Abstract

Land movements, i.e., subsidence and uplift, represent a great concern that threatens the sustainable development of many societies around the world from environmental and socioeconomic viewpoints. The Po Plain, a sedimentary basin in northern Italy, contains numerous regions that have been affected by a widespread land subsidence and uplift of natural and anthropogenic origins since the mid 20th century. Most subsidence in the Po Plain is anthropogenic due to its abundance in onshore gas reservoir formations and shallow aquifer systems. The identified uplift, however, is mostly associated with tectonic activities. In this work, a multidisciplinary approach is proposed for the investigation and quantification of the superposition of natural and anthropogenic effects in the Po Plain. A critical assessment on the available datasets of land movements in the Po Plain is performed along with the creation of a fluid (gas and water) production dataset as a first step in the spatial allocation of the phenomena and assessment of their superposition. Then, a specific area in the Po Plain is selected where ground movements have been affected by both a strong water production and underground fluid storage, together with the presence of natural components. A thorough research is performed in order to collect and analyze wells and other available data for the uppermost part of the Po Plain to characterize the sedimentary bodies involved in water production. The research is initially applied in a 3D numerical modelling approach involving the geological modelling of the aquifer system followed by the characterization of the petrophysical and mechanical properties. The geological model is then used to set up the fluid-flow model where the hydrodynamic parameters are assigned and the production scenarios are set up. Finally, the ground displacement analysis is addressed via a stress-strain finite element model, assuming an uncoupling approach, such that the land movements of the area are jointly analyzed and defined using the results from the modelling and simulation process and the results obtained by available studies of ground movements induced by the Underground Gas Storage (UGS) system. Finally, the analysis of an InSAR time series dataset and that of published maps, describing the contribution of both natural and anthropogenic components, is integrated for the full understanding of the phenomena affecting the area of study. This work proves groundwater production to be the main factor affecting subsidence in the area of study characterized by the UGS and minor-producing water

wells compared to other areas in the Po Plain with extensive water production. In addition, an existing post-processing technique of InSAR time series is proved effective in identifying and quantifying the physical phenomena affecting ground movements. The following outcomes can be considered for the further development of a coupled simulation approach of the aquifer and UGS systems, and applying InSAR time series ground deformation in correlation with other monitoring methods for better characterizing the deformation of the shallow layers associated with groundwater activities, and analysis of horizontal components.