

**NERIS Workshop 2015**  
27-29 April 2015. Milano, Italy

**SOIL VULNERABILITY MAPS FOR  
PREDICTIVE PURPOSES IN DECISION  
MAKING PROCESSES FOR POST-ACCIDENT  
RECOVERY IN SPAIN**

**Cristina Trueba** [cristina.trueba@ciemat.es](mailto:cristina.trueba@ciemat.es);

**Milagros Montero** [milagros.montero@ciemat.es](mailto:milagros.montero@ciemat.es);

**Blanca García-Puerta** [garciapuertab@gmail.com](mailto:garciapuertab@gmail.com)

**CIEMAT**

- ❖ Large areas of agricultural land may be affected by restrictions, due to accumulation of RN in soils → impact in the production and way of life of affected population
- ❖ For an adequate and realistic optimization of the protection, the design and planning of the recovery strategies → must take into account the LOCAL SPECIFICITY
- ❖ Fukushima accident has highlighted this need → the mapping of contamination and soil characteristics has helped to identify those areas with higher levels of soil-to-plant TF and where treatment with agricultural countermeasures is feasible and effective

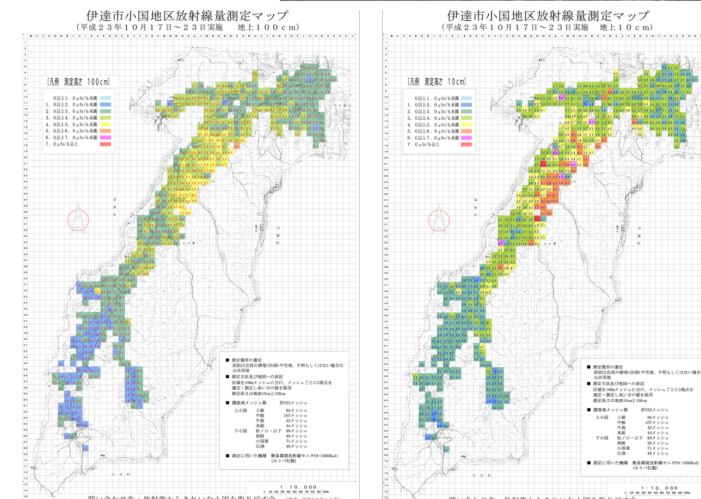
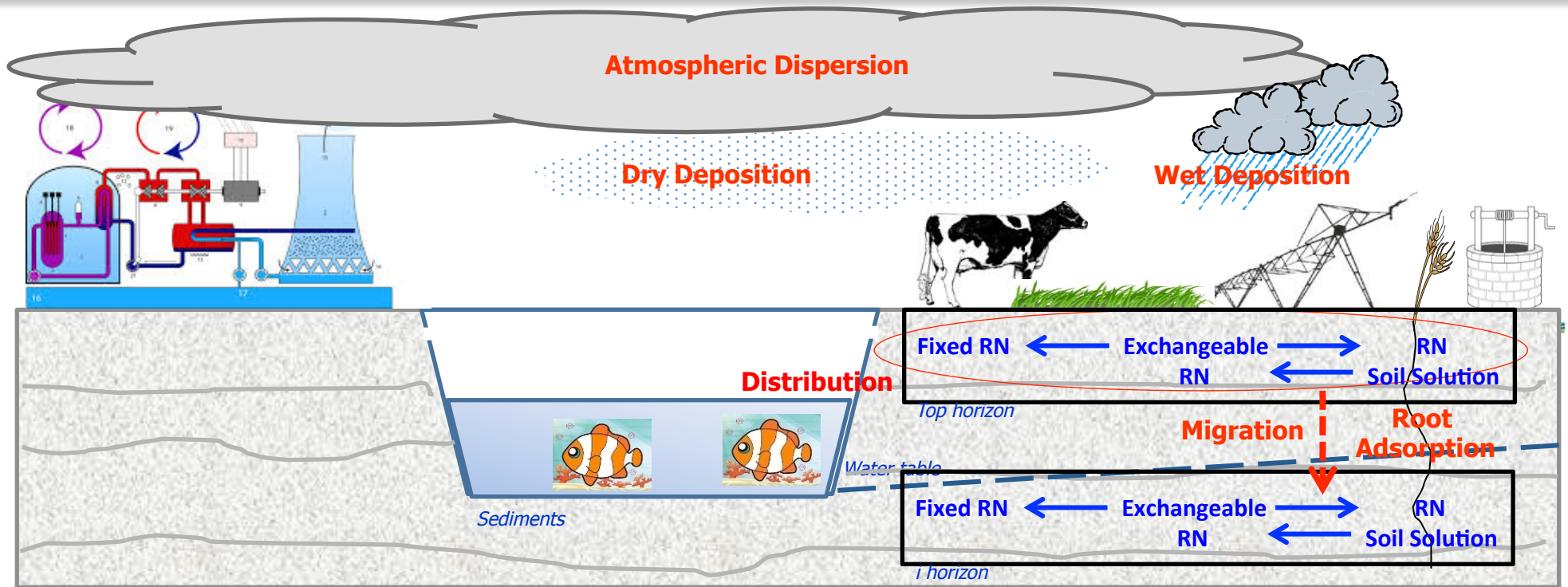


Photo: E. Gallego



Information and site specific parameters:

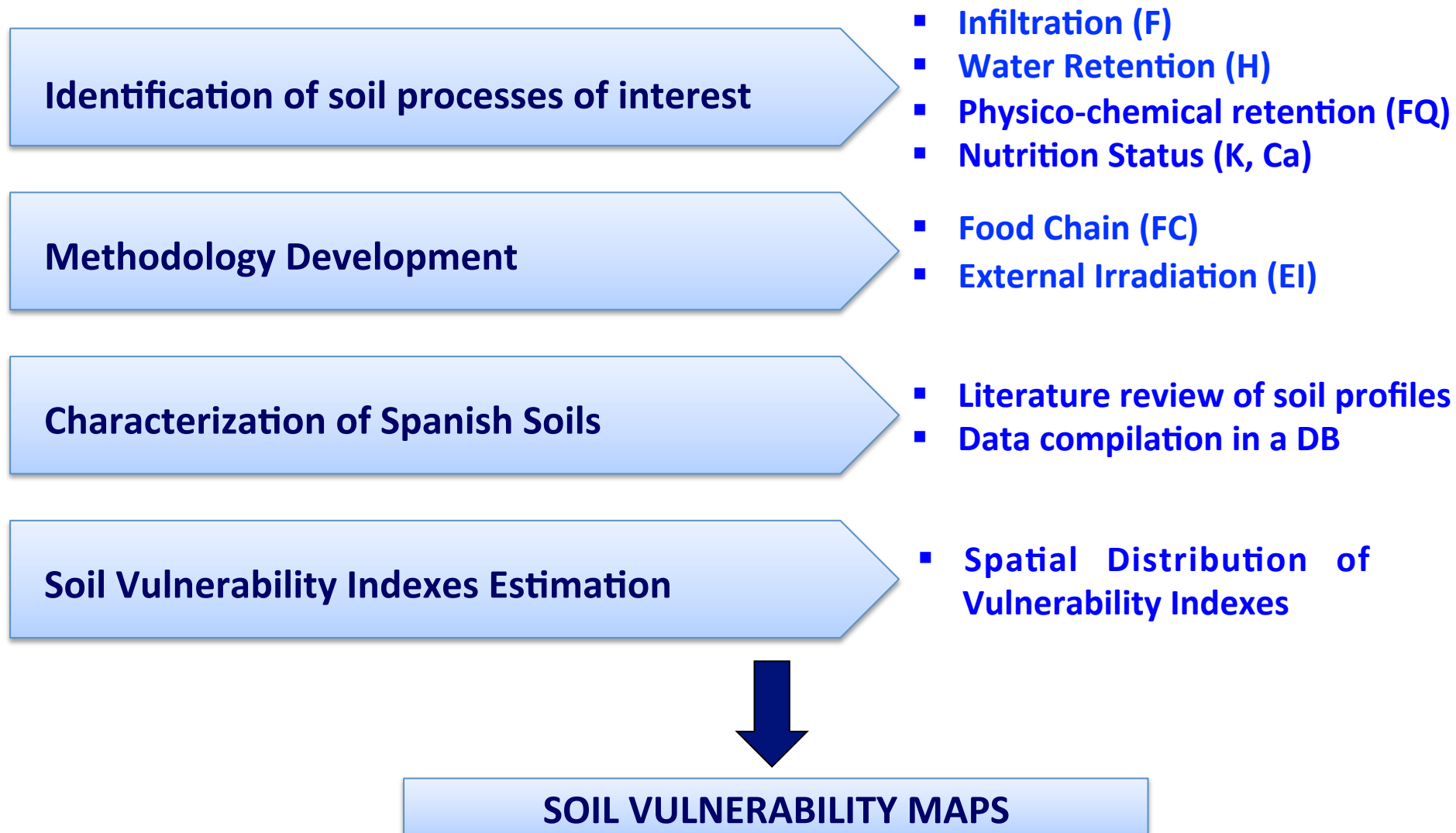
- Behavior and fate of RN in soils
- Soil uses and agricultural practices
- Dietary habits of affected population

### Different scales of local specificity: first step REGIONAL (within Europe)

No Chernobyl deposition on Spanish soils: the parameter values obtained from contaminated soils in Europe, were not sufficiently representative of our soils and climate:

### Radiological Vulnerability of Spanish Soils in case of a Nuclear Accident

- ❖ **Objective:** to develop a methodology to assess the potentiality of Spanish soils, according to their specific properties, to transfer  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  to the population.
- ❖ Potentiality, defined as **Radiological Vulnerability**, allows the categorization of Spanish soils by means of indexes representing, qualitatively, the maximum to minimum transfer capacity, identifying the areas of most concern.
- ❖ Predictions help to prioritize rehabilitation areas, in the decision-making processes for post-accident recovery.



## Physical behavior

$^{137}\text{Cs}$  and  $^{90}\text{Sr}$ :

- Entrance with water
- Migration in soil solution

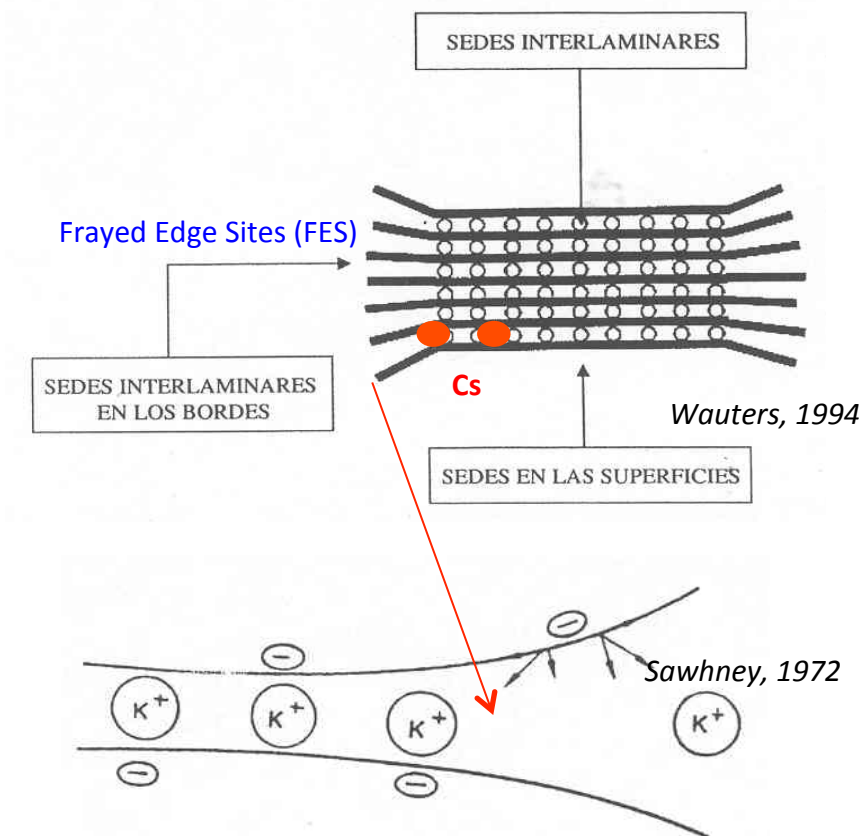
## Physico-chemical behavior

$^{137}\text{Cs}$ :

- Fixed in irreversible way when adsorbed in the selective, and small in number, frayed edge sites (FES) of micaceous clays (illite)
- Competes with K

$^{90}\text{Sr}$ :

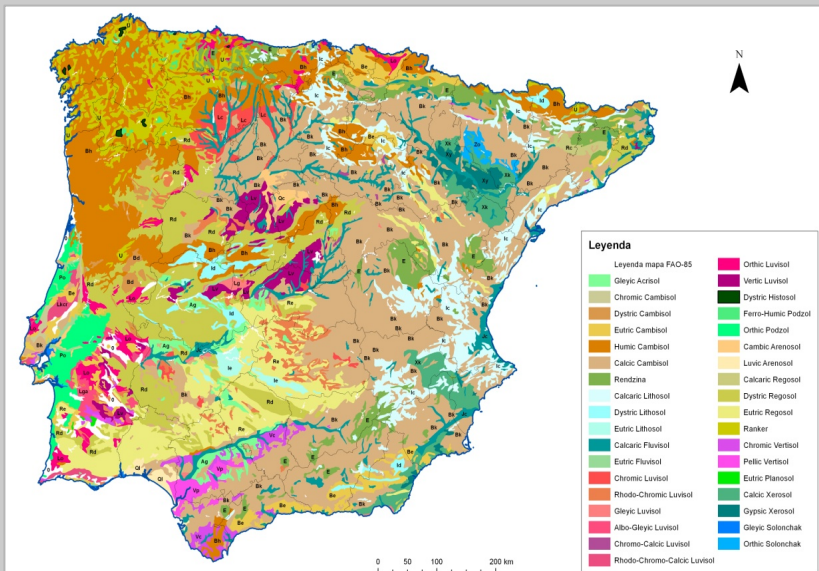
- Not fixed; takes part in exchangeable reactions
- pH conditions its solubility
- Competes with Ca



Vulnerability Indexes for food-chain	IF_FC	IH_FC	IFQ <sub>Cs</sub> _FC	IFQ <sub>Sr</sub> _FC	IK_FC	ICa_FC
Soil processes	Infiltration rate	Water retention	Cs:Physico-chemical retention	Sr:Physico-chemical retention	K status	Ca status
Soil properties	Texture, Structure, Dominant clay type	Texture, Structure, Porosity, Water capacity	Texture, CEC clay	pH	Exch. K content	Exch. Ca content
Reference parameter 60 cm depth	F (mm/h) (top layer)	R (mm/cm)	CEC (cmol/kg)	pH	K (cmol/kg)	Ca (cmol/kg)
<b>Minimum</b> <b>Low</b> <b>Medium</b> <b>High</b> <b>Maximum</b>	$F \leq 1,0$ $1,0 < F \leq 5,0$ $5,0 < F \leq 20,0$ $20,0 < F \leq 50,0$ $F > 50,0$	$R \leq 2,0$ $2,0 < R \leq 3,0$ $3,0 < R \leq 4,0$ $4,0 < R \leq 5,0$ $R > 5,0$	Clay 2:1 non exp Clay 2:1 exp Clay 1:1 Peat Sand	$pH > 7,5$ $6,5 < pH \leq 7,5$ $5,5 < pH \leq 6,5$ $4,5 < pH \leq 5,5$ $pH \leq 4,5$	$K > 1,00$ $0,50 < K \leq 1,00$ $0,25 < K \leq 0,50$ $0,10 < K \leq 0,25$ $K \leq 0,1$	$Ca > 10,0$ $5,0 < Ca \leq 10,0$ $2,0 < Ca \leq 5,0$ $1,0 < Ca \leq 2,0$ $Ca \leq 1,0$

**Maximum vulnerability: at higher infiltration rates and higher water retention, Cs: sandy soils (no fixation) and minimum K status / Sr: low pH and minimum Ca status**

## SPANISH SOIL PROFILE DATABASE



2014

2.177 SOIL PROFILES



1.657 Complete for estimations

Literature review, data compilation and processing to standardize, units, coordinates, nomenclatures, ....

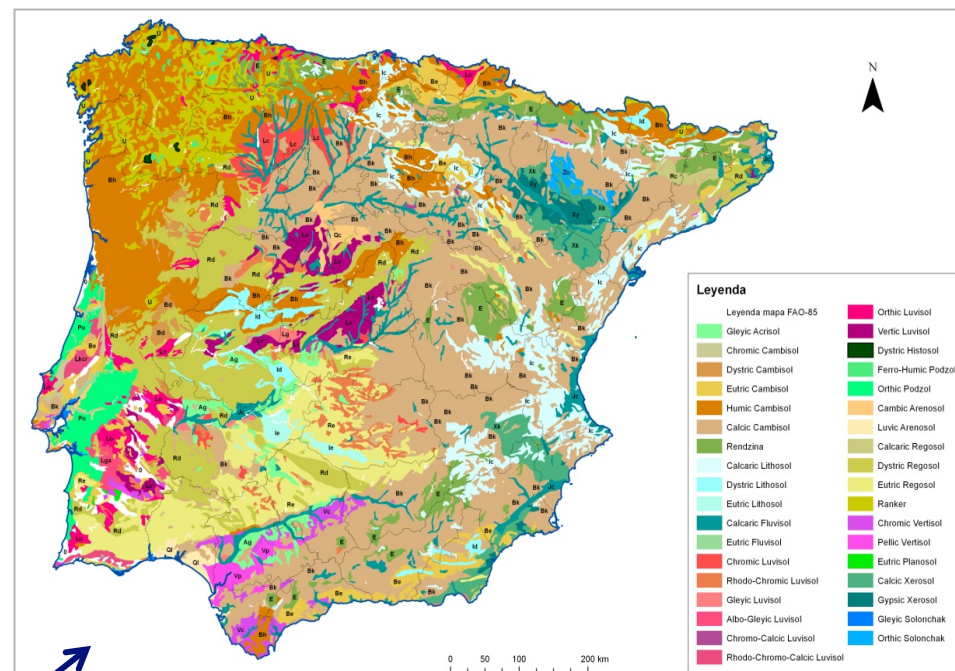
ID	PROVINCIA	N. PERFIL	HOJA	MUNICIPIO	SITUACION	USO	PENDIENTE	FUENTE	LONG. G	LONG. M	LONG. S	LAT. G
1	A	1	796	ADSUBIA	MATORRAL	CEREAL	35	CSCV95, PAG. 150	3	38		
2	A	2	0	BENEXAMA	BARRANCO FRANCO. CARRETERA FO	ENCINAR, PI	35	CSCV95, PAG. 145	0	0	0	0
3	A	3	820	CASAS SOLANA	CARRETERA BOCAIRENTE-VILLENA, Kr	FRUTALES	2	ICONA95e, PAG. 79	49	38		
4	A	4	820	BARRANCO FRANCO	CARRETERA FONTANARES-BENICAN	ENCINAR (Q	35	ICONA95e, PAG. 88	0	47	38	
5	A	5	820	ALCOY	CAMINO BARCHELL-RIO POLOP	PINAR (PINL	5	ICONA95e, PAG. 53	32	38		
6	A	6	821	AGRES	CASA DE LOS CARROS	PINAR (PINL	30	CSCV95, PAG. 88	0	29	38	
7	A	9	822	BENISA	CARRETERA BENISA-SERRALLONGA	CULTIVOS	2	CSCV95, PAG. 103	0	3	38	
8	A	24	893	SANTA POLA	CARRETERA A CARTAGENA, Km. 25, S/4	FRUTALES	1	ORTI285, PAG. 101	0	38	38	
9	A	26	893	SANTA POLA	CARRETERA CARTAGENA, Km. 25, SALI	MATORRAL	6	ORTI285, PAG. 103	0	38	38	
10	A	27	913	ORIHUELA	TERRENO ABANCALADO	CITRICOS (N	6	ETAGS478	0	57	38	
11	A	28	913	EL MOJON	DEHESA DE PINO HERMOSO. FRENTE	CITRICOS (LI	6	ETAGS478	0	58	38	
12	A	29	913	TORREMANOJO	ALMENDRA	15	ETAGS478	0	53	38		
13	AB	4	741	VILLARROBLEDO	CASA DEL PINTADO	CEREAL	1	GMIGUEL85, PAG. 43	2	25	40	39
14	AB	5	741	MINAYA	ESTACION DE FERROCARRIL. VENTA VI	CEREAL	1	GMIGUEL85, PAG. 43	2	20	55	39
15	AB	11	764	MUNERA	CUARTO DE MANUELI	CEREAL, OLI	3	GMIGUEL85, PAG. 45	2	27	38	
16	AB	13	705	ALBACETE	LABOR DE ACEQUIOMI	CEREAL	2	GMIGUEL85, PAG. 43	2	1	39	
17	AB	17	916	POZOHONDO	CEMENTERIOI	VIÑEDO, CEF	8	GMIGUEL85, PAG. 44	1	53	40	38
18	AB	20	840		CARRETERA ALBADALEJO-VILLAPALA	MATORRAL	30	SANTOS79, PAG. 362	2	42	38	
19	AB	21	840		CARRETERA ALBADALEJO-VILLAPALA	ENCINAR, J/	26	SANTOS81, PAG. 159	2	42	38	
20	AB	22	840	VILLANUEVA DE LA	CARRETERA ALBADALEJO-VILLAPALA	MATORRAL	14	SANTOS81, PAG. 160	2	42	38	
21	AB	23	840		CARRETERA JAEN-ALBACETE, Km. 85,2	MATORRAL	5	SANTOS79, PAG. 396	2	33	38	
22	AB	24	840	EL OJUELO	CAMINO A EL SALOBREI	MATORRAL	50	SANTOS79, PAG. 361	2	33	38	
23	AB	25	841	VIANOS	A 1 Km. AL SUR DEL PUEBLOI	CEREAL	1	SANTOS79, PAG. 402	2	30	38	
24	AB	26	866		BARRANCO DE LOS PINOS. DOLINAI	PRADERA	5	ALIAS81b, PAG. 1912	2	1	39	
25	AB	27	866		A 1,5 Km. DE LA BIFURCACION DE LA CA	PRADERA	0	ALIAS81b, PAG. 1913	2	25	38	
26	AB	28	866	RIOPAR	A 1 Km. DE LA FUENTE DEL ESPINO. DOL	PASTIZAL	0	ALIAS81b, PAG. 1912				
27	AB	29	866		A 200 m. DE LA FUENTE DEL ESPINOI	MATORRAL	0	ALIAS81b, PAG. 1911				
28	AB	30	866	RIOPAR	PICO DE ARGEL. DOLINAI	PASTIZAL	0	ALIAS81b, PAG. 1910				
29	AB	31	868	CANCARIK	A 350 m. AL NOROESTE DEL PICO DE LA	MATORRAL	30	HERNANDEZ82, PAG. 41				
30	AB	32	868	CANCARIK	A 600 m. AL NOROESTE DEL PICO DE LA	ERIAL	5	HERNANDEZ82, PAG. 41				
31	AB	33	868	CANCARIK	PARTE LLANA AL PIE DEL PICO DE LAS	MATORRAL	5	HERNANDEZ82, PAG. 41				
32	AB	34	868	CANCARIK	PICO DE LAS CABRAS. CERROI	ERIAL	0	HERNANDEZ82, PAG. 41				
33	AB	35	889	LETUR	A 1,4 Km. DE MAJAL. ALTO (1442 m.)	ATEF CEREAL	0	ICONA93, PAG. 41				
34	AB	36	889	LETUR	A 1,5 Km. DEL VERTICE ANGULAI	MATORRAL	50	ICONA93, PAG. 67				
35	AB	37	889	SOCOIVOS	A 0,8 Km. AL OESTE DE TAZONAI	VIÑEDO	0	ICONA93, PAG. 46				
36	AB	38	889	SOCOIVOS	A 1,5 Km. DE TAZONAI	ALMENDRA	5	ICONA93, PAG. 78				
37	AB	39	840		SIERRA DEL REUMBRAR. CARRETERA/	ENCINAR, J/	30	SANTOS81, PAG. 159				
38	AB	40	840		SIERRA DEL REUMBRAR. CARRETERA/	MATORRAL	24	SANTOS81, PAG. 160				



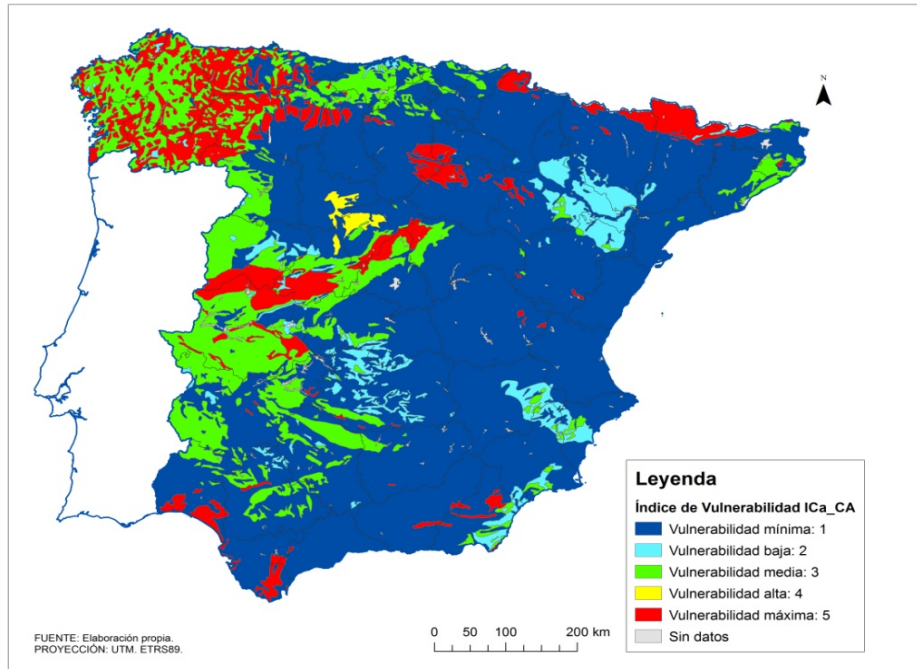
## BASE MAP TO REPRESENT THE VULNERABILITY INDEXES

**1<sup>ST</sup> EDITION:**  
Soil Map of the CEC (Commission of the European Communities, 1985),  
scale 1:1.000.000.

**2<sup>ND</sup> EDITION:**  
Soil Geographical Data Base of Europe: **SGDBE v.3 (EC, 1995)**,  
scale 1:1.000.000



**Spatial distribution based on the SMU (Soil map units) of SGDBE v.3**



## ICa\_FC

Calcareous soils → min values

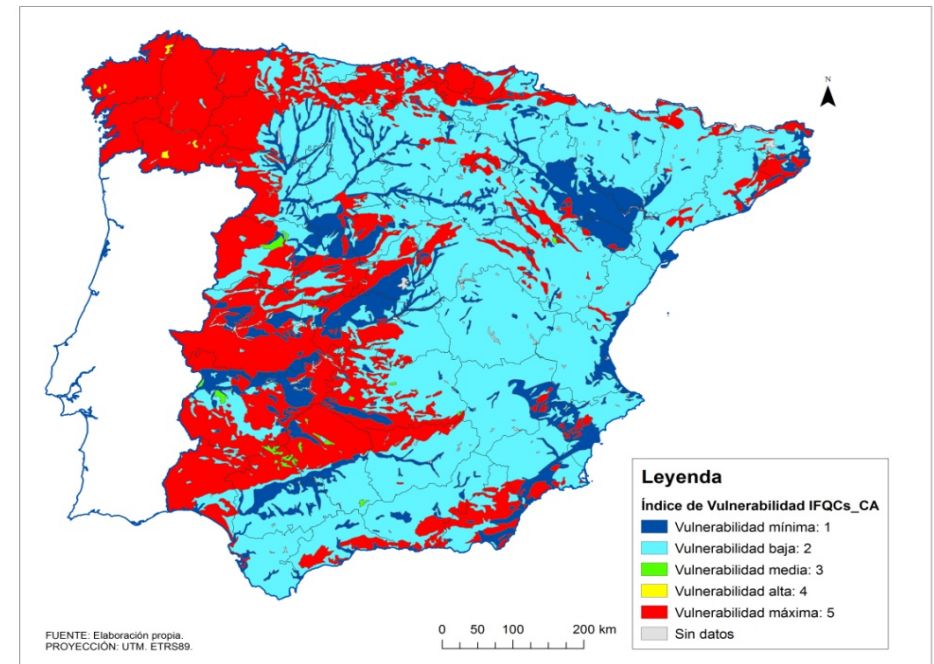
Acidic soils, with lower pH and Ca status → higher values

## IFQ<sub>Cs</sub>\_FC

Clear difference between lithologies:

Acidic: coarse texture, Cs not fixed → max values

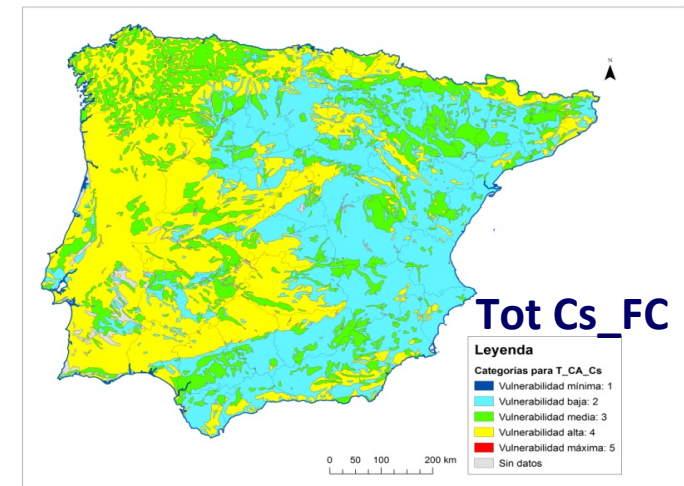
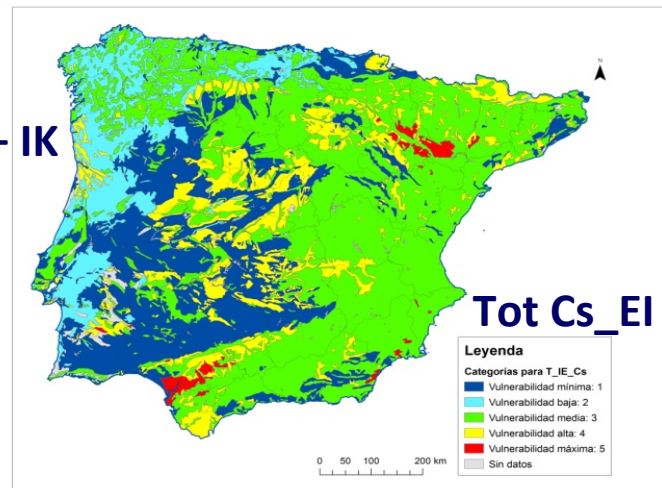
Calcareous: clayey texture, different type and percentage → min values



## GLOBAL VULNERABILITY MAPS: combination of individual indexes

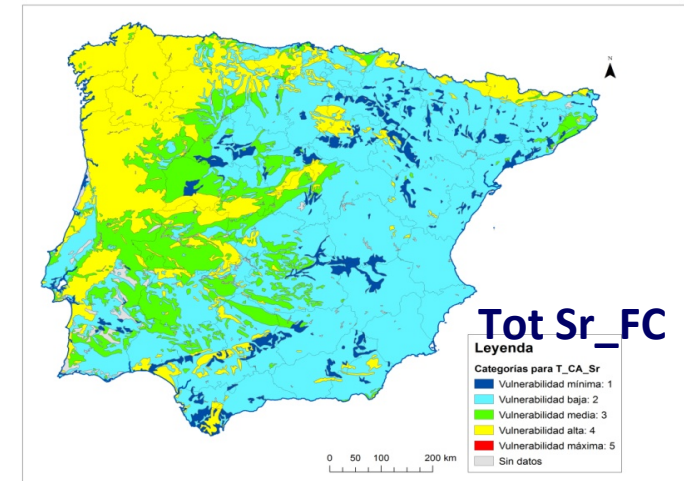
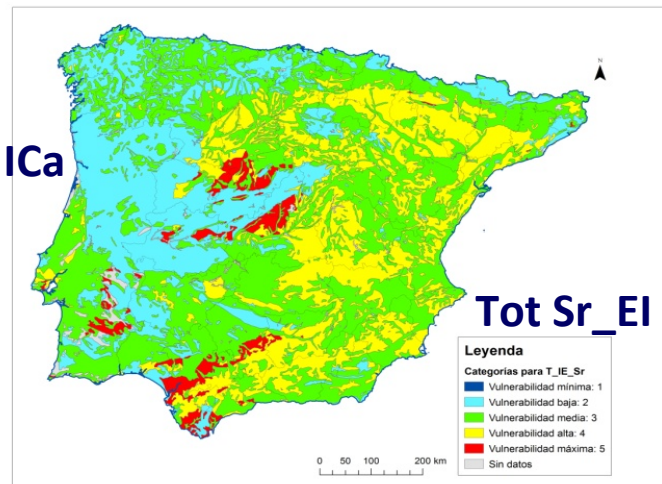
$$\text{Tot Cs\_EI} = \text{IF} + \text{IH} + \text{IFQCs}$$

$$\text{Tot Cs\_FC} = \text{IF} + \text{IH} + \text{IFQCs} + \text{IK}$$

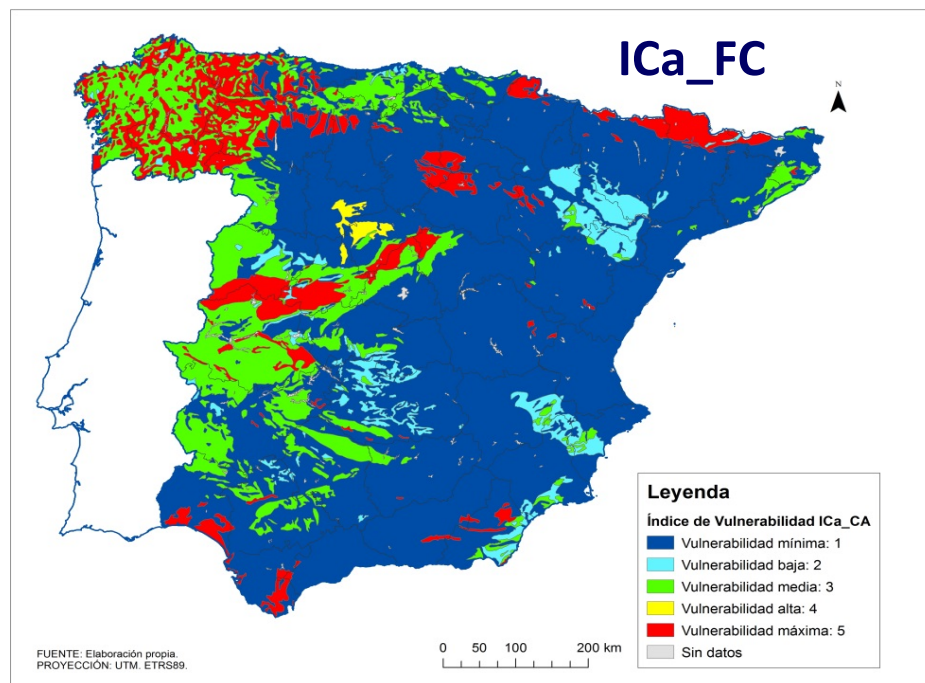
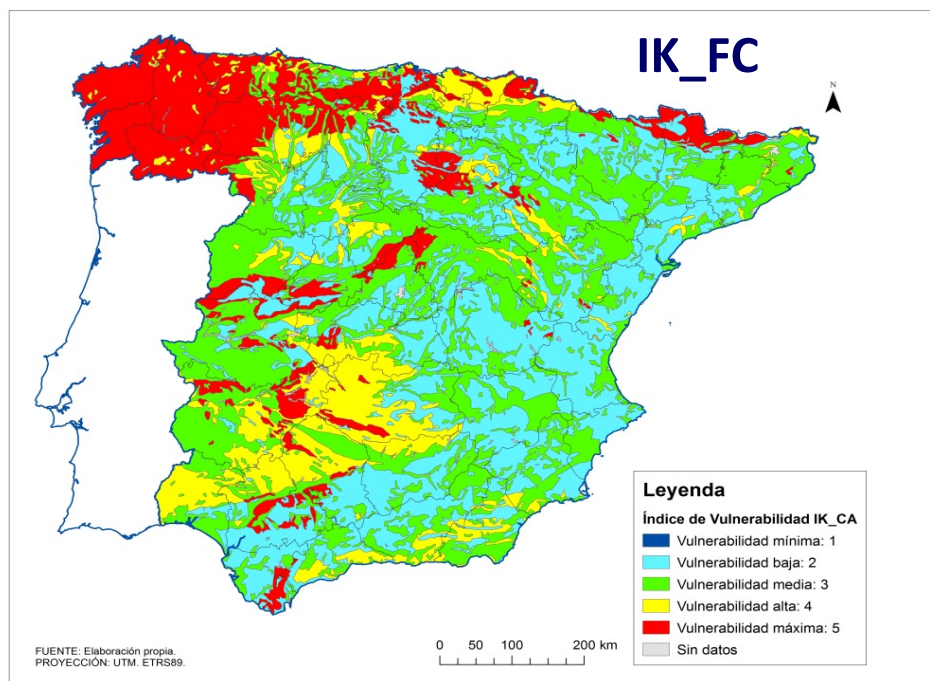


$$\text{Tot Sr\_EI} = \text{IF} + \text{IH} + \text{IFQSr}$$

$$\text{Tot Sr\_FC} = \text{IF} + \text{IH} + \text{IFQSr} + \text{ICa}$$



Vulnerability maps regarding K and Ca status, identify those areas where rehabilitation is a priority. Case study on the application of K fertilizer and liming to decrease the potentiality to transfer  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$ :

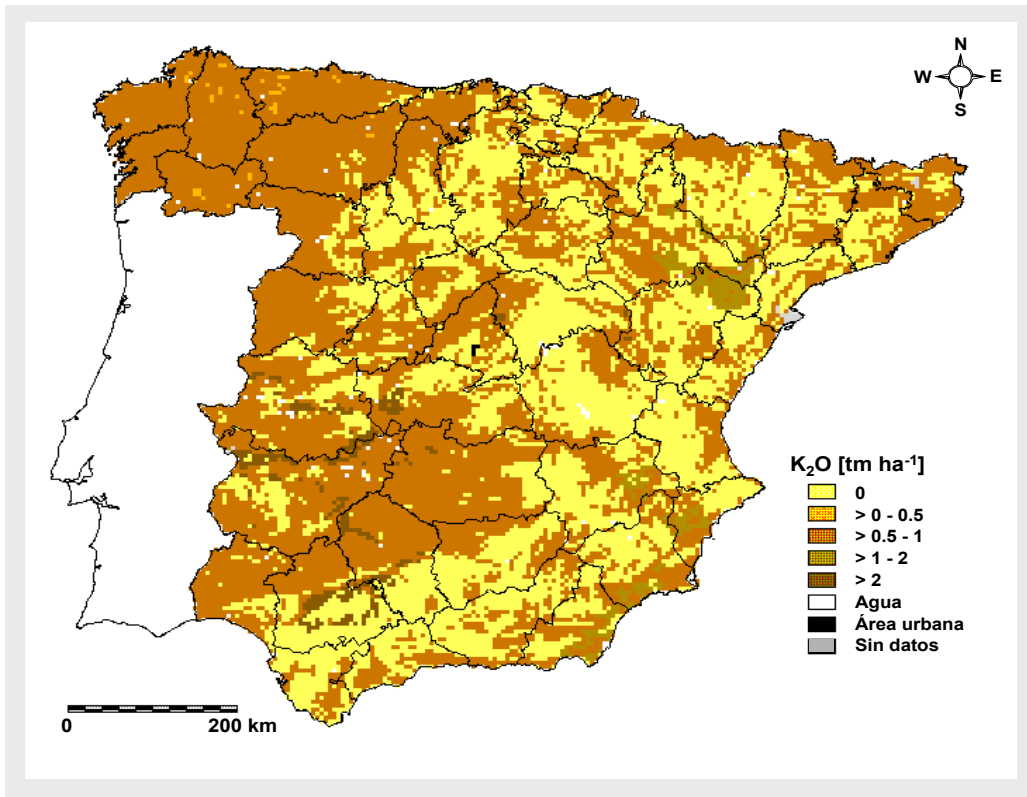


From the nutritional status on K and Ca, the application of K fertilization and liming is assessed under two assumptions:

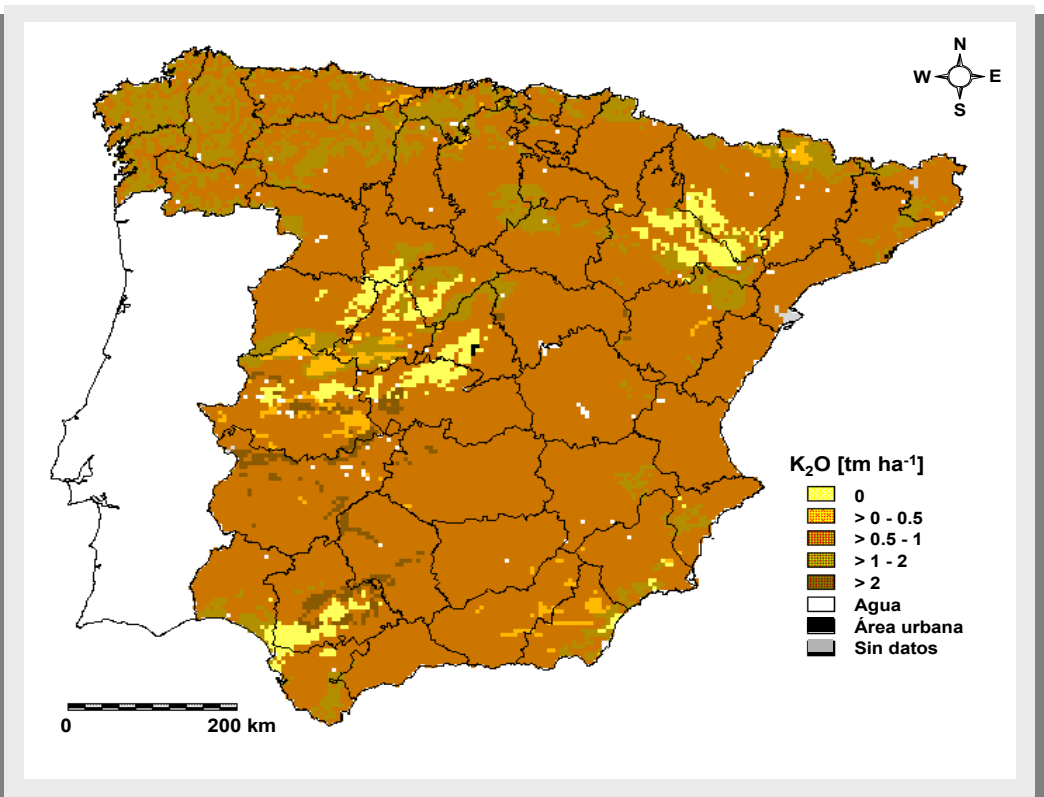
- ❖ *Standard agricultural practice: correcting the deficiencies of K and Ca in soils.*
  - ❖ *Agricultural countermeasure: applying the quantities of K and Ca that reduce to minimum values the soil vulnerability.*
- 
- Only the decrease of the potentiality of transfer of RN is taken into account.
  - No other factors such as machinery, costs, side effects, ..., are considered.
  - The total quantities ( $\text{tm ha}^{-1}$ ) to be added are estimated without considering their distribution with time.

## Potassium fertilizer

### Standard agricultural practice

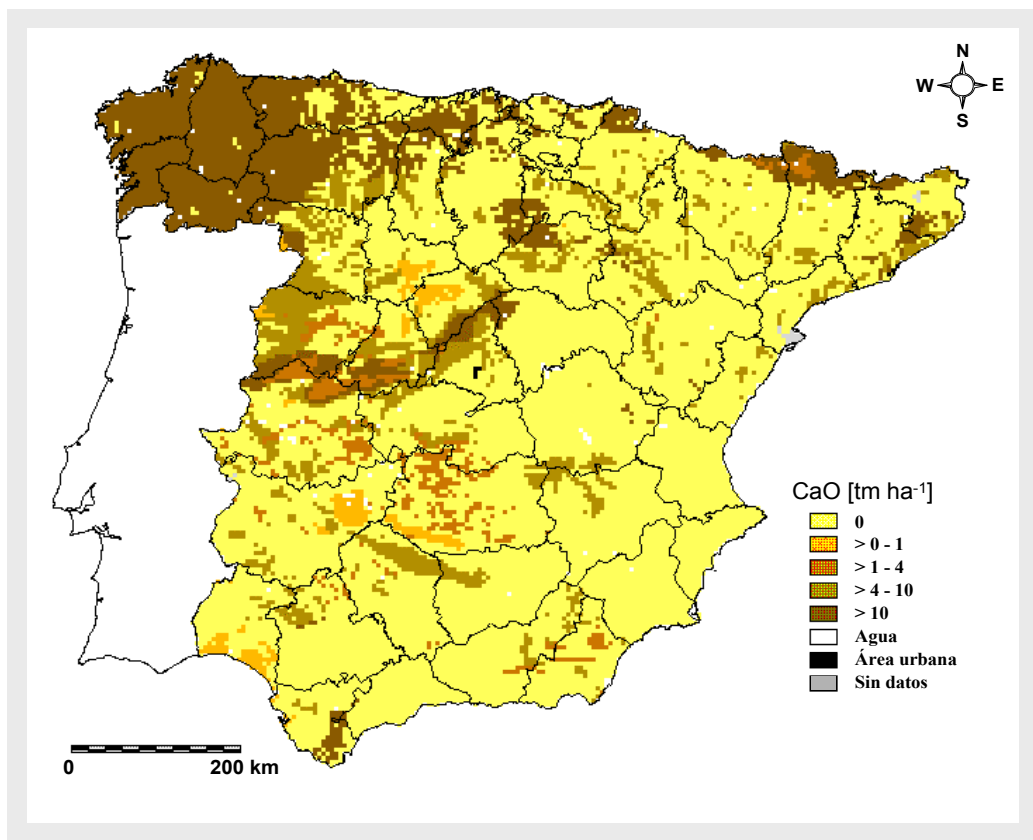


### Agricultural countermeasure

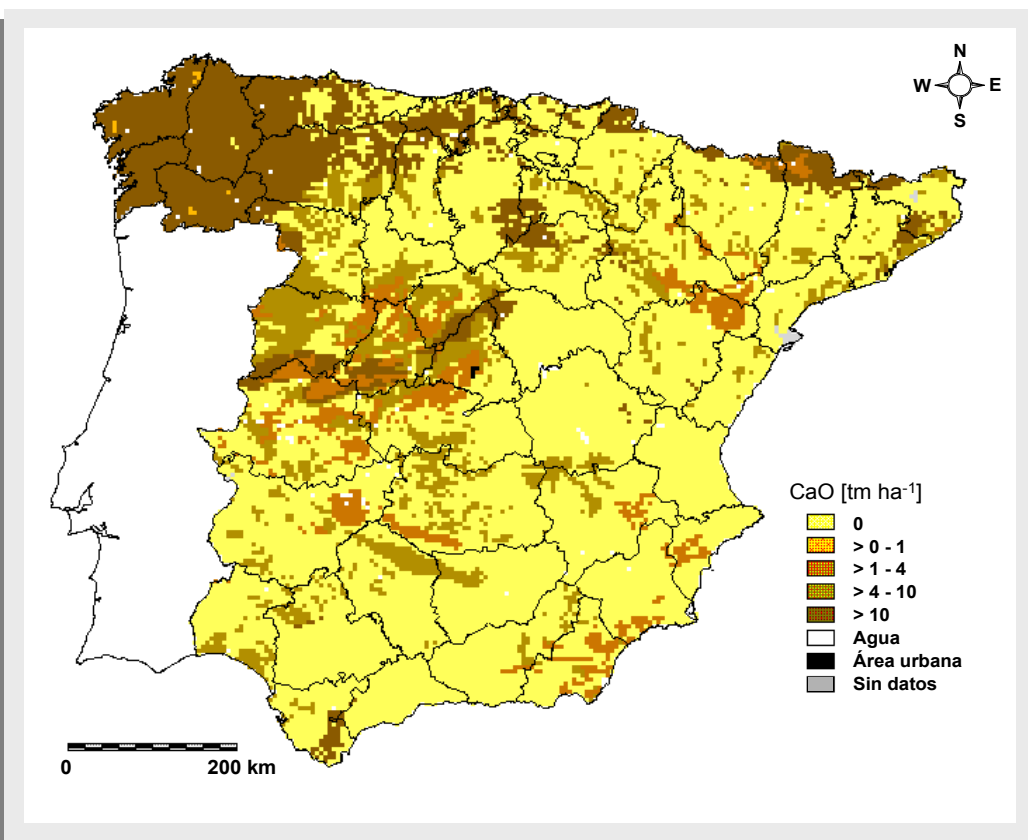


## Liming

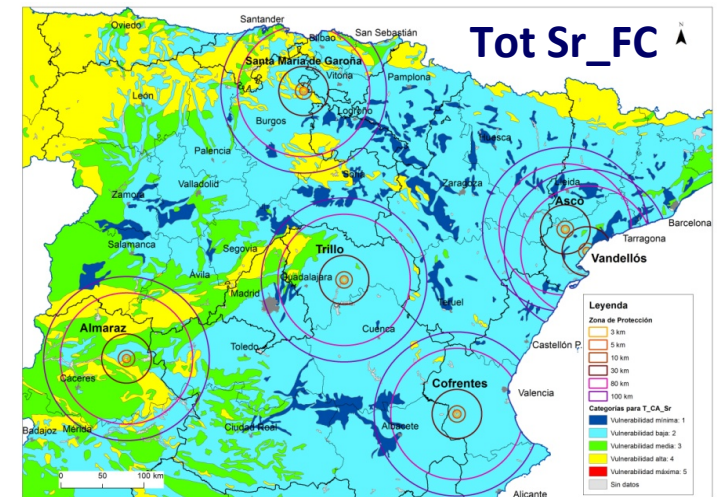
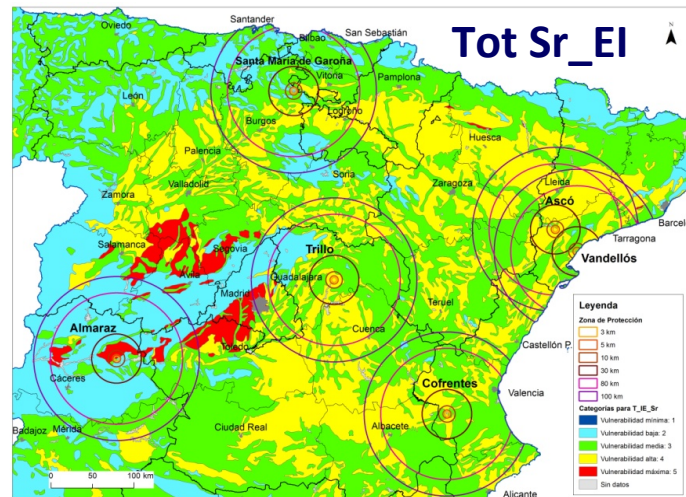
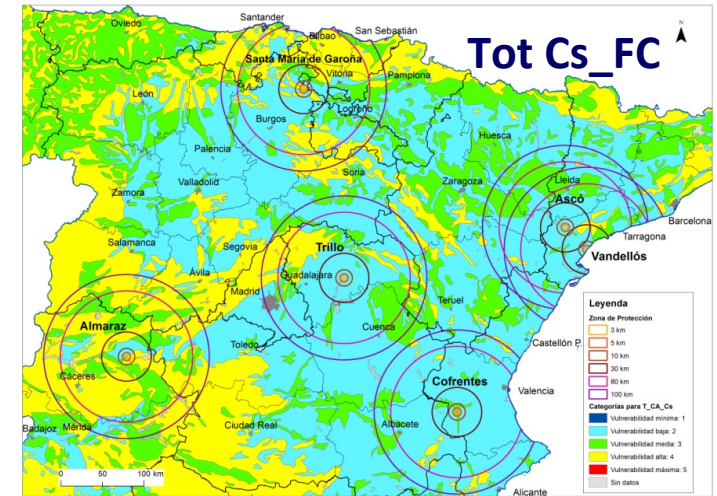
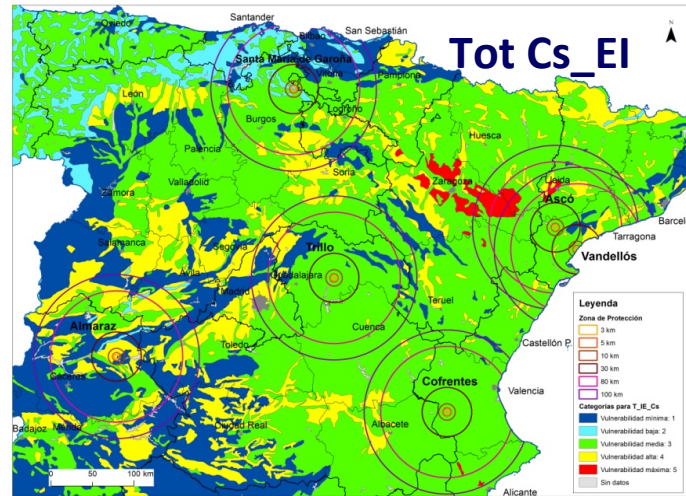
### Standard agricultural practice



### Agricultural countermeasure

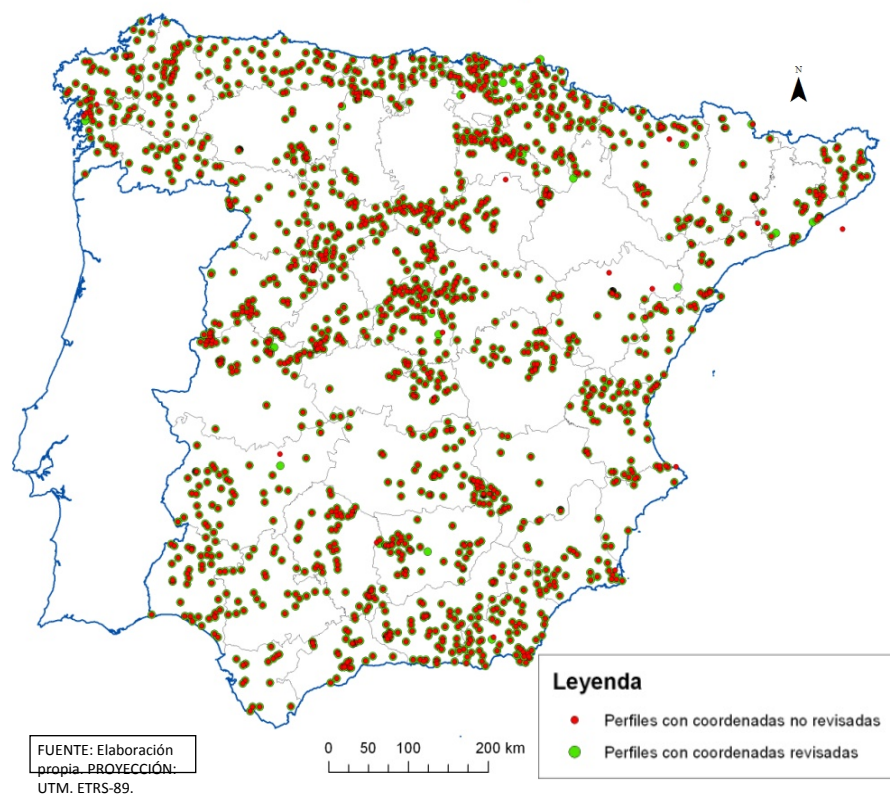


Increasing the local specificity to the EPZs of NPP, will require more data to increase the reliability of the vulnerability assessment?

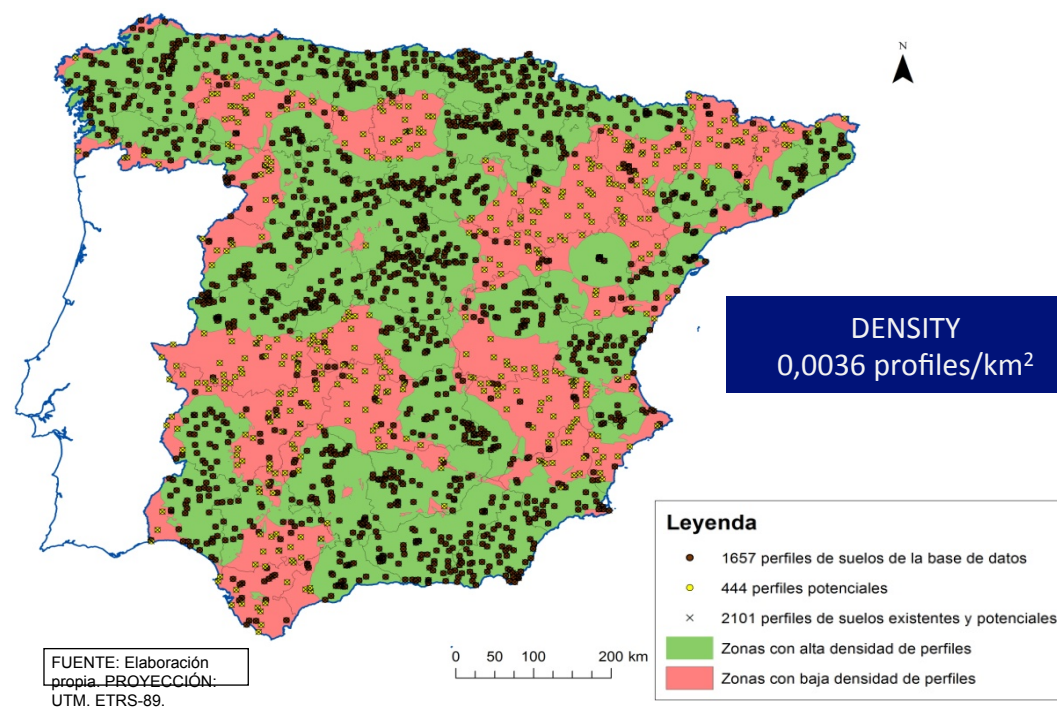




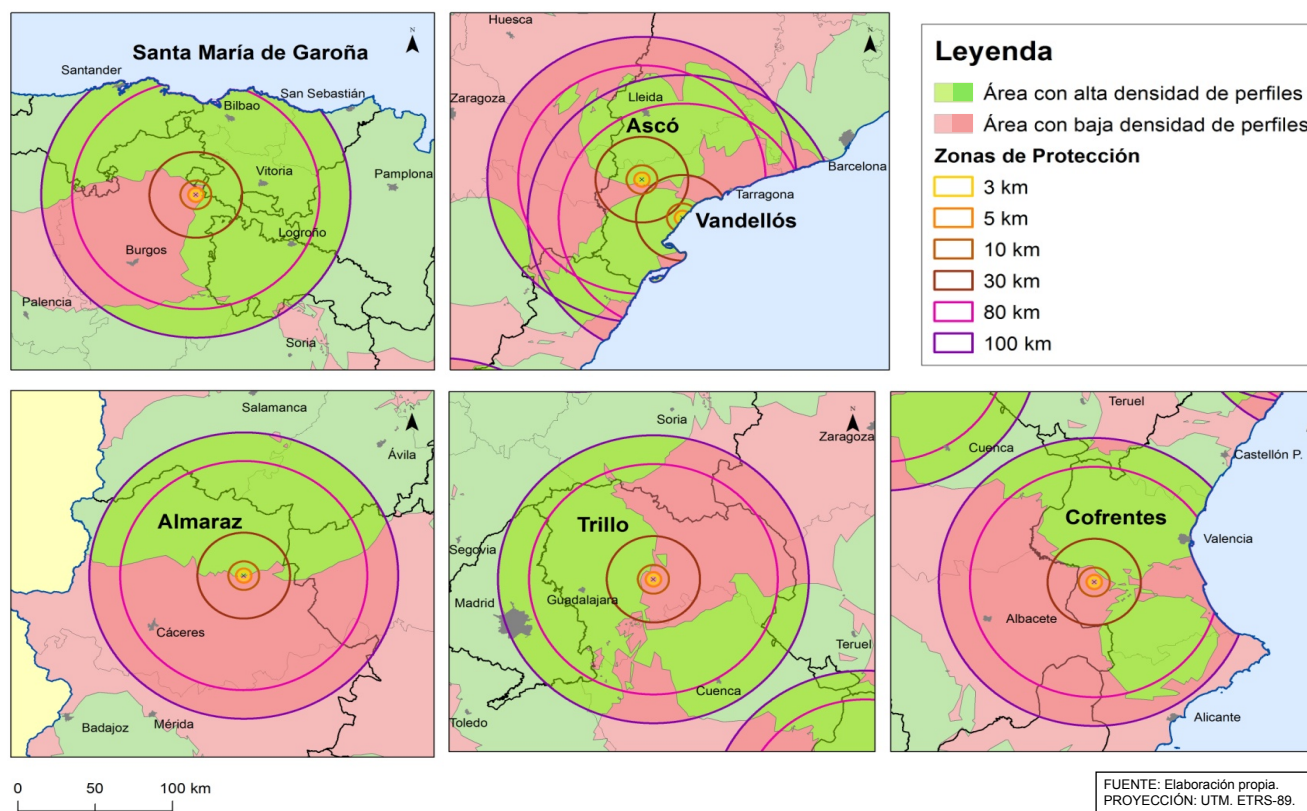
Location of the 1.657 soil profiles at 1.000.000 scale, to asses the vulnerability in Peninsular Spain



Distribution and density analysis to determine if the information is enough to assess the vulnerability in the surroundings of NPP



Identification of areas with high and low profile density → to balance the soil characterization, some green areas will need a reduction of soil profiles and pink ones will need more soil profiles



- ❖ The methodology developed, estimates the radiological vulnerability of Spanish soils, according to their specific properties.
- ❖ The results, in form of vulnerability maps, show the trends of the behavior of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$ , allowing to prioritize rehabilitations areas in the decision-making processes.
- ❖ A case study regarding the vulnerability due to nutrient status, allows to plan the K fertilizer and liming applications to reduce the vulnerability.
- ❖ Increasing the local specificity scale, will require more detailed parameters and information to improve reliability.

**THANK YOU FOR YOUR ATTENTION!**