LOCAL FACTORS TO MAKE RISK MAPS, FOR POTENTIAL NUCLEAR ACCIDENT AFFECTED FARMING AREAS, TO BE APPLIED IN THE DECISION-MAKING PROCESS

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INTRODUCTION

In a post-accident situation, the decision-making process for the recovery of an affected farming area is especially relevant and needs a wide range of factors to be taken into account. On one hand those related to environmental aspects, as climate, soil type and the processes that are developed on it. On the other hand, additional elements which have to do with social or cultural aspects, as agricultural practices and land use and other socio-economical factors such as population density and dietary habits, should be considered. The more specific and local those factors are, more effective and precise will be the response and less the uncertainties in the decision-making process.

Risk maps as planning tools can help to identify those areas which are more vulnerable to high levels of soil-to-plant transfer and where the application of remediation techniques to mitigate the consequences could be feasible and effective.

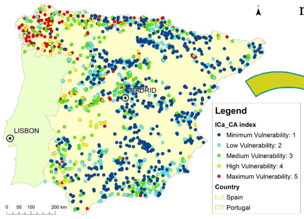
The ultimate objective is to analyse the response mechanism of the affected ecosystem and thus, provide decision-makers enough information and as clear, comprehensive and accurate, locally oriented, as possible, to optimise the recovery. This poster presents a methodology design to elaborate risk maps, considering local factors, to be used by the decision-makers in the preparedness and management of a nuclear post-accident exposure situation. The methodology is expected to be reproducible in any spot in Europe, and scalable for different territorial levels. Here, an approach to the Spanish case in Almaraz NPP (Cáceres province) is presented, aiming to establish a recovery strategy priorisation in the 100 km around the power plant.

How to integrate all the aspects that should be taken into account within a methodology is a huge challenge. If in addition it is easy to apply by the decision-makers and useful for the whole society, it is a confidence.

METHODOLOGICAL DESIGN

1. RADIOLOGICAL SOIL VULNERABILITY

VULNERABILITY INDEX OF THE SPANISH SOIL PROFILES

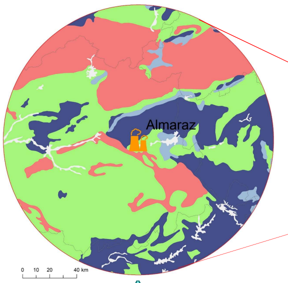


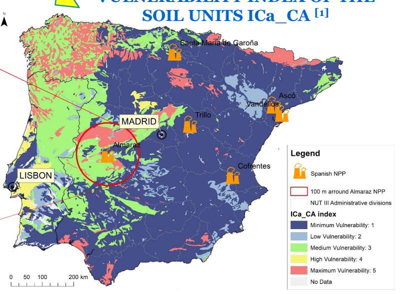
From the soil data extracted from a Spanish soil profiles data base, with a total of 1683 soil profiles, six different radiological **vulnerability indexes** were assessed[1] and represented by using the European soil map[2] as base map.

One of them is the vulnerability index derived from the calcium content, for the food chain, (ICa_CA). The more soil Ca content, and the lower the ICa_CA index, the less Sr is transferred to the plants (crops).

In the case of the transfer soil to plant for the Cs, the assessed vulnerability index is related to the content of K in the soil. In the same way, the higher the content of K in the soil, the less Cs is transferred to the plants.

VULNERABILITY INDEX OF THE SOIL UNITS ICa_CA [1]





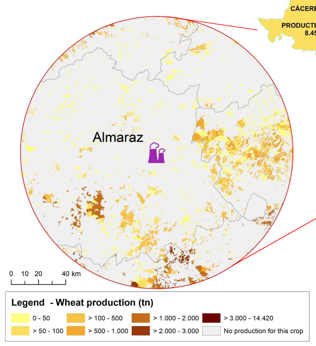
NOTE: Maps' projection is UTM – Datum ETRS89. Zone 30.

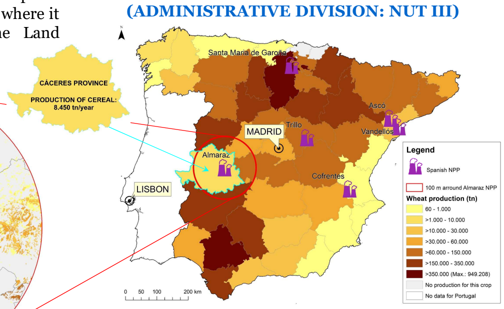
2. AGRICULTURAL PRODUCTION

The Spanish national statistics present **agricultural production** data[3] at the NUT III level (provinces) as the more detailed geographic units. However, taking into account the importance of the local specificities, the production has been distributed to the smaller administrative units (municipalities).

Besides, the production of every crop has been linked to the land use areas where it is grown by using the Corine Land Cover[4] as base map.

WHEAT PRODUCTION PER PROVINCE (ADMINISTRATIVE DIVISION: NUT III)





Here rainfed wheat production has been presented as representative crop in Spain and in the 100 km area around Almaraz NPP.

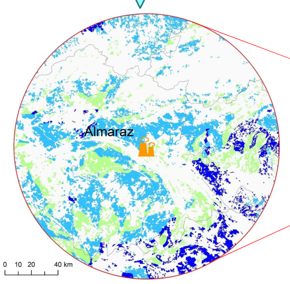
This example highlights the importance of considering the local specificities since the relevant differences between the province production map and the production around Almaraz NPP can be perfectly seen.

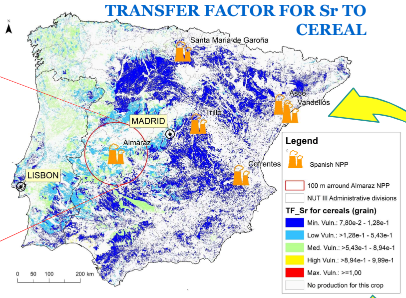
It has been considered that rainfed wheat crop is grown in the following land use units (CORINE classes)

CORINE CLASSES
- Non-irrigated arable land (211)
- Annual crops associated with permanent crops (241)
- Complex cultivation patterns (242)
- Land principally occupied by agriculture, with significant areas of natural vegetation (243)
- Agro-forestry areas (244). In Spain, mainly "Dehesa"

3. SOIL TO PLANT TRANSFER FACTORS

TRANSFER FACTOR FOR Sr TO CEREAL



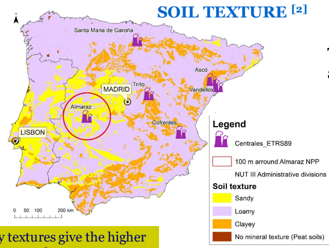


Soil plant transfer factors for cereals (grain) extracted from the bibliography [5], where the texture is taken into account, have been adjusted considering also topsoil Ca content [6], in order to obtain a more accurate **planning map**:

$$TF\_Sr = \frac{(TF_{upper} - TF_{med})}{1 - Ca_f} x (Ca_{med} - Ca_f) + TF_{med}$$

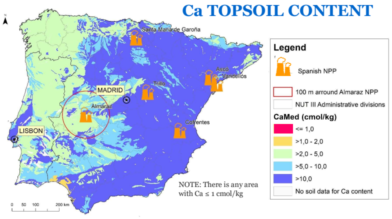
The TF_Sr allows to quantify the vulnerability of each area where wheat is grown.

SOIL TEXTURE [2]



Sandy textures give the higher Transfer Factors

Ca TOPSOIL CONTENT



The less the Ca, the higher the Sr transfer factor

Comparing the initial vulnerability soil map obtained from the soils' Ca content –ICa_CA, and the **resultant transfer factor map for cereals** –TF_Sr, it follows that:

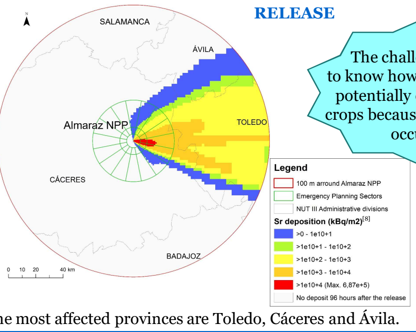
- The areas with higher ICa_CA vulnerability are practically uncultivated. Those areas have, mainly, a sandy texture, where the Sr is more bioavailable.
- In the rest of the areas, although the tendency is relatively similar in both maps, it is clear that loamy texture reduces the vulnerability, thus, clear blue areas in TF_Sr were green in ICa_CA. Meanwhile sandy areas remain with the same index in both maps (the green ones). In the same way, sandy soils increase its vulnerability in the central area of Almaraz map, changing from dark blue to clear blue.

As seen, in the Iberian Peninsula minimum (dark blue) or low (clear blue) transfer factors are the most representative. However, at a local scale, higher transfer factor values can be more representative, as in some spots within the area under study, where Ca values under 5 cm/kg can be found.

4. DEPOSIT MAP

A hypothetical Sr **deposit** obtained by using JRODOS System.[7]

DEPOSIT OF Sr FROM AN ALMARAZ NPP RELEASE



The most affected provinces are Toledo, Cáceres and Ávila.

5. CROSSING THE DEPOSIT AND THE TF_Sr

The challenge now is to know how to manage the potentially contaminated crops because of the deposit occurred.

Priority indexes have been obtained crossing the transfer factor map for cereals and the deposit map. A **risk map prioritising actions** is represented.

Deposit factor \ TF_Sr index	Min. Vuln.	Low Vuln.	Med. Vuln.	High Vuln.	Max. Vuln.
Min. Severity	5	5	4	4	3
Low Severity	5	4	4	3	3
Med. Severity	5	4	3	2	2
High Severity	5	4	3	2	1
Max. Severity	5	4	3	2	1

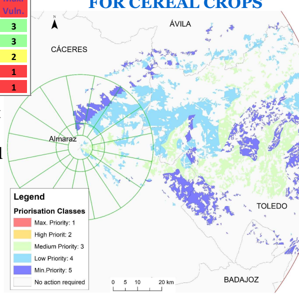
Areas affected by the same deposit quantity, are given different priorities.

Less deposit does not implies less risk, and vice versa.

For instance, in the case study, some areas are given lower priority action than the one resulting from applying only the TFSr index (which would be the planning value).

Reality modulates the action plans.

PRIORITY ACTION MAP FOR CEREAL CROPS



6. CONCLUSIONS

Risk maps for the decision-making process are the result of the combination of the soil vulnerability, the food chain impact and the deposit probability of a released radionuclide, after a nuclear accident.

Those maps can be used in the preparedness phase to determine the potential foodstuff and feedstuff restriction areas, or to stablish where remediation and recovery measures could be applied.

The developed methodology combines improvements in the decision-making process to reduce uncertainties since it considers the local specificities, and its applicability at any European spot.

A case study integrating all the inherent aspects of a particular area with a specific accident has been shown. This result could help in the management of the situation to prioritise actions. Next step will be to use the probability of occurrence of deposit, rather than just a single case, to obtain more effective planning maps to manage a post-accident situation.

REFERENCES: [1] Trueba, C. et al. 2000. Estimación de Índices de Vulnerabilidad Radiológica para los Suelos Peninsulares Españoles. [2] European Commission. 1995. Soil Geographical Data Base of Europe, v3. [3] MAGRAMA. 2016. Anuario de Estadística 2015. [4] EEA 2016. Corine Land Cover 2012. [5] IAEA 2010 .Technical reports series nº 472. [6] Montero, M. et al. 2001. Methodology for Decision Making in Environmental Restoration After Nuclear Accidents: TEMAS System. [7] https://resy5.iket.kit.edu/JRODOS/. [8] Protective Measures, Nordic Guidelines and Recommendations. 2014.

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