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Review

The threat of soil salinity: A European scale review

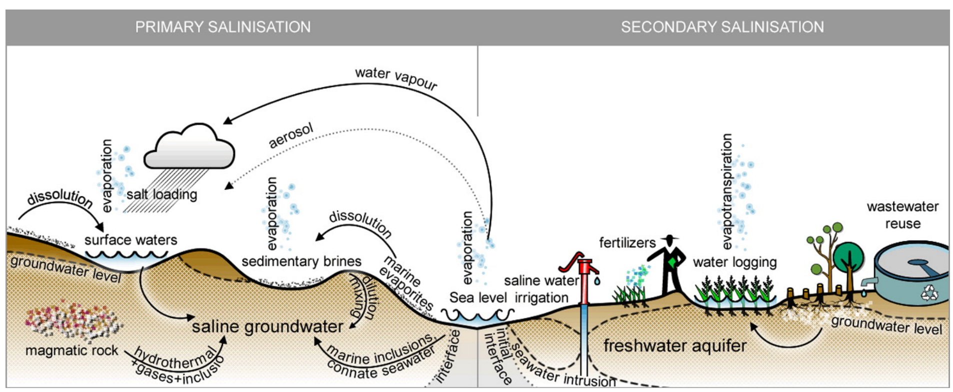
I.N. Daliakopoulos [a], I.K. Tsanis [a,b,*], A. Koutroulis [a], N.N. Kourgialas [a], A.E. Varouchakis [a], G.P. Karatzas [a], C.J. Ritsema [c]

[a] School of Environmental Engineering, Technical University of Crete, Chania, Greece
[b] Department of Civil Engineering, McMaster University, Hamilton, Ontario, Canada
[c] Soil Physics and Land Management Group, Wageningen University, Wageningen, The Netherlands

HIGHLIGHTS

- State of the art regarding drivers, effects, indicators, monitoring, modeling and management of soil salinity at European scale is presented.
- Current state of soil salinity in Europe is introduced by compiling a variety of sources.
- Knowledge gaps and aspects beyond the state of the art regarding the soil threat of salinisation are highlighted.

GRAPHICAL ABSTRACT



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ABSTRACT

Soil salinisation is one of the major soil degradation threats occurring in Europe. The effects of salinisation can be observed in numerous vital ecological and non-ecological soil functions. Drivers of salinisation can be detected both in the natural and man-made environment, with climate and the foreseen climate change also playing an important role. This review outlines the state of the art concerning drivers and pressures, key indicators as well as monitoring, modeling and mapping methods for soil salinity. Furthermore, an overview of the effect of salinisation on soil functions and the respective mechanism is presented. Finally, the state of salinisation in Europe is presented according to the most recent literature and a synthesis of consistent datasets. We conclude that future research in the field of soil salinisation should be focused on among others carbon dynamics of saline soil, further exploration of remote sensing of soil properties and the harmonization and enrichment of soil salinity maps across Europe within a general context of a soil threat monitoring system to support policies and strategies for the protection of European soils.

* Corresponding author at: School of Environmental Engineering, Technical University of Crete, Chania, Greece.
E-mail address: tsanis@hydromech.gr (I.K. Tsanis).

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Contents

1. Introduction

Soil salinisation is a term that includes saline, sodic and alkaline soils (van Beek and Tóth, 2012), respectively defined as (a) high salt concentration, (b) high sodium cation (Na^+) concentration, and (c) high pH, often due to high CO_3^{2-} concentration, in the soil. Soil salinisation leads to the alteration or even disruption of the natural biological (Smith et al., 2015), biochemical (Decock et al., 2015), hydrological (Keesstra et al., 2012) and erosional (Berendse et al., 2015) Earth Cycles. High salinisation levels can thus result to the loss of the emerging resources, goods and services of soil, impacting agricultural production and environmental health (Rengasamy, 2006), eventually evolving into a sociocultural and human health issue (Brevik et al., 2015) that hinders economic and general welfare.

Soil salinisation is a widespread phenomenon, with saline and sodic soils covering 932.2 Mha globally (Rengasamy, 2006), and one of the major soil degradation threats worldwide, with mismanaged irrigation affecting 34.19 Mha (Mateo-Sagasta and Burke, 2011) or over 10% of the total irrigated land (Aquastat, 2016). Europe contributes about 30.7 Mha or 3.3% of the global saline and sodic soils (Rengasamy, 2006). Global soil salinisation hotspots include Pakistan, China, United States, India, Argentina, Sudan and many countries in Central and Western Asia (Aquastat, 2016; Ghassemi et al., 1995), while at European scale the Mediterranean coastline stands out (Geeson et al., 2003). Effectively, this soil threat has gained worldwide attention in the State of the Art, as concern has grown about irrigation mismanagement (Young et al., 2015), organic (Drake et al., 2016; Singh et al., 2016; Srivastava et al., 2016; Wu et al., 2014) and inorganic amendment selection and quantification (Ahmad et al., 2016; Mao et al., 2014), and the role of plant tolerance (Singh et al., 2015) and soil fauna (Oo et al., 2015) in the adaptation and soil reclamation process.

A wide range of traditional and state-of-the-art amelioration methodologies against soil salinisation has been documented (Panagea et al., 2016), nevertheless, they can be very case specific. In order for reclamation studies to be efficiently upscaled or effectively adapted to local problems, a review of the state of soil salinity in Europe is essential. The objective of this review is to show the State of the Art on soil salinisation in Europe based on scientific publications and reports. Each chapter describes the State of the Art at global scale and concludes with findings and discussion at the European level.

2. Drivers and types of salinisation

2.1. Primary salinity

Primary salinisation is the development of salts through natural processes, mainly including physical or chemical weathering and transport from parent material, geological deposits or groundwater (Fig. 1). Soil may be rich in salts due to parent rock constituents such as carbonate minerals and/or feldspar. Closely related to this, geological events or specific formations can increase salt concentration in groundwater and therefore in superimposed soil layers. This can occur when, after capillary effects or evapotranspiration cause salinity affected groundwater to rise, previously dissolved salts accumulate at or near the surface (Chari et al., 2012; Geeson et al., 2003). These drivers affect the soil depending on aquifer architecture and hydraulic conductivity of geological layers and soil characteristics such as porosity, structure and texture, clay mineral composition; compaction rate, infiltration rate, water storage capacity, saturated and unsaturated hydraulic conductivity and finally potential salt content (Chesworth, 2008; van Beek and Tóth, 2012). In total, the types of saline or saline prone soil formed as listed by WRB (2014) are shown in Table 1. Naturally saline soils occur in Spain, Hungary, Slovakia, Greece, Austria, Bosnia, Serbia, Croatia, Romania, Bulgaria, Ukraine and the Caspian Basin (Geeson et al., 2003; Jones et al., 2008; Trnka et al., 2013; van Beek and Tóth, 2012; van Camp et al., 2004).

Apart from the long-term accumulation of salts in the soil profile, natural soil salinisation can also pre-exist due to once submerged soils under seawater. During this period, seawater fills the voids of the sediments (connate water, e.g. Edmunds et al. (1987)) and remains enclosed within the marine deposits (Wendland et al., 2008), even after the seawater incursion. Besides historical marine waters, contemporary sea level rises may cause seawater to flood coastal land, either for long (marine transgressions) or short (storm flood events, tsunamis) periods. In addition, these rises may boost lateral seawater intrusion into coastal areas that are hydraulically connected to the sea, causing wide-spread soil salinity problems across regions near the coast, as observed in Western Netherlands, Denmark, Belgium, North-eastern France, and South-eastern England (Raats, 2014; Trnka et al., 2013; van Weert et al., 2009).