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Single-station seismic noise measures, microgravity, and 3D electrical tomographies to assess the sinkhole susceptibility: the "Il Piano" area (Elba Island – Italy) case study

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Sudden subsurface collapse, cavities, and surface depressions, regardless of shape and origin, as well as doline are currently indicate by means of the term "sinkhole". This phenomenon can be classified according to a large variety of different schemes, depending on the dominant formation processes (soluble rocks karstic processes, acidic groundwater circulation, anthropogenic caves, bedrock poor geomechanical properties), and on the geological scenario behind the development of the phenomenon. Considering that generally sinkholes are densely clustered in "sinkhole prone areas", detection, forecasting, early warning, and effective monitoring are key aspects in sinkhole susceptibility assessment and risk mitigation. Nevertheless, techniques developed specifically for sinkhole detection, forecasting and monitoring are missing, probably because of a general lack of sinkhole risk awareness, and an intrinsic difficulties involved in detecting precursory sinkhole deformations before collapse. In this framework, integration of different indirect/non-invasive geophysical methods is the best practice approach. In this paper we present the results of an integrated geophysical survey at "Il Piano" (Elba Island – Italy), where at least nine sinkholes occurred between 2008 and 2014. 120 single-station seismic noise measures, 17 3D electrical tomographies (min area 140.3 m2, max area 10,188.9 m2; min electrode spacing 2 m, max electrode spacing 5 m), 964 measurement of microgravity spaced in a grid of 6 m to 8 m were carried out at the study area. The most likely origin for these sinkholes was considered related to sediment net erosion from the alluvium, caused by downward water circulation between aquifers. Therefore, the goals of the study were: i) obtaining a suitable geological and hydrogeological model of the area; ii) detecting possible cavities which could evolve in sinkholes, and finally iii) assess the sinkhole susceptibility of the area. Among the results of the integrated geophysical survey: a) the H/V method allowed to estimate the mean thickness of the alluvium; b) the 3D-ERTs permitted to characterise the electrical behaviour of the materials; and c) the microgravity provided suitable information on the spatial distribution of lower density materials that according to the resistivity values, are lenticular sand and gravel bodies, within a sandy silt layer. The integrated geophysical surveys, joined to an accurate historical reconstruction of the development and environmental transformation of the area, and a geomorphological and hydrogeological characterization of the area allowed the collection of a large amount of data. Such data make possible to interpret the trigger of sinkhole phenomena, and draw a zonation of the sinkhole prone areas: during heavy rain events the inner flow regime may switch from laminar to turbulent and thus be able to erode and transport fine sediment within the lenticular bodies. The removal of the finest sediments increases the permeability of the body, producing macroscopic voids. Therefore, this study shows that the main source of sinkhole at "Il Piano" is related to the removal of fine-grained material, and also to the human activities (e.g., new buildings, infiltration, changes in groundwater pumping and in the sub-superficial hydrological system) that could influence the formation or the re-activation of sinkholes at the surface.