EIP-AGRI Focus Group

Soil salinisation

STARTING PAPER

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Introduction

Salinisation is one of the major threats to soil at the global scale and also in Europe several million ha of agricultural land are deemed to be affected by salinisation (Daliakopoulos et al., 2016). Salinisation has an impact on a number of soil functions, in particular, a direct negative effect on soil biology and an indirect effect leading to loss of soil stability through changes in soil structure. The impaired soil functionality caused by excessive soil salinity reduces the yield of crops, most of which are sensitive or have low levels of tolerance to elevated salt content in soils (Hill and Koenig, 1999). The impact ranges from slight crop loss to complete crop failure, depending on the type of crop and the salt content in the soils. In fact, the effects of soil salinity represent some of the most significant limitations to agricultural production (Shrivastava and Kumar, 2015). Beside on food production, salinisation has an effect on several other soil ecosystem services, namely, on provision of freshwater for livestock, wild animal and plants, on regulation of groundwater quantity and quality and on soil water and wind erosion, on supporting habitats and also on recreational areas and aesthetic values of the landscape (Stolte et al., 2016).

With the term soil salinisation, we usually refer to three different processes:

- Salinisation, which is the accumulation of water-soluble salts in the soil profile, mainly chloride, sulphate, carbonate and bicarbonate of sodium, magnesium, calcium, and potassium.
- Sodification, as the progressive saturation of the exchange complex with sodium (mainly from sodium carbonate).
- Alkalinisation, which is the increase in pH reaction in the soil solution over 8.5.

All soils that contain soluble salts in the amount higher than 0.1-0.2% (or ECe>2 dS/m) within their profile are referred to as salt-affected, or saline soils.

There are different classifications of salt affected soils, one of the most adopted is that reported by van Beek and coll. (van Beek et al., 2010) which considers saline, sodic, and saline-sodic soils (Tab. 1).

Table 1. Classification of salt-affected soils.

Classification	**Electrical Conductivity of the saturated paste extract (ECe dS.m-1 at 25ºC)**	**Soil pH in water**	**Exchangeable Sodium % (ESP[1])**	**Sodium Absorption Ratio (SAR[2])**
Saline	> 4.0	< 8.5	< 15	< 13
Sodic	< 4.0	> 8.5	> 15	> 13
Saline-sodic	> 4.0	< 8.5	> 15	> 13

[1] ESP = Exchangeable [(Na)/(Ca + Mg + K + Na)] x 100

[2] SAR = Exchangeable (Na)/RADSQ[(Ca + Mg)*0.5]

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Salinisation of agricultural soils is mainly caused by high evapotranspiration rates and soil characteristics that impede water drainage and cause salt accumulation in the upper layers. It can occur in coastal areas where seawater enters the aquifer and in inland areas where salts are naturally present in soils. The problem can be aggravated by improper management practices, poor irrigation water quality and variations in rainfall and temperature patterns due to climate change. Agricultural mismanagement, in particular, is mostly due to lack of knowledge, or adequate consideration, about the consequences of adopting an agro-technique or a water management system (e.g. improper irrigation) in a specific soil condition. Then the fight against soil salinisation should adequately consider prevention, besides site-specific crop-soil management and soil remediation.

Innovative water and farming practices can help to counter the problem. The adaptation to local saline conditions can also offer opportunities to differentiate locally adapted varieties in the market and obtain higher revenues. Both lines of action may contribute to compensate the productivity loss caused by soil salinisation and preserve soils for agriculture.

This Focus group is expected to provide answers and recommendations to the following question: How to maintain agricultural productivity by preventing, reducing or adapting to soil salinity?

The Focus Group should carry out the following main tasks:

1. Make an inventory of European areas affected by soil salinisation and the current agricultural practices in these areas
2. Identify and assess the sustainability of good and innovative farming practices from various pedoclimatic contexts within the EU, which can prevent and reduce the threat of soil salinisation or control its negative effects.
3. Explore opportunities to add market value to locally adapted varieties which are (more) tolerant to salt stress so as to compensate yield reduction.
4. Discuss the potential of minor crops with increased tolerance to salt stress.
5. Propose potential innovative actions and ideas for Operational Groups.
6. Identify needs from practice and possible gaps in knowledge concerning soil salinisation which may be solved by further research.

In the first meeting, the Focus Group will address the first four tasks, while the remaining two tasks will be addressed during the second meeting.

The purpose of this starting paper is to outline the topic at hand and identify points for discussions in the first meeting, by formulating needs, mapping existing or new solutions, and asking questions to the group.

1. What is the extension of the areas affected by soil salinisation in Europe? Why it is so difficult to have a reliable estimation?

1.1 Mapping

The localization and extend of the area affected by soil salinisation is still controversial. Using the FAO/UNESCO soil map of the world (1970-1980), FAO estimated that in Europe, including arable and non-arable lands, saline soils are 6.7 Mha, or 0.3% of total area, and sodic soils 72.7 Mha, the 3.6%. According to Stanners (1995), salinisation affects around 3.8 Mha in Europe. More recently, other estimates report that saline and sodic soils cover about 30.7 Mha of Europe (Rengasamy, 2006).

In 2008, JRC has produced an updated version of the Soil Geographical Database of Europe (SGDBE) which among other threats presents the limitations to agricultural use posed by salinity and sodicity (Tóth et al., 2008).

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The map produced in the framework of the EU FP7 RECARE project (http://recare-project.eu/) collects different sources and reports both territorial and localized information about agricultural limitations due to soil salinity and seawater intrusion (Fig. 1).

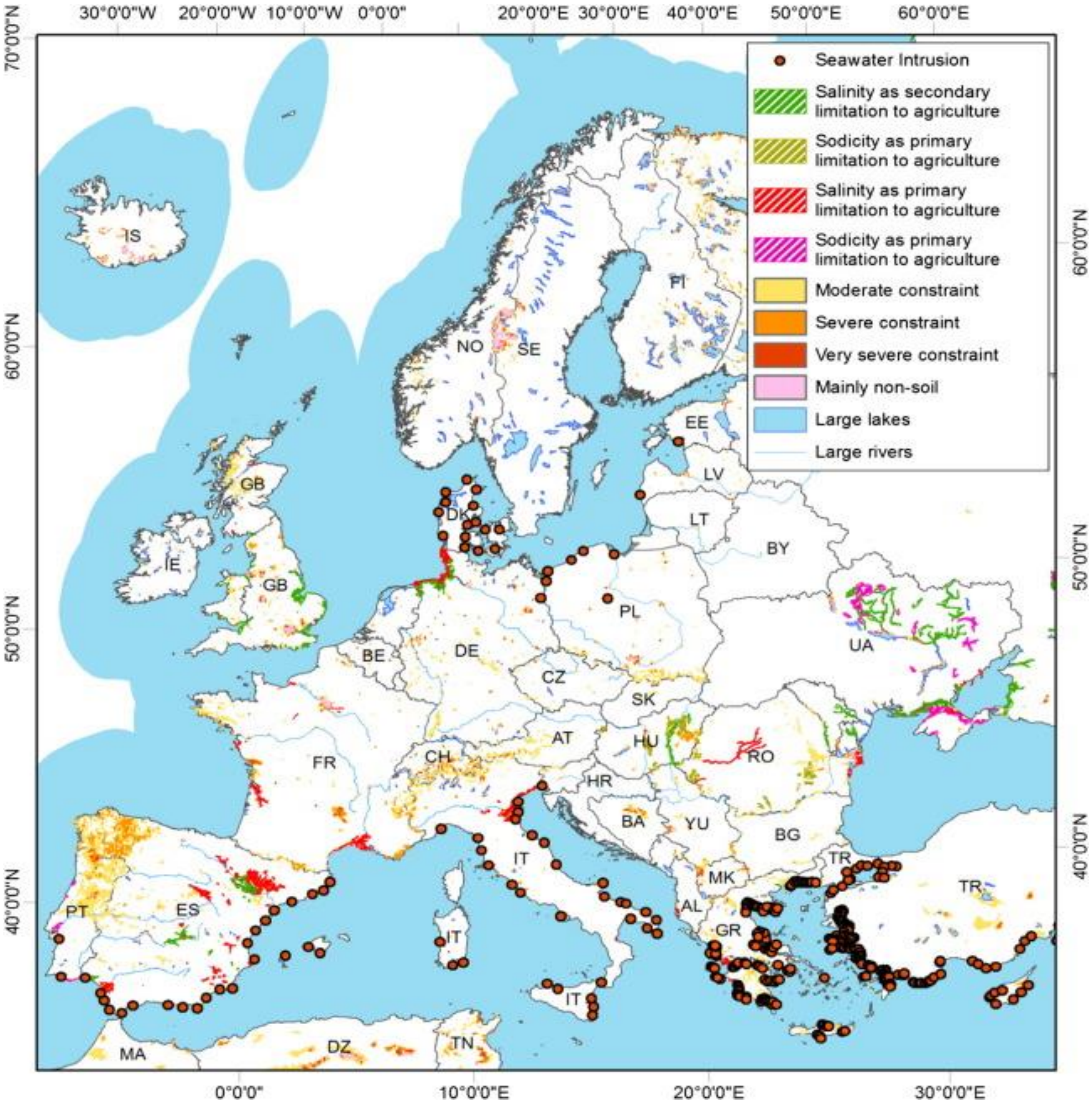

Figure 1. Saline (EC > 4 dScm-1 within 100 cm soil depth) and sodic (Na/T > 6% within 100 cm soil depth) soils as primary and secondary limitations to agricultural use and areas of seawater intrusion in the European Union (Daliakopoulos et al., 2016).

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However, the actual extension of soil salinisation is still uncertain. Although it is well known that many coastal areas with inland sea water intrusion may be affected by soil salinisation, especially under Mediterranean climate, as reported by the current EU map, the diffusion of salt affected soils in internal and continental lands, on salt rich parent materials, appears to be largely underestimated. Saline and sodic soils can form from the fine marine or fluvial and lacustrine sediments, far from the current sea shore, on plains but especially on hilly environments. For instance, studies on gypspiferous soils and on soils with parent materials rich in sodium have demonstrated that the presence of soils with a Salic or Sodic horizon is more extensive than previously estimated, and in particular much larger than that of Solonchak, Solonetz and Gypsisols. In addition, the WRB soil classification system considers many kinds of salt affected soils, besides Solonchaks, Solonetz, and Gypsisols (Costantini et al., 2013). In particular, the Sodic qualifier applies on soils that have 15 percent or more exchangeable Na plus Mg on the exchange complex within 50 cm of the soil surface throughout. Salic soils must have a salic horizon[3] starting within 100 cm of the soil surface and Hyposalic ones an ECe of 4 dS m-1 or more at 25 °C in some layer within 100 cm of the soil surface. The Hyposodic qualifier lets eligible soils that have 6 percent or more exchangeable Na on the exchange complex in a layer, 20 cm or more thick, within 100 cm of the soil surface. It is to be highlighted that many sodic soils are only Hyposodic in depth. This means that most herbaceous crops are not much affected by sodium. Nevertheless, in the plains the Sodic layer may not permit water to drain, leading to waterlogging at the surface. But it is on the slopes and clayey substrata that the occurrence of Sodic and Hyposodic soils causes particularly harsh problems. In fact, the presence of a high sodium percentage on the cation exchange complex lets the clay particles lose their tendency to stick together when wet. Soils became impermeable in depth to both water and roots, and geomorphologically unstable. Subsurface water, in particular, flows over the Sodic soil horizon and is lost in lateral drainage, so that it may create tunnels, leaving cavities that eventually collapse to form gullies. These soilscapes are affected by a great variety of erosive phenomena, in some cases producing typical landscapes and important ecological environments, like those with different kinds of badlands ("biancane" and "calanchi", Calzolari and Ungaro, 1998). The limited thickness of the "solum", and the very low permeability of the C horizons and substratum, are the main constraint of the soil type, favouring runoff and water erosion.

Another issue related to the estimation of extent of saline soils, is that the trend of soil salinisation is considered to have increased in the last decades, making unreliable the comparison of data taken from areas surveyed in different times. The trend is assumed to further increase in the future, as a consequence of current climate, land use, and management changes (Trnka et al., 2003), then the present estimates of extension and degree of soil salinisation are most probably to be exceeded in a few years' time.

The need of a better information about saline soils is well acknowledged in Europe. To this regard, the EU launched an activity on the delineation of agricultural areas with natural handicap (EU 1305/2013), which considered soil salinisation. In this framework, every EU country, by the year 2018, should have prepared and transmitted to the JRC a map of agricultural areas limited by soil salinity. Another effort is played by the Global Soil Partnership (GSP), promoted by the FAO. In the year 2019, it has been planned to produce a Global Soil Salinity Map (GSSMap), and the European Soil Partnership, continental branch of the GSP, has committed European countries to collaborate to this effort.

Task 1: Make an inventory of European areas affected by soil salinisation and the current agricultural practices in these areas

Discussion questions to the focus group:
- ***What are the reasons of incomplete mapping results on soil salinity?***
- ***How could they be improved?***

1.2 Monitoring

[3] A salic horizon must have: 1) averaged over its depth at some time of the year, an electrical conductivity of the saturation extract (ECe) of 15 dS m-1 or more at 25 °C, or an ECe of 8 dS m-1 or more at 25 °C if the pH (H2O) of the saturation extract is 8.5 or more; and 2) averaged over its depth at some time of the year, a product of thick-ness (in centimetres) and ECe (in dS m-1) of 450 or more; and 3) a thickness of 15 cm or more.

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A problem in the studying and monitoring of saline soils in the field is determined by the dependency of salinity values on the weather and local soil variability (Castrignanò et al., 2008; Raimondi et al., 2010), as well as on the variable quality of irrigation water (Tedeschi and Menenti, 2002). Therefore, salinity values, especially in topsoil, may change according to the amount of seasonal rainfall, soil site characteristics, quantity and management of irrigation water, all factors that are particularly variable just in the areas where many salts affected soils are concentrated. Then farmers may little appreciate the effects of soil salinisation in the short run, especially when they have to face incipient, seasonal, or periodic salinity (De Pascale et al., 2012). The shortcut is particularly frequent when the communication between soil scientists and farmers, allowing the interpretation of soil properties in the light of current or potential agronomic problems, is insufficient. Impeding understanding causes prevents the adoption of proper counteracting measures.

Moreover, soil salinity can be detected in the laboratory with different methodologies. Although the electrical conductivity of the saturated paste extract is a reference, many empirical relationships are assumed to relate the value of saturated paste to that in different suspensions of soil and water, namely, in proportion of 1.1, 1:2.5, and 1:5. Other empirical relationships are used to correspond electrical conductivity to Total Dissolved Solids (TDS), taking NaCl as a reference (USDA, 1954).

On the other hand, there are currently other promising methods of analysis and monitoring soil salinity at the farm level beyond traditional wet chemistry, namely proximal sensors, like electromagnetic induction techniques (Doolittle and Brevik, 2014).

Discussion questions to the focus group:

- ***How could be the collaboration between soil scientists and agronomists improved and early detection methods of soil salinisation implemented at the farm level?***
- ***Are there any good practices?***

2. What are the current practices and strategies adopted at farm and territorial levels in salt affected areas to tackle the salinisation problem?

Human interventions at both farm and territorial levels are often drivers of the salinisation problem and farming practices can worsen it (secondary salinisation). There are many examples of farmlands irrigated with saline water or other ill-suited irrigation practices, often coupled with poor drainage conditions (Mateo-Sagasta and Burke, 2011; Geeson et al., 2013; Li et al., 2012). The issue is deemed to harshen especially in the coastal areas, because of the continuing deterioration of the quality of groundwater used for irrigation, caused by overpumping and consequent intrusion of seawater into the ground water.

At **territorial level**, man-induced salt accumulation can occur in previous salt-free soils due to errors in designing and constructing irrigation projects. Filtration from unlined canals and reservoirs can produce a shallow water table and increased waterlogging (Barros et al., 2012). Land clearing may mobilise salts that have accumulated in the soil layers. On the other hand, soil management at the farm level can control soil salinity, by substituting water systems at low technological input (e.g., sprinkler irrigation, surface irrigation) with high input systems (e.g. drip and localized irrigation), improving local drainage, and refine soil management (e.g. seedbed placement, organic matter application).

The inventory of the causes of soil salinisation, on the one hand, and of agricultural practices that are adopted to cope with soil salinity, on the other hand, is extremely useful for the modelling of interactions between climate, soil and management practices, and for designing new solutions for irrigation and agricultural soil management. In Table 2 some examples are reported, taken from the RECARE project (**http://recare-project.eu/**).

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Table 2. Technologies used is salts affected soils and their Sustainable Land Management (SLM) category. Adapted from RECARE project, 2016

Technology	SLM category*
Leaching (provided good drainage conditions)	A
Surface water flushing	A
Implementation of drainage systems	S,
Drip irrigation	S, A
Increase of irrigation water every 3-4 watering events	A, M
Irrigation with saline water at less sensitive growth stages	A
Mixing of saline/non-saline water	M, A
Alternate/cyclic irrigation with saline and fresh water	A, S
Alternative water resources (e.g. reuse of wastewater)	S, M
Land use change from irrigated to rainfed	M, V, A
Desalinisation of irrigation water	S, M
Mechanical removal of surface salt crust	A, S
Careful use of machinery (no heavy machinery)	M
Green manuring - mulching with manure	A
Use of compost or other organic soil amendments	A, M
Mulching with leaves/bark or other material	S, A
Use of inorganic amendments (e.g. CaSO4.2H2O, H2SO4)	A
Biological reduction (phytoremediation or bioremediation)	A, V, M
Introduction of salinity-hypoxia tolerant plants	M, V
Intervention to the nutrition of plants (e.g. fertilisers)	A
Grafting seedling on proper rootstock	A
Inoculation with mycorrhizal associations	A
Biopriming with Trichoderma harzianum	A

**A: Agronomic; M: Management; S: Structural; V: Vegetative.*

3. Are there innovative and sustainable farming practices which can prevent soil salinisation, control or mitigate its negative effects?

Management decisions are rarely straightforward or clear-cut because of the range of factors and complexity of interactions that contribute to salinity and determine management priorities (complex interactions, slow hydrologic response, cost vs effect, land ownership). A wide range of traditional and state-of-the-art amelioration methodologies against soil salinisation, which can be adopted at the farm level, has been already documented (Intrigliolo et al., 2015). However, they can be hardly generalized, since possible practices of "saline agriculture" are constrained by pedoclimatic and morphological conditions, as well as by the territorial setting and water infrastructures (reclamation and irrigation systems) and competition between alternative use of water (agriculture, civil needs and industrial activities, tourism, wildlife and natural preserves). On top of that, because of the consequences of the current climate change and growing world population, many more lands are deemed to be affected by soil salinization, or to be forced to tackle harsher conditions. Since the process of soil salinisation can be highly dynamic in space, time and intensity, there is the **need of a continuous innovation in crop, soil, and water management, within the different agricultural systems and local settings.**

Task 2: Identify and assess the sustainability of good and innovative farming practices from various pedoclimatic contexts within the EU, which can prevent and reduce the threat of soil salinisation or control its negative effects.

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Discussion questions to the focus group:
- Discuss the state of the art and the possible innovations or improvements in adopting strategies to prevent, control, or mitigate the negative effects of soil salinisation, also in consideration of the current climate change and increasing competition between alternative water uses, such as:

3.1 Water management

Which solutions can be adopted to manage salinity in irrigation water?

- Desalinisation of water to remove soluble salts has often been referred to as a technical possibility but at the present stage of available technologies it is doubtful if this method can have any large-scale application in the utilization of saline water for irrigation of most agricultural crops, at least in the near future.
- There are situations where good quality water is available for irrigation but not in adequate quantities to meet the evapotranspiration needs of crops. Under these conditions, the strategies for obtaining maximum crop production could include mixing of high salinity water with good quality water to obtain irrigation water of medium salinity for use throughout the cropping season.

Discussion question to the focus group:
- ***Are there any new technical solutions to reduce salinity in irrigation water at the farm level which are already available or in the pre-industrialization phase?***

Which strategies can be adopted to minimise the application of salts?

- **Water management practices** can often be modified to obtain a more favourable distribution of salts in the profile and therefore better crop yields, water quality remaining the same. Even when only scarce water quality is available, more frequent irrigations maintain higher soil water contents in the upper parts of the root zone while reducing the concentration of soluble salts. The sprinkler and particularly the drip method of irrigation are generally more amenable to increased frequency of water applications. In surface irrigation methods however, more frequent irrigations almost invariably result in an appreciable increase in water use.
- Drainage is a primary method of controlling soil salinity. **Improving soil water drainage** reduces the permanence of salts in the rooting soil volume.
- The adverse effects of the high salinity of irrigation water on the crops can be minimized by **using good quality water for irrigation at the more critical stages of growth, e.g. germination, and the saline water at the stages where the crop has relatively more tolerance**. Research is in due course to define the best options considering the tolerance of crops at different growth stages, critical stages of growth vis-a-vis soil salinity.
- Another option to minimise the effects of salinity is to minimise the total water application and the subsequent accumulation of salts in the field. This can be accomplished through **converting to a rainfed production system**; maximizing effectiveness of precipitation to reduce the amount of irrigation required; adopting a combination of highly efficient irrigation and tillage practices to reduce irrigation applications required. Since some salts are added through fertilisers or as components (or contaminants) of other soil additives, soil fertility testing is warranted to refine nutrient management programmes.

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- **Smart Farming** represents the application of modern Information and Communication Technologies (ICT) into agriculture. Smart Farming has a real potential to deliver a more productive and sustainable agricultural production, based on a more precise and resource-efficient approach. From the farmer's point of view, Smart Farming should provide the farmer with added value in the form of better decision making or more efficient exploitation operations and management. Among Smart Farming techniques, precision farming points to regulate agricultural management to soil spatial and temporal variability. Smart Farming can also provide great benefits in terms of environmental issues, for example, through more efficient use of water, or optimisation of treatments and inputs. The **adoption of precision farming seems to be a very promising option to mitigate the risk of soil salinisation.**

Discussion questions to the focus group:

- ***Which innovations can be envisaged for the improvement of the interactions between water and crop management in areas at risk of soil salinisation?***
- ***Are there recommendations to good irrigation practices to areas affected by soil salinization?***
- ***Which benefits can be foreseen with the adoption of smart farming techniques?***

Which innovations are possible in the use of extra water for leaching?

- To prevent excessive salt accumulation in the soil, it is necessary to **remove salts periodically by application of water in excess of the evapotranspiration needs.** The excess water applied will remove salts from the root zone provided the soil has adequate internal drainage. This concept is quantified in the term 'leaching requirement' (LR). By definition, LR is the fraction of total water applied that must drain below the root zone to restrict salinity to a specified level according to the level of tolerance of the crop.
- Application of excess water, above that needed for meeting the evapotranspiration needs, though useful for salinity control, puts a high demand on the water resources on the one hand and increases the salt load of the drainage water on the other. It therefore appears that **controlling the interval between irrigations is the most important management practice** for obtaining higher yields with high salinity water and this could be achieved by the sprinkler, drip or the surface irrigation methods.
- **Alternate rainfed and irrigation cultivation systems**: the salt leaching due to rainfall is enhanced by leaving uncultivated soils during some growing seasons. Similarly, alternating rainfed cultivation with irrigation might reduce the long-term soil salt accumulation in case of irrigation applications with salty water.
- Leaching requirement is usually calculated by considering evapotranspiration demand and crop needs, but seldom tuned according to soil characteristics and hydrology. However, **considering local pedological features** can decrease considerably the amount of the LR.

Discussion question to the focus group:

- ***Which methods or guidelines are advisable in considering soil features to dimension the use of extra water for leaching?***

3.2 Soil management

Which are the most promising <u>soil management practices</u> able to reduce the impact of soil salinity on crop performance?

In addition to water management, soil management practices may help reduce the impact of soil salinity on crops. Different biological, physical and chemical methods can be adopted for mitigation. The following list is reported as an example.

- <u>Biological methods:</u>

  - Incorporating crop residues or green-manure crops improves soil tilth, structure as well as water infiltration. This provides safeguard against adverse effects of salinity. In order for this to be effective, regular additions of organic matter (crop residue, green manure, sludge, compost) must be made.
  - Mulching with crop residue, such as straw, reduces evaporation from the soil surface which in turn reduces the upward movement of salts. Reduced evaporation also reduces the need to irrigate. Consequently, fewer salts accumulate.
  - Application of biological agents to increase crop resistance to salinity. Various types of symbiotic associations of mycorrhizae are commercially available in order to mitigate the impacts of salinity on crops, to improve existing soil properties or to induce a priming effect.

- Physical methods
  - Accumulation of salts close to the surface is a typical feature of saline soils. Deep tillage would mix the salts present in the surface zone into a much larger volume of soil and hence reduce its concentration and impact.
  - Many soils have an impervious hard pan which hinders the salt leaching process. Under such circumstances "chiseling" would improve water infiltration and hence downward movement of salts.
  - Similarly, mechanical removal of salt surface salt crust improves water infiltration, besides allowing crop emergence.
  - Saline soils show weak aggregation potential and therefore have a high tendency to compaction. A careful use of machinery, avoiding heavy machinery, is of uttermost importance to avoid the loss of macro-porosity and the worsening of internal drainage.

- Chemical methods
  - Various mineral products can be used to correct soil pH, such as Gypsum as conditioner of sodic soils or products releasing phosphoric and sulphuric acid for saline soils.

Discussion question to the focus group:

- ***Soil management practices are generally well accepted by farmers, but limitations can be posed by their cost of implementation, product availability, or tuning to the local conditions. Which strategies could overcome these limitations?***

3.3 Salinisation Modelling

Numerical models are used to analyse the salinity genetics and dynamics, estimate effects of interventions in the groundwater systems and land use on groundwater salinity, flow and solutes transport. The majority of water and solute transport computer models use Richard's equation for the movement of water in unsaturated soil and Fick's convection diffusion equation for advection and dispersion of salts. Inputs include relations between variable unsaturated soil moisture content, water tension, water retention curve, unsaturated hydraulic conductivity, dispersivity and diffusivity. Model examples are MT3D, MOCDENSE, SEAWATER, Feflow, SWAP, DrainMod-S, UnSatChem, Hydrus, SUTRA, SHARP, FEFLOW, SWIP, MOCDENSE, HST3D etc.
Guidelines and models able to stewardship soil management practices are continuously developed to produce Decision Support Systems tailored to the diverse pedoclimatic setting and salt tolerant species.

Discussion question to the focus group:

- ***How can we implement soil ecosystem services beyond food production in modelling?***
- ***In particular, sustainability should also consider the interactions between crop, soil and water management, and carbon and nutrient dynamic, use of agrochemicals, salinization and pollution of water bodies, soil water and wind erosion, loss of biodiversity, and supporting of habitats.***

3.4 Farming practices which can prevent the risk of soil salinisation

Primary salinisation can affect soils formed from saline sediments and bedrocks also far from the current coastal areas. Usually these continental lands support rainfed crops, and saline and sodic soils may form just because of excessive bulldozing and earth movements. It is the activity carried out to prepare the fields for the plantation of tree crops, namely deep ploughing and slope reshaping, which may cause the outcrop of the salt affected layers, and the reduction of soil functionality, until the partial failure of the cultivation (Costantini et al., 2018).

Tree crops are often established after land preparation, in order to adapt fields to mechanization. As a result, the soil may undergo truncation and/or mixing of pedogenic horizons, as well as enhanced erosion, which lead to degradation of soil functionality. When the soil parent material is rich in salts, as in marine sediments, the resulting soil profile can show diffuse or concentrated salt accumulation (Fig. 2).

Precise tuning of slope reshaping and earth movements before tree crop plantation can prevent the outcropping of salty sediments and the risk of soil salinization

In the case of woody perennial crops, rootstock choice can play a major role for salt tolerance since there are some chlorides excluding rootstocks that do not accumulate toxic chloride ions in the rootstocks. This is for instance the case of the Cleopatra Mandarin for citrus trees (Syvertsen and Levy 2005) or the Virginiana rootstock to be employed for Kaki cultivars (Besada et al. 2016).

Discussion questions to the focus group:

- ***Which procedures should be followed for the proper dimensioning of slope reshaping and earth movements before crop plantation?***
- ***Which agronomic practices in tree crop plantation, like a proper choice of rootstock, can be followed to adapt tree cultivation to soil salinity risk?***

Figure 2. Consequences of excessive earth movements before the plantation of a vineyard (Italy). Salt efflorescences and death vines in the foreground, leopard-like spots of Sodic soils in the background vineyard (Photo Costantini).

4. Which opportunities can be found for locally adapted varieties, potentiality for minor crops with increased tolerance to salt stress?

Crop and variety tolerance to soil salinity can range widely (Katerji et al., 2003) so that a proper cultural choice allows farmers to have many possibilities to adapt farming to the local soil salinity conditions. But **moderate soil salinity can be also an opportunity to develop new agricultural strategies**. In spite of the overall negative effect of an excess of salts on many crops, **it has been demonstrated that a moderate salinity, or a salinity in depth, may increase the quality of certain food production** (De Pascale et al., 2001). The excellence of some local food, like the renown **"Pachino" tomato in Sicily**, is determined by the characteristics of climate, soil, and saline water, which interplay with management to produce a high-quality tomato. Another example is the moderate salinity of the deeper soil horizons, which can enhance the **quality outcome of tree production, like for some wine and table grape cultivars** (Costantini et al., 2010).

The market valorisation of the interaction between the natural factors of crop production, agricultural husbandry and food processing is the reason of the success of many protected foods with a Denomination of Origin (e.g., wines, olive oils, cheeses, vegetables). In this framework, also soil limiting characteristics and properties can play a role in enhancing food quality or inducing the synthesis of molecules which convey particular tastes to the food (Costantini and Bucelli, 2014).

Some species have been identified as particularly interesting due to their adaptive response to water stress conditions. Some examples can be found in the Mediterranean region where plants have developed different strategies to respond to drought, including morphological, physiological and phenological adaptation (Agudelo, 2015). There are two types of plants which are especially interesting when talking about introducing new crops, these are Xerophytes and Halophytes. These species have developed different strategies to adapt to very extreme conditions of water stress and salinity respectively. However, while some of these species such as Salicornia have been already assessed for oil production, biofuel and food production, many others have not been identified for a specific industry. Moreover, those which are edible have a very small market niche. That is why the main importance in this regard is how to exploit this kind of crops. Furthermore, in the specific case of halophytes, it has been identified a possible bio-remediation potential as some of them are able to extract salts from the soil. Even thought, presently, the extraction proportion is not relevant for them to be included in the rotation plans to contribute in improving or maintaining the soil quality, these traits may be promoted via breeding techniques. What seems to be clear is that halophytes can be used in regions with poor proportion of agricultural development due to their salinity problems. As the average cost of introducing a new variety in the market is around 1-1.5 million euros and it lasts around 10-12 years, it seems difficult that this could be afforded with public funds. A possibility could be to study the matter together with private companies in a private-public partnership. Some public research centres are focusing their work on local varieties and crops which are of minor interest for the private sector. Their effort has been of importance since by doing that they are also keeping the gene pool of the crop. The main difficulty is to place a product in such a small market niche. This kind of effort may be promoted while keeping the focus on obtaining a marketable product by, again, private-public partnerships.

There is a wide range in the relative tolerance of agricultural crops to soil salinity (Bernstein, 1980). Proper choice of crops and rootstocks can result in high yield and good economic returns even when using high salinity water, whereas use of such water for growing a relatively salt-sensitive crop may be questionable (Galletto et al., 2014). Currently crop and rootstock breeding programmes are addressing salt tolerance for several crops, including tree crops, small grains, and forages. But the focus should not only be directed towards obtaining highly resistance genotypes but also in obtaining more productive species and varieties. Often the increased crop performance character is maintained under salt stress conditions. In this sense, plant emergence is the most critical phase as salts are generally accumulated in the soil surface where the root system is first exploring. Some field crops are particularly susceptible to particular salts or specific elements or to foliar injury if saline water is applied through sprinkler irrigation methods. Similarly, selection and breeding of salt-resistant crop

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varieties, scions and rootstocks, offer tremendous possibilities of utilizing saline water resources for crop production.

Task 3. Explore opportunities to add market value to locally adapted varieties which are (more) tolerant to salt stress so as to compensate yield reduction

Task 4. Discuss the potential of minor crops with increased tolerance to salt stress.

Discussion question to the focus group:

- ***Although it is possible to find significant examples of locally adapted varieties and successful minor crop, their diffusion is still limited to niches of the market. Are there really economically viable solutions that could enhance the opportunities given by adapted varieties and minor crops?***

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