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Scenario Modelling Of Climate Change's Impact On Salinization Of Coastal Water Resources In Reclaimed Lands

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Abstract

A numerical model accounting for variable density flow and transport was built up to quantify the actual and future (2050) salinization trends of a coastal aquifer in the Po delta (Northern Italy). SEAWAT 4.0 was employed to model the interaction between the surface drainage system and the underlying aquifer. PEST was employed for inverse parameter calibration using hydraulic heads and groundwater salinities as constraints. The calibrated model was used to predict the behavior of the coastal aquifer using a multiple scenario approach: increase in evapotranspiration induced by temperature increase; increase in the frequency of extreme high rainfall events; extreme drought conditions; and irrigation canals dewatering due to salinization of the Po River branches. For each scenario, two sub-scenarios were established to account for the projected local sea level rise. The first three scenarios have only minimal effects on the aquifer salinization, while the fourth forecasts a severe aquifer salinization due to enhanced upward fluxes of saline and hypersaline groundwater. The scenarios quantified the possible future salinization trends of groundwater and could be useful to identify adaptation strategies which allow to better manage water resources of this and similar areas. Results show that the Po delta will experience a significant salinization by 2050 and that the major cause is autonomous salinization via seepage of saline groundwater rather than enhanced salt-water intrusion due to sea level rise. The enhanced autonomous salinization will increase the salt export into the drainage canals that are also employed for irrigation, posing serious treats to the local flourishing agricultural economy.

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1. Introduction

Climate change will increase the actual sea level at the global scale and especially in the Mediterranean region [1]. The projected future rates of forced warming and drying over the Mediterranean are predicted to be higher than in the past century [2]. This will turn into forced changes in surface air temperature, Mediterranean Sea annual-mean evaporation and surface freshwater fluxes, which will challenge the current water supply management in areas close to the coast. Thus, with the progressive loss of surface water resources due to anthropogenic pollution and the intensive agriculture water demand, groundwater resources will be gradually more stressed, especially in reclaimed coastal areas [3, 4, 5]. In these fragile environments, the relative sea level rise (RSLR) and changes in recharge and evapotranspiration patterns, will probably accelerate water resources depletion both quantitatively and qualitatively [6]. Thus, an improved understanding of the spatial distribution of groundwater salinity fluxes and of the factors controlling these fluxes is urgently required to support the sustainable management of coastal resources in the near future [7]. As many low-lying coastal areas, the Po delta hosts a coastal aquifer which was found to be affected by autonomous salinization caused by the upward flux of hypersaline groundwater eluted from peat lenses and from the underlying silty clay aquitard [8]. The agricultural land drainage system used to maintain these low-lying areas dry was identified as the main mechanism responsible of the upward flux [9]. Since the extensive canal network in the Po delta acts as a strong head control on the local unconfined aquifer and given that the head-controlled systems were demonstrated to be more prone to the effect of RSLR [5], a detailed representation of the drains/aquifer system is required to numerically simulate both actual and future seawater intrusion and saline seepage. For these reasons, to quantify the foreseeable impacts of climate change on the shallow unconfined aquifer of Po delta, a conceptual model was developed based on detailed topography and bathymetry, stratigraphic information from analysis of well logs and driller's reports, hydrodynamic information from heads monitoring and pumping tests and hydrogeochemical information from multi-level sampling. Based on the conceptual model, a three-dimensional density-dependent groundwater flow model coupled with solute transport was developed and calibrated [10].

In this paper, the calibrated model was employed to create a series of different scenarios to investigate the effects of projected climate changes on groundwater salinity by 2050. The projected scenarios allowed identifying the zones of influence of RSLR and of extreme drought events; additionally they allowed to quantify the increase in salinization of the groundwater system, the salt loads discharged towards the surface water system and the changing volumes of freshwater.

2. Methodology

2.1. Site location and its geomorphological evolution

The study area is located in the coastal floodplain of the Po River (Northern Italy) (Fig. 1). It covers 860 km2 (from 44°32' N to 44°58' N, from 12°00' E to 12°17' E), of which 76% is farmland and woodland, 21% is marsh lagoon (predominantly salt marshes) and 3% is urban area. The surface water system is complex since it is constituted by a dense network of drainage and irrigation canals, brackish coastal lagoons and rivers, by which the water is diverted by gravity following the seasonal agricultural and environmental needs. During the whole year, the excess water collected by the drainage network is pumped out into the main collector channels and discharged to the sea. The total mean annual volume of water that is pumped out of the study area to maintain this lowland dry is about 430 Mm3/y.

To have a clear picture on how the reclamation network, and in general the surface waters, interact with the subsurface, an overview on the geomorphological evolution of this area is required.