-based runoff and erosion model STREAM (Sealing Transfer Runoff Erosion Agricultural Modification). Catena 46, 189-205.

Cerdan O., Le Bissonnais Y., Couturier A., Saby N. 2002. Modelling interrill erosion in small cultivated catchments. Hydrological Processes 16 (16), 3215-3226.

CORINE, 1992. Corine soil erosion risk and important land resources in the southern regions of the European Community, Publication EUR 13233 EN, Luxembourg, 97p.

Dubertret, L., 1945. Geological map of Lebanon at a scale of 1.50.000. Sheets of Beirut and Zahlé. Republic of Lebanon, Minister of public affairs, Beirut, Lebanon.

FAO, 1986. Conservation and management of soils in the countries under development. Bulletin pédologique 33, 1-98.

FAO, 1990. Land cover map at a scale of 1.50.000. Sheets 6 and 7. FAO.

Gèze, B., 1956. Soil map of Lebanon at a scale of 1.200.000. Republic of Lebanon, Ministry of Agriculture. Explicative note, 52p.

Gobin, A., Govers, G., 2001. PESERA (Pan-European Soil Erosion Assessment). EC Contract no. QLK5-CT-1999-01323, First Interim Report, 69p.

Harris, M.T. and Boardman, J., 1990. A rule-based Expert System Approach to Predicting Waterborne Soil Erosion. In: J. Boardman, D.L. Foster and J.A. Dearing (Editors), Soil Erosion on Agricultural Land. John Wiley & Sons Ltd, pp. 401-412.

Khawlie, M., 1991. Balancing natural resources within environmental systems in Lebanon. Proc. Man & the Environment in Lebanon, UNESCO, Beirut, Lebanon, 51-84.

Kirkby, M.J., Imeson, A.C., Bergkamp, G., Cammeraat, L.H., 1996. Scaling up processes and models from the field plot to the watershed and regional areas. Journal of Soil and Water Conservation, 51 (5): 391-396.

Le Bissonnais, Y., Montier, C., Jamagne, M., Daroussin J., King, D., 2002. Mapping erosion risk for cultivated soil in France. Catena, 46, (2-3) 207-220.

Moussa, R., Voltz, M., Andrieux, P., 2002. Effects of the spatial organization of agricultural management on the hydrological behaviour of a farmed catchment during flood events. Hydrological Processes 16,393-412.

Renschler, C. S., Harbor, J., 2002. Soil erosion assessment tools from point to regional scales—the role of geomorphologists in land management research and implementation. Geomorphology 47, 189-209.

Souchère, V., Cerdan, O., Dubreuil, N., Le Bissonnais, Y., King, C. 2005. Modelling the impact of agri-environmental scenarios on overland flow in a cultivated catchment (Normandy, France). Catena 61 (3-4), 229-240.

Ryan, J., 1983. Soil conservation in Lebanon. Journal of soil and water conservation 38(5), 404-406.

Zurayk, R., 1994. Rehabilitating the ancient terraced lands of Lebanon. Journal of soil and water conservation 49(2), 106-113.

Fig. 1. Location of the study area within Lebanon

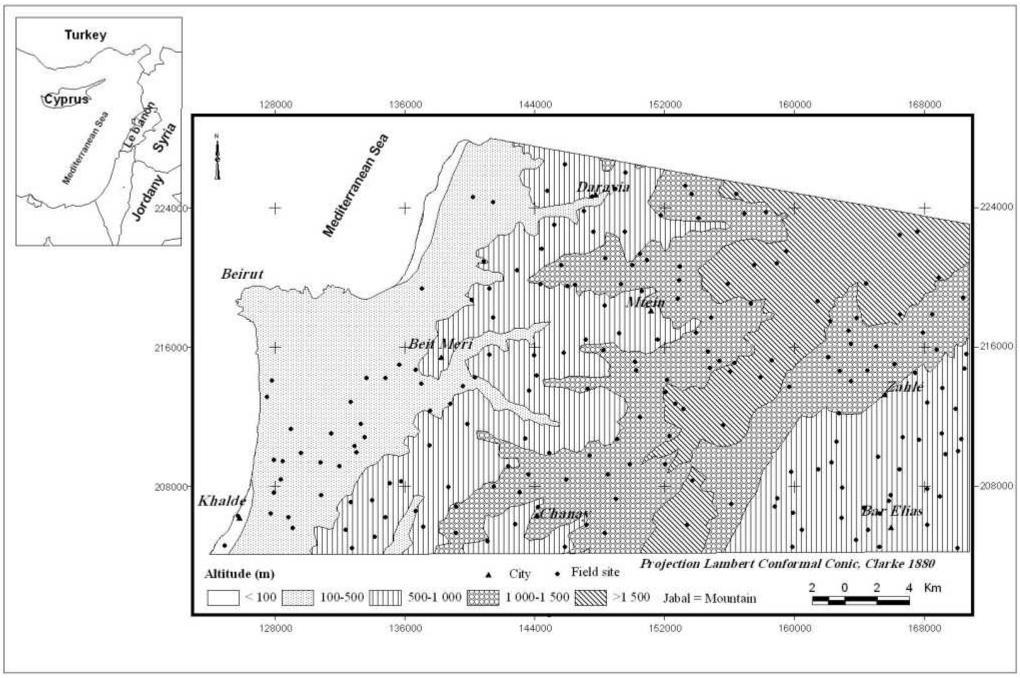

Fig. 2. Flow diagram of the modelling approach to elaborate the soil erosion risk map