A publication from the DESIRE project - funded by the European Union's 6th Framework Program 'Global Change and Ecosystems'

July 2010

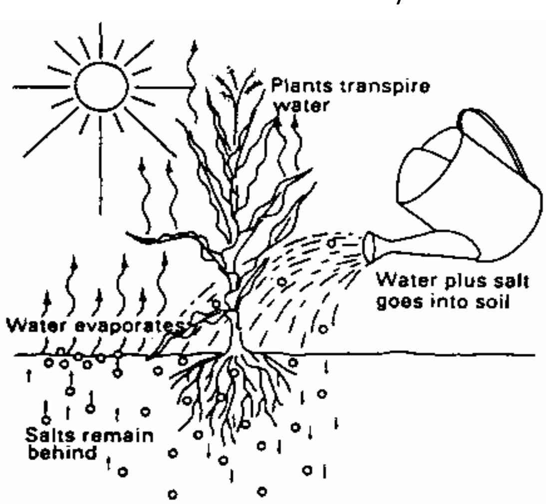
Info-brief 1

Tackling salinization of soils in arid and semi-arid regions

Based on reports from DESIRE sites in Greece and Russia

Why is it a problem?

Salinity of soils can occur naturally due to properties of the bedrock or natural environment. Soluble salts, - originating from weathering of the bedrock, capillary rise of salty groundwater, or in dust, rain or snow, - may accumulate within or on the surface of the soil. This reduces plant growth and crop yield, - in extreme circumstances to the point of plant death. The soil structure deteriorates, limiting passage of water. The salts include sodium chloride, and magnesium and calcium sulphates and bicarbonates. These affect plants directly through toxicity, and indirectly, by lowering root water uptake due to increasing osmotic pressure potential. In dry climates continuous salt accumulation can lead to a desertified landscape where nothing will grow, while in humid or subhumid climates salinization may occur seasonally. A warm, sunny climate is perfect for growing and ripening many food crops, as long as there is sufficient water. Where there is not enough natural water harvested from rainfall, irrigation using water from rivers and groundwater may be used. If the irrigation water is poor quality, e.g. salty, the irrigated soil can also soon become salinized (salty) or alkaline, and consequently infertile. This is secondary salinization.



How salinization of soils develops in a warm dry climate
(Source: Agromisa Agrobrief 6)

More about the salinization process

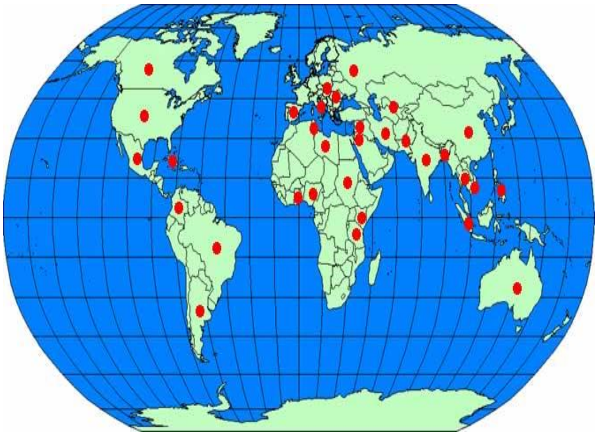
Why does salinization happen?

Salt accumulation in soil has various causes. In general primary salinization is due to natural soil characteristics, or salts blown in on winds from the sea. Secondary salinization happens where human activities play a part. There are three main processes that can cause salinization:

1. Salinization happens where the **water table is close to the ground surface**. This may occur where salts accumulate by water evaporation in the soil surface layers. The warmth of sunshine causes evaporation at the surface and water rises up through the soil from the groundwater by capillarity through the soil pores. Salt crusts can build up on the soil surface, and within the soil as a pan. The groundwater may be naturally salty if the bedrock has marine origins.
2. The excessive use of water for **irrigation in dry climates** causes salinization, especially where soils are heavy textured, and the irrigation water itself may contain too many dissolved salts. Cultivation increases evaporation and salt concentration.
3. The **intrusion of saltwater** occurs in coastal areas, especially where seawater seeps into the aquifer and replaces groundwater that has been over-exploited. This is particularly evident along Mediterranean coastal areas as water is pumped up and extracted for irrigation and the tourist industry.

SALINITY refers to the concentration of dissolved salts in water, but is usually measured in terms of electrical conductivity (EC). There is no linear relationship, because different salts have different effects, but in general the higher the salt concentration, the better a solution can conduct electricity. The international unit of measurement is deci Siemens per meter (dS/m), or micro Siemens per centimeter (μS/cm). Soils with an EC > 4dS/m are considered saline, but plants vary considerably in their tolerance of salinity, and alfafa is affected by only 2dS/m.

Saline soils are sometimes described as sodic, or alkaline, if there is a high proportion of sodium, that causes dispersion of soil particles and loss of soil structure.



Countries of the world tackling major salinity problems– over 77 million hectares of salinized land are caused by human activities http://tinyurl.com/cx47u

Regional distribution of salt-affected soils, in million hectares

Regions	Total area	Saline soils		Sodic soils	
	Mha	Mha	%	Mha	%
Africa	1,899	39	2.0	34	1.8
Asia, the Pacific and Australia	3,107	195	6.3	249	8.0
Europe	2,011	7	0.3	73	3.6
Latin America	2,039	61	3.0	51	2.5
Near East	1,802	92	5.1	14	0.8
North America	1,924	5	0.2	15	0.8
Total	12,781	397	3.1%	434	3.4%

Source: FAO Land and Plant Nutrition Management Service

Combating desertification in DESIRE study sites

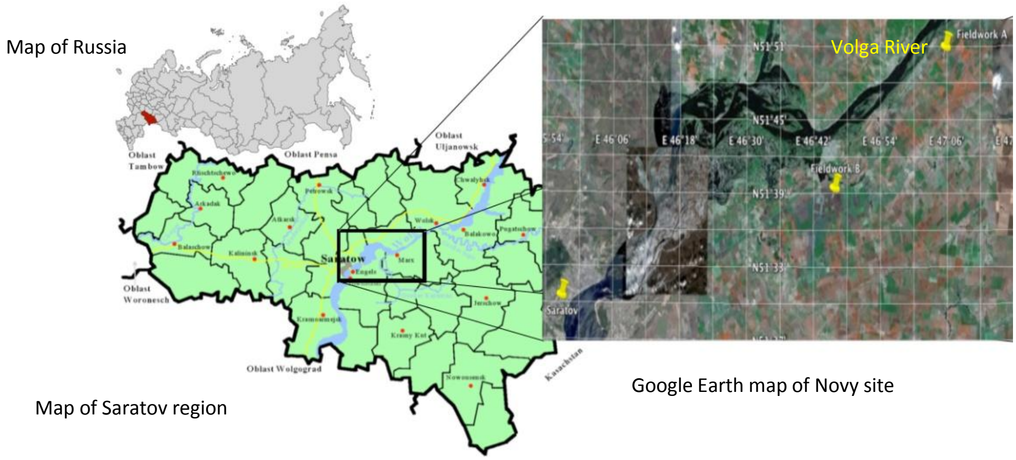
The DESIRE study sites have different desertification problems but they are all addressing them in the same way. Scientists and stakeholders together have used the WOCAT-DESIRE decision support tool to choose appropriate technologies to combat desertification and promote sustainable land use, http://tinyurl.com/y69d5sh The measures have been trialled over 2 or more years, and successful outcomes can be recommended to other similar areas.

The Novy Study Site and Dzhanibek Research Station, Russia

At the Novy site in the Saratov region of Russia cultivation of annual and perennial crops is impossible without providing water by irrigation. However, the irrigated fields are prone to salinization and loss of fertility, as the groundwater used is saline.

When there were huge collective farms, in Soviet times, water for irrigation was pumped from the Volga river and distributed from stationery sprinkler systems. Now there are smaller collective farms and independently owned farms, using an old traditional method of irrigation by furrow. A slope of 2-3% is needed to direct the water along the furrow. However this is not an optimum use of the water either, as there are losses by seepage and runoff, and soil salinity is increased.

The DESIRE project is investigating more sustainable alternatives, with precision irrigation over large areas of forage crops and drip irrigation on vegetables. The Soviet-style sprinkler system, constructed in the 1960s, used huge volumes of water and caused waterlogging and rising groundwater tables, sufficient to change conditions from semi-arid to semi-humid.



Location of the Novy study site *(Source: J. Croes)*

The Novy and Dzhanibek Sites, Russia (continued)

Measurements showed that salts in the soil at depth were dissolved and moved into the rooting zone. The salts are toxic to plants in high concentrations and the change in the soil water osmotic pressure even reduces the availability of water to plants. Organic matter is washed out of the soil and structural changes result in soil compaction and reduced hydraulic conductivity and water retention. The dry steppe climate has a long summer. From May to September temperatures reach 45 °C. The winter lasts from December to March, when up to 28 cm of snow can fall. Total annual precipitation averages 400 mm/year, and a major part of this is snow. For the land user, salts may accumulate in depressions causing patchy crop growth but encouraging weeds that thrive in those conditions. Cultivation cannot be achieved without irrigation, but sprinkler irrigation with large volumes of water has resulted in salinization and decreasing fertility and yields. The irrigated crops include cereals, and vegetables such as potatoes.

Furrow irrigation of vegetables has disadvantages:
1) unproductive use of irrigating water
2) sharp increase in sub-surface and ground water levels
3) over watering of plant roots
4) pollution of the sub-soil/ground waters by chemicals
5) soil erosion by flowing water, and leaching of plant nutrients in the soil

Drip irrigation of vegetables is better because it provides:
1) significant minimisation of irrigation water doses
2) easy adaptation of the irrigation regime to water demand
3) prevention of water leaching to the underlying ground water
4) decrease in ecological risks for the surrounding area

Precision irrigation

Precision irrigation makes good use of scarce water resources, by targeting only areas where water is needed. It works by having a mechanised system that responds to automatic monitoring of plants, soil, ground water and landscape properties. One way of improving the supply of freshwater is to harvest snow-melt water that may accumulate under small depressions in the landscape and above salty ground water. Small wells access these lenses of freshwater within the saline groundwater.

The Novy and Dzhanibek Sites, Russia (continued)

Since 2007, drip irrigation has been used successfully in the garden plots of families in Romashky and Elton villages, Pallasovsky District, Volgograd Region, Russia.

Innovations in easy and inexpensive monitoring

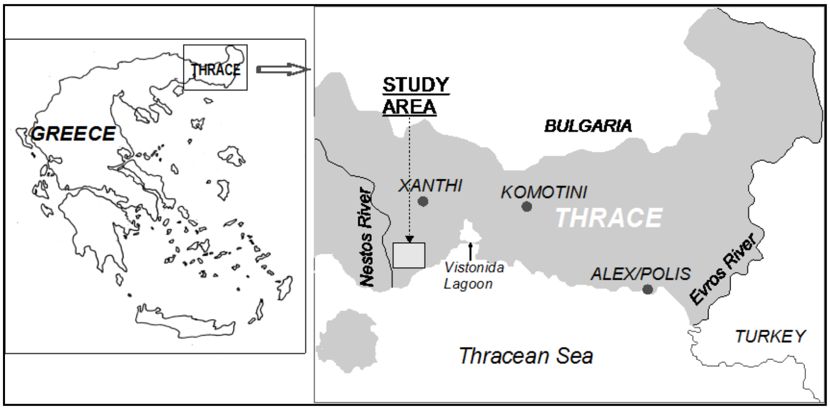
Researchers have used ordinary digital cameras to measure variations in visible light reflectance of plants and soils. They found that plants stressed by salinity may wilt and not reflect light so well. Also, with reduced growth there will be more bare soil visible between plants than with a healthy crop. They hope they can develop this research into a low-cost method to monitor crop water stress on a large scale.

They have also found that the high soil alkalinity (pH) and relatively low electrical conductivity are positively correlated with increased root biomass. This is very unusual compared to findings reported in scientific literature. It is peculiar that a rise in electrical conductivity (higher salts) does not automatically imply a decrease in root biomass. As expected, increased electrical conductivity is negatively correlated with plant water content at this site.

The alfalfa plants show poor and patchy growth where they are stressed by salinity

Large cracks on the soil surface indicate alkaline conditions

The Nestos river basin site, Maggana, Greece



In the 1950s and 1960s, a drainage, flood protection, and wetland management scheme was set up on the Nestos delta. Unfortunately these interventions changed the way in which groundwater was recharged, and a restriction in available sources of surface water. The aim had been to increase the area of cultivatable land, but the huge increase in demand for water for the crops resulted in widespread problems with soil salinization, decrease in groundwater storage, degradation of aquifers and gradual extinction of coastal wetlands.

The most affected region is that of Maggana in the eastern part of the Nestos river delta. Soil salinity has become a problem for farmers after 20-30 years of pumping up water for irrigation. Over-pumping of the aquifer has resulted in seawater intrusion, and the level of saline groundwater is now only 1m below the surface. Evaporation at the soil surface in the hot dry summer months brings salts to the surface. The application of gypsum (calcium sulphate) may reduce alkalinity and salinity, but may not necessarily be economical, as the soil must remain moist for the chemical reaction to happen.

Some farmers use deep tillage of the subsoil, to mix the surface and deeper soil layers. However, this often results in an impermeable hardpan, that limits drainage and causes further problems.

New ways to increase production are being investigated, especially by improving the supply of freshwater, and monitoring its use for maximum efficiency. Surface freshwater and saline groundwater for irrigation have been investigated with local landusers, on adjacent fields of the same farm. The results from 2009 show a marked increase in yield if surface freshwater is used for irrigation. Experiments will also set out to discover how quickly a benefit is seen if the groundwater irrigation water is replaced by freshwater. It may also be possible to consider planting crops that can develop and be harvested within the cooler wetter seasons.

Irrigation water quality

Surface water		Groundwater	
EC (µS/cm)	581 (±322)	EC (µS/cm)	2247 (±103)
pH	7.39 (±0.07)	pH	7.50 (±0.17)
SAR	0.49	SAR	2.41
Ca^{2+} (mg/L)	358 (±535)	Ca^{2+} (mg/L)	263 (±161)
Na^{+} (mg/L)	35 (±8)	Na^{+} (mg/L)	172 (±3)
Mg^{2+} (mg/L)	20 (±27)	Mg^{2+} (mg/L)	73 (±11)
K^{+} (mg/L)	7 (±2)	K^{+} (mg/L)	5 (±5)
Cl^{-} (mg/L)	107 (±83)	Cl^{-} (mg/L)	437 (±33)
SO_4^{2-} (mg/L)	26 (±4)	SO_4^{2-} (mg/L)	271 (±21)
NO_3^{-} (mg/L)	2 (±1)	NO_3^{-} (mg/L)	8 (±1)

Irrigation from surface water (left) and groundwater (right) in adjacent fields

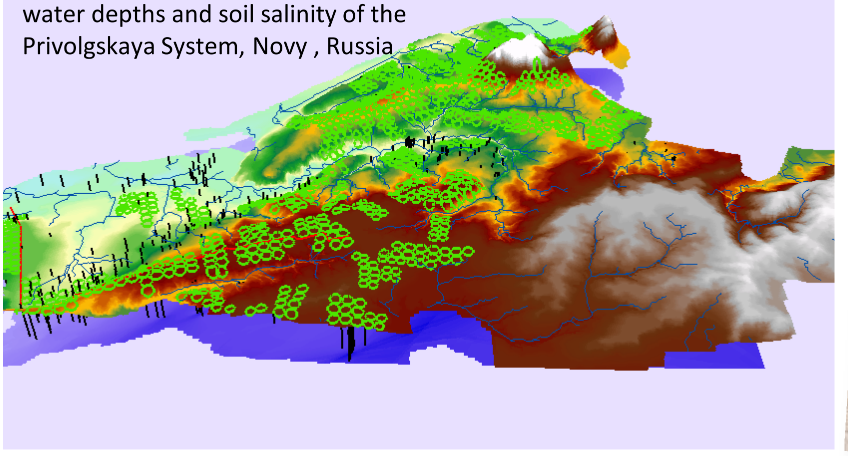
3 April 2009

17 June 2009

22 July 2009

31 August 2009

The yield is 9.3 tn/ha with less salty surface water irrigation (left) but only 3.4 tn/ha with salty groundwater irrigation (right), - note the white salts deposited on the surface of the soil. (*All Nestos photos by I. Gkiougkis)*



View of area covered by a database for monitoring large scale ground water depths and soil salinity of the Privolgskaya System, Novy , Russia

Conclusions

The successful technologies for preventing salinization of soils in the DESIRE study sites focus on more efficient and more effective use of the scarce, least saline water supplies. Detailed automated monitoring of soil and climatic conditions can be used to programme the precision sprinklers or drip irrigation systems for optimum control. Management of acceptable water, either from outside the area or harvested in some way (snow melt, or good quality wastewater, for example) is crucial. Choosing winter crops, (rather than summer, or perennial crops), crops may utilise the least saline water more efficiently and sustainably.

Written and compiled by Nichola Geeson

For more information see:

•The Harmonised Information System on the DESIRE website, http://tinyurl.com/y7e25j7

•Description of the Novy and Dzhanibek sites (Russia) is based on research by Prof. A. Zeiliguer, and O. Ermolaeva, Moscow State University of Environmental Engineering; W. Beets and J. Croes, Wageningen UR

•Description of the Nestos delta site (Greece), is based on research by Dr. I. Diamantis, I. Gkougkis, and A. Pechtelidis, Democritus University of Thrace.

References and further reading

•Beets, W. (2009) DESIRE MSc thesis: Detecting and monitoring vegetation water stress
•Croes, J. (2009) DESIRE MSc thesis: Detecting the effect of sodic soils on alfafa
•Iannetta, M. and Colonna, N. (2008). salinization. LUCINDA booklet B3. http://geografia.fcsh.unl.pt/lucinda/
•Munns, R. The Impact of Salinity Stress
•CSIRO Division of Plant Industry
•Canberra ACT, Australia
•http://www.plantstress.com/Articles/salinity_i/salinity_i.htm
•Posthumus, H. Saline Soils. Agrobrief 6. Agromisa Foundation, Wageningen, The Netherlands. http://www.agromisa.org/

The DESIRE project (2007-2012) is funded by the European Commission, VI Framework Program, 'Global Change and Ecosystems' and brings together the expertise of 26 international research institutes and non-governmental organisations (NGOs). This project is implemented by ALTERRA - research institute for the green living environment in the Netherlands.

Website: http://www.desire-project.eu
Contact DESIRE coordinator: Coen.Ritsema@wur.nl
Contact DESIRE Communications: ngprojects@googlemail.com

ALTERRA WAGENINGEN UR

DESIRE A global initiative to combat desertification

SIXTH FRAMEWORK PROGRAMME