Impact of Global changes on soil vulnerability in the Mediterranean basin.

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Context: Impact of global changes

- **Soil erosion responds both to the total amount of rainfall and to differences in rainfall intensity,**
- Changes in plant biomass (soil surface canopy cover, biological ground cover).
- Changes from snowfall to rainfall.
- Snow melt
- **Increase in fire occurence**
- Finally, if farmers react to climate change by implementing different crops, crop varieties or even change land use patterns.

- **What would be the impact of global changes on the soil resources in a vulnerable area: The Mediterranean Basin**

Lebna Catchment (North Tunisia)

Mediterranean soil erosion and vulnerability to global change during the 21st century

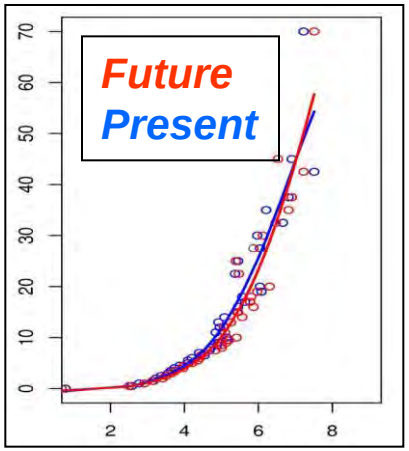
- Because of the difficulty to implement relevant regional erosion assessment the methodology is based on a multiscale approach

- To define climate and (induced… or not) land use change scenario at local and regional scales

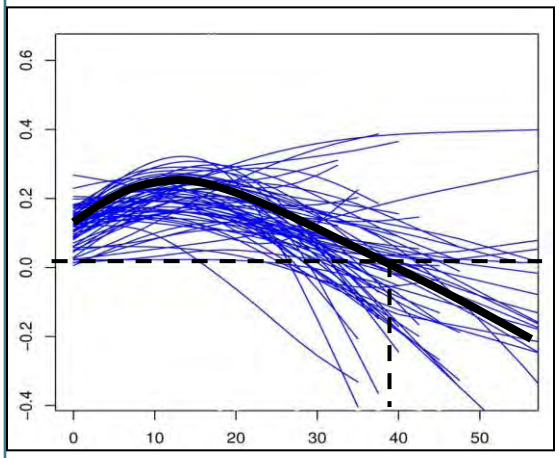
- To develop or adapt soil erosion modelling methodologies at different scales

The Climate scenario

> Evaluation and adaptation of Climate Change scenario to the Mediterranean basin



- GCM ARPEGE-Meteo France v3.0 & V4 - IPCC-B2 and A1B scenario from 1960 to 2099
- Development of disaggregation methodologies 50km → 1 km → 30 m to account for the altitude and topography.
  - For temperatures, we used linear relationships with altitude from field measurements (actual meteorological data around the watersheds),
  - the relationship between altitude and rainfall is more complex for daily events: non-linear relationship with altitude varying along the season for the Mediterranean region.

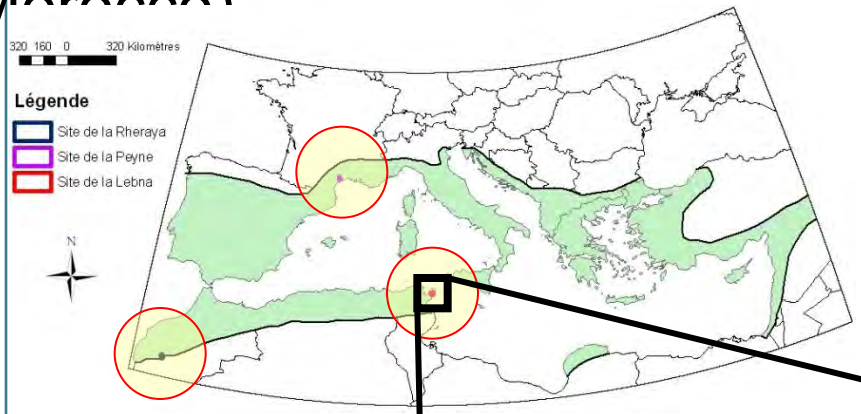


The Land use scenarios

- **Constrains:**
  - Cropland, slopes (<5%) and altitudes <1000m.
  - Permanent cultures, altitude <1000m.
  - Urban expansion on low slopes (Population + 15% in the North, + 250% in the South, FAO statistics)
  - Fires by 2 in 2050, by 3 in2100 (+ 3.5°C in summer)
- **Scenario 1: (Knowledge is king) : expansion of irrigated agriculture (technological development).**
  - Increase in croplands and permanent cultures, decrease of forests
- **Scenario 2: (Big is beautiful): Cropland abandonment, increase of natural ecosystems and mixed land uses (agro-forestry..).**
- **Scenario 3: (Convulsive change): as a result of drought and periods of high temperature, cropland are converted to degraded zones or natural ecosystems modified by fires .**

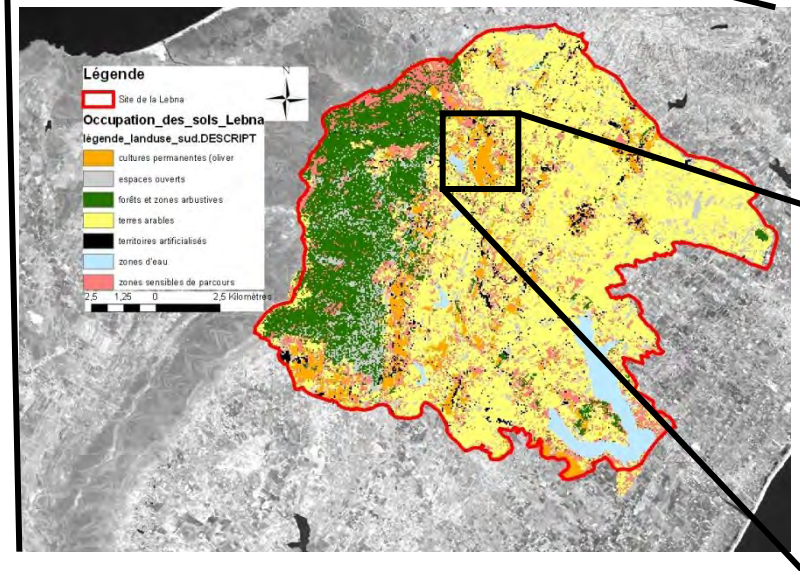
Refer to Mouillot et al., 2002; 2003; 2005; Kok et al., 2006; Rounsevell et al., 2005; Spangenberg, 2007; Thuiller et al., 2006.

Modelling approach: progressive upscaling (France, Tunisia, Morocco)



Nested approach, 3 different scales:
→Modification of the input parameter classifications (new pedotransfert functions, new land uses categories…)

Bigger catchment with existing erosion assessments (dams, field campaigns, gauging stations)



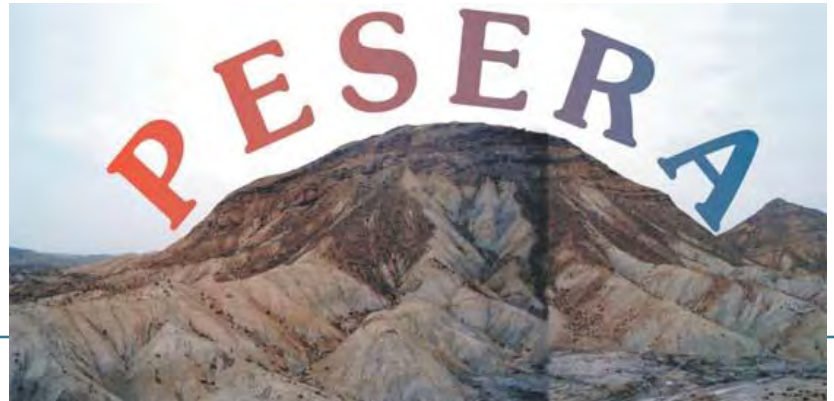
Gauged zero order catchments

PESERA approach

The Pan-European Soil Erosion Risk Assessment Project
To develop, calibrate and validate
a **"physically based"** and spatially distributed model to quantify soil erosion relevant to European scale

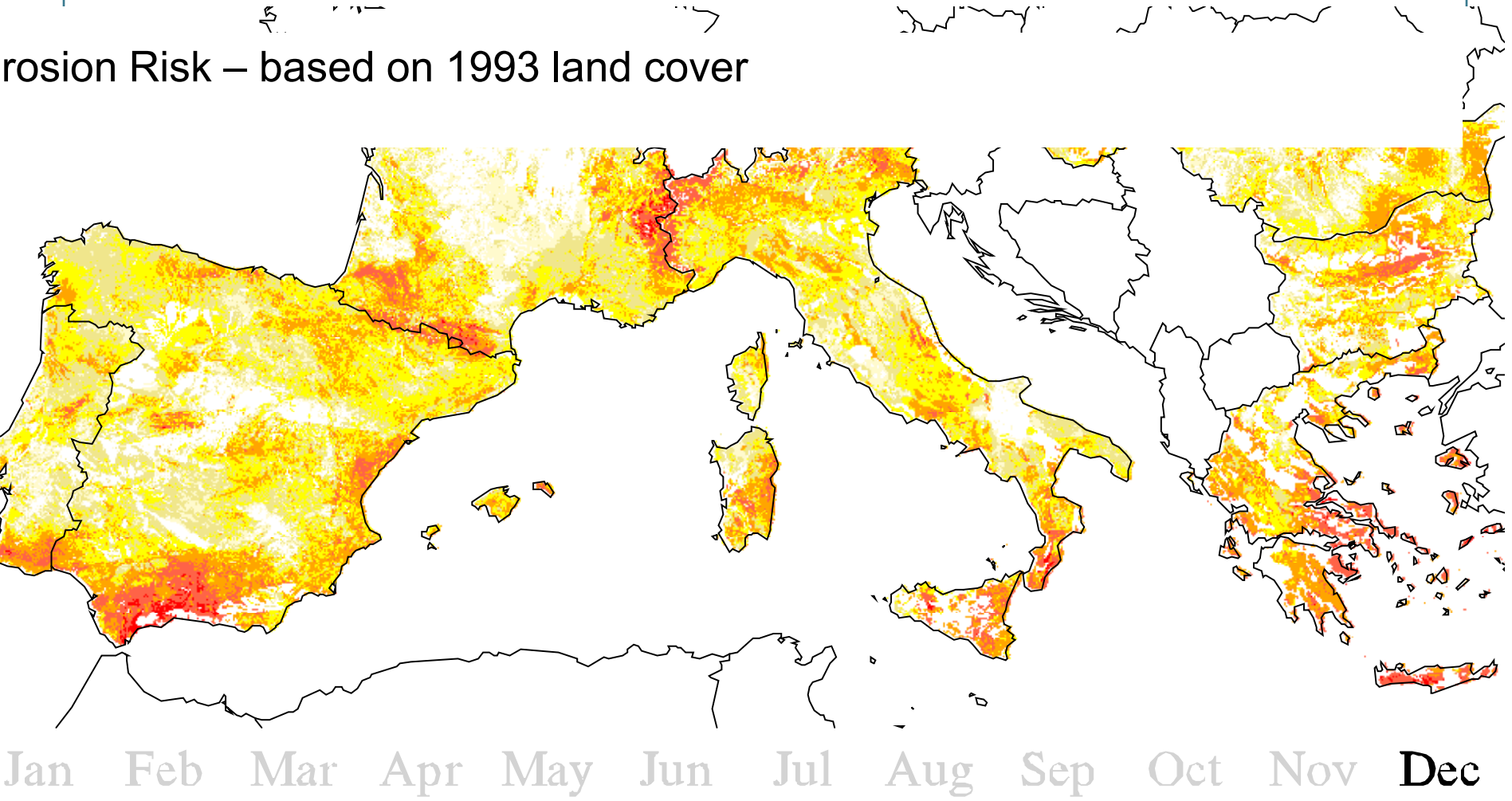
Crop growth, snow melt routines
1D-hydrological balance
combined with a
physically based sediment transport equation

$$S = \sum_{Storms} \left[k_1 \Lambda + k_2 \Lambda^m \left(q\Lambda - \Theta \right)^n \right]$$

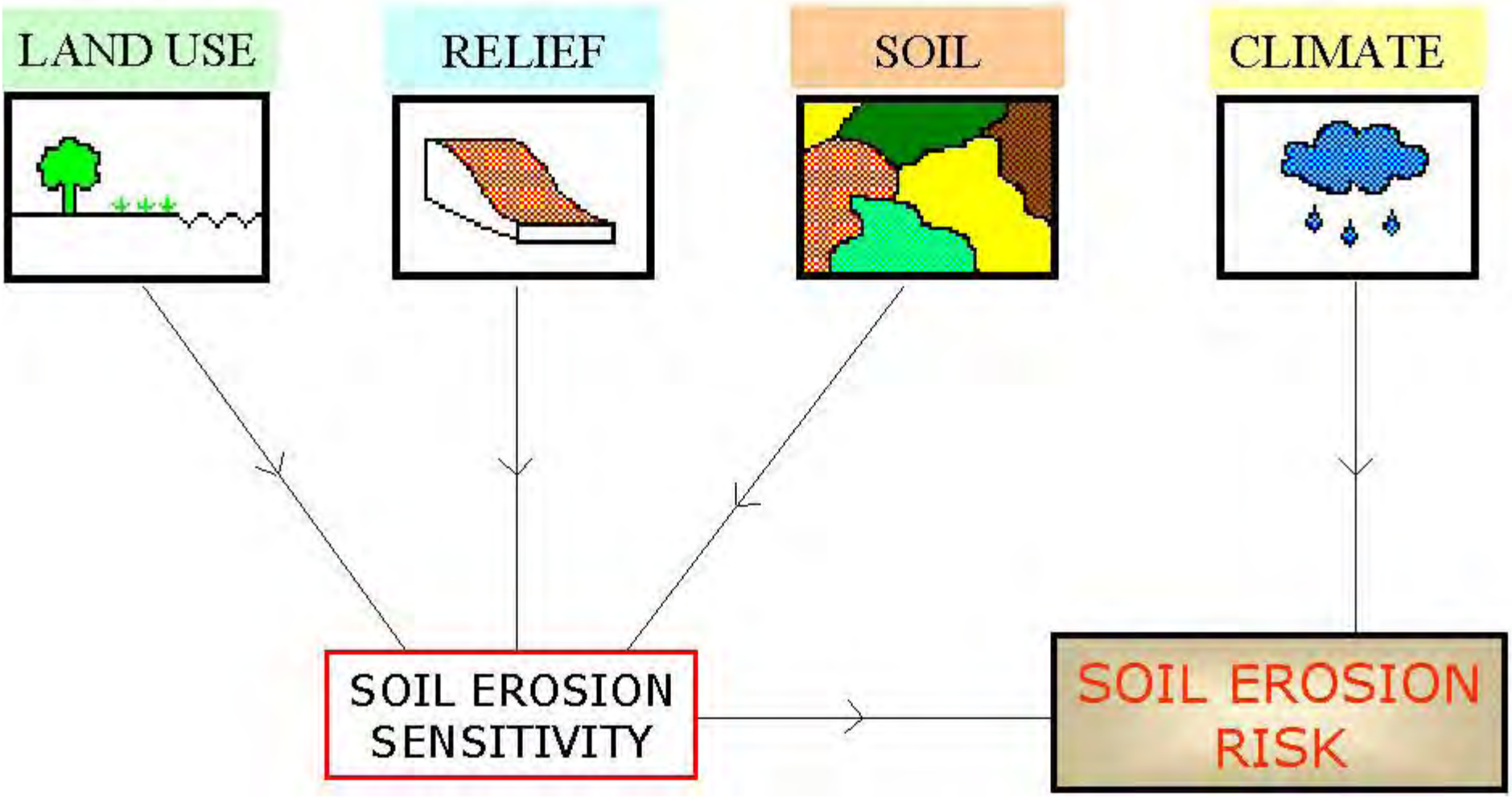


PESERA approach

rosion Risk – based on 1993 land cover

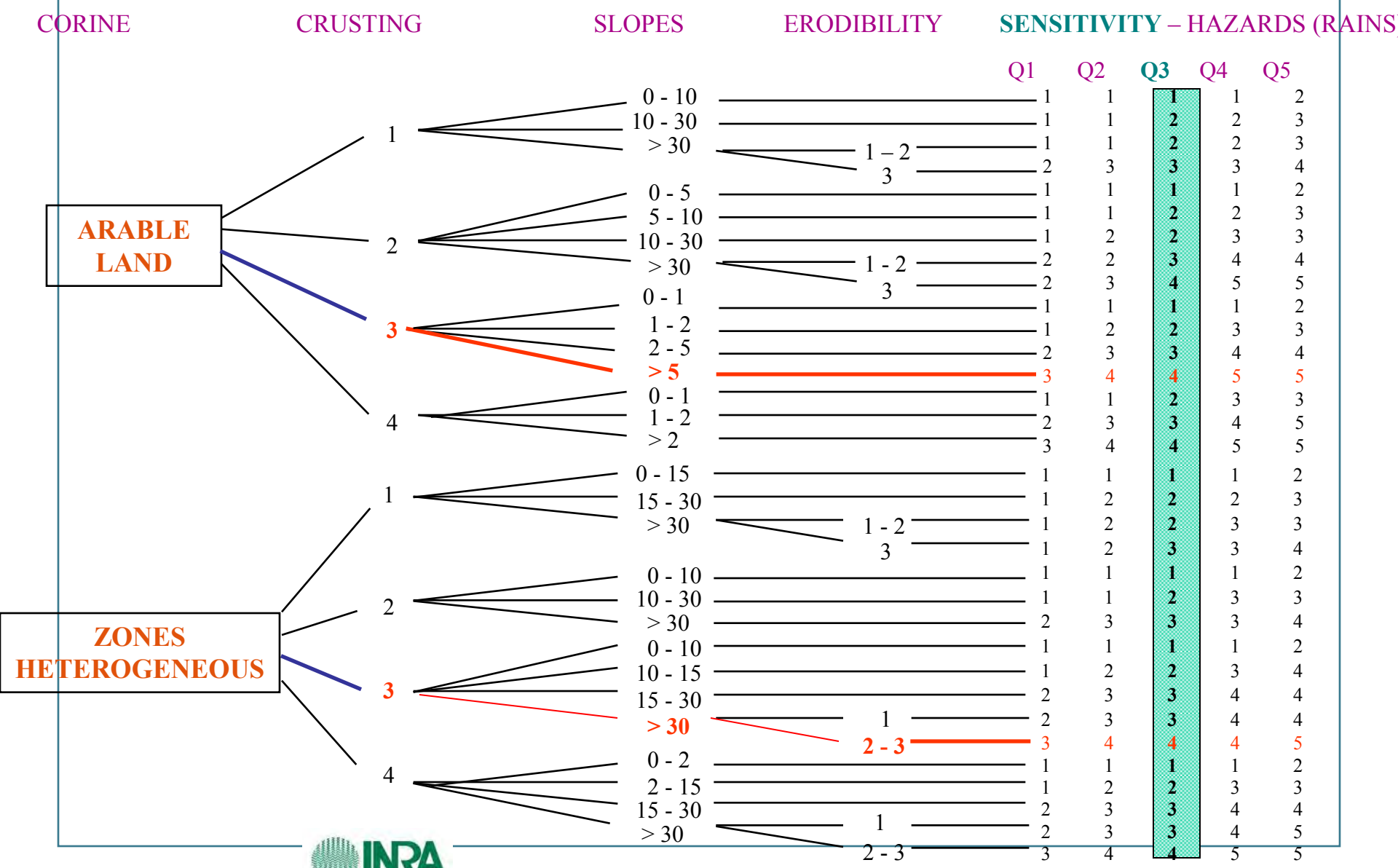


The MESALES approach



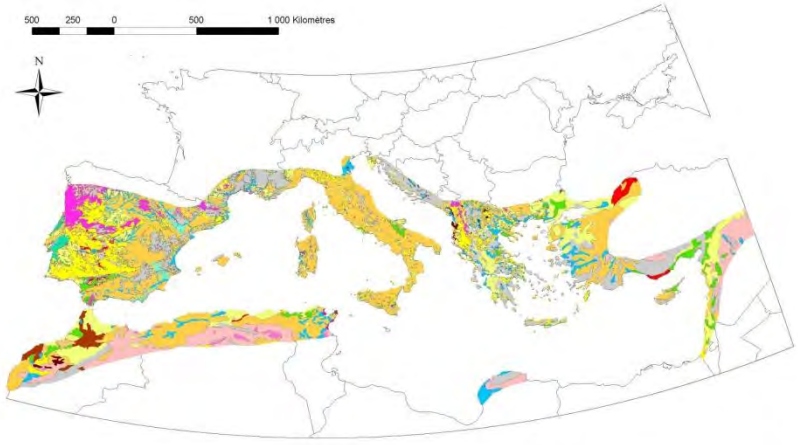
http://eusoils.jrc.it/ESDB_Archive/serae/grimm/erosion/inra/europe/analysis/maps_and_listings/web_erosion/presentation.html

MESALES Approach



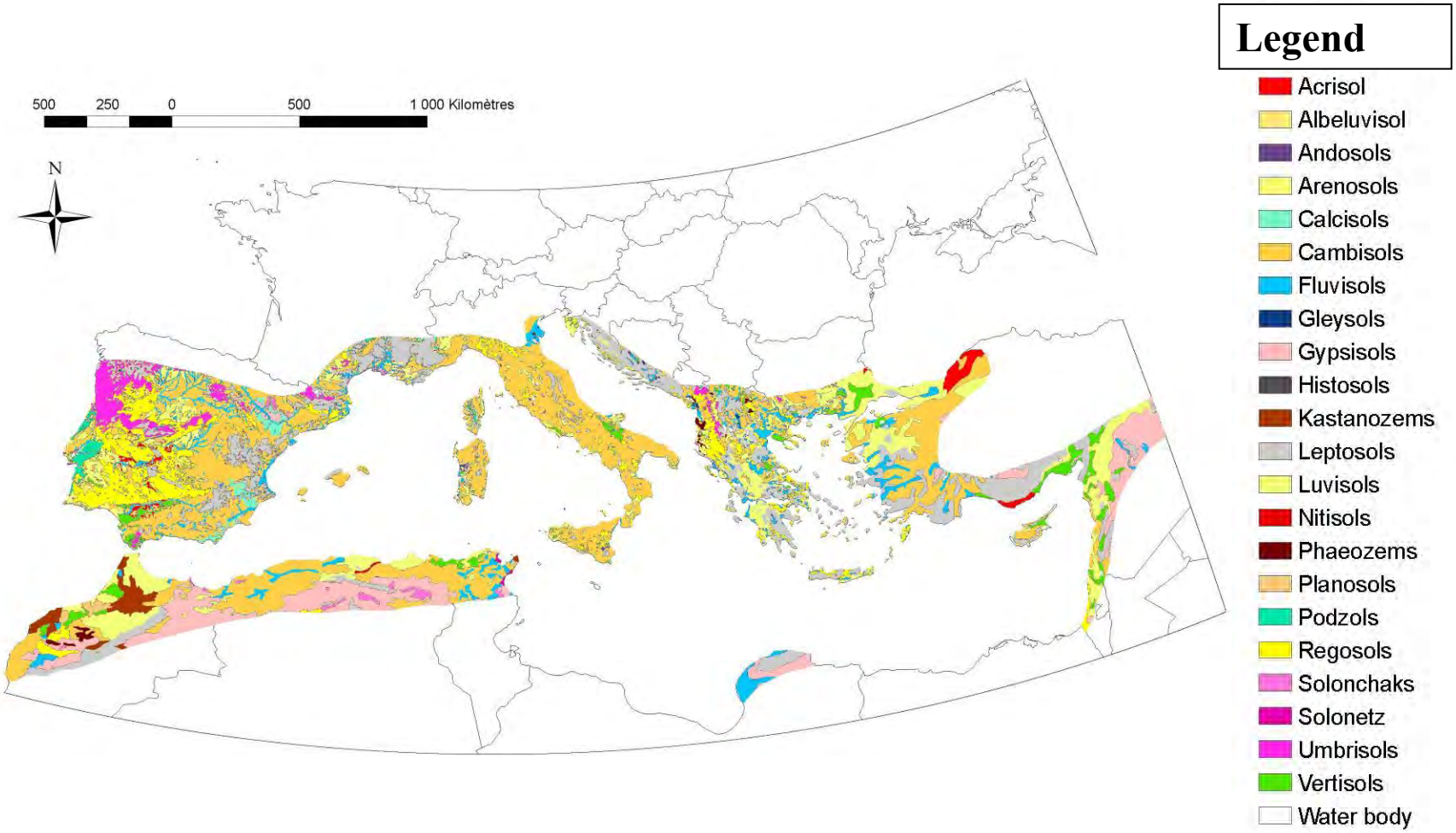
Input parameters: Soil properties

- Homogeneized World Soil Database,
- Elaboration of pedotransfert rules to derive :
  - **Erodibility**
  - **Crusting**
  - **Water storage capacity**
  - **Soil depth**
- Rules developed on the basis of the higher resolution pedological and geological maps on the experimental catchments (La Peyne, Lebna, Rheraya)

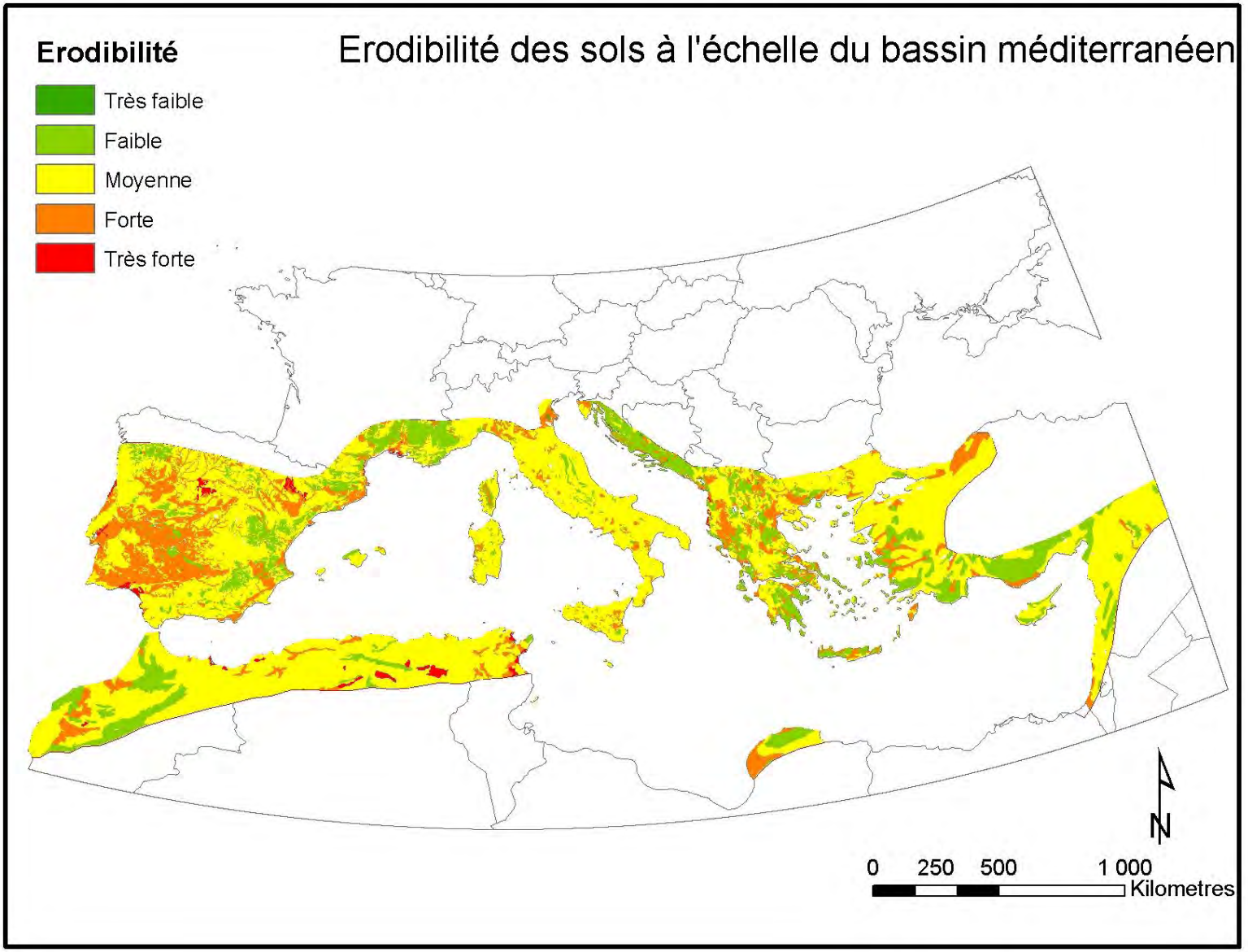


Carte des sols du bassin méditerranéen

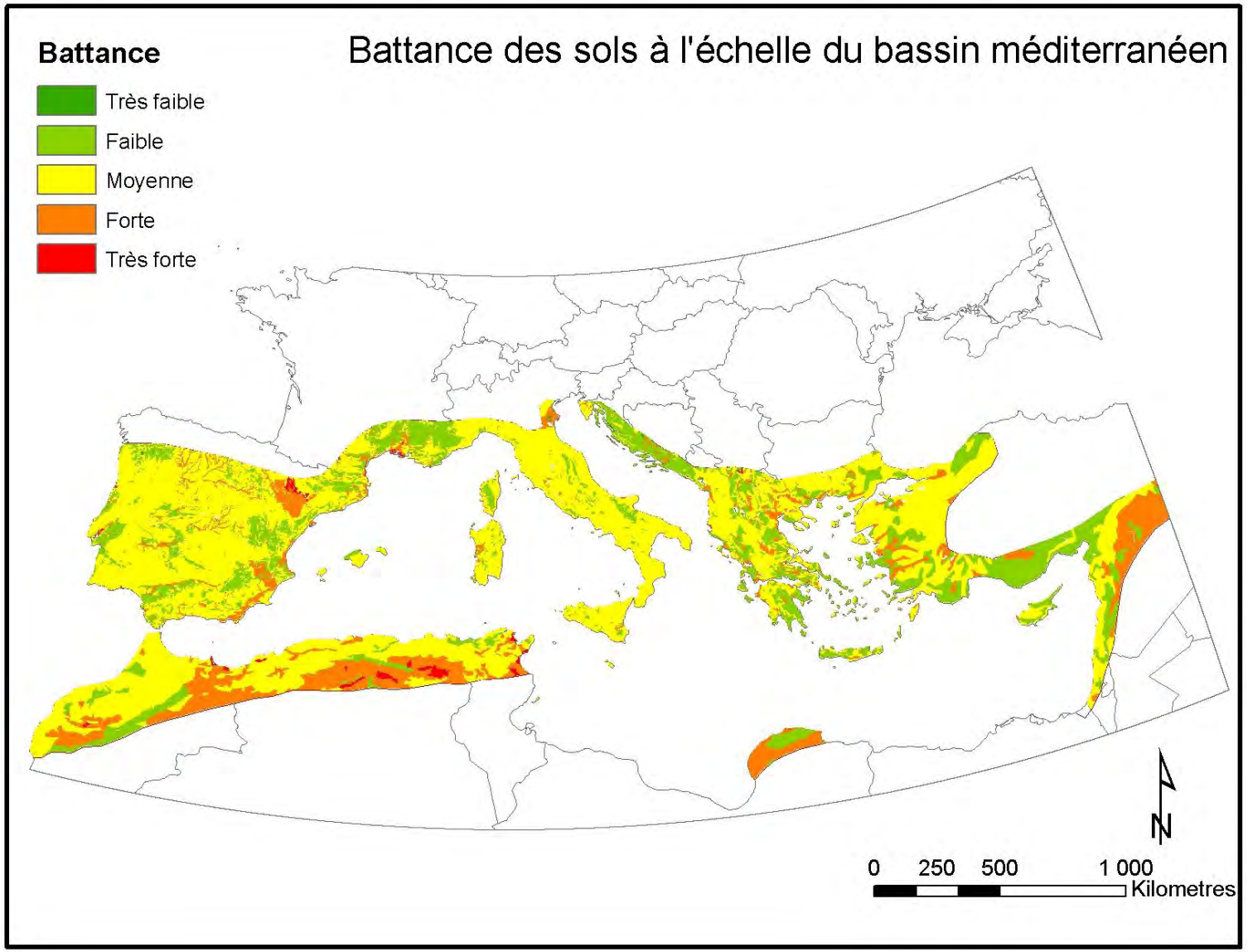
Input parameters: Soil properties



Input parameters: Soil properties, Erodibility

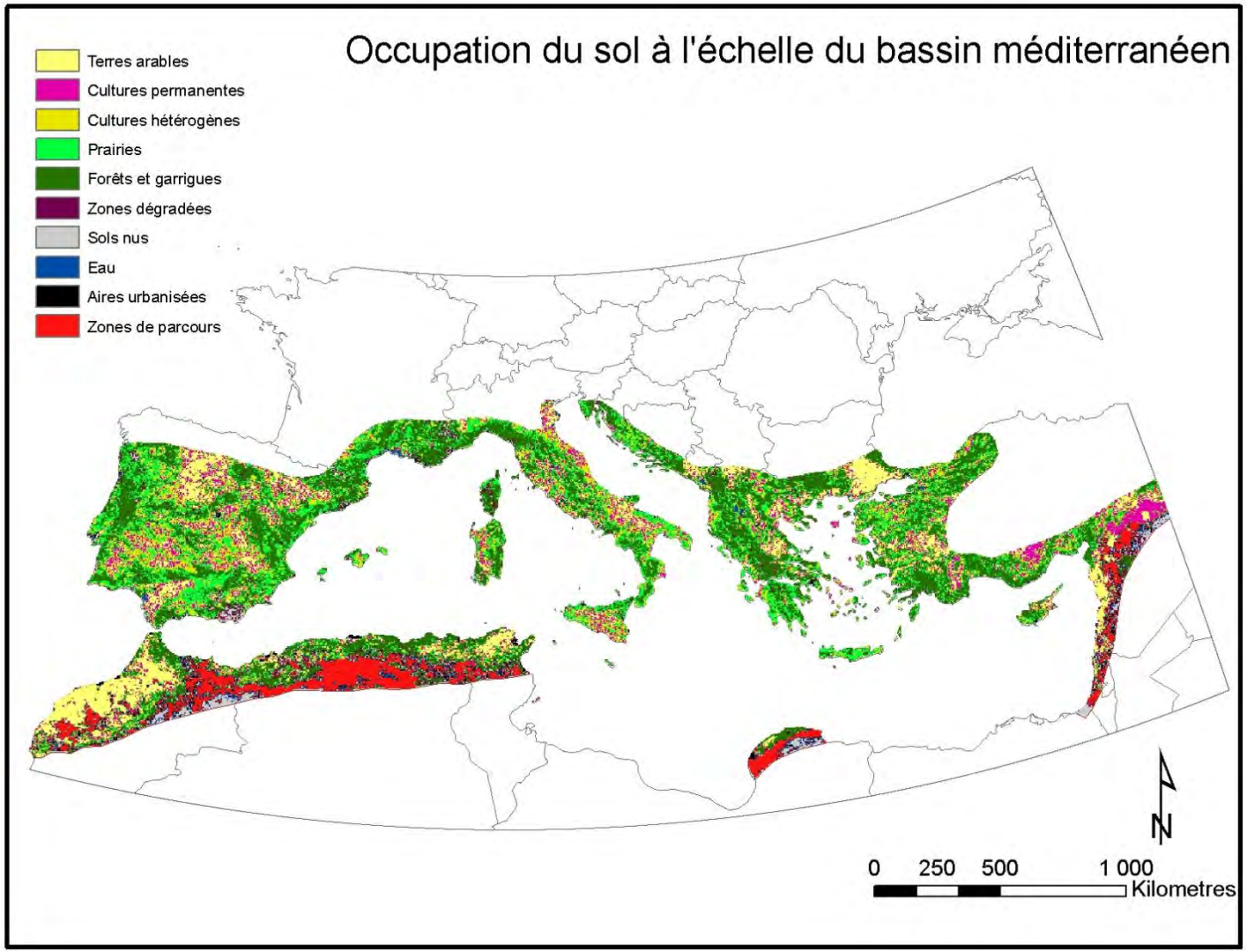


Input parameters: Soil properties, Crusting

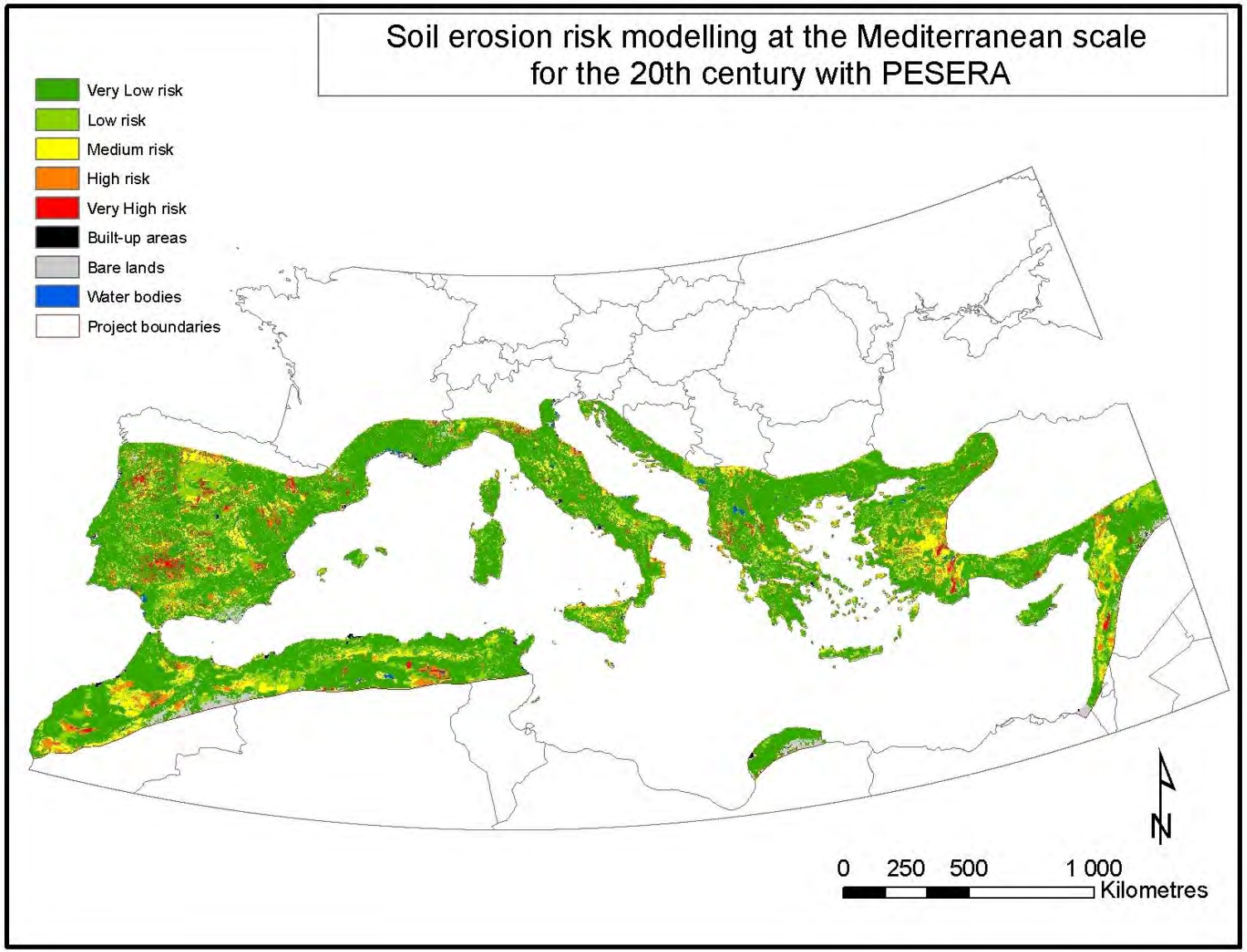


Input parameters: Land use

> **Corine Land Cover and Global Land Cover**



Results: PESERA Current conditions



> Results:

- An average around 2 ton/ha/an (1.2 for Europe).
- high erosion rates represent around 20% of the area.

> Comparison:

- PESERA - MESALES, more than 75% of the pixels have a maximum of 1 class difference.
- % of area < **1**/ton/ha/yr: **66**% for MESALES and **67**% for PESERA.
- % of area > **3**/ton/ha/yr: **17**% for MESALES and **18**% for PESERA.
- Seasonality in the response with the highest rates in Autumn for both models.

> An analysis of the difference between PESERA and a reference soil erosion map on the Mediterranean part covered by CORINE Land Cover (Cerdan et al., 2010), also highlight an overall good agreement (64% of the pixels presenting differences below 1 ton/ha/an and73 % below 2 ton/ha/an).

> Differences:

- the relative importance that the models give to the different input parameters. Model sensitivity analysis showed that PESERA is much more sensitive to the erodibility parameter than MESALES (Cheviron et al., 2011). Areas showing high erodibility values compared to the other parameters will thus be treated differently, the PESERA model assigning higher erosion rates.

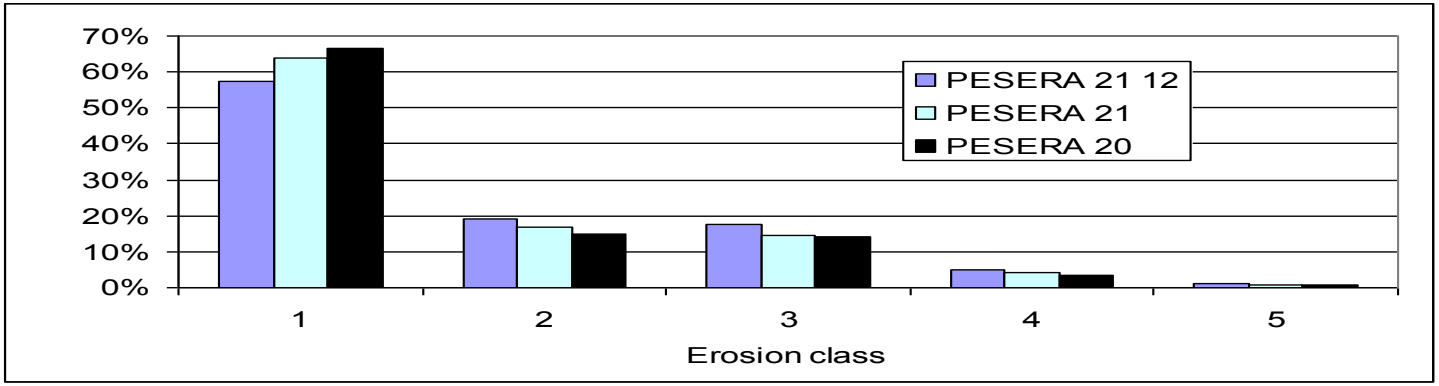
Results

> Future climate

- Significant increase of of area > **3**/ton/ha/yr.
- Increase more sensitive in the south part of the basin.

> Landuse scenarios:

- Strongest effects for the intensification of agriculture scenario.
- The degradation of the land to open spaces or the practice of mixed agriculture seems to have similar impact on soil erosion.
- Influence of land use seems to be more important

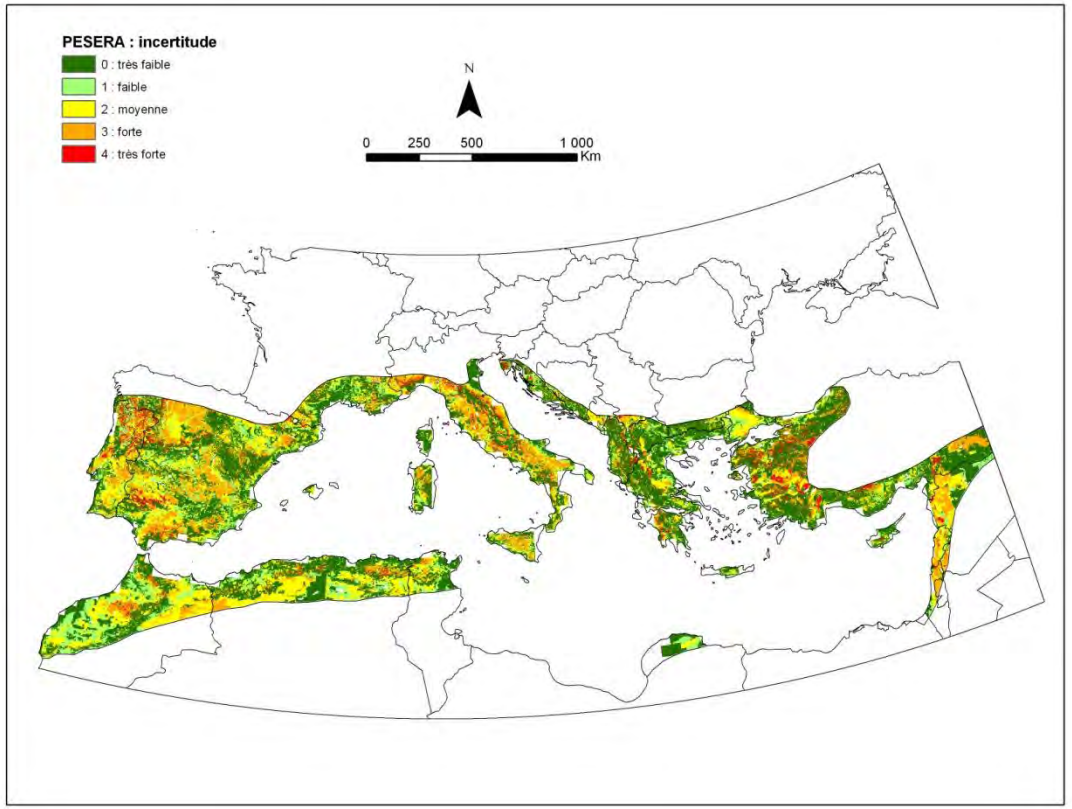


Evaluation:

- To assess the validity and the overall coherence of the simulated erosion rates, apart from the comparison between the results of both models or a reference map, a sensitivity analysis has been carried out to point out the impact of potential low quality of some of the input data,
- **Uncertainties**
  - Simulation of best-worst case scenarios with both models
  - Best- worst case scenarios elaborated in function of the quality of the input data
    - Best cases if all the data contains a certain error that goes in favour of soil protection
    - Worst case if all the data contains a certain error that goes in favour of soil erosion
    - The difference between the two maps gives the maximum range of errors due to the input parameter uncertainties
    - For example, for land use, the mixed class “arable / forest” has been reclassified either in “forest” for the best case scenario or in “arable” for the worst case scenario.
- **For each pixel, the model which is closest to the validation datasets and were the difference worst – best is minimum will be selected**

Evaluation:

- the bigger the difference between the scenarios, the more sensitive the model will be to these uncertain parameters



- This map is thus showing the maximum possible difference, it is in fact not likely that all the pixels of a simulated map present a systematic over-or underestimation of all the input parameters. We can observe that for **57% of the area have a maximum of one class** difference; for these pixels we can consider that the uncertainty due to the input data is limited. On the other hand, for the **21% that show at least a three class difference**, the obtained results potentially contain high errors.

Conclusions:

- **This study permitted to produce a coherent soil erosion map for the Mediterranean basin**
- **Different methodologies tend to give converging results**
- **Not still able to exactly distribute the rates but the trends are consistent**
- **the indirect effect of climate change (i.e. land use change as an adaptation to the new climatic conditions) may induce significant increase of the erosion rates particularly if the demand for food production is to increase.**
- **A sensitivity analysis also demonstrated that more than 20% of the simulated area could potentially possess high prediction errors.**