An evaluation of the *MEDALUS ESA index* (environmental sensitivity to land degradation), from regional to plot scale

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ABSTRACT

An assessment of the sensitivity to land degradation have been carried out for the region of Extremadura, SW Spain, by means of the modelling approach developed in the European Commission funded MEDALUS project (Mediterranean Desertification and Land Use) which identifies such areas on the basis of an index (ESA index) that incorporates data on environmental quality (climate, vegetation, soil) as well as on anthropogenic factors (management). Two maps of environmental sensitivity to degradation with different legend resolution (4 and 8 classes of sensitivity) have been made.

The results of the model were validated at different spatial scales, i.e.; regional and farm scales. True field data on degradation-related variables at the different spatial scales have been used in order to undertake the validation procedures. Selected farms covering different physiographical and socioeconomic characteristics were used to gather data at farm scale. Data gathered from the National Inventory of Soil Erosion was also used to validate the model at the regional scale.

Palabras clave: ESA index. MEDALUS, Land Degradation, Desertification, Environmental Sensitivity.

INTRODUCTION

Land degradation represents a remarkable issue which is widespread over large areas of the world where soils have suffered from a loss of biological production and resilience caused by both, natural and anthropogenic factors (Blum, 1998; Mainguet, 1994). The phenomenon involves a reduction of the renewable resource potential by one or a combination of processes acting upon the land. The resource potential usually relates to the primary productivity of the systems, their agricultural suitability and also their natural biotic functions (Sombroek and El Hadji, 1993). In order to properly understand this phenomenon, it is important to identify and describe their main driving forces and the sensitivity of the lands.

To this respect, the concept of environmental sensitivity aroused several decades ago in order to identify areas prone to land degradation on the basis of their environmental characteristics. An environmentally sensitive area to degradation (ESA) could be considered as a spatially delimited area in which some key aspects related to its sustainability are unbalanced and not sustainable for a particular environment (Basso et al., 2000).

On the European Commission funded MEDALUS project, a method was developed based on GIS techniques in order to identify the sensibility to land degradation and desertification. The method is based on the computation of an index i.e., the ESA index, which involves several environmental (climate, soil vegetation) and anthropogenic (management) parameters in its calculation (Kosmas et al., 1999). This method has been applied in several regions and countries of the Mediterranean region. Nevertheless, efforts putted towards the validation of the results have rather been applied, mainly due to the lack of data for model validation at regional scales.

Usually, those methods devoted to model sensitivity to land degradation assume scale dependent uncertainties that depend on the quality and accuracy of the original data used to generate models.
The main goal of this work is to test the reliability of the ESA index method and the resulting maps of land degradation, calculated for the Region of Extremadura, SW spain, at different spatial scales i.e., the whole Extremadura region and farm scales.

Study area
The autonomous region of Extremadura is located in south western Spain. Most of the region is made up of vast stretches of undulating to flat peneplains and river depressions made up of old schist and greywacke as well as geologically more recent alluvial deposits. Reliefs of quartzite and granite dominate the three main mountain ranges that intersect the undulating plains. Two major drainage basins formed by the Tagus and Guadiana rivers are located in Cáceres and Badajoz respectively, which constitutes the two principal administrative divisions of the region (provinces). Climate is Mediterranean semiarid to dry subhumid with some oceanic influences.

METHODS

Two maps of different legend resolution were constructed on the basis of the computed ESA index since the method provided in Kosmas et al. (1999). The methodology for determining the MEDALUS ESA index and maps of environmental sensitivity in Extremadura are described in Lavado et al. (2009). Final map classes ranged from 1 (Non affected) to 4 (Critical) for the map of 4 classes and from 1 (Non affected) to 8 (Critical 3) for the map of 8 classes.
An extensive number of 2,990 field data points were gathered from the data base of the Spanish National Inventory of Soil Erosion in order to validate the maps a the regional scale. Data selected from this data base refers to 9 degradation-related variables: Sheet erosion (Sheet), total soil covered by woody vegetation (FccTot), percentage of soil covered by vegetation (Scover), livestock grazing intensity (Grazing), depth of the A soil horizon (DeepMO), permeability (Drainage), bulk density (BulkDensity), roots content (Root) and soil organic matter content (MO).
At the farm scale, a number of 54 selected farms covering different physiographical and socioeconomic characteristics were used and filed surveys were carried out (in 2 to 4 representative areas by farm) in order to collect data from several degradation-related indicator variables. An index, Deg2 (which summarized data on soil crusts, outcrops, surface stoniness, livestock path density and bulk density) was composed and used for map validation with other data on sheet erosion (Sheet), bare soil (Bare), soil covered by woody vegetation (Woody), livestock grazing intensity (Grazing), soil depth (Sdepht), water retention capacity (Retention), soil organic matter (MO) and gully erosion (Gully).
Expected *vs*. observed statistical behaviour of the 9 independent variables at the regional and at the farm scale, ordered by class of sensitivity, were analyzed for the maps of 4 and 8 classes as a way to assess the performance of the ESA maps. Spearman Rank correlations were calculated to this respect. Maps of ESA (and hence the underlying model used to draw them) could be considered of higher quality when more coincidences exist between the observed, i.e. the positive or negative correlations obtained between the independent variables and the classes of sensitivity; and the expected correlations. Expected correlations are deduced from known relationships between soil degradation and the set of variables selected. As an example, it is expected that regional areas or farms characterized as critical will show, on average, higher values of sheet erosion and lower organic matter content than other located characterized as having lower sensitivity, this will result in correlation values in the sense: higher sensitivity → higher erosion (positive correlation) and higher sensitivity → lower organic matter content (negative correlation).

RESULTS

Tables I and II shows the results obtained in the process of maps validation.
At the regional scale the expected vs. observed sign (positive or negative) of the correlations, along with their values and statistical significance for the maps of 4 and 8 classes show a coherent behaviour for all 9 variables in terms of the observed vs. expected sign of the correlations (same sign for observed and expected values). This reflects a good general performance of the model and the generated maps at this scale, that is, the classes of sensitivity behave as expected in terms of the variables used. Seven out of the nine variables used for map validation behave well in terms of the high values of correlation observed. Particularly the percentage of soil covered by vegetation, root content and observed sheet erosion features, proved to have the higher correlations with sensitivity in both maps, all of them positioned in the upper quartile of the range of correlation variability. The depth of the A horizon also performed well for the 8-classes map. Poorer suitabilities were obtained for livestock grazing intensity and soil permeability, both situated on the lower quartile of variability for both maps

Table I: Spearman R correlations between each of the 9 independent variables used at the regional scale for ESA maps validation and the classes of sensitivity obtained by partitioning the values of ESA index. Value and statistical significance along with observed and expected sign of the correlation (expressed as +, positive correlation, or –,negative correlation) are also indicated. * p<0.05, ** p<0.001, ns = not significant. See text for variable acronyms.

	Map 4 classes			Map 8 classes		
	Spearman R	Observed sign	Expected sign	Spearman R	Observed sign	Expected sign
FccTot	-0.220 **	-	-	-0.233 **	-	-
Sheet	0.266 **	+	+	0.280 **	+	+
Grazing	0.041 *	+	+	0.012 ns	+	+
DeepMO	-0.261 **	-	-	-0.284 **	-	-
MO	-0.184 **	-	-	-0.180 **	-	-
Drainage	-0.064 **	-	-	-0.100 **	-	-
BulkDensity	0.187 **	+	+	0.189 **	+	+
Roots	-0.276 **	-	-	-0.305 **	-	-
Scover	-0.339 **	-	-	-0.365 **	-	-

At the farm scale, based on the method proposed for map validation, the maps showed less correlation with the classes of sensitivity (p<0.05), and less variables performed significantly on a statistically sense. While most of the variables, regardless of the degree of significance, showed coherent behaviour in terms of the sign of the correlation, sheet erosion indicators and grazing intensity showed contradictory signs, particularly sheet erosion which was significant for both maps. However, other variables at the farm scale as Deg2, which synthesized values of some relevant indicators of land degradation (explained in methods), as well as gully presence detection and water retention capacity performed well in terms of the sign and signification of the correlations obtained.

Table II: Spearman R correlations between each of the 9 independent variables used at the farm scale for ESA maps validation and the classes of sensitivity obtained by partitioning the values of ESA index. Value and statistical significance along with observed and expected sign of the correlation (expressed as +, positive correlation, or –,negative correlation) are also indicated. *p<0.05, ns = not significant. See text for variable acronyms.

	Map 4 classes			Map 8 classes		
	Spearman R	Observed sign	Expected sign	Spearman R	Observed sign	Expected sign
Deg2	0.322 *	+	+	0.378 *	+	+
Sheet	-0.270 *	-	+	-0.273 *	-	+
Bare	0.014 ns	+	+	0.004 ns	+	+
Woody	-0.155 ns	-	-	-0.160 ns	-	-
Grazing	-0.265 ns	-	+	-0.268 *	-	+
Sdepth	-0.169 ns	-	-	-0.180 ns	-	-
Retention	-0.239 ns	-	-	-0.312 *	-	-
MO	-0.161 ns	-	-	-0.263 ns	-	-
Gully	0.299 *	+	+	0.321 *	+	+

CONCLUSIONS

The method proposed for mapping sensitivity to land degradation and to validate the results showed to be well performing at the regional scale. Performance at more local scales (farms) proved to be less efficient when reflecting the influence of livestock grazing intensity and sheet erosion, but good enough on the basis of other general degradation indicators as bulk density, crusts, stoniness and gully presence.

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