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# Joint application of the *ModRMMF* and *IC* models of soil erosion and sediment connectivity: improvement of modelling predictions

European Geosciences Union General Assembly 2013
Vienna | Austria | 07 – 12 April 2013

**Session SSS9.7:** *Validation and uncertainty in soil erosion modelling: achievements and challenges*

## Introduction

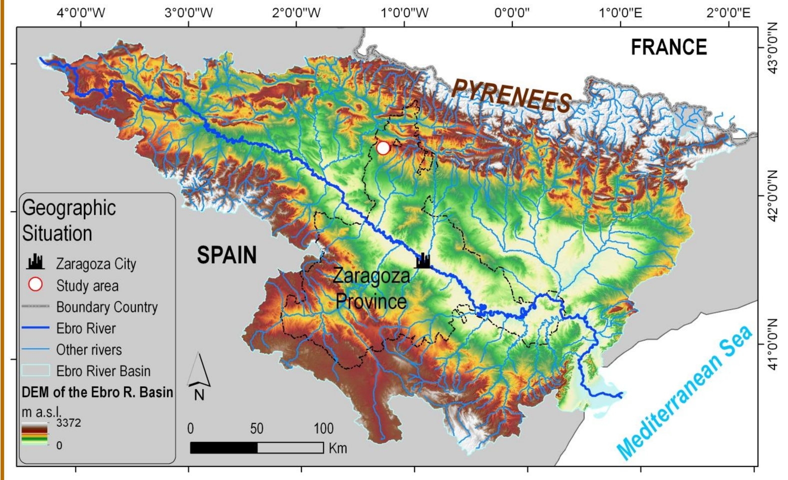
Soil detachment, sediment delivery and redistribution are non-linear processes that depend on many factors and their values change as a function of the different temporal and spatial scales. Therefore the development of accurate and broad models is a difficult task and most approaches cover a limited number of processes.

**Objective:** To boost the predictive ability of two models by their joint application in a Mediterranean agricultural system.

**Goals:**
1) Run the *ModRMMF* and *IC* models in a small agricultural system (*Cereal Plot*) at very high spatial scale (1 x 1 m).
2) Joint analysis of the results in order to identify those areas with net soil loss and deposition.
3) Run the calibrated IC model in *"La Reina" gully catchment* (5x5 m scale) to assess the potential soil redistribution,

## Study Area

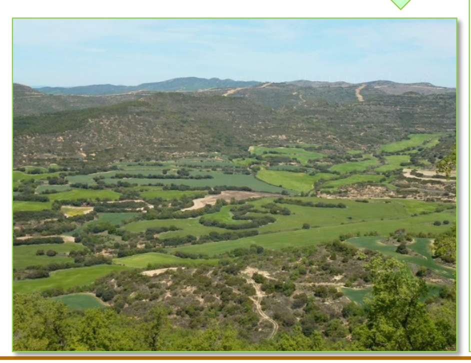
*"La Reina" gully catchment* (185 ha) is located in the External Ranges of the Spanish Pre-Pyrenees and within the Ebro Basin.

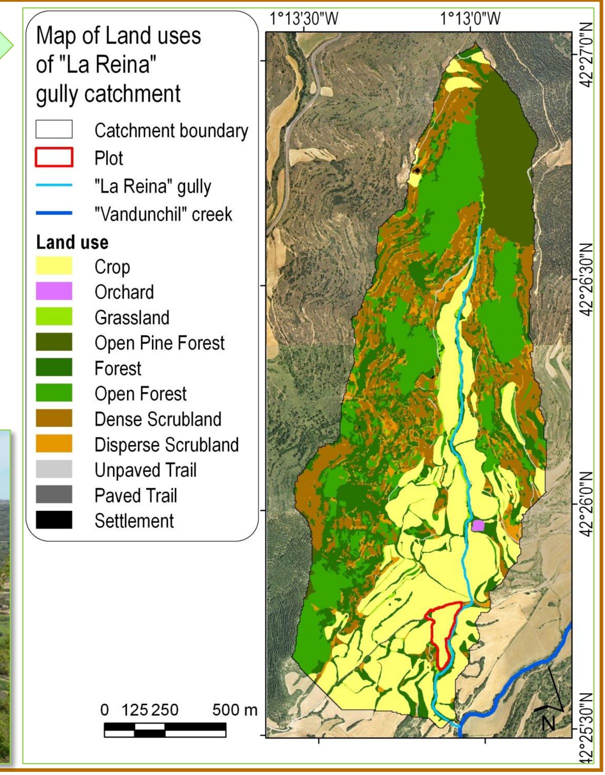



Climate is continental Mediterranean and the average annual rainfall was 514 mm in the latest 25 years (1987-2011).

This area presents numerous man-made infrastructures (paved and unpaved trails, drainage ditches, stone walls and barriers, buffer strips) that modify the runoff pathways and the effect of these landscape linear elements (*LLEs*) is included in the *IC* model.

The *Cereal Plot* (1.9 ha) is located in the lower part of the "La Reina" gully catchment and is divided into 4 sub-units.






## The *ModRMMF* model

The *Modified Revised Morgan, Morgan and Finney* model (*ModRMMF*; López-Vicente and Navas, 2010) is an enhanced version of the *RMMF* model (Morgan, 2001).

It estimates monthly and annual rates of soil detachment by splash ($F$, Mg ha$^{-1}$ yr$^{-1}$) and runoff ($H$, Mg ha$^{-1}$ yr$^{-1}$) and compares the total rate of detachment with the runoff transport capacity ($TC$, Mg ha$^{-1}$ yr$^{-1}$) to calculate the values of soil erosion ($E$, Mg ha$^{-1}$ yr$^{-1}$):

$$E_{i,m} = \min\left(F_{i,m} + H_{i,m},\ TC_{i,m}\right)$$

It includes the improvement presented by Morgan and Duzant (2008) to consider the effect of slope angle, $S$ (radians), on the quantity of rain received per unit area, $ER$ (mm), and also the effect of the infiltration processes in the estimation of the effective cumulative runoff, $CQ_{eff}$ (mm):

$$ER_{i,m} = R_m\left(1 - A_{i,m}\right)\cos S_i$$

$$CQ_{eff-i,m} = \left(CQ_{0B-i,m} - Kfs_i\, ee_m - SS_{max-i,m}\, ee_m\right)\sin S_i$$

### Input acquisition

*A total of 613 sampling points were settled in the Cereal Plot.*
*All input and output maps were generated with ArcMap™ 10.0.*

## The *IC* model

The *Index of runoff and sediment Connectivity* model (*IC*; Borselli et al., 2008) takes into account the characteristics of the drainage area (upslope module) and the flow path length that a particle has to travel to arrive at the nearest sink (downslope module) to provide an estimate of the potential connection between the sediment eroded from hillsides and the stream system:

$$IC_K = \log_{10}\left(\frac{D_{up,K}}{D_{dn,K}}\right) = \log_{10}\left(\frac{W_K \cdot S_K \cdot \sqrt{A_K}}{\sum_{i=K,n_K} \frac{d_i}{W_i \cdot S_i}}\right)$$

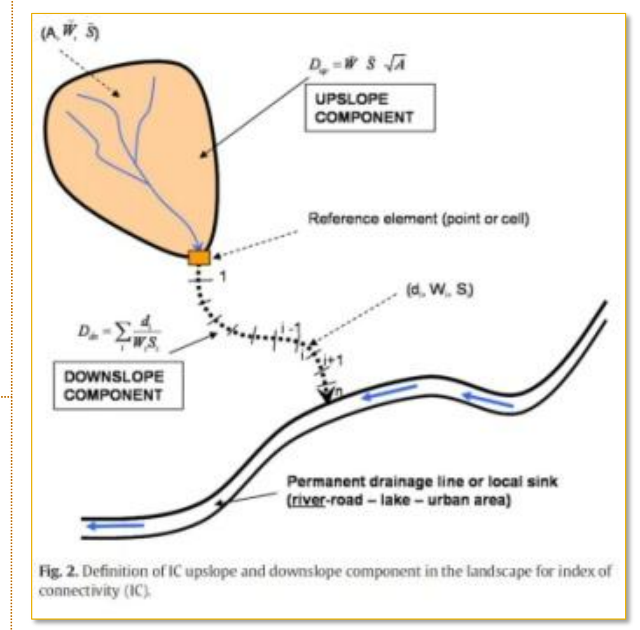
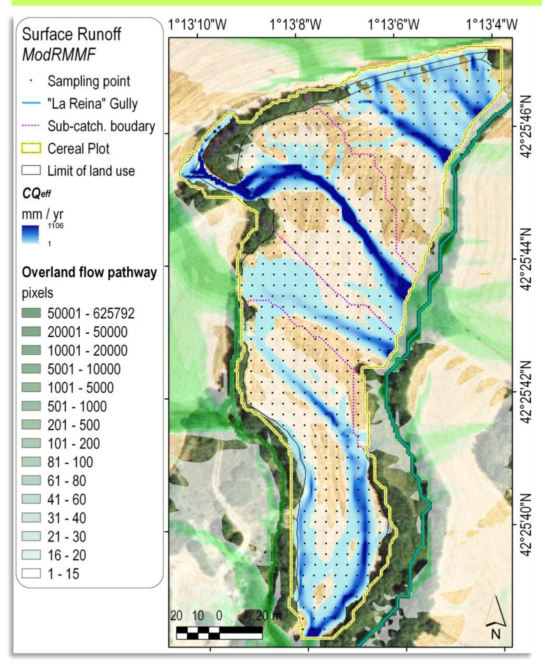


Fig. 2. Definition of IC upslope and downslope component in the landscape for index of connectivity (IC).

This model was successfully used by Cavalli et al. (2012) and López-Vicente et al. (2013) in medium-size agricultural and mountainous catchments in Northern Italy and Northeastern Spain to identify areas with net soil loss and deposition.

## Surface Runoff — *ModRMMF* model — Soil Erosion

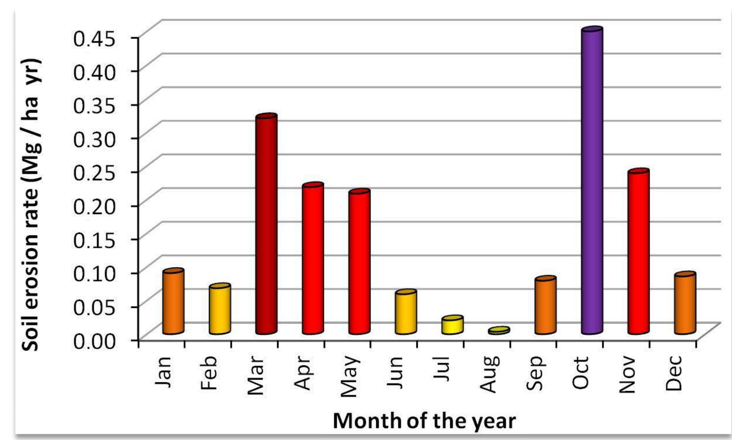


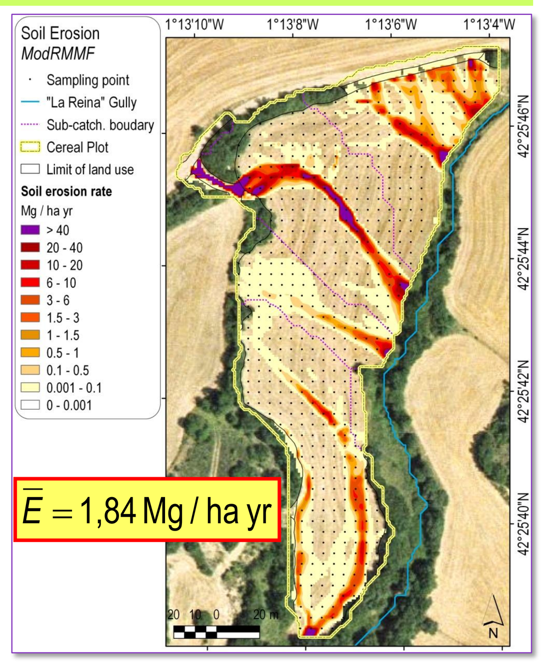

The map of cumulative runoff, calculated with a multiple flow algorithm (MD), allowed identification of areas with predominant rill erosion or with main interrill erosion.

**Northern part:** Both rill and interrill erosion, presence of multiple outlets.

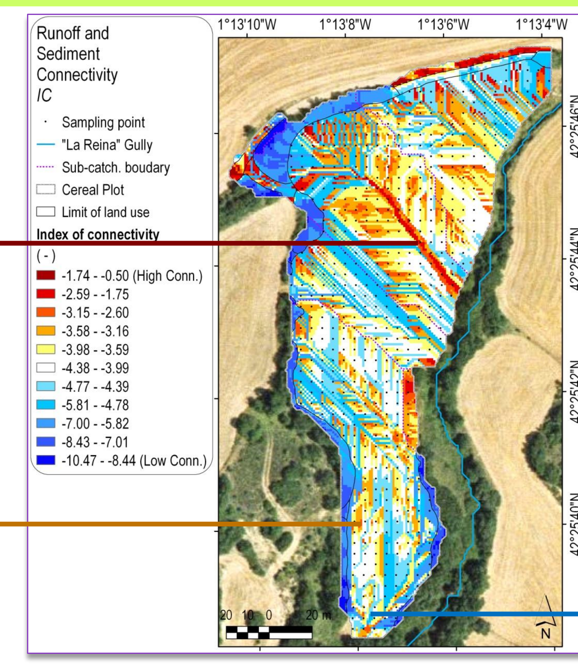
**Southern part:** Predominant interrill erosion, presence of tillage erosion and only one outlet.

Soil erosion ($E$) has high spatial ($sd$ = 15.5 Mg / ha yr) and temporal variability (78% of total $E$ in 5 months).



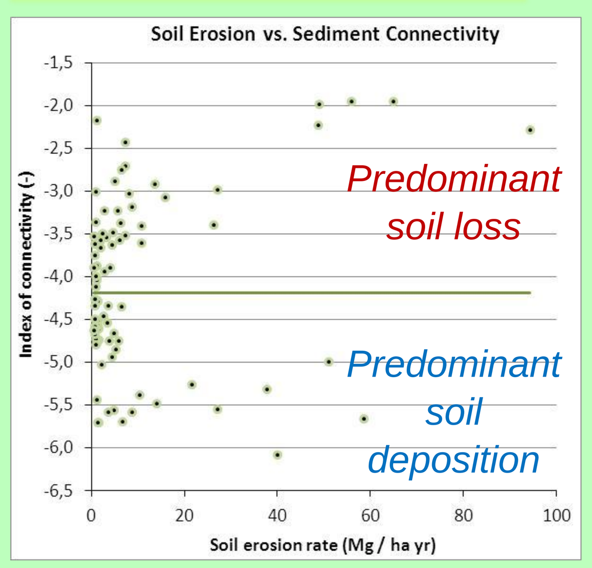

## *IC* model: Sediment Connectivity




- The map of sediment connectivity mirrors the spatial pattern of soil erosion though the values of *IC* (-10.5 – -0.5) present a higher spatial variability, especially in those areas where the soil erosion model predicts both very low and very high rates.
- Sediment connectivity is high in the unpaved trails and those areas with concentrated overland flow.
- The IC model let us identify pixels and small patches with low connectivity within areas with predominant processes of soil loss.

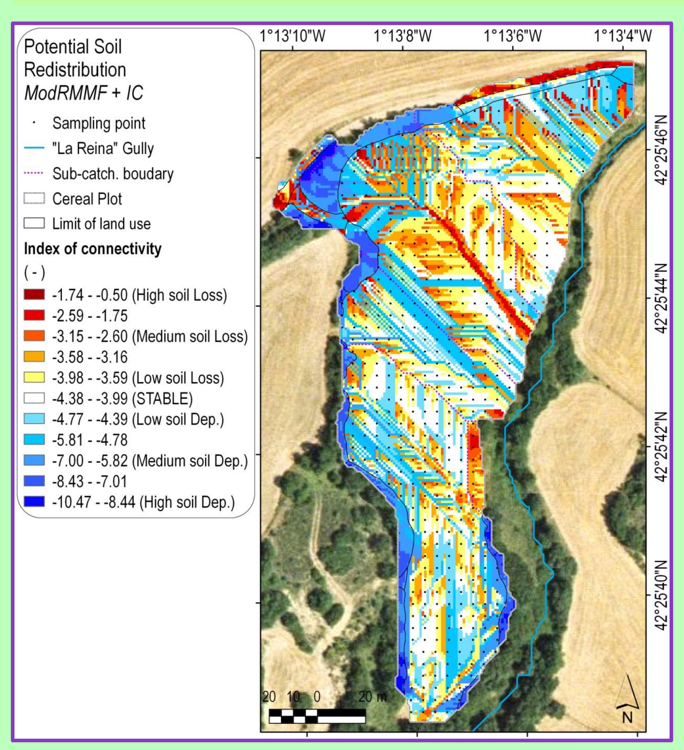
## Joint analysis of the *ModRMMF* and *IC* models

### 1) Comparison of predicted values

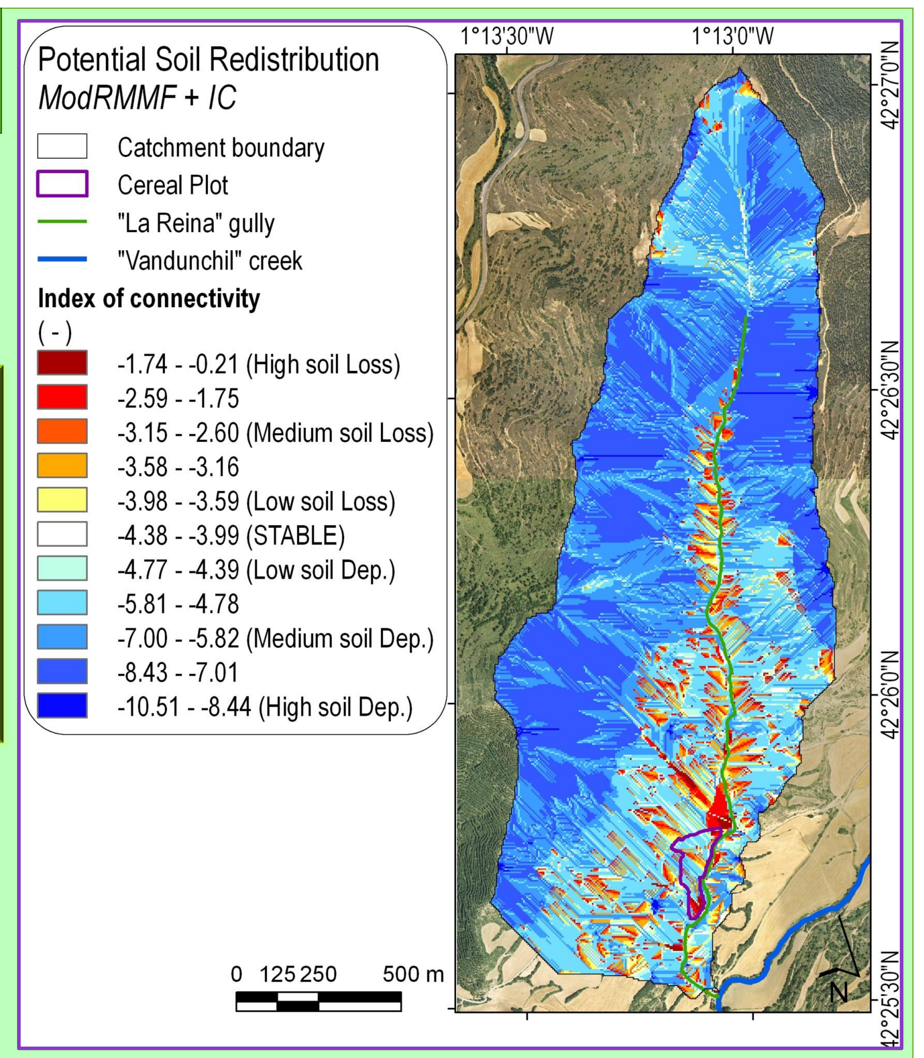



*Two populations with an inflexion point in the value **IC** = -4.19*

### 2) Potential soil redistribution in the Cereal Plot




### 3) Potential soil redistribution in the "La Reina" Catchment




## Conclusions

- The combined use of a soil erosion model and a runoff and sediment connectivity model allows identifying the areas affected by processes of intense soil erosion and those areas where the soil redistribution dynamics favour the occurrence of net soil loss or net soil deposition.
- The combined used of the *ModRMMF* and *IC* models is a good choice because it makes more valuable the results obtained with each model separately and helps to obtain a better interpretation of the generated maps.

**Acknowledgements**

This research was funded by the Project *"Erosion and redistribution of soils and nutrients in Mediterranean agroecosystems: radioisotopic tracers of sources and sinks and modelling of scenarios (EROMED) (CGL2011-25486/BTE)"* of the Spanish Ministry of Economy and Competitiveness (former Ministry of Science and Innovation).

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