LIFE08 ENV/IT/436

PROJECT *ACT*

ADAPTING TO CLIMATE CHANGE IN TIME

SOIL: IMPACTS, VULNERABILITY AND POSSIBLE ANSWERS

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Soil is an extremely complex and variable medium. Over 320 major soil types have been identified in Europe and within each there are enormous variations in physical, chemical and biological properties.

As soil formation is an extremely slow process, soil can be considered essentially as a non-renewable resource. Soil is important for the existence of living species on our planet and carries out a series of functions making it essential for maintaining the environmental balance. Despite this, it is too often perceived only in terms of support to agricultural production and as a physical base on which to develop human activities. Soil functions must be protected because of both their socio-economic and environmental importance.

The most commonly forms of unsustainable land use are overcultivation, overgrazing, deforestation, and poor irrigation practices. In addition the impact of human activities on soil include erosion, decline in organic matter, local and diffuse contamination, sealing, compaction, decline in biodiversity, salinization, floods and landslides. A combination of some of these threats can ultimately lead arid or sub-arid climatic conditions to desertification [(COM(2006) 231)].

European strategy on Soil:

European Commission 2001-2010 6th EU Environment Action Programme (6EAP). In the document “**Environment 2010: - Our Future, Our Choice**”:

- the importance of soil is outlined because it acts as ‘sinks’ which absorb carbon dioxide from the air.
- a new policy must be developed because it takes thousands of years to create;
- the importance to develop a strategy for soil protection

Towards a Thematic Strategy on Soil Protection” (COM(2002) 179 2002) the Commission identified the main eight threats These are:

- erosion
- organic matter decline,
- contamination
- salinization
- compaction
- soil biodiversity loss
- sealing,
- landslides and flooding.

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The proposed Directive - COM(2006) 232 final – also includes:

- The establishment of a common framework to protect soil on the basis of the principles of preservation of soil functions, prevention of soil degradation, mitigation of its effects, restoration of degraded soils and integration in other sectoral policies.

- The requirement for land users to take precautionary measures when their use of the soil can be expected to significantly hamper soil functions.

- Identification of areas at risk of erosion, organic matter decline, salinisation, contamination, compaction and landslides, and establishment of national programs of measures. To ensure a coherent and comparable approach, the identification of risk must be carried out on the basis of common elements. These elements include parameters which are known to be driving forces for the different threats. Risk reduction targets and programs of measures to reach those targets will have to be adopted. Programs can build on standards and measures already identified and implemented in national and Community contexts.

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Soil salinization

Salinization refers to **an excess of salts in soil, due to natural and human causes. It can reach levels that can compromise vegetation and farming activities causing negative effects on the soil’s biodiversity and on its resistance to erosion**.
An italian map indicating the extent and characteristics of salt-affected soils soils is still not available but a lot of information has been collected by Universities and regional soil services.
RAMSOIL project (http://www.ramsoil.eu) provides a general overview of the different types of scientifically acknowledged soil salinity risk assessment methods. Different countries use various methodologies for risk assessment.

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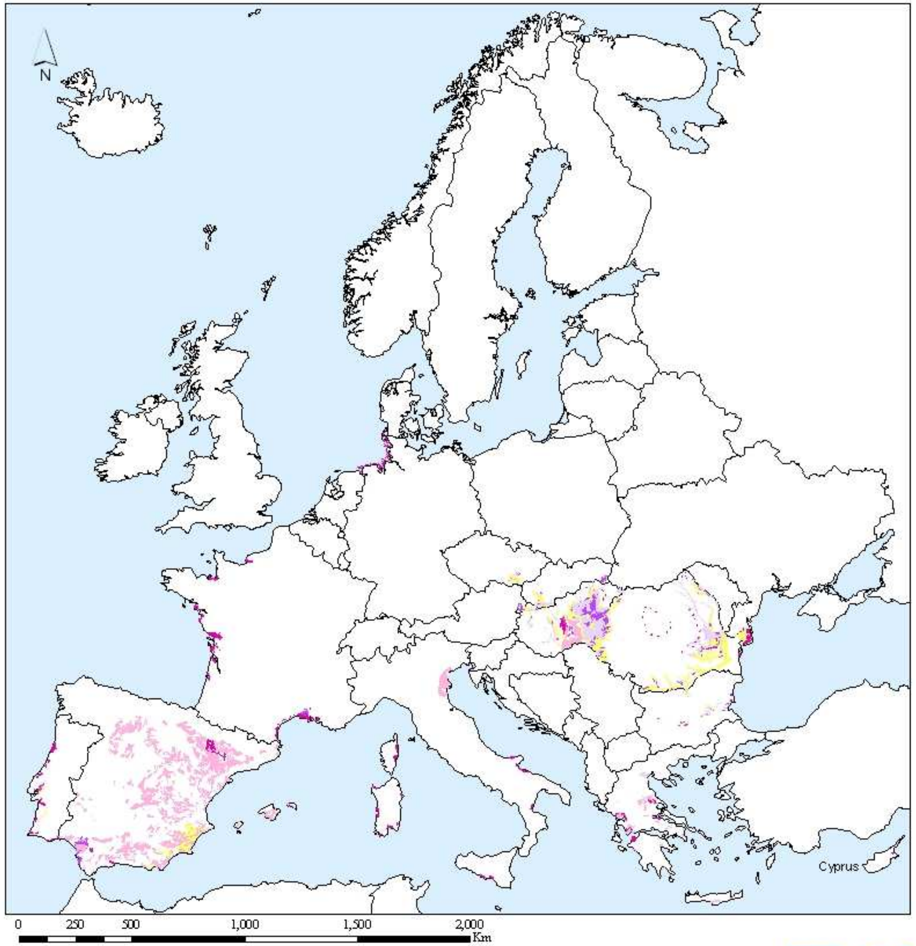
Saline and Sodic Soils in European Union



Saline and Sodic Soils

Legend

- ■ Saline > 50% of the area
- ■ Sodic > 50% of the area
- ■ Saline < 50% of the area
- ■ Sodic < 50% of the area
- ■ Potentially salt affected area

The map shows the area distribution of saline, sodic and potentially salt affected areas within the European Union. The accuracy of input data only allows the designation of salt affected areas with a limited level of reliability (e.g. < 50 or > 50% of the area); therefore the results represented in the map should only be used for orientating purposes.

MAP INFORMATION

Spatial coverage: 27 Member States of the European Union where data available.

Pixel size: 1km
Projection: ETRS89 Lambert Azimuthal Equal Area

Input data - source
Soil data - European Soil Database v2
1:1.000.000 scale Map of Salt Affected Soils in Europe (Szabolcs) 1974)

BIBLIOGRAPHIC INFORMATION

Tóth et al. (2008) Updated Map of Salt Affected Soils in the European Union
In: Tóth, G., Montanarella, L. and Rusco, E.(Eds.)
Threats to Soil Quality in Europe
EUR 23438 – Scientific and Technical Research series
Luxembourg: Office for Official Publications of the European Communities p.61-74

Digital datasets can be downloaded from
http://eusoils.jrc.ec.europa.eu/

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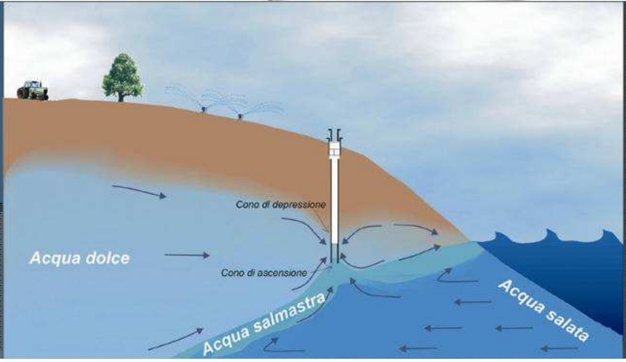


Commonly three types of approaches exist to identify areas at risk Eckelmann et al, 2006):

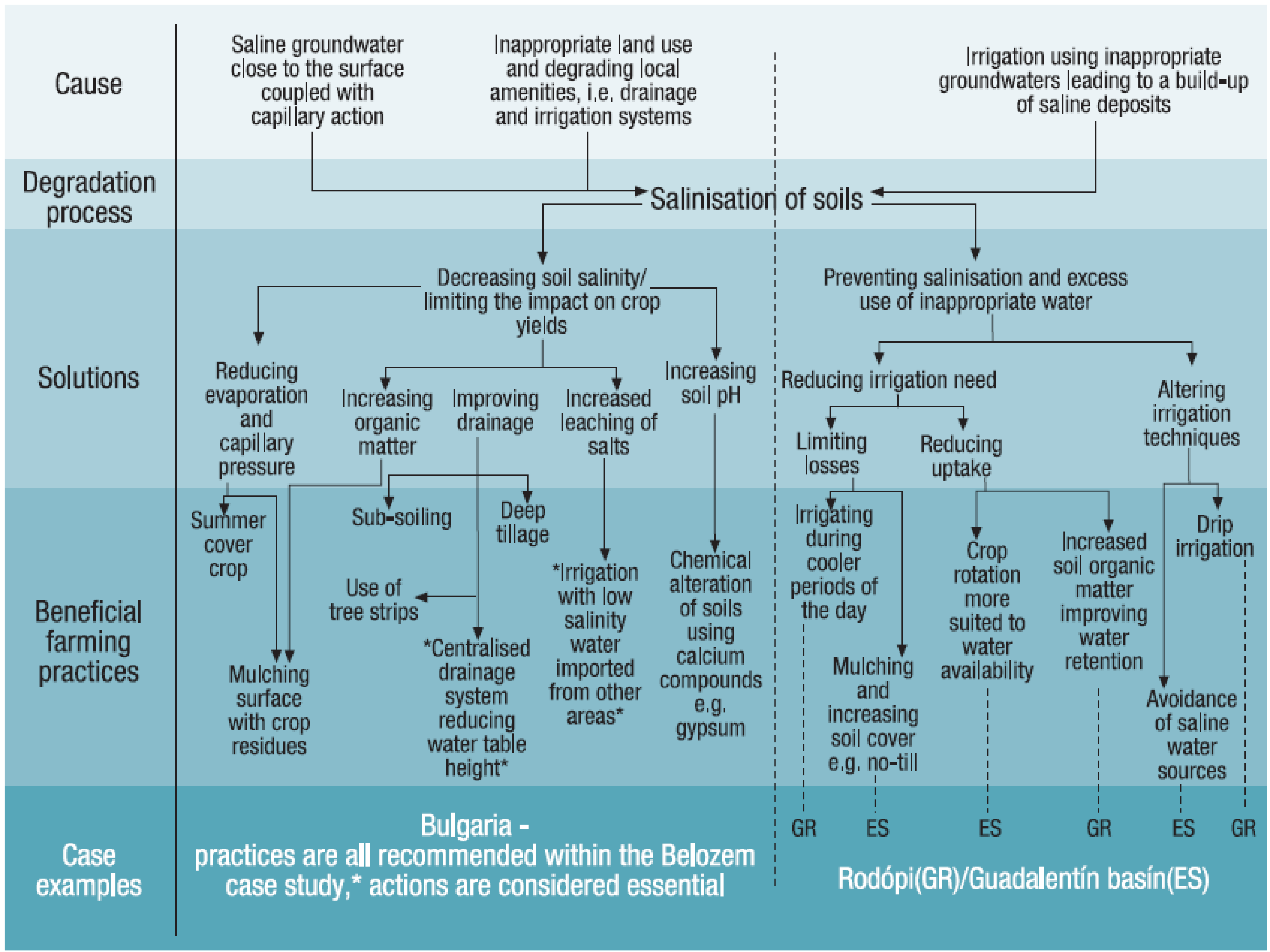
- Qualitative approach;
- Quantitative approach;
- Model approach

There are salinity risk assessment methodology in use in Hungary, Slovakia and Spain. Only Hungary has an official recognized assessment. Slovakia and Spain has a methodology used by scientists. Greece and Cyprus do not have it, but they provided information about their preferred method.

SPAIN:

Integration of two simple models in a GIS to evaluate salinization risk in Irrigated land in Valencia [De Paz, J.M., Visconti, F., Zapata, R. & Sánchez, J. (2004). The Use of Two Logical Models Integrated in a GIS to Evaluate the Soil Salinization in the Irrigation Land of Valencian Community (Spain). Soil Use and Management, 20: 333-342.]

Soil salinisation: causes, solutions and beneficial farming practices (SoCo project)



Cause

Saline groundwater close to the surface coupled with capillary action

Inappropriate land use and degrading local amenities, i.e. drainage and irrigation systems

Irrigation using inappropriate groundwaters leading to a build-up of saline deposits

Degradation process

Salinisation of soils

Solutions

Decreasing soil salinity/ limiting the impact on crop yields

- Reducing evaporation and capillary pressure
- Increasing organic matter
- Improving drainage
- Increased leaching of salts
- Increasing soil pH

Preventing salinisation and excess use of inappropriate water

- Reducing irrigation need
  - Limiting losses
  - Reducing uptake
- Altering irrigation techniques

Beneficial farming practices

Summer cover crop

Mulching surface with crop residues

Sub-soiling

Deep tillage

Use of tree strips

Centralised drainage system reducing water table height

Irrigation with low salinity water imported from other areas

Chemical alteration of soils using calcium compounds e.g. gypsum

Irrigating during cooler periods of the day

Mulching and increasing soil cover e.g. no-till

Crop rotation more suited to water availability

Increased soil organic matter improving water retention

Avoidance of saline water sources

Drip irrigation

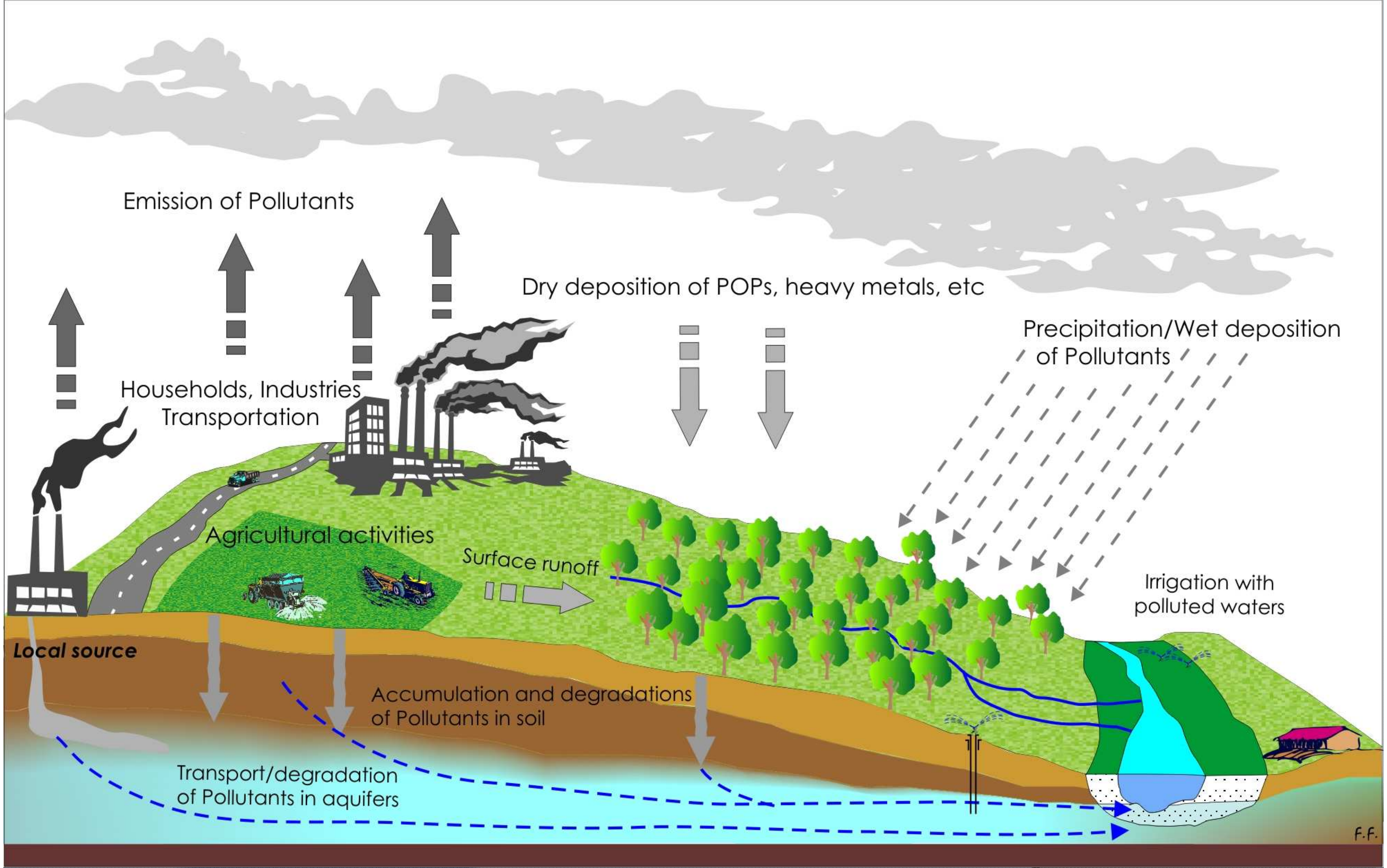
Case examples

Bulgaria -
practices are all recommended within the Belozem case study,* actions are considered essential

GR ES ES GR ES GR

Rodópi(GR)/Guadalentín basín(ES)

Diffuse soil contamination



Emission of Pollutants

Dry deposition of POPs, heavy metals, etc

Precipitation/Wet deposition
of Pollutants

Households, Industries
Transportation

Agricultural activities

Surface runoff

Irrigation with
polluted waters

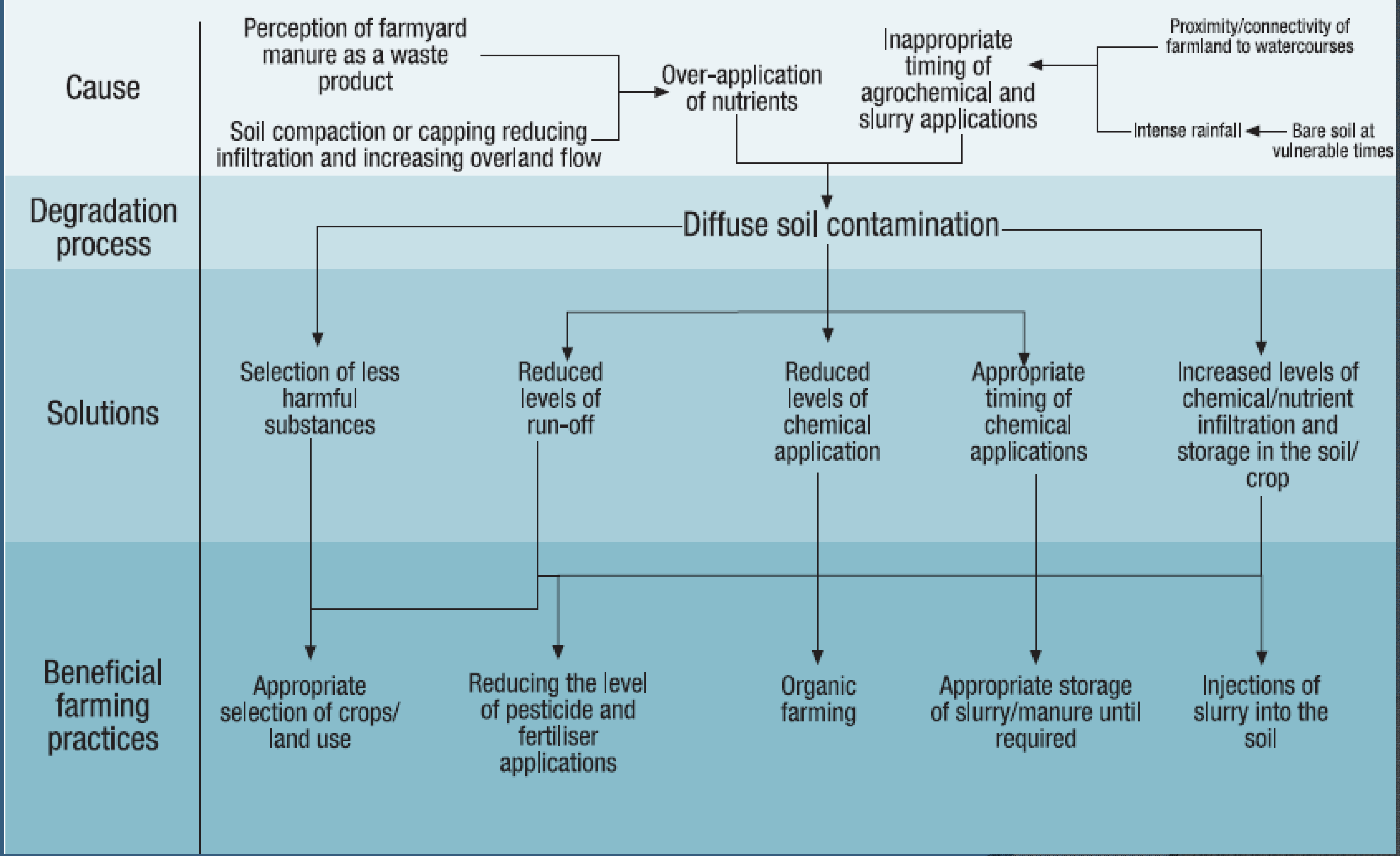
Local source

Accumulation and degradations
of Pollutants in soil

Transport/degradation
of Pollutants in aquifers

F.F.

Diffuse soil contamination: causes, solutions and beneficial farming practices



Cause

Perception of farmyard manure as a waste product

Soil compaction or capping reducing infiltration and increasing overland flow

Over-application of nutrients

Inappropriate timing of agrochemical and slurry applications

Proximity/connectivity of farmland to watercourses

Intense rainfall

Bare soil at vulnerable times

Degradation process

Diffuse soil contamination

Solutions

Selection of less harmful substances

Reduced levels of run-off

Reduced levels of chemical application

Appropriate timing of chemical applications

Increased levels of chemical/nutrient infiltration and storage in the soil/ crop

Beneficial farming practices

Appropriate selection of crops/ land use

Reducing the level of pesticide and fertiliser applications

Organic farming

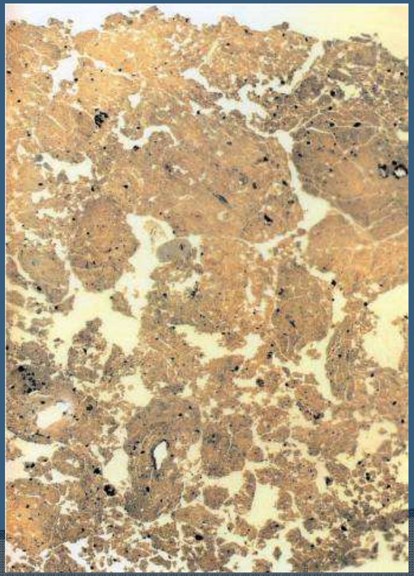
Appropriate storage of slurry/manure until required

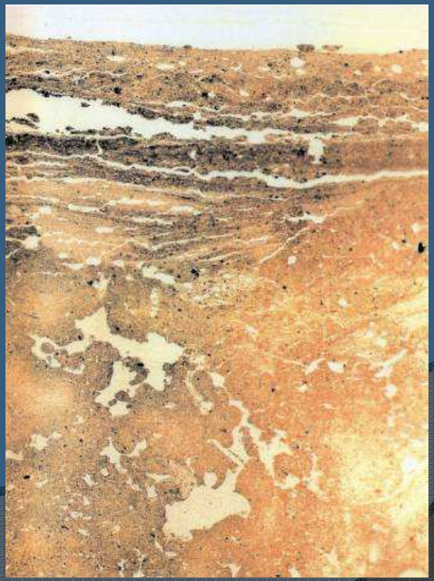
Injections of slurry into the soil

Soil compaction

Compaction, which is mainly due to the use of agricultural machinery, occurs when soil particles are pressed together, reducing the pore space between them. This induces important changes in the soil's structural properties and behaviour, such as the temperature and moisture regimes, the balance and the liquid and gas phases that form the soil. Apart from the topsoil, layer, compaction is also frequently formed at the depth of cultivation (plough sole). The result is not only the reduction of soil functions but also a drastic reduction of water infiltration with subsequent *runoff* increase.

Even if, at European level, a map of natural susceptibility of soils to compaction has been carried out, there is not yet a proposed methodology





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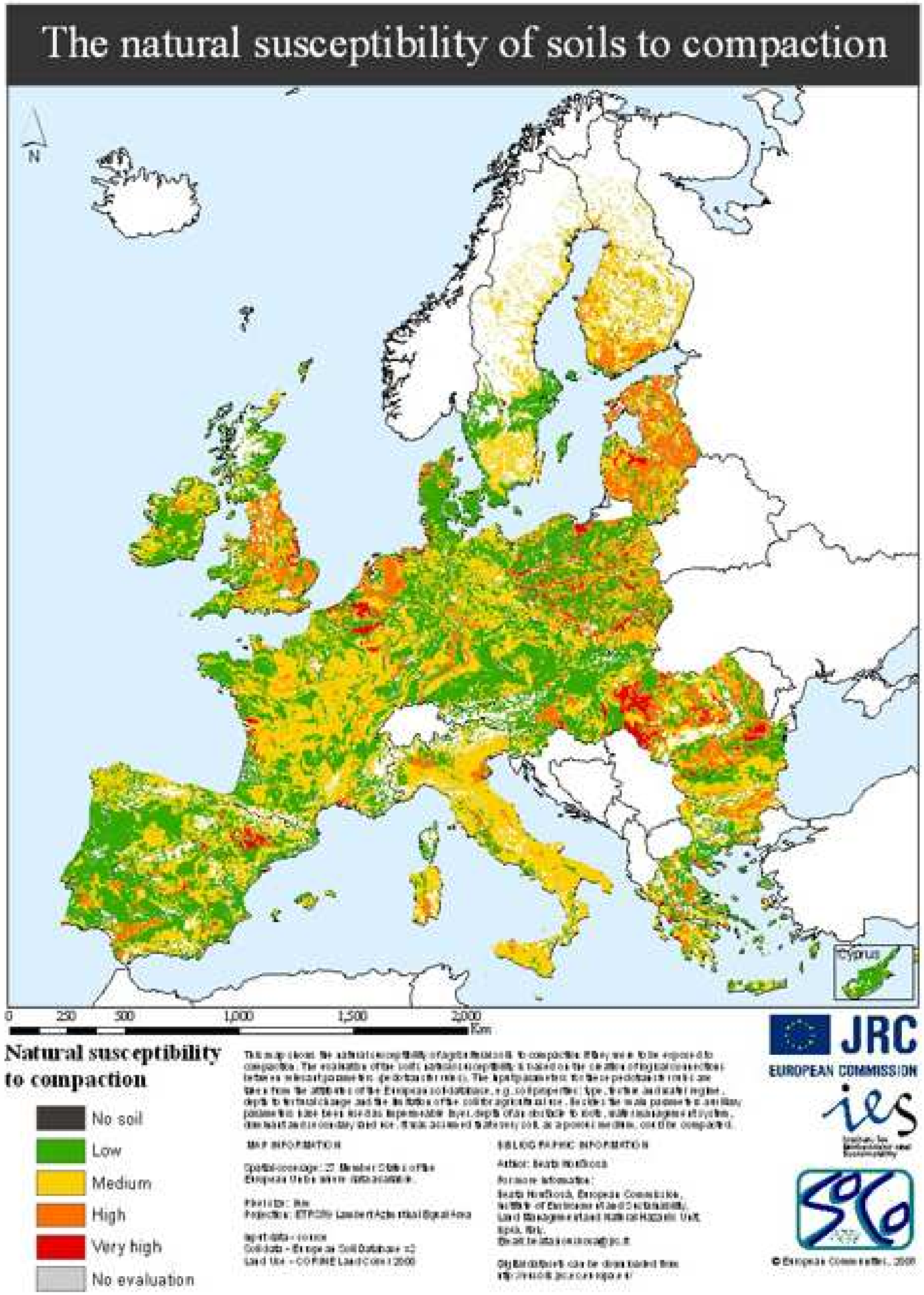
The natural susceptibility of soils to compaction
N
Cyprus
0
250
500
1,000
1,500
2,000
Km
Natural susceptibility to compaction
No soil
Low
Medium
High
Very high
No evaluation
MAP INFORMATION
BIBLIOGRAPHIC INFORMATION
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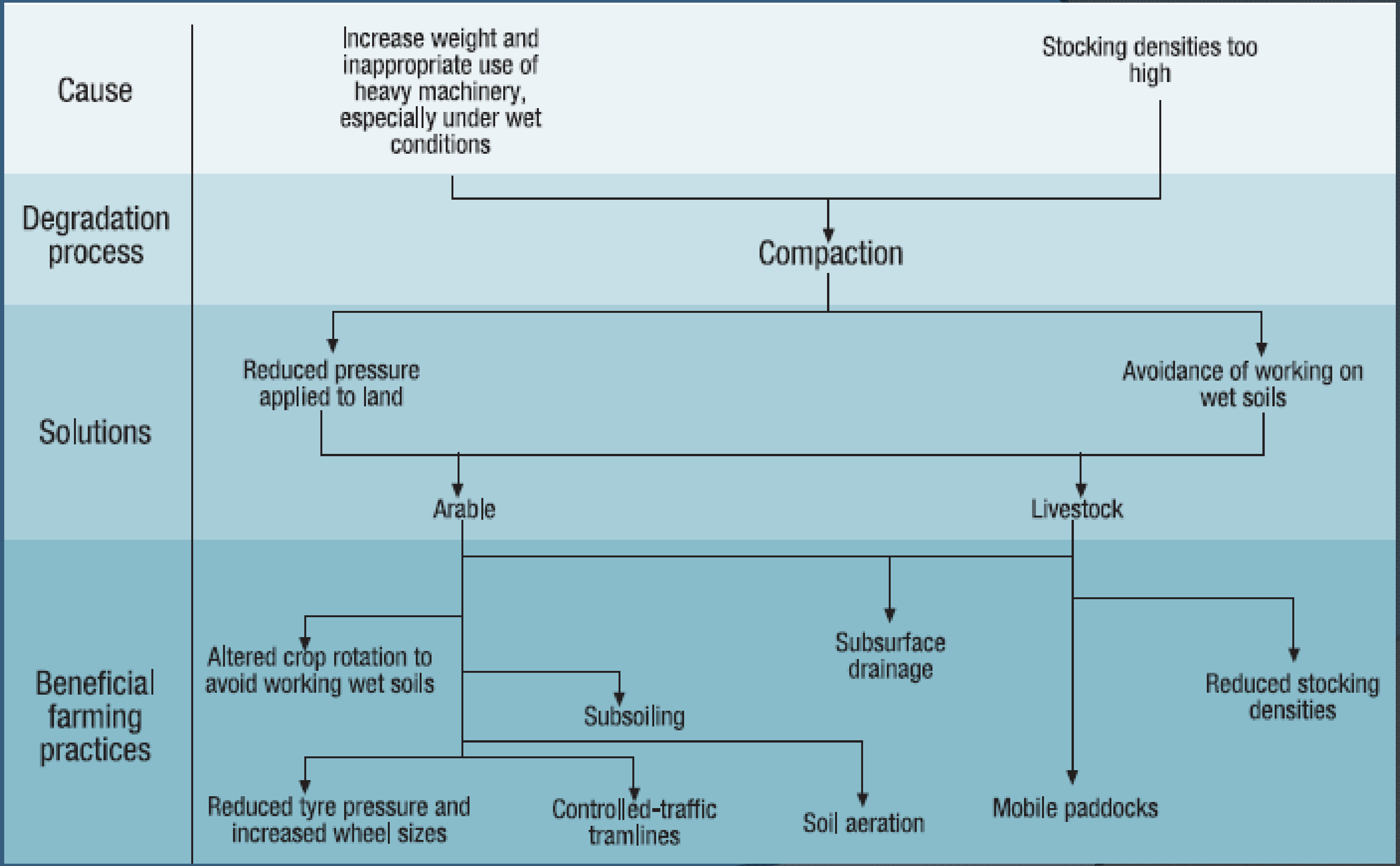
Compaction: causes, solutions and beneficial farming practices



Cause

Increase weight and inappropriate use of heavy machinery, especially under wet conditions

Stocking densities too high

Degradation process

Compaction

Solutions

Reduced pressure applied to land

Avoidance of working on wet soils

Arable

Livestock

Beneficial farming practices

Altered crop rotation to avoid working wet soils

Subsoiling

Subsurface drainage

Reduced stocking densities

Reduced tyre pressure and increased wheel sizes

Controlled-traffic tramlines

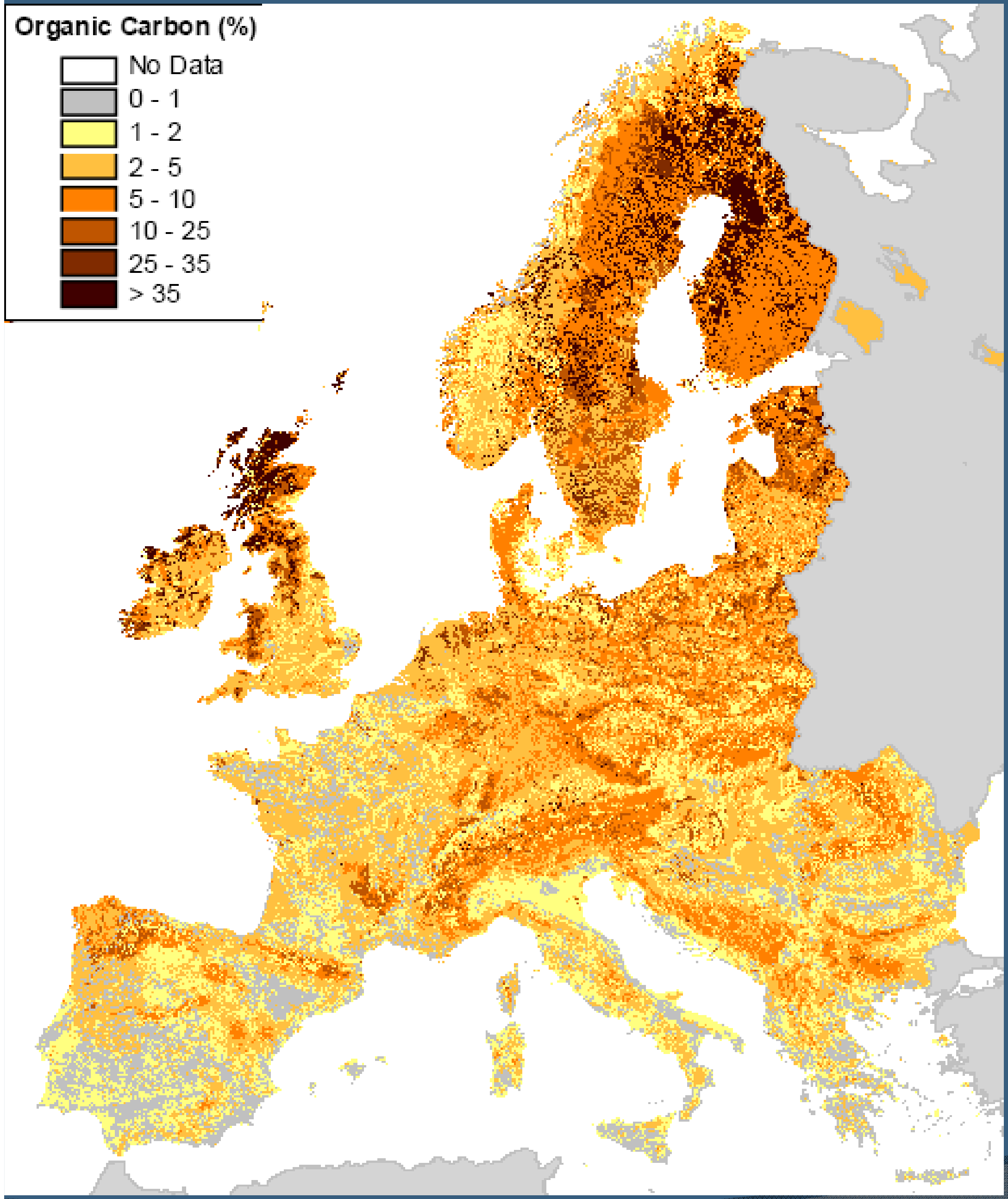
Soil aeration

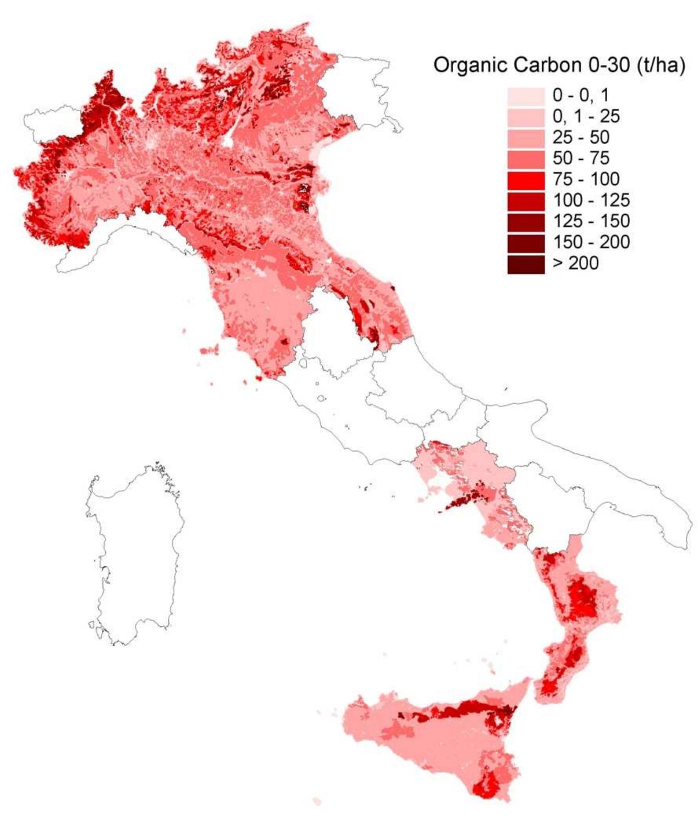
Mobile paddocks

Organic matter decline

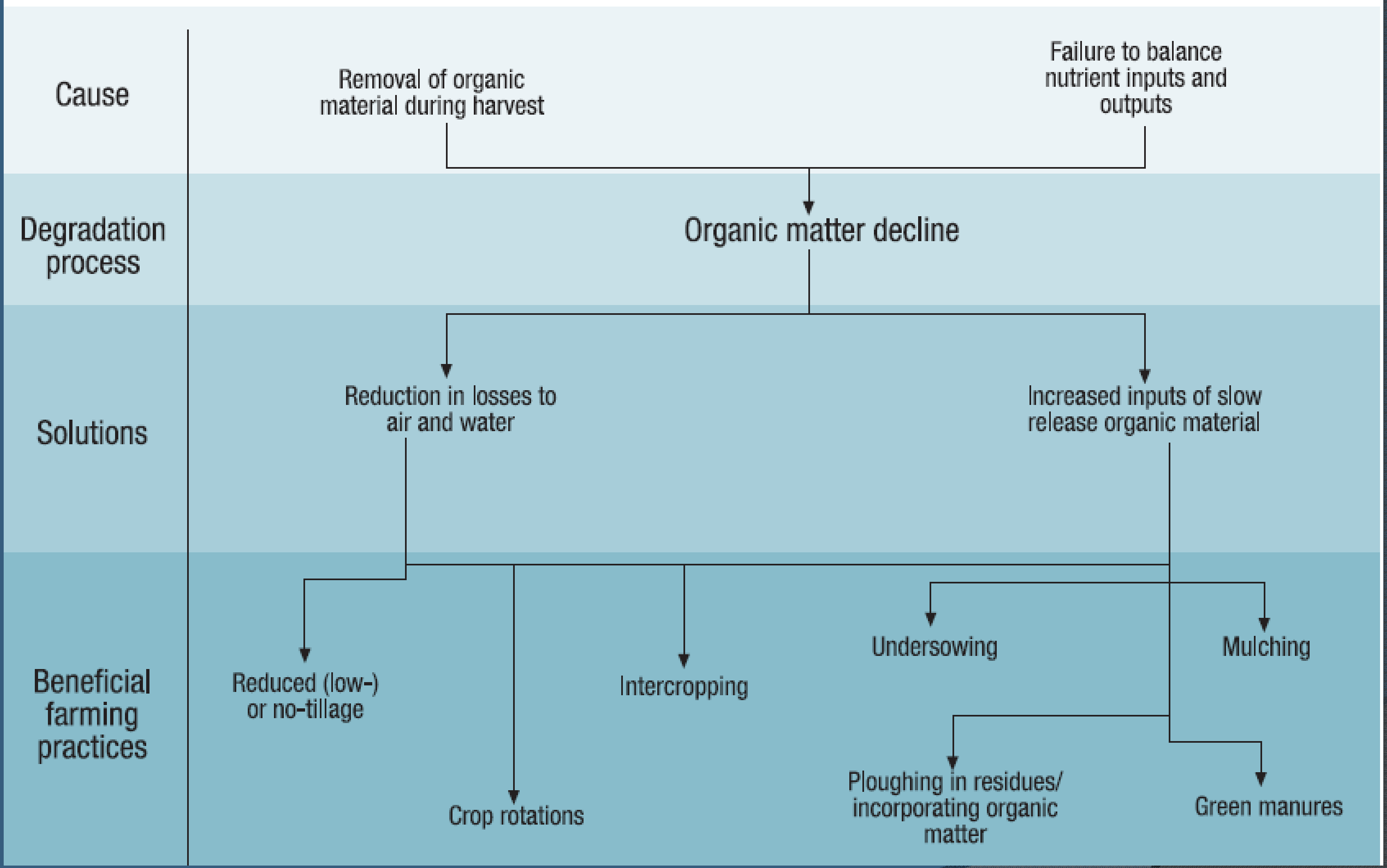
Organic carbon (OC), which represents 60% of soil organic matter, carries out an essential positive function on many soil properties. It facilitates the aggregation and stability of soil particles reducing erosion, compression, cracking and the formation of surface crusts. Organic carbon binds effectively with various substances, improving soil fertility and its control capacity and increasing microbial activity. It also makes nutritional elements, such as nitrogen and phosphorus, available to plants. Knowing the amount of OC stored in the soils is an important element to determine their condition.

The proposal for a directive of the European parliament and of the council, gives a table annex 1: “Common elements for the identification of areas at risks of soil organic matter”. Different elements that could play an important role are identified to assess risk areas for organic matter. Named are soil typological unit (STU), soil texture (clay content), soil organic carbon (total, humus concentration and stock) climate, Topography, land cover, and land use.


Organic Carbon (%)
No Data
0 - 1
1 - 2
2 - 5
5 - 10
10 - 25
25 - 35
> 35


Organic Carbon 0-30 (t/ha)
0 - 0, 1
0, 1 - 25
25 - 50
50 - 75
75 - 100
100 - 125
125 - 150
150 - 200
> 200

Organic matter decline: causes, solutions and beneficial farming practices



Cause

Removal of organic material during harvest

Failure to balance nutrient inputs and outputs

Degradation process

Organic matter decline

Solutions

Reduction in losses to air and water

Increased inputs of slow release organic material

Beneficial farming practices

Reduced (low-) or no-tillage

Crop rotations

Intercropping

Undersowing

Mulching

Ploughing in residues/ incorporating organic matter

Green manures

Soil erosion

Erosion is a physical phenomenon that results in the removal of soil and rock particles by water, wind, ice and gravity. Most present-day concerns about soil erosion, leading to its perception as a process of degradation, are related to accelerated erosion, where the natural rate has been significantly increased by human activities’ [Eckelmann et al., 2006].
By removing the most fertile topsoil, erosion reduces soil productivity and biodiversity. Where soils are shallow, may lead to an irreversible loss of natural farmland; even where soil depth is good, loss of the topsoil is often not conspicuous but nevertheless potentially very damaging

In many cases soil erosion requires corrective operations especially in highly important farmlands, economically relevant ones or, in any case, in areas where the erosion tolerance rate (factor T) exceeds the provided standards. The erosion tolerance rate (expressed in tons/hectare/year) enables a controlled productive and protective use of the soil. It should therefore be generally lower with respect to the soil formation speed (pedogenesis).

The erosion rate is very sensitive to both climate and land use, as well as to detailed conservation practice at farm level. The Mediterranean region is particularly prone to erosion because it is subject to long dry periods followed by heavy bursts of erosive rain, falling on steep slopes with fragile soils.

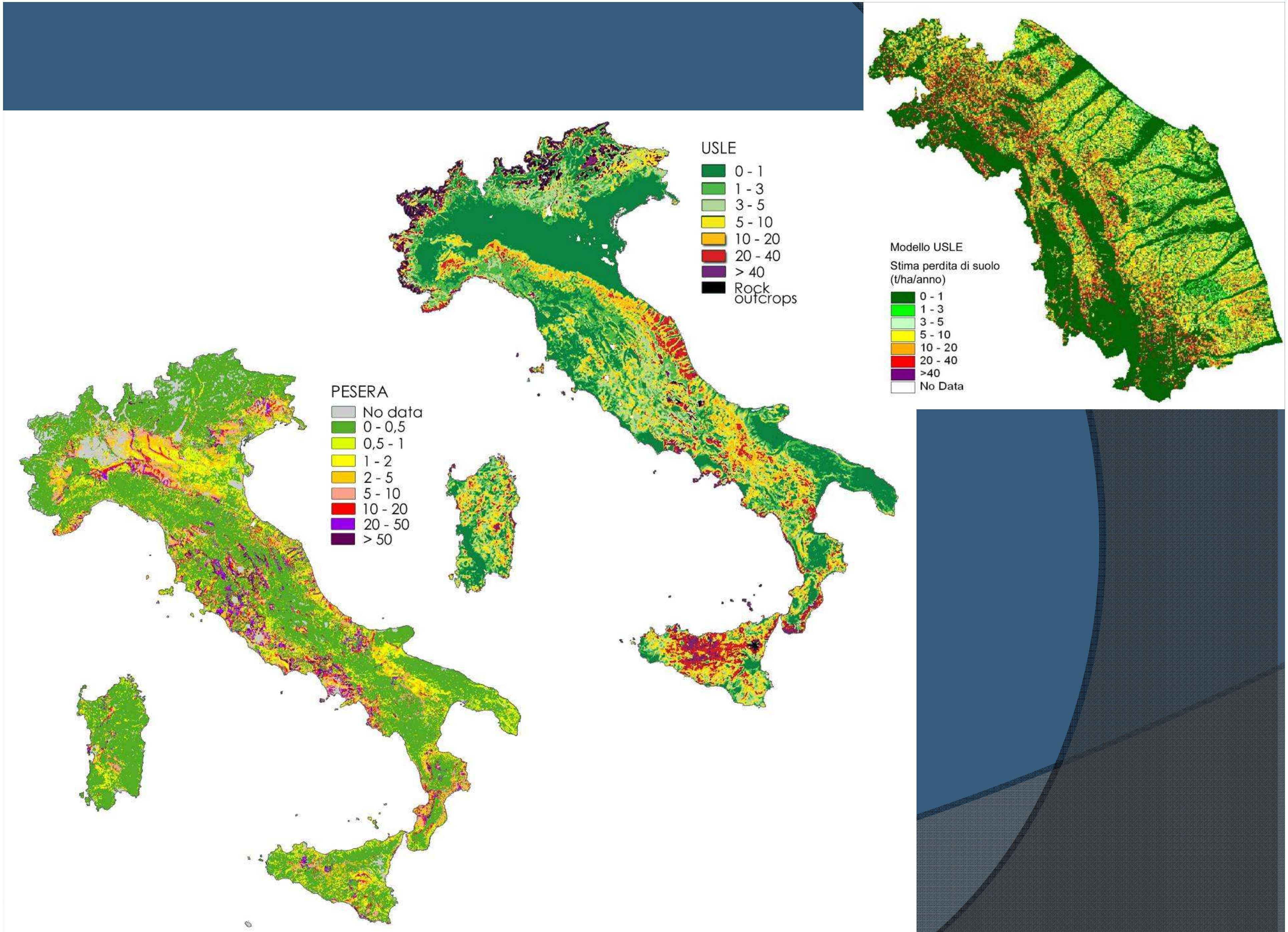
Assessment of soil loss is carried out by using empirical models and physically-based ones or considering qualitative or quantitative models.

Models are adopted according the following criteria:
- temporal resolution (single rainfall events or temporal average)
- spatial scale (field size, watershed, regional, etc.)
- data availability
- possibility to be integrated into a GIS.

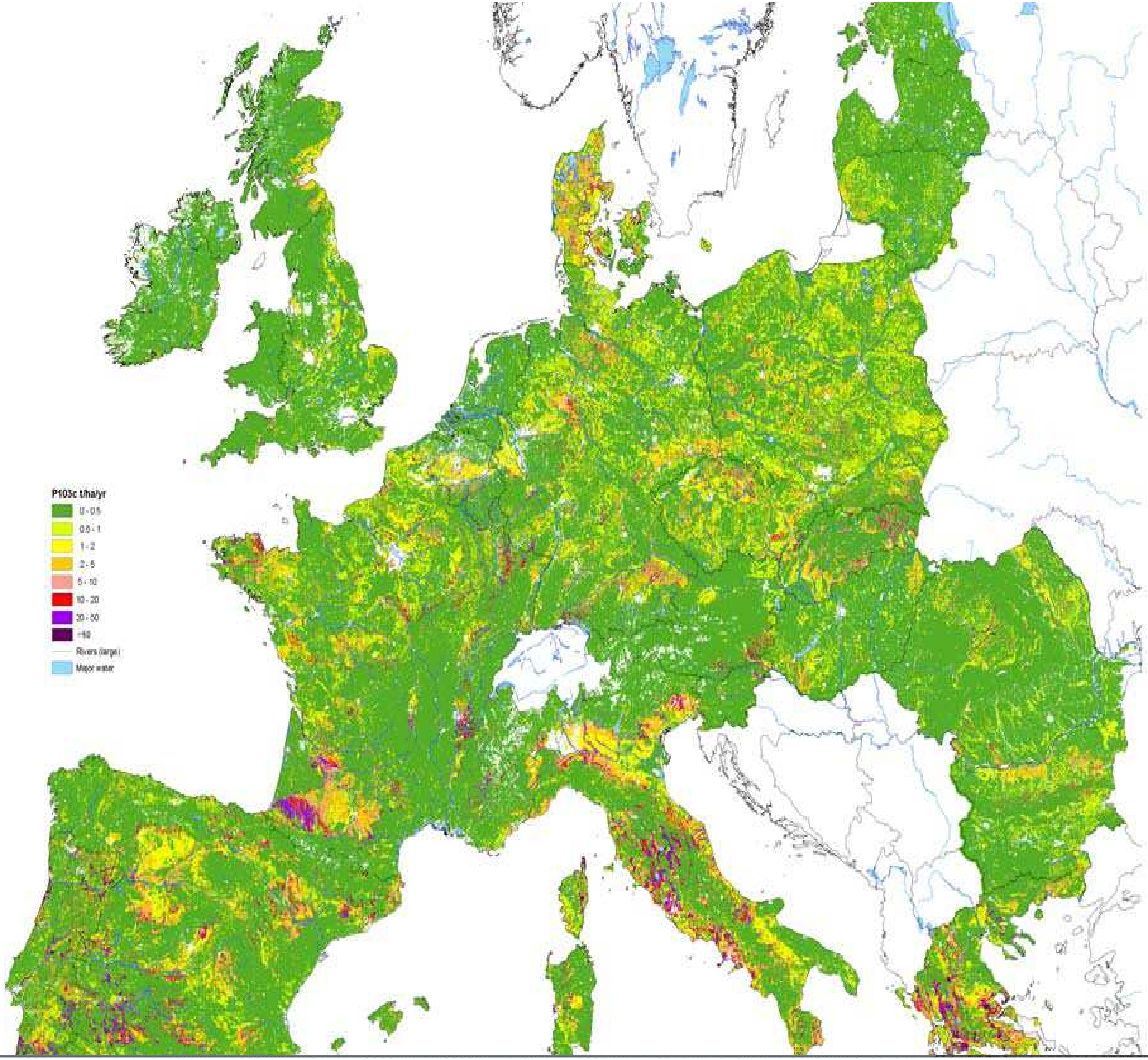
In Italy the most used is the USLE models (*Universal Soil Loss Equation*) that : provides a quantitative estimates of sediment loss (t/ha • year) by rill and inter–rill erosion caused by water.

The Soil Loss equation is $A = R * K * L * S * C * P$
where:

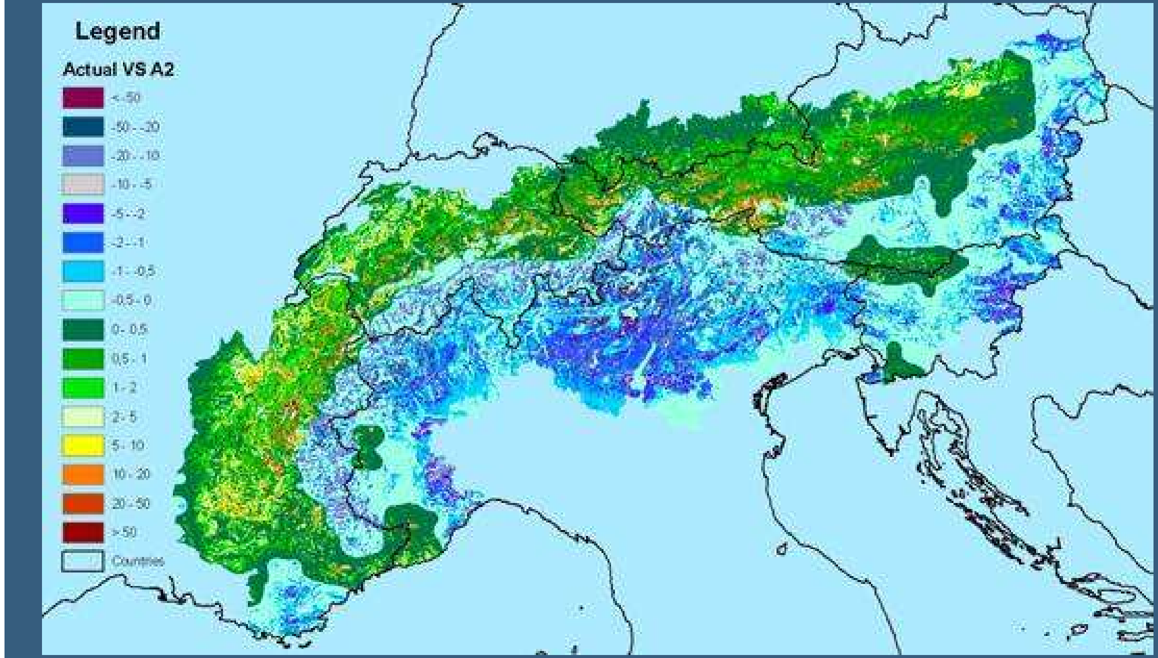
A = mean annual soil loss (t/ha • year)
R = rainfall erosivity factor
K = soil erodibility factor
L = slope length factor
S = slope factor
C = cover management factor
P = human practices aimed at erosion control


USLE
0 - 1
1 - 3
3 - 5
5 - 10
10 - 20
20 - 40
> 40
Rock outcrops
PESERA
No data
0 - 0,5
0,5 - 1
1 - 2
2 - 5
5 - 10
10 - 20
20 - 50
> 50
Modello USLE
Stima perdita di suolo (t/ha/anno)
0 - 1
1 - 3
3 - 5
5 - 10
10 - 20
20 - 40
>40
No Data

PAN-EUROPEAN SOIL EROSION RISK ASSESSMENT: THE PESERA MAP (JRC-IES, 2003)



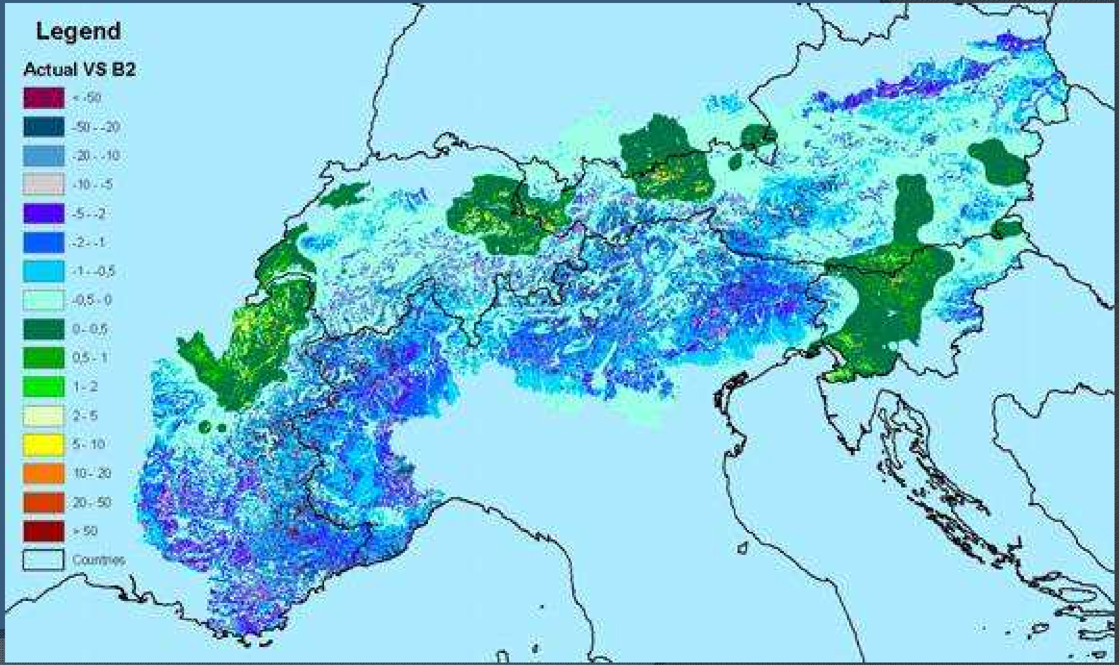
Among all land degradation processes soil erosion is certainly the most studied threat with relation to climate change (all soil erosion models provide for climatic parameters). Recently the application of the RUSLE model has allowed the construction of a soil erosion risk map in alpine areas on the basis of climatic data from 1960-1990 and IPCC scenarios A2 and B2 (2070-2100) [Bosco C. *et alii*, 2008]. These predicted soil erosion trends are attributable only to changes in rainfall regime.



The map shows the IPCC A2 scenario (2070 - 2100) of soil erosion by water in the alpine territory.

IPCC A2 Scenario is referred to a very heterogeneous world, whose basic feature is the conservation of local identities. This map is derived from the RUSLE model which calculates the sediment loss by soil erosion.

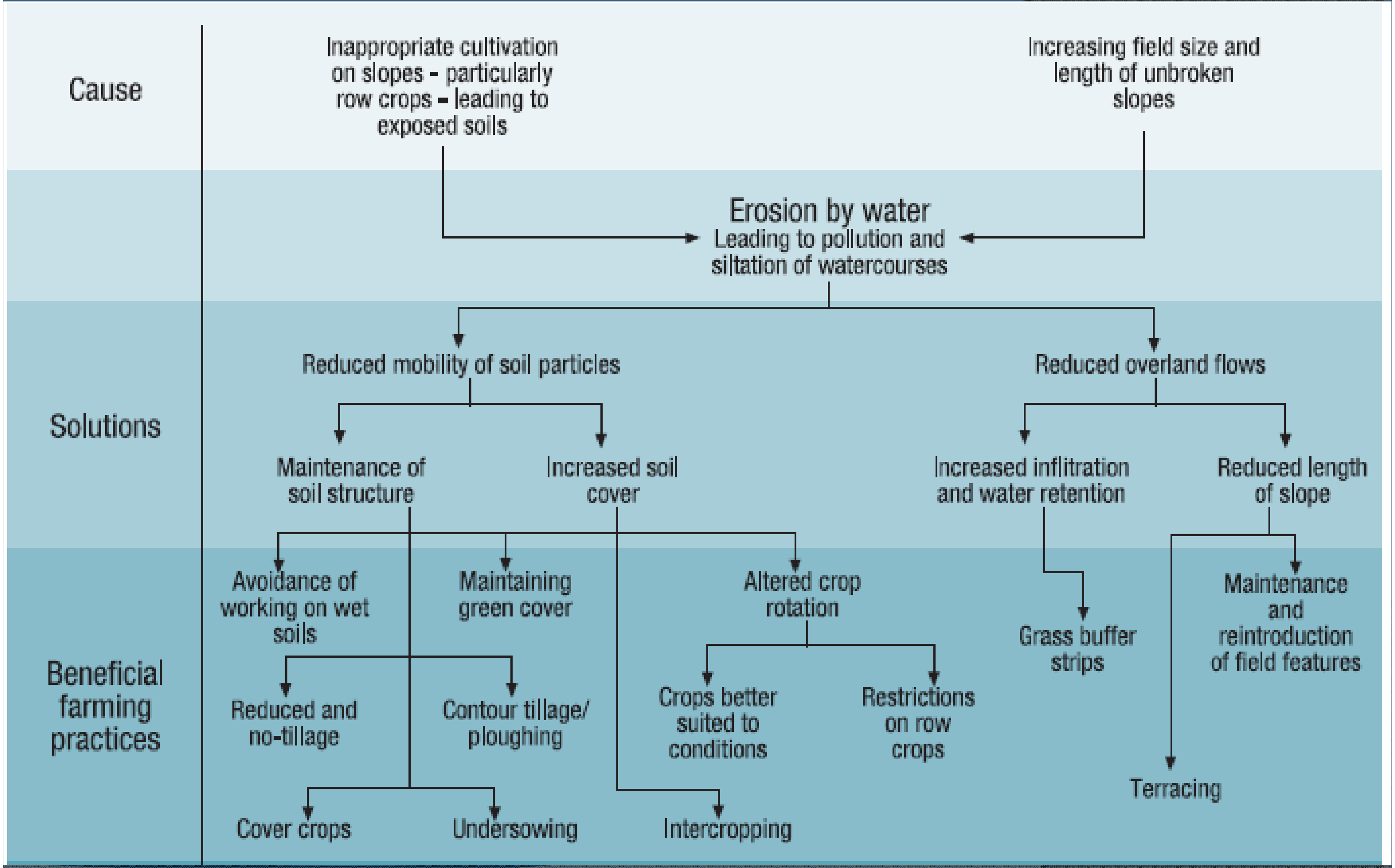
B2 Scenario is referred to a demographic trend similar to A1 scenario, but stronger emphasis is given to global solutions for economic, social and environmental sustaibnability. Raw materials exploitation and energy consuptions are reduced. Specific action aimed at climate protection are not planned.



The estimation of soil loss under climate change scenarios could be improved by evaluating future variations of the cover management factor. The change of the rainfall pattern and intensity, and of the soil cover are important factors for the relationship between soil erosion and climate change [Bosco C. *et alii*, 2008].

However, other mathematical models (e.g. WEPP – Water Erosion Prediction Project, EPIC – Erosion Productivity Impact Calculator) are also available for simulating soil erosion and the influence of climate change, The choice of one model over another must be calibrated on local situation, depending on various environmental variables (soil, climate, political framework). In terms of processes rainfall intensity is certainly the most direct and important factor controlling erosional change under climate change.

Erosion by water: causes, solutions and beneficial farming practices (SoCo Project)



Cause

Inappropriate cultivation on slopes - particularly row crops - leading to exposed soils

Increasing field size and length of unbroken slopes

Erosion by water

Leading to pollution and siltation of watercourses

Solutions

Reduced mobility of soil particles

Reduced overland flows

Maintenance of soil structure

Increased soil cover

Increased infiltration and water retention

Reduced length of slope

Beneficial farming practices

Avoidance of working on wet soils

Maintaining green cover

Altered crop rotation

Grass buffer strips

Maintenance and reintroduction of field features

Reduced and no-tillage

Contour tillage/ ploughing

Crops better suited to conditions

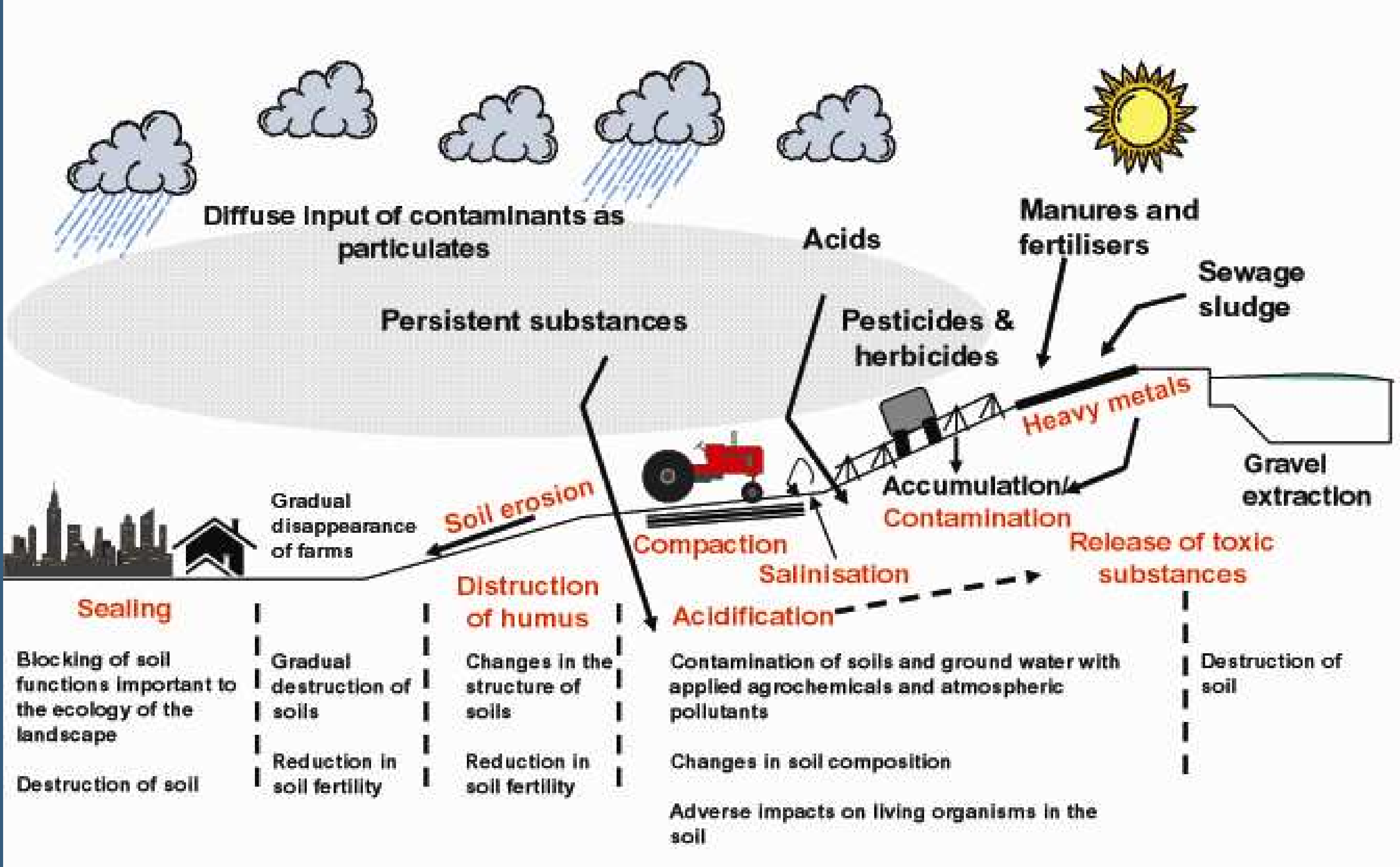
Restrictions on row crops

Terracing

Cover crops

Undersowing

Intercropping



Scheme of threats that compromise soil functions. Desertification is the final degradation stage (after JRC-IES)

Desertification

A combination of some of these threats can ultimately lead arid or sub-arid climatic conditions to desertification [(COM(2006) 231)].

It occurs because dryland ecosystems, which cover over one third of the world's land area, are extremely vulnerable to over-exploitation and inappropriate land use and it is due mainly to climate variability and unsustainable human activities.
“A common misunderstanding is that desertification is linked to the presence of deserts. The truth is that desertification can and does occur far from any climatic desert, as the presence or absence of a nearby desert has no direct relation to desertification” (Dregne, 1986).

Because of its breadth, complexity and dynamism, desertification is difficult to monitor and assess (Eswaran *et alii*, 2001).

The identification of ecosystem affected by desertification could be valued at national, regional or local scales. Depending on the used scales, the studies on assessing risk of desertification combine different climatic, soil, vegetation, and socio-economic attributes to estimate pressure on land and state of soil and vegetation.

The most common methodology used is the identification of Environmentally Sensitive Areas (ESA's) through a multi-factor approach based on both a general and a local knowledge of the environmental processes acting. The original application, employed in three pilot areas of Medalus project (Agri basin in Italy, island of Lesvos in Greece and Alentejo region in Portugal) is based on the classification of four quality indices, obtained as the geometric mean of the available environmental and socio-economics parameters

ESAs= (SQI * CQI * VQI * MQI)1/4

Soil texture
Rock fragment
Soil depth
Parent material
Slope gradient

Soil quality index

Rainfall
Aridity index
Aspect

Climate quality index

Fire risk
Erosion protection
Drought resistance
Plant cover

Vegetation quality index

Land use type
Land use intensity
Policy

Management quality index

ENVIRONMENTALLY SENSITIVE AREAS (ESAs)

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The final value corresponds to a number ranging from 1 to 2 and identifies four different stages of land degradation (see the table).

Type	**Subtype**	**Range of ESAs**
Critical	C3	> 1,53
Critical	C2	1,42-1,53
Critical	C1	1,38-1,41
Fragile	F3	1,33-1,37
Fragile	F2	1,27-1,32
Fragile	F1	1,23-1,26
Potential	P	1,17-1,22
Not affected	N	<1,17

- Critical: Areas already highly degraded through past misuse, presenting a threat to the environment of the surrounding areas.
- Fragile: Areas in which any change in the delicate balance of natural and human activity is likely to bring about desertification.
- Potential: Areas threatened by desertification under significant climate change, if a particular combination of land use is implemented or where offsite impacts will produce severe problems
- Not affected: Areas with deep to very deep, nearly flat, well drained, coarse-textured or finer soils, under semi-arid or wetter climatic conditions, independently of vegetation

Within Desertnet project, Junta de Andalucia has tried to elaborate ESA index considering three times frames: the 2040s, the 2070s and the 2100s.

http://www.desertnet.org/

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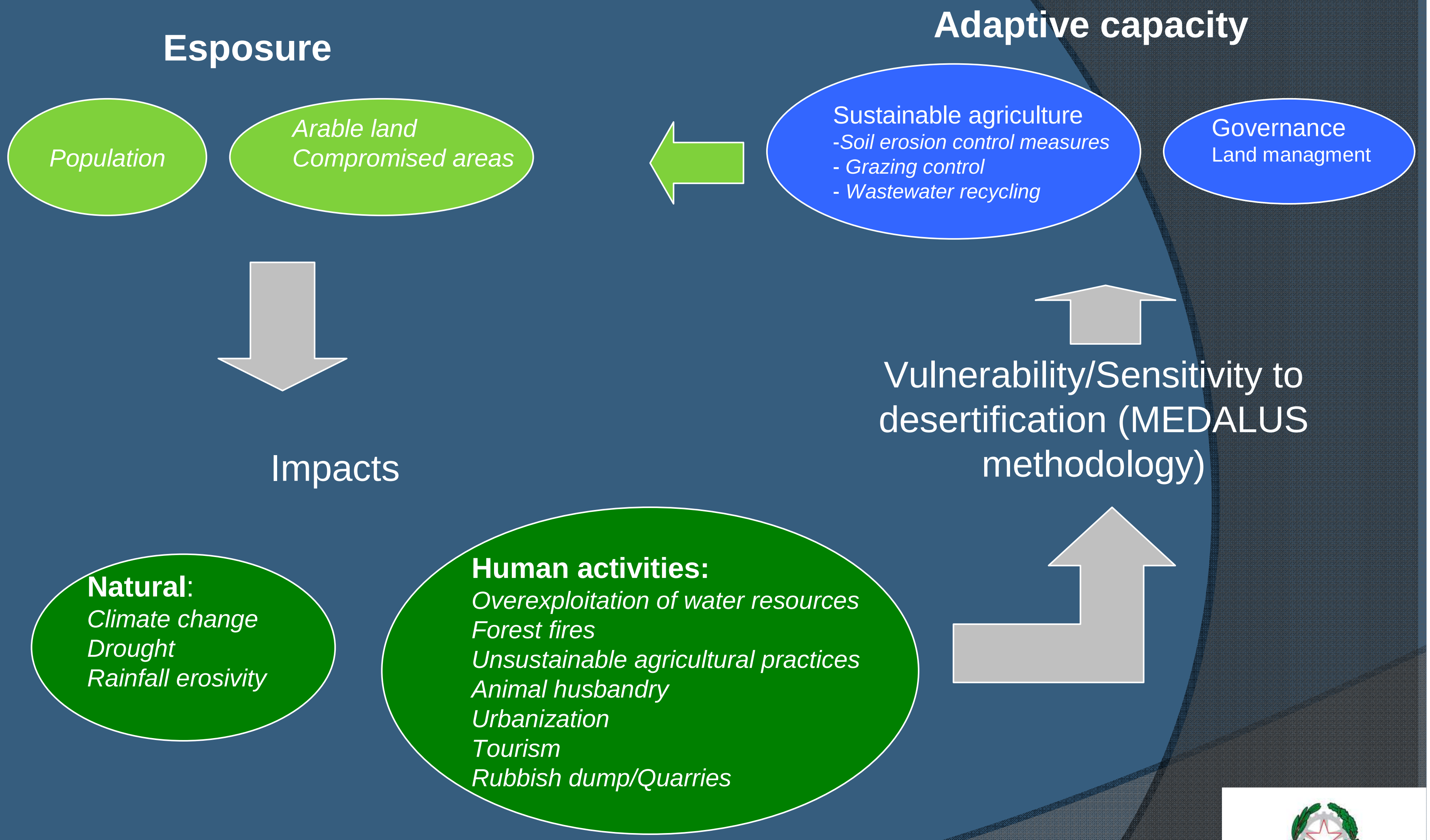
Adaptive capacity

A possible measure to mitigate land degradation is the adoption of conservative land-use management. Common conservation agriculture schemes include reduced tillage and no-tillage systems, often combined with intercrop cultivation and mulching to preserve the natural soil structure and a vegetative soil surface cover.

Different projects have highlighted the important effects of applying soil conservation practices in agriculture and their links with other environmental objectives.

Grazie per l’attenzione!



Esposure

Population

Arable land
Compromised areas

Impacts

Natural:
Climate change
Drought
Rainfall erosivity

Human activities:
Overexploitation of water resources
Forest fires
Unsustainable agricultural practices
Animal husbandry
Urbanization
Tourism
Rubbish dump/Quarries

Vulnerability/Sensitivity to desertification (MEDALUS methodology)

Adaptive capacity

Sustainable agriculture
-Soil erosion control measures
- Grazing control
- Wastewater recycling

Governance
Land managment

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