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Greenhouse Soil Moisture Deficit under Saline Irrigation and Climate Change

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Abstract

The sustainability of protected horticultural crops in the Mediterranean region, typically under deficit irrigation and intensive cultivation practices, is facing increasing risks due to soil salinization. Climate change may augment this threat to ecosystem services. In this study, the SALTMED leaching requirements model was calibrated using soil moisture measurements from time domain reflectometry (TDR) sensors. Measurements are performed on a small-scale Solanum lycopersicum (tomato) greenhouse experiment that simulates semi-arid conditions in the RECARE Project Case Study in Greece (Timpaki basin in Crete). The use of local planting soil with initial Electrical Conductivity (EC_e) 1.8 dS m^{-1} and local cultivation practices aim to replicate prevailing conditions at the Case Study. Plants are drip irrigated with two NaCl treatments: slightly (S) saline (EC_w= 1.1 dS m^{-1}) and moderately (M) saline water (EC_w = 3.5 dS m^{-1}), resulting to very high and excessively high EC_e, respectively. Based on these approaches, the calibrated SALTMED model was used for simulating groundwater degradation by seawater intrusion. In order to estimate crop yield in a warmer future, climate model data obtained from 9 GCMs for the "worst case" Representative Concentration Pathway of 8.5 W m^{-2} of the 5th phase of the Coupled Model Intercomparison Project are corrected for bias against historical observations with the Multisegment Statistical Bias Correction method. Preliminary results predict that to sustain greenhouse productivity at current levels in the future, a substantial increase of water demand will be required.

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1. Introduction

Global population, currently 6.5 billion approximately, is expected to reach 9 billion by 2050 [1]. A result of this profound global growth is a significant increase in food and water demand [2]. At the same time, natural resources are under significant threats due to non-optimal management, but also climate change. However, soil and water resources of high quantity and quality are needed to sustain these rates of growth, as well as the current welfare. Soil salinization, defined as an excessive accumulation of salts in soil at levels that hinder crop production [3], is one of the most ominous soil degradation threats [4]. The main cause of human induced (or secondary) soil salinisation is poor quality or mismanaged irrigation [5]. Between 34 and 45 Mha [5] or over 10% of irrigated land [6] all over the world are characterized as salt-affected.

In coastal agricultural regions, and especially in arid and semiarid areas such as those of the Mediterranean basin, soil resources and crop production are highly compromised due to irrigation with saline water. In Greece, water demand is largely covered by groundwater resources; yet, the overexploitation promotes seawater intrusion thus undermining groundwater quality (Fig. 1). Soil salinization due to seawater intrusion poses a threat to the local water security, plaguing about 9% of the approximately 1.4 Mha of irrigated land [7]. Due to a more arid climate, the coasts of southern Greece face a relatively greater risk of seawater intrusion progressing at a great distance inland [8]. With intensive agriculture constituting the main factor that strongly impacts water resources availability, the island of Crete (Fig. 1) is no exception to this rule. Under the threat of climate change, the sustainability of the current agricultural system of these regions is highly uncertain. Motivated by these challenges, we investigate the projected changes in water resources requirements under the combined stress of soil salinisation and climate change. The approach involves the use of State of the Art climate datasets and the SALTMED model [9] under the typically optimised greenhouse cropping conditions at the RECARE Project Case Study in Greece, Crete.

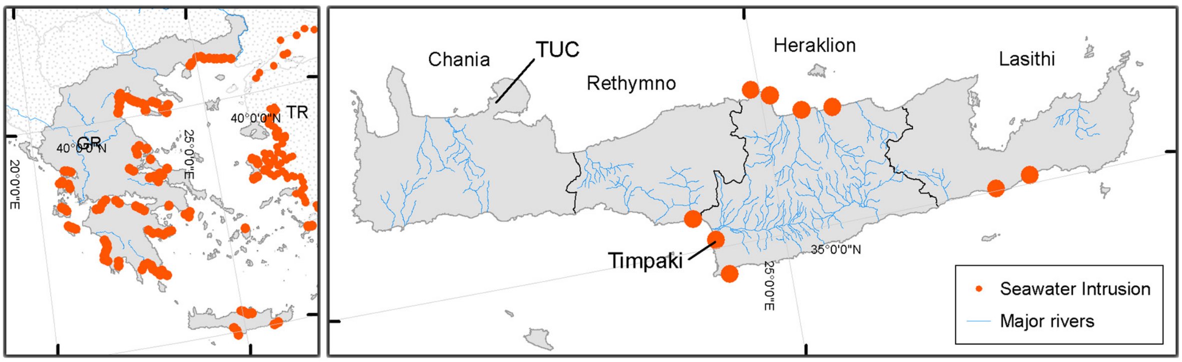

Fig. 1. Areas of seawater intrusion in Greece (left) and specifically in Crete (right).

2. Methodology

Salt-affected soils can be classified into three categories; saline, saline-sodic and sodic soils [10], with the latter being the most problematic [4]. Saline soils are those for which a solution extracted from a water-saturated soil paste (EC_e) values greater than 4 dS m^{-1}, and at the same time exhibit Sodium Adsorption Ratio (SAR) values less than 13. On the other hand, sodic soils have SAR values greater than 13 and EC_e values less than 4 dS m^{-1} [4]. The SALTMED model [9] is based on mathematical equations that depict nutrient and irrigation water uptake by the plant roots under specified soil, irrigation quantity and quality, nutrient concentration, and climate conditions. Based on those, SALTMED can estimate soil profile Electrical Conductivity (EC) and crop yield through time. SALTMED estimates the additional amount of water required under saline irrigation to avoid yield loss or Leaching Requirements (LR) as: