EIP-AGRI Focus Group

Soil salinisation

MINIPAPER: ecosystem services and salinisation

MONTSE NÚÑEZ, TIBOR TÓTH.

funded by European Commission

1 Introduction

Ecosystem services are the benefits that humans freely gain from the natural environment and from properly functioning ecosystems (MEA 2005). **Soils are a central resource for the delivery of ecosystem services beyond being important for plant growth**. The main ecosystem functions of a healthy agricultural soil and of a soil covered with natural vegetation are:

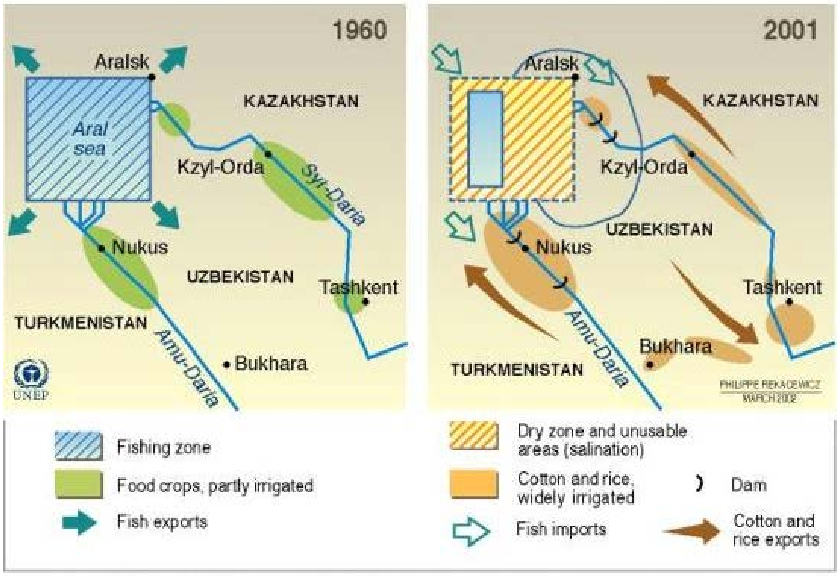
- **Physical support for plants**: it anchors them and gives them water, nutrients, air, temperature control and a medium for associations (e.g., mycorrhiza).
- **Nutrient cycling**: soil is a natural recycling system. It decomposes organic matter into inorganic and their nutrients can be reused again.
- **Regulation of the water supply and water purification**: soils store water for use by plants, replenish aquifers underneath, regulate floods, and purify contaminated water as water passes through the soil.
- **Carbon sink**: plants absorb carbon from the atmosphere and soils stabilise it, which helps offset greenhouse gas emissions and regulate the climate change.
- **Habitat for microorganisms**: microbiota improves soil quality, thus conditions for plant growth.
- **Enjoyment**: agricultural and natural landscapes have a cultural aesthetic value that creates tourism (ecotourism) in rural areas and recreation.

Maintaining healthy soils means protecting the delivery of these ecosystem services. This is crucial to conserve natural ecosystems and for a sustainable agricultural production. Sustainable means viable on the long term for the three pillars of sustainability: environment, social, and economic. Sustainable agriculture requires, thus, that the farmer selects the practice to apply thinking not only about maximising the production of today, but also considering the consequences that the choice of a practice may have on tomorrow's soil quality.
When a healthy soil is affected by salinisation, its quality declines. This, in its turn, may affect the delivery of the ecosystem services mentioned above. This decline may happen at different, non-exclusive spatial scales:

1) on the place where the bad practice is done, which is what we call in this mini-paper **on-site effects**
2) beyond the area where the bad practice is done, which are what we call **off-site effects**.

A famous example of the dramatic off-site consequences that improper agricultural practices can have on soil salinisation and thus on soil quality and ecosystem services at landscape scale is that of the Aral Sea basin (Figure 1). Two rivers were diverted to promote agricultural production in the desertic Aral basin. At the beginning, agricultural production flourished thanks to irrigation, improving farmers income and life quality. This created negative consequences off-site: some years later, salinity of the sea increased due to lower river inflows to the sea. High salt concentrations killed fish and other aquatic species and also led to salinization of adjacent croplands. Water consumption raised to flush salts to counteract secondary salinization. Pesticides and lots of agrochemicals were used to keep crop yields up, contributing to an ecological disaster and forcing farmers to abandon their lands and to move to other areas.

funded by European Commission



Source: Philippe Rekacewicz, *An Assassinated Sea*, in Histoire-Géographie, initiation économique, page 333, Classe de Troisième, Hatier, Paris, 1993 (data updated in 2002); *L'état du Monde*, 1992 and 2001 editions, La Découverte, Paris.

Figure 1: The shrinking of the Aral Sea: socio-economic impacts. Retrieved from: http://www.columbia.edu/~tmt2120/impacts%20to%20life%20in%20the%20region.htm

The Aral Sea is an example of soil quality degradation where soil salinisation played an important role. Though not as extreme as the Aral Sea, similar situations may arise due to the use of unsuitable practices. To avoid that to happen, farmers should choose, among all practices, those that prevent salinisation problems while keeping soil quality and the delivery of ecosystem services on-site and off-site. But what are these good practices?

In the following pages, we will discuss how ecosystem services production can be affected in primary and secondary salinised soils. **Primary salinisation** is the development of salts in soils due to natural processes. It is naturally present in the environment. **Secondary salinisation** is introduced by human intervention and is also called anthropogenic salinisation. We will also analyse the recommended practices to prevent soil salinisation and to preserve the delivery of ecosystem services.

2 Ecosystem services in primary salinized soils

Primary salinisation is the development of salts in soil through natural processes mainly including physical or chemical weathering and transport from parent material, geological deposits or groundwater (Daliakopoulos et al 2016). Principal division of the primary salinized ecosystems in the EU is coastal or inland. Although several species overlap between these, in general coastal ecosystems are wetter and dominated by sodium-chloride. Many of the inland ecosystems are formed on sodic soils, dominated by sodium-bicarbonate, and prone to drought during some time of the year. The reason for this difference is the source of water/salt, provided by the sea in the coastal areas, or by the shallow water table/salt rich marine sediment inland.

The most typical ecosystems of the salt-affected soils are wetlands and grasslands in the EU, and the main utilization of these is hayfield or grazeland.

The sources of salts are ancient, the salt content of soil is, at large temporal scale, in equilibrium with the sea level, water table level, precipitation, temperature etc., but shows almost instantaneous changes due to sudden events in some soil layer, due to changes in water status. Typical short-term change is the appearance/disappearance of salt efflorescence, caused by an upward seepage of saline water in dry periods.

With long term changes, such as the present global climate change, continuous shifts can be seen, such as spread of salinity in the maritime areas due to seawater intrusion, and decrease of salt content in the soil due to dropped level of saline water table inland.

By checking out Table 1, several ecosystem services of the primary salinized soils can be identified with varying importance at different locations. All the services are constrained by increasing salinisation.

Table 1. The most relevant soil specific ecosystem services.

MAIN GROUP OF SERVICES	INDIVIDUAL SERVICES	INDICATORS
Regulating service	Climate regulation	Carbon sequestration
	Protection from erosion	Soil loss
	Pollination	Contribution of soil to the diversity of pollinators
	Capacity to retain and degrade pollutants	Nitrogen-retention capacity
Provisioning services	Suitable amount and quality of food and raw material	Annual yield
	Timber	Annual timber volume growth
	Fodder	Annual fodder yield or number of supported grazing animals
	Water	Infiltration
Habitat supporting services	Biodiversity	Contribution of the soil to vegetation diversity in case of grassland/wetland

Perhaps the most important of these is the habitat supporting service of the salt-affected soils. Due to inherent variability of these soils, often the salinized landscape is a mosaic of non-saline/slightly saline/saline areas. In Europe the lowland grasslands/wetlands were mostly converted into arable fields by plowing/drainage, but some of the most difficult areas remained intact, due to salinity. Such areas comprise very important fragments of non-saline areas as well as last refugees. The European flagship national parks, such as Camargue, Doñana, Wadden Sea, Hortobágy, Margherita di Savoia protect rare and invaluable biodiversity, characteristic for drier areas also.

These habitats have their characteristic diverse ancient land use systems, as pastoralism, fishing, collection of medicinal plants, reeds etc., which are archives of millennia old ethnic cultures, surviving in a shrunken natural environment in the vast anthropogenic landscape.

The mission of each National Park is to keep its own particular natural heritage and these struggle with the effect of climate change as drying lakebeds, increased or decreased soil salinity etc. **The technical knowledge available for desalinization of agricultural areas is not enough to solve their problems and there is a need for new knowledge to be developed**, which is often targeting opposite objectives, such as shallower water table/increased soil salinity, compared to the typical reclamation of salt-affected agricultural lands consisting of chemical reclamation and drainage. A good example of this is the significant changes occurred in the state of the shallow saline lakes (or soda pans) in the last decades in the Danube-Tisza Interfluve (Hungary). Because of long-term tendencies in regional and local hydrological and meteorological conditions (e.g. channelization, precipitation extremities, consecutive droughts, groundwater extraction), the number of saline lakes dropped from 230 to 37 between 1951-2001. Saline lakes are important habitats for shorebirds and turned into marshlands and grasslands with decreased salt content and alkalinity. The plan – not yet realized – is to reverse to some extent the „desalinization" process by raising the saline water table level. According to the plans, Danube water will be lifted to the elevated plateau and seepage of this water will rise the water table and contribute to the temporal waterlogging there. Constant waterlogging is not needed, subsoil moisted by water table, and precipitation will ensure the required water during breeding season. Such lakes regularly dry out during summer (Molnár et al., 2019).

funded by European Commission

3 Ecosystem services in secondary salinized soils

Secondary salinisation is introduced by human intervention and is also called anthropogenic salinisation. In cropped lands, secondary salinisation essentially results from incorrect use of irrigation water. Irrigation water necessarily contains a certain amount of salts. The level of salinity depends partly on natural causes (leaching of rocks and soils) and partly on human causes (uncontrolled withdrawing and spilling of pollutants into water bodies). The anomalies of the rainfall regime, as well as the increased evaporative demand of the atmosphere, accelerate the deterioration of the quality of the water bodies used for irrigation. Consequently, soil salinisation must be understood as one of the consequences of climate change, as well as a threat to the soil fertility.

Agriculture is traditionally the sector that, in addition to producing food and some primary goods, offers ecosystem services for the whole of society. These include the preservation of agro-biodiversity, soil fertility and productivity. A number of good practices have been codified in agronomy to avoid the risk of soil salinisation. The good practices cover a wide range of actions, from land development to irrigation techniques (Table 2).

Table 2. Good agricultural practices to control soil salinisation, soil quality and delivery of ecosystem services on-site. Practices focus on practices to control on-site soil salinisation and can potentially have negative effects on other ecosystem services (eg. set-aside on soil erosion) and/or have negative environmental impacts elsewhere (eg soil leaching and deposition of salts on a downstream wetland, affecting its biodiversity), see section 4.

Soil management	Levelling, smoothing and shaping the fields (in plain lands)
	Interruption of the impermeable layers within the soil profile
	Scarifying
	Ploughing in of crop residues into the soil
	Facilitate the drainage (by gravity) inside the soil profile
Artificial drainage	Draining of water by application of negative pressure
	Natural draining (by gravity)
Soil leaching	Supplying freshwater in case of insufficient rainfall to prevent salt accumulation in the soil profile
Irrigation method	Aiming at keeping high the soil water content (and lowering the soil-water pressure head) near the root system (drip irrigation, submersion)
Rotation of crops with different salt tolerance	In accordance with the annual rain regime. As an example: less tolerant species in winter; in spring-summer, those that are tolerant to soil salinity; set-aside in fall (autumn rains bring salinity back to acceptable levels); return with irrigation with saline (or brackish) water on the same plot at alternate years
Use of water with different levels of EC_w	Using fresh water only during salt sensitive pheno-phases; alternating fresh and brackish water (so as to prevent salts accumulated in the soil); mixing brackish and fresh water
Rice cultivation	Dry, buried seeding, intermittent flood irrigation, drip irrigation and flooding with brackish/saltine water in salt-tolerant rice varieties are alternative new techniques currently under evaluation by EIP-AGRI operational groups (EIP-AGRI 2019a, b). The aim is to reduce water consumption and weed populations, pests and diseases while keeping soil salinity under control.

For the farmer, adopting these good agricultural practices (Table 2) may often lead to increased farm costs and lower production per area, hence economic benefits, the next first harvests. At the same time, the productivity is consistent with the soil constraints and brings to the farmer a continued (i.e. sustainable) yield and economic benefit on the long run that lessen the environmental impacts of food production. For society, the adoption of these practices translates into a series of ecosystem services. These include, for instance, the presence of farmers in the area and less pressure on freshwater resource availability (positive synergies). Farmers who help preserving ecosystem services should be economically sustained for adopting these

funded by European Commission

practices via direct or indirect payments (payment for ecosystem services) and those who not, should be taxed more (internalisation of environmental externalities).

3.1 Negative synergies between soil salinisation and other soil degradation processes:

A salinised soil is also prone to other soil degradation processes due to a cascade of effects: salinisation leads to stunted growth and plant decline, as well as to **biodiversity loss**, **including soil microbiota**, a key component for plant growth, food production, climate and other ecosystem services. When the soil microbial activity is reduced, and the plant canopies do not cover the ground and, and at the same time roots are insufficiently developed, **soil erosion** speeds up. The above ground biomass and the root systems cover important ecological functions:

- Protecting the soil surface from the water and wind energy, which induces soil erosion. Eroded topsoil is rich in organic carbon, a very important component for a good quality soil. Moreover, carbon lost from soil can lead to additional carbon losses to the atmosphere, thus contributing to **climate change**
- **Soil fixing** through the root architectural characteristics, length and density;
- Reducing the surface **water run-off** and increasing the **rainwater infiltration** into the soil profile.

Yield and biodiversity loss, soil erosion, climate change, modification of the hydrological cycle. Unquestionably, **soil salinisation can endanger many ecosystem services and biodiversity in a row**. Negative synergies between salinisation and other soil degradation processes appear depending on conditions related to soil and climate: for instance, a saline sandy soil of littoral landscapes or marshlands is especially susceptible to wind erosion because of the absence of aggregates. Whereas a clay soil will favour mud or crust during a wetting and drying cycle, respectively (Terres et al 2014).

A couple of real examples of negative synergies are the following:

- In various cropland areas in Pakistan concomitant soil salinisation and erosion has adversely affected soil quality, leading to reduced crop quantity and quality and ecologic and economic losses. Salt-tolerant varieties are used to adapt but preventing further soil salinisation by adopting good practices (Table 2) is key to preserve fertile soils, which are progressively scarcer in the country.
- As saline water table level drops, saline soils turn into sodic soils. Saline soils with their shallow water table/regular waterlogging are able to provide constant vegetation cover. Sodic soils have lower productivity (Ivits et al 2013) due to the limited water availability and movement, and with increasing dryness the productivity further decreases. Clay dispersion contributes to illuviation and the increasing clayiness further aggravates the problem of limited water availability for the plants. As a consequence, few specialized plants are stunting with low biomass on dry clayey sodic soils.

4 On-site and off-site effects of soil salinisation

Soil is an environmental compartment connected to aquifers and water bodies downstream via the water cycle. Consequently, salts that are washed away from the soil to keep soil salinity under control and to maintain crop productivity do not magically disappear but are transported to and accumulate in other ecosystems, affecting their ecological value.

One must differentiate between **two types of consequences of soil salinisation on ecosystem services** (Figure 1):

- **On-site effects**: costs in the field under production leading to reduced soils' natural capital and its capacity to deliver ecosystem services on the long run. On-site effects include yield drop, reduced amount of crop options at increased salinity levels, and synergies with other regulating and cultural services, as described in section 1 and 3 above. There are plenty of agricultural areas that showcase on-site effects of soil salinisation: some examples are the coastal deltas of Llobregat (horticulture) and Ebro (mainly rice) in Spain (BFSC 2019, Universitat de Barcelona 2017), the coastal Orb delta (vineyards and crops) in France (Bless et al 2018) and the coasts of Sardinia (Mas-Pla et al 2014), all due to irrigation with low-quality water and/or influxes of seawater through the river and the aquifers. In Saharan oases in Tunisia, excessive irrigation of date palms with high saline water coupled with unfavourable soil properties (sandy with high infiltration) makes shallow saline groundwater rise (Haj-Amor et al 2017). Strategies for managing these problems include those listed in Table 2.

- **Off-site effects**: costs in other croplands and natural ecosystems. Salts leached out the soil profile reach aquifers underneath. This high saline freshwater may be the water source of a neighbour farmer or ironically be used to irrigate other plots of the farmer who leached the salts out the first crop land. Salts can also arrive at non-saline wetlands and terrestrial ecosystems, leading to a biodiversity turnover from glycophytic to halophytic species and to soil degradation in the natural environment. Off-site effects may typically exceed on-site's; unfortunately, they are more complex to measure and are usually not assessed (externalities).

Watering can: www.jing.fm (Creative Commons CC0); watered plant: www.pngwing.com (non-comercial use); Water pump: www.pngwing.com (non-comercial use); shrubs: www.pngwing.com (non-comercial use);

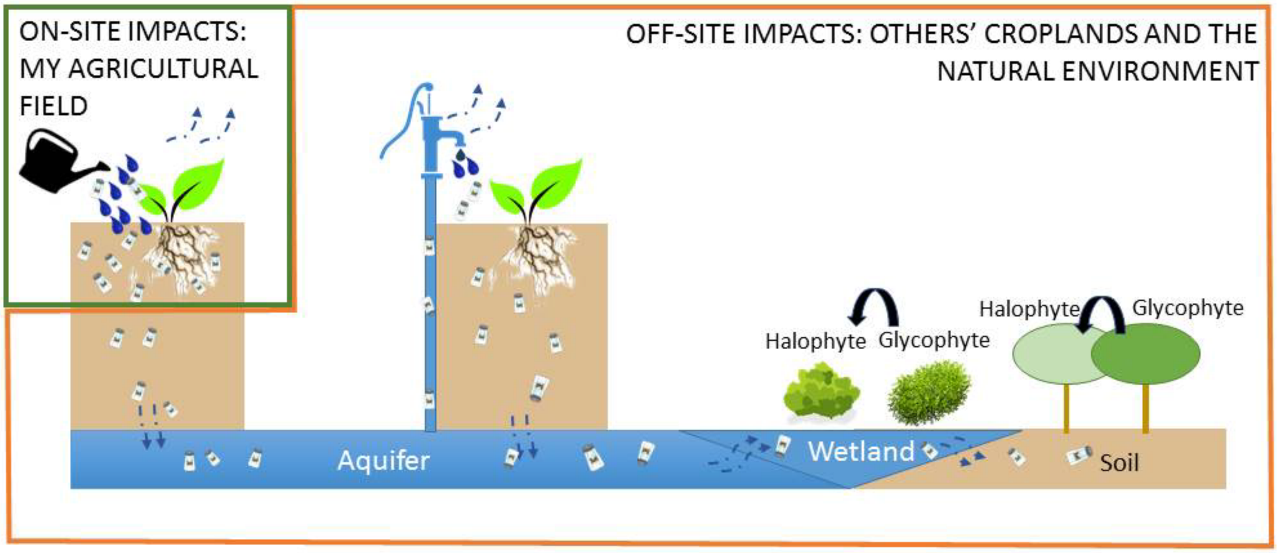


Figure 2: on-site and off-site negative consequences of soil salinisation, example of irrigation induced salinisation. A system thinking is needed to truly reduce salinisation impacts on the global, connected environment.

Due to the connection between environmental compartments at the local, regional and global scales, **one shall measure on-site plus off-site effects of soil salinisation to claim that a technological solution is sustainable** (Figure 2). A holistic, "life cycle thinking" perspective is therefore much needed. Looking "at the whole picture" allows for identifying unintended trade-offs that occur when decision-making processes are guided by a partial view of a problem, in this case, addressing only on-site soil salinisation effects without taking care of effects elsewhere. This includes environmental, social and economic consequences, which are the three dimensions of sustainability. A good example that applies this "whole picture perspective" is a life cycle assessment (LCA) study that evaluated salinization impacts due to irrigated agriculture in the coastal wetland of Albufera de Adra (Southern Spain, Amores et al 2013). The study showed that soil salinization was not problematic because irrigation was done with good quality water. However, the broad scope of the assessment allowed to identify that groundwater pumping for irrigation was leading to increased seawater intrusion in the Nueva lagoon, raising its salinity and leading to biodiversity damages on the lagoon-dwelling species. Impact of salinisation on ecosystem quality was much worse (>95%) than impacts of all the other pollutant emissions together (i.e. fertilisers, pesticides, and greenhouse gases), highlighting the need for holistic sustainability evaluations for meaningful decisions on ecosystem preservation.

5 Knowledge gaps, potential innovations and sustainability of innovations (problems and opportunities)

CATEGORY	KNOWLEDGE GAPS	POTENTIAL INNOVATIONS	SUSTAINABILITY OF INNOVATIONS	
			PROBLEMS	OPPORTUNITIES
On-site impacts on ecosystem services	Agronomic research has focused on estimating/measuring the effects of soil salinisation on crop yield. Very little is known about the effects of soil salinisation on other on-site ecosystem services.	1. Carry out case studies for different crop/crop rotations under different soil and climate conditions where to test and quantify impacts of soil salinity on soil quality aspects apart from yield decline. E.g. microbiome, variety of crops that can be grown under different salinity levels, soil carbon sink, soil compaction.	Requires much funding for site experiments and multidisciplinary work involving various research fields, such as agronomy, soil science and systems thinking.	Extensive criteria to support market strategies that reward good practices for soil conservation and the delivery of ecosystem services on-site.
Off-site impacts on ecosystem services	Agronomic research has focused on estimating/measuring the effects of soil salinisation on crop yield. Very little is known about the effects of soil salinisation on the delivery of off-site ecosystem services. This due to the lack of analytical methods considering the environment as a whole	2. Analyse salt transport and deposition processes via experiments at regional scale (watershed). 3. Analyse effects that high concentrations of salts have on ecosystems at multiple biodiversity levels (species, habitat, landscape…).	Requires much funding for site experiments and multidisciplinary work involving various research fields such as soil science, environmental science, hydroecology science, chemistry, and biology.	Extensive criteria to support market strategies that reward environmentally sustainable practices.
Monetization of ecosystem services	Several agronomic operations can have contrasting effect on specific ecosystem services. Knowledge of monetary value of ecosystem services can provide direct help in such dilemmas	4. Location-specific ecosystem service values for typical EU salt-affected agricultural areas could provide the basis of common understanding for every stake holder.	Such monetization would be complicated by the price differences between the member states.	Monetization would be very much compatible with the current system of incentives, also carried out by financial means.

6 Potential innovative projects/Operational Groups

TITLE	DESCRIPTION	STAKEHOLDERS	EXPECTED RESULTS/IMPACT
Optimal management for sustaining current salinity status	In nature protected areas the maintenance of biodiversity is the most important objective. There is a wide range of agronomy versus grazing possible in such areas. Several combinations of land uses should be tested for maintaining/enhancing	Farmers Nature conservationists Local, national, EU administration	Optimal location-specific land management can contribute to the long-term goals of agroenvironmental objectives.

TITLE	DESCRIPTION	STAKEHOLDERS	EXPECTED RESULTS/ IMPACT
	biodiversity of protected animals/plants.		
Environmental sustainability assessment of innovative agricultural practices to combat soil salinisation in nature protected areas	Innovative techniques to control soil salinity are many times promoted as being more environmentally friendly. This cannot be claimed if the ecological consequences of the salts leached down to the aquifer and/or to the surrounding natural area are not assessed.	Farmers Management body of the natural park or local authority Experts in agriculture Experts in environment	Innovative techniques that truly aim at being more (environmentally) sustainable
Marketing plan for agricultural products grown in salinized soils with sustainable on-site and off-site practices	Consumers increasingly prioritise products respectful with the environment. EU policies give competitive advantages to greener products though incentives. This market configuration encourages business models that promote sustainable agri-food products coming from unique areas (salinized soils) and communicate the innovation to society/consumers.	Farmers Consumers Local agribusinesses Supermarkets Society Socioeconomists Experts in marketing Local, regional administration	Rising farmers' profit and boosting the economy of the producing area; It contributes to preserve the natural environment and nature-agriculture mosaics

7 Needs from practice and further research

- Matching limitations of nature protection with agronomic practice in the typical EU salt-affected agricultural areas. Farmers would benefit a list of banned/permitted/favourable operations during growing season and outside that, for the possible range of crops that are grown in their areas in order to make reasonable decisions.
- Raise awareness among farmers and stakeholders along the value chain of agricultural products of the off-site effects of soil salinisation on ecosystems and the importance of ecosystem services to sustain agricultural production and human well-being. Rural associations like the French initiative centres to promote agriculture and rural systems (CIVAM in French), which connect farmers, rural population and civil society to encourage a more sustainable agriculture, are fit-for-purpose platforms.
- Develop mathematical models and regionalised indicators that generalise the learnings drawn from:
  - potential innovation 1: models and indicators to assess impacts of soil salinity on soil quality aspects apart from yield decline such as synergetic effects on the soil microbiome and soil erosion
  - potential innovation 2: models and indicators to assess the transport of salts out of soils and the sedimentation in aquifers and other water bodies
  - potential innovation 3: models and indicators to assess the consequences of high salt concentrations on natural environments and taxa.
- The short term expected effect of climate change on provision of ecosystem services in typical EU salt-affected agricultural areas.

funded by European Commission

8 References

Amores MJ, Verones F, Raptis C, Juraske R, Pfister S, Stoessel F, Antón A, Castells F, Hellweg S. 2013. Biodiversity impacts from salinity increase in a coastal wetland. Environmental Science and Technology 47: 6384-6392

Bless A E, Colin F, Crabit A, Devaux N, Philippon O, Follain S. 2018. Landscape evolution and agricultural land salinization in coastal area: A conceptual model. Science of the Total Environment 625:647-656.

Daliakopoulos IN, Tsanis IK, Koutroulis A, Kourgialas NN, Varouchakis AE, Karatzas GP, Ritsema CJ. 2016. The threat of soil salinity: A European scale review. Science of the Total Environment 573: 727-739.

EIP-AGRI 2019a. Saving water in rice cultivation through the introduction of innovative agronomic techniques. Available at: https://ec.europa.eu/eip/agriculture/en/find-connect/projects/ahorro-de-agua-en-el-cultivo-del-arroz-mediante-la

EIP-AGRI 2019b. evelopment and adaptation of rice dry seeding in the Ebro Delta. Available at: https://ec.europa.eu/eip/agriculture/en/find-connect/projects/puesta-punto-y-adaptaci%C3%B3n-de-la-siembra-en-seco-de

Haj-Amor Z, Tóth T, Ibrahimi M-K, Bouri S. 2017. Effects of excessive irrigation of date palm on soil salinization, shallow groundwater properties, and water use in a Saharan oasis. Environmental Earth Sciences 76:590

Ivits E, Cherlet M, Tóth T, Lewinska KE, Tóth G. 2013. Characterisation of productivity limitation of salt-affected lands in different climatic regions of Europe using remote sensing derived productivity indicators. Land Degradation & Development 24: 438-452

MEA 2005. Ecosystems and human well-being: synthesis. Millennium Ecosystem Assessment. Island Press, Washington, DC.

Molnár, S, Bakacsi Zs, Balog K, Bolla B, Tóth T. 2019. Evolution of a salt-affected lake under changing environmental conditions in Danube-Tisza Interfluve. Carpathian Journal of Earth and Environmental Sciences 14: 77-82

Terres JM, Hagyo A, Wania A (eds). 2014. Scientific contribution on combining biophysical criteria underpinning the delineation of agricultural areas affected by specific constraints. Methodology and factsheets for plausible criteria combinations. Report EUR 26940 EN. Joint Research Centre. Available at: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC92686/lbna26940enn.pdf

Universitat de Barcelona. 2017. NEURICE project controls soil salinity in Ebro Delta with new varieties of salt-tolerant rice. Available at: https://www.ub.edu/web/ub/en/menu_eines/noticies/2017/08/016.html

BFSC. 2019. River Llobregat Water Reclamation Project. Barcelona Field Studies Centre. Available at: https://geographyfieldwork.com/LlobregatWaterReclamation.htm

Mas-Pla J, Ghiglieri G, Uras G. 2014. Seawater intrusion and coastal groundwater resources management. Examples from two Mediterranean regions: Catalonia and Sardinia. Research Reviews 10: 171-184. Available at: https://publicacions.iec.cat/repository/pdf/00000222%5C00000035.pdf

funded by European Commission