D.3.5.3 – Scientific Publication

Document Control Sheet

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Work Package Leader	University of Urbino "Carlo Bo" – (UNIURB)

Status	Final
Author (s)	Simone Galeotti (UNIURB) Gaia Galassi (UNIURB) Vittorio Giorgetti (SINERGIA consulenze – external advisor)
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1. INTRODUCTION

Results of numerical simulation developed within activities 3.3 and 3.4 in conjunction with territorial hazard mapped in activity 3.2 will be the basis to develop a model for the risk of salt intrusion at different climate change scenarios.

The model will consider the pressure of sea level change in the different hydrological conditions and will include other territorial pressure.

The model will produce three high-resolution maps of Adriatic coastal aquifers vulnerability to salt ingression according to the three different scenarios of climate change (high, medium and low).

The description of the model and the results obtained has been included in a scientific publication, prepared and released by the LP and WP3 leader University of Urbino.

2. Process

The publication is authored by Gaia Galassi, Giorgio Spada and Simone Galeotti. The title is “Salt intrusion in coastal aquifers in Northern Adriatic Basin: a conceptual model for mapping the risk in climate change scenarios”.

A first abstract was submitted in February 2021 to the Euro-Mediterranean Conference for Environmental Integration.

The proposal was officially accepted on the 15th of April, while the Conference took place in Sousse, Tunisia, between the 10th and the 13th of June 2021.

Mrs. Gaia Galassi attended the conference as official speaker and the paper was presented in one of virtual rooms of the programme, on the 11th of June 2021 (ID29). The overall programme can be retrieved here (page 71):

https://emcei.net/source/files/Program_EMCEI.pdf

The scientific paper will be published soon in the "Recent Advances in Environmental Science from the Euro-Mediterranean and Surrounding Regions - Proceedings of Euro-Mediterranean Conference for Environmental Integration – Year 2021".

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Tunisia, 15 April 2021

Acceptance & Invitation Letter

Conference Paper Reference: 29
Title: Salt intrusion in coastal aquifers in Northern Adriatic Basin: a conceptual model for mapping the risk in climate change scenarios.
Author(s): Gaia Galassi, Giorgio Spada, Simone Galeotti

Dear Gaia Galassi,

We are delighted to inform you that our Scientific Committee has accepted your above referenced abstract to be presented **online** as an **Oral Communication** at the 3rd Euro-Mediterranean Conference for Environmental Integration (EMCEI 2021) which will be held in Sousse, Tunisia from 10 to 13 June 2021.

And, know that your abstract won't be scheduled for inclusion in the **final conference program** and your **extended abstract** (if any) won't be published in the **conference proceedings** by Springer and indexed in Scopus unless at least one of the authors cited above **registers online** and pays the **registration fees** by **10 May 2021**.

On behalf of the Scientific Committee, we would like to thank you for your submission and we warmly invite you to attend online the EMCEI 2021. The high level of interest in the conference confirms its global relevance and international impact. More than **811 abstracts** have been received from **72 different countries** worldwide. The conference will gather influential scholars from all over the world and top scientists have already confirmed their participation.

Please consult our website (www.emcei.net) on a regular basis for more details.

With best regards,

EMCEI

Prof. Mohamed Ksibi
General Chair of EMCEI 2021
Co-Editor-in-Chief of the Euro-Mediterranean Journal for Environmental Integration
University of Sfax, Tunisia

11 JUN. 14:00—16:00 GMT+1

Session: T5-OS1
Virtual Room 5

- **ID 29: Salt intrusion in coastal aquifers in Northern Adriatic Basin: a conceptual model for mapping the risk in climate change scenarios.**
  Gaia Galassi, Giorgio Spada, Simone Galeotti
- **ID 214: Numerical simulation of the microclimate of an olive cuttings greenhouse installed under mediterranean climate**
  Sanae Chakir, Adil Bekraoui, Hassan Majdoubi, Mhamed Mouqallid, Allal Senhaji
- **ID 65: Spatiotemporal variability of rainfall in Friuli-Venezia Giulia (north-eastern Italy)**
  Tommaso Caloiero, Ilaria Cianni, Roberto Gaudio
- **ID 311: Using runoff models to assess Regional Climate Models simulations: Effect of structural uncertainty**
  Hamouda Dakhlaoui, Djebbi Khalil
- **ID 68: Impact of hydropower plants on the river hydromorphological processes in the context of climate change**
  Vytautas Akstinas, Jūratė Kriaučiūnienė, Darius Jakimavičius
- **ID 76: Effects of the Saharan dust events on air quality in Gabes and Sousse Tunisian cities**
  Houda Chtioui, Karim Bouchlaghem, Mohamed Hichem Gazzah
- **ID 124: Evolution of the Aridity Index (1870-2015) in the SW of the Iberian Peninsula**
  Mónica Aguilar-alba, Arturo Sousa, Julia Morales, Leoncio García-barrón3
- **ID 164: Assessment of seawater intrusion in the coastal plain aquifers of Essaouira basin using geochemical approaches**
  Mohammed Bahir, Otman El Mountassir, Driss Ouazar, Abdelghani Chehbouni, Driss Dhiba, Paula M Carreira
- **ID 232: Evaluating the CLIRAD and RRTMG shortwave radiation parameterization for the Brazilian global model with interactive aerosols**
  Jayant Pendharkar, Silvio Nilo Figueroa, Phani Murali Krishna R, Dirceu Herdies, Debora Alvim, Paulo Kubota
- **ID 290: Composition and structure of juvenile ichthyologique assemblages in the El Bibane lagoon (South-East Tunisia)**
  Hanem Djabou, Olfa Sayari, Aziz Naloufi, Elena Barcala, Othman Jarboui

3. Abstract

Abstract number: EMCEI-2020-P29

Abstract title: Salt intrusion in coastal aquifers in Northern Adriatic Basin: a conceptual model for mapping the risk in climate change scenarios.

Authors: Gaia Galassi, Giorgio Spada, Simone Galeotti

Abstract: The Adriatic region is highly vulnerable to the adverse impacts of climate change. Among climate-related impacts that could affect coastal areas, salt intrusion is receiving increasing attention over the last years. The Northern Adriatic coasts are subject to the influence of touristic pressure, which entails increased extraction of groundwater during the peak season. In addition, climate change acts to exacerbate the processes responsible for salt intrusion, including sea level rise but also drought increase that, in turn, implies an increase in pumping for agriculture. In this context, it is important to understand the potential risk of salt ingression in coastal aquifers, to address plans for groundwater resource sustainable management. In this work, a conceptual model for the risk assessment to salt intrusion in the North Adriatic basin forced by future scenarios of climate change is proposed. It is referred to a broad area (almost 2000 km of coasts), involving three Countries (Italy, Croatia and the short portion of Slovenia facing the Adriatic coast) and including a variety of geological, morphological and socio-economic conditions. The model considers both the aquifer susceptibility (as intrinsic characteristic and topography) and the hazard threats (sea level rise, storm surge and pumping), as well as the economic loss associated with restoration costs. For sea-level rise and storm surge, year 2100 scenarios resulting from IPCC RCP 8.5 have been considered in the model. Pumping has not been included as a predictable factor because it will depend not only on the distribution of wells, but also on the evolution of the economic context and the political and administrative choices related to use of water resources. Hence, pumping is introduced in the model as a variable: in this way, the model output is not simply a static map containing information about risk but, by comparing alternatives in planning, will produce a dynamic tool to address government's choices about water resource use. The model uses a GIS-based-analysis, with available information included as layers. The analysis has been performed along a 5 km buffer from the coast to the interiors, for a 1 km x 1km grid (scaled on a 250mx250m for the test area). For the assessment of each risk component, a systems of weights and ranks has been applied. The model output shows that the risk of salt ingression in the Northern Adriatic basin is low to medium in average, with a geographical variability mainly related to aquifer susceptibility. The occurrence of extreme storm surges, combined with sea level rise, increases the risk in specific areas. Applying a forward approach, the model also allows to establish an "acceptable" level of pumping at specific location. A test of the model in a sample area (municipality of Fano, Italy) has allowed to determine the usefulness of the model to compare different locations in planning the use of groundwater resources.

4. Scientific Paper

Salt intrusion in the coastal aquifers in the Northern Adriatic basin: a conceptual model for mapping the risk under climate change scenarios.

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1. Introduction

Climate change consequences are affecting a variety of human and biophysical systems, and they are of peculiar importance for water resource issues, exacerbating the existing problems both in terms of quality and availability [1]. The Adriatic region is highly vulnerable to the adverse impacts of climate change. For example, recent studies demonstrate significant change in the seasonal amplitude of the Sea Surface Temperature signal, with an increase of extreme events [2]. Among climate-related impacts that could affect coastal areas, salt intrusion has received increasing attention over the last years. Beside the problem related to saltwater intrusion in estuaries and deltas, mainly related to tidal processes (see, i.e. [3]), salt ingression in coastal aquifers is strictly connected both to climate change and human activities [4] The Northern Adriatic coasts are subject to touristic pressure, which entails increased extraction of groundwater during the peak season. In addition, climate change exacerbates the processes responsible for salt intrusion, including sea-level rise but also drought that, in turn, implies an increase in pumping for agriculture. In particular, sea-level rise forced by changes to atmospheric pressure, thermal expansion of oceans and melting of ice sheets and glaciers is expected to play a role in sea water intrusion [5].

Plans for groundwater resource management, therefore, demand a realistic estimate of future local sea level response for a range of the most likely to the worst-case scenarios of global warming. This is a fundamental pre-requisite to achieve a sustainable management of coastal water resources.

This work aims to analyse the risks of salt intrusion in coastal aquifers related to climate change scenarios for the Norther Adriatic Basin. To this end, a conceptual model that includes the main factors affecting salt intrusion has been built up and used to produce map of risk.

2. Methods and Data

The assessment of the risk of salinization must simultaneously consider vulnerability, which embeds the probability of occurrence and the potential loss. This encompasses economic consequences due to the contamination of groundwater supply, impacts on human health due to well contamination, or multiple consequences on ecological systems. According to Simpson et al. [6], the risk assessment of salt intrusion in coastal aquifers is Vulnerability per Loss (L), where Vulnerability is defined as the product of aquifer susceptibility (S_A) by hazard threat (H_T). For the combination of the different components of Vulnerability and Loss, following the approach delineated by Eriksson et al. [7], a system of weights has been introduced. The risk is given by:

$$R = \sum_{i=1}^{n} S_{Ai} \cdot W_i \times \sum_{j=1}^{n} H_{Tj} \cdot W_j \times \sum_{k=1}^{n} L_k \cdot W_k \qquad (1)$$

Where i, j and k are referred to the components of risk for aquifer susceptibility, hazard threats and Loss, respectively, and $W_{i,\, j,\, k}$ are the associated weights. For the assessment of each component of S_A, H_T and L, the parameters contributing to each variable introduced in the model have been associated to a rank (from 1, very low, to 5, very high).

To assess the risk component deriving from aquifer susceptibility (S_A), both intrinsic characteristics and topography have been considered. The intrinsic characteristics are based on hydrogeology. For topography, both the elevation and the distance from the coast have been considered. Data are derived from the Copernicus database, and pertain to the EU-DEM v.10 products. Hydrogeology data are derived from the International Hydrogeological Map of Europe published by the Federal Institute for Geosciences and Natural Resources, and the rating results from the combination of the ranking of two parameters, i.e., aquifer type and lithology.

Hazard threats (H_T) is analysed in terms of Sea level rise (SL), Storm Surge Level (SS_L) and pumping from wells (P_w). For SL, both steric and geodynamic components have been modelled according to IPCC scenarios. For the steric component, data from MEDCORDEX experiment [8] have been used, based on CNRM-CM5 General Circulation Model, CNRM-RCSM4 v1 regional Circulation Model, and CMIP5 Ensemble Members r8i1p1 (RCP 8.5). The geodynamic component has been modelled with the program SELEN [9] using the ICE-6G_C (VM5a) global model of Peltier et al. [10] for the viscoelastic component and the ice melting projection developed by Slangen and van de Wal [11] for the current ice melting of Antarctica, Greenland and small (Alpine-type) glaciers. For SSL, we have used data from the work of Vousdoukas et al. [12], based on a hydrodynamic model forced by CMIP5 climate model wind and pressure fields [13] to generate projections of extreme storm surge levels along the European coastlines; data modelled for a return period of 10 yrs according to RCP 8.5 are used here. For pumping Pw, uniform and complete information at the Adriatic Basin level are not available. Hence, as a first approximation, in the computation of risk, P_W is assumed equal to 1. Real values of P_W can be introduced by applying the model at a small scale level to compare alternatives. The ranking for P_W follows the methodology proposed by Kennedy [14] and refined by Klassen et al. [15], using well density per grid unit and volume of water extracted per day.

The economic loss (L) has been considered in terms of restoration costs, and in terms of loss of income and economic damage deriving from the non-availability of water for specific economic sectors. Based on the Corine Land Cover map, classes which could imply a potential use of water in agriculture and in industry have been identified and associated to a rank for the restoration costs.

3. Results

The map of risk obtained by applying equation (1) to the 1 km x 1 km grid is shown in Fig. 1. For each grid cell, a value of risk ranging from 1 to 51 is obtained. This value does not account for pumping, which is introduced as a dynamic variable for orienting planning and administrative choice.

The model has been tested to a case study area in the coastal area of the Municipality of Fano (Marche, Region, Italy), at the mouth of Metauro river. To this purpose, for the Aquifer susceptibility (SA) we have refined the information of aquifer type with the aid of the more detailed geological map of Marche Region (scale 1:10.000) and the elevation has been verified using a DTM at 1:10000 scale. This has allowed to rescale the map on a grid with a resolution of 250mx250m (Fig.2). The application to the study area has allowed testing a higher resolved model version, including real values of pumping.

4. Discussion

From the map of risk it is possible to establish the “acceptable” level of pumping. The value of hazard threat (HT) associated to pumping (and hence the rank for PW) necessary to increment the computed risk of a given value, depends on the absolute value of the assessed risk R; solving the forward problem it is hence possible to obtain a PW value for a given increment in total risk, at i-grid cell:

$$P_{Wi} = \left(\frac{R_i + Inc}{S_{Ai} \times L_i} - H_{T-Pi}\right) \times W_{Pi}^{-1} \qquad (2)$$

where $R_i$is the risk at the *i*-grid cell(with Pw=1), HT-Pi is the hazard threat value obtained only considering the first two terms (SI and SSL) and WPi is the weight for PW. A simulation based on risk values obtained with different combinations of SA, HT and L has been run to obtain PW rank necessary to increment the total risk of 5, 10 or 15 units. In general, the maximum rank of P_W =5 implies an increment of the total risk only if the assessed risk has a medium value (R>15 for an increments of 5 units, R>25 for an increment of 10 and R>30 for an increment of 15). For high values of R (>35), even low rank of PW can contribute to a significant increment of the total risk.

To understand the variation of risk in function of the density of wells (or volume of water extraction) we have considered two single grid cells, evidenced by the black squares in Fig.2. For the northern cell (cell-A), the resulting risk (assumption Pw=1) is R=16.8, whereas for the southern cell (cell-B) R=15.6. Based on a value of Pw=3, which accounts for the existing 46 wells within cell-A, the total risk increases to R=23.1 for this cell unit. In cell-B the assessed risk remain R=15.6, since the cell includes only 1 well, giving a Pw=1.

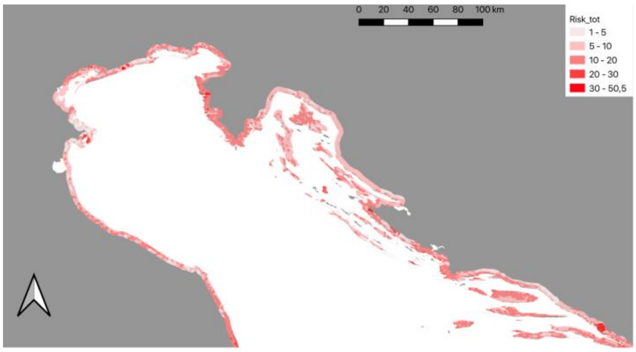

Fig. 1. Case study area of Fano: risk of salt ingression on a grid 1km x 1km and 250 x250m.

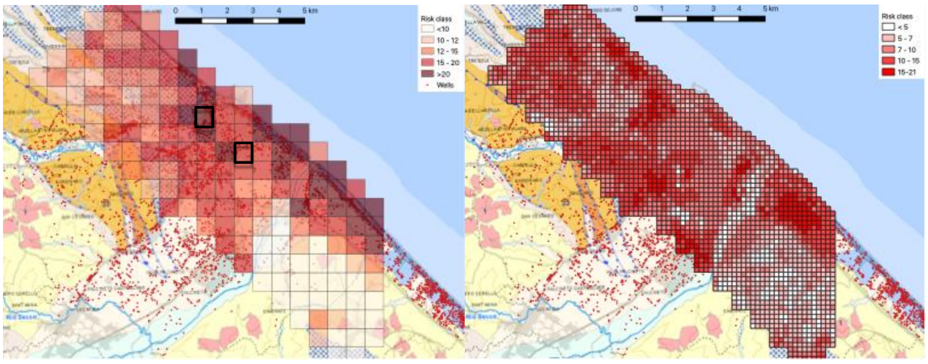

Fig. 2. Case study area of Fano: risk of salt ingression on a grid 1km x 1km and 250m x250m.

5. Conclusions

Two main results have been obtained. First, the risk map for salt intrusion for the Northern Adriatic Basin, allows defining a first, broad scale, understanding of the risk of salt intrusion in coastal aquifers under future climate change scenarios. Second, the model developed provides a useful tool for planning the use of water resources over coastal areas. In fact, based on model results, an “acceptable”(previously established) level of pumping can be introduced as an independent variable in the computation of the total risk, which provides crucial information for addressing and planning water resource usage in a sustainable way.

Our analysis reveals that, in the study area, an understanding of the problem of salt intrusion and of its future evolution is still hindered by limited knowledge of some of the key variables involved.

Acknowledgment

This work has been funded by the ASTERIS Project (Adaptation to Saltwater inTrusion in sEa level RIse Scenarios), co-funded by the Interreg Italy-Croatia Program.

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