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Marco ANZIDEI [1], Giovanni SCICCHITANO [2*], Sebastiano TARASCIO [2], Giorgio DE GUIDI [3], Carmelo MONACO [3], Giovanni BARRECA [3], Gianfranco MAZZA [4] Enrico SERPELLONI [1] & Antonio VECCHIO [5]

COASTAL RETREAT AND MARINE FLOODING SCENARIO FOR 2100: A CASE STUDY ALONG THE COAST OF MADDALENA PENINSULA (SOUTHEASTERN SICILY)

Abstract: Anzidei M., Scicchitano G., Tarascio S., De Guidi G., Monaco C., Barreca G., Mazza G., Serpelloni E. & Vecchio A., *Coastal retreat and marine flooding scenario for 2100: a case study along the coast of Maddalena Peninsula (southeastern Sicily).* (IT ISSN 0391-9838, 2018).

The coastal area of southeastern Sicily (Italy) is undergoing weak land subsidence, heavy coastal retreat, land flooding and exposed to severe storms associated with high-waves, also in consequence of the global sea level rise, which is expected to raise even more that 1 m by 2100 AD depending on different estimates. This value will be even larger in subsiding coasts, entailing widespread environmental changes, coastal retreat, marine flooding and loss of land, which will be subtracted to human activities.

To understand the impact of rising sea level on the coast of Maddalena Peninsula, near the town of Siracusa, we realized a very high resolution Digital Terrain Model (DTM) through aerial photogrammetric surveys, obtained by Unmanned Aerial Vehicles (UAV) on which we projected the expected coastline for 2100 AD.

Here we show a detailed marine flooding scenario for 2100, as generated from: i) high resolution DTM, ii) rate of land subsidence from GPS data and iii) predicted sea level projections from the IPCC AR5 reports (RCP2.6 and RCP8.5). Our analysis estimates a maximum relative sea level rise at 0.20 m and 0.65 m for 2050 AD and 2100 AD, respectively for AR 8.5 scenario. The increased sea levels will cause relevant morphological changes to the investigated coast with a maximum beach retreat of 27 m and a loss of land of 7400 m^2, affecting building integrity and people safety.

Key words: Sea level rise, vertical land motion, flooding scenario 2100 AD, UAV, Sicily

Riassunto: Anzidei M., Scicchitano G., Tarascio S., De Guidi G., Monaco C., Barreca G., Mazza G., Serpelloni E. & Vecchio A., *Scenario di regressione costiera e sommersione marina per il 2100: il caso di studio lungo la costa della Penisola della Maddalena (Sicilia sud-orientale).* (IT ISSN 0391-9838, 2018).

L'area costiera della Sicilia sudorientale è attualmente soggetta ad una debole subsidenza, insieme ad un pesante arretramento della linea di riva e ad un'alta vulnerabilità all'impatto di forti mareggiate. Tutto ciò anche in conseguenza del costante innalzamento del livello del mare che si stima crescerà fino ad 1 m al 2100. Per comprendere l'effetto del sollevamento del livello del mare atteso per la costa della Penisola della Maddalena, vicino la Città di Siracusa, abbiamo realizzato un Modello Digitale del terreno (DTM) ad altissima risoluzione, utilizzando tecniche aerofotogrammetriche con Sistemi Aerei a Pilotaggio Remoto (SAPR), sul quale abbiamo opportunamente applicato il sollevamento del livello del mare previsto. Presentiamo gli scenari dettagliati di sommersione al 2100 generati utilizzando: 1) DTM ad alta risoluzione, 2) tassi di subsidenza da dati GPS e 3) Proiezioni di sollevamento del livello del mare emessi dall'IPCC AR5 reports (RCP2.6 and RCP8.5). Le nostre analisi stimano un aumento del livello del mare tra 0.2 m e 0.65 m al 2050 e 2100, rispettivamente. L'aumento del livello del mare potrebbe indurre significativi cambiamenti morfologici alle aree costiere investigate con un massimo arretramento della costa fino a 27 m e con una perdita di 7400 m^2 di terre emerse e conseguenti danneggiamenti a edifici e messa a rischio delle persone.

Termini chiave: innalzamento del livello del mare, movimenti terrestri verticali, scenario 2100 AD di sommersione, UAV.

[1] *Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy*
[2] *Studio Geologi Associati T.S.T., Via Galliano 157, Misterbianco (CT), Italy*
[3] *Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Università di Catania, Italy*
[4] *Area Marina Protetta del Plemmirio, Siracusa, Italy*
[5] *LESIA-Observatoire de Paris, PSL Research University, Paris, France*

* *Corresponding author: Giovanni Scicchitano, scicchitano@studiogeologitst.com*

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INTRODUCTION

The coastal area of Maddalena Peninsula, located in southeastern Sicily (fig. 1), is undergoing intense coastal

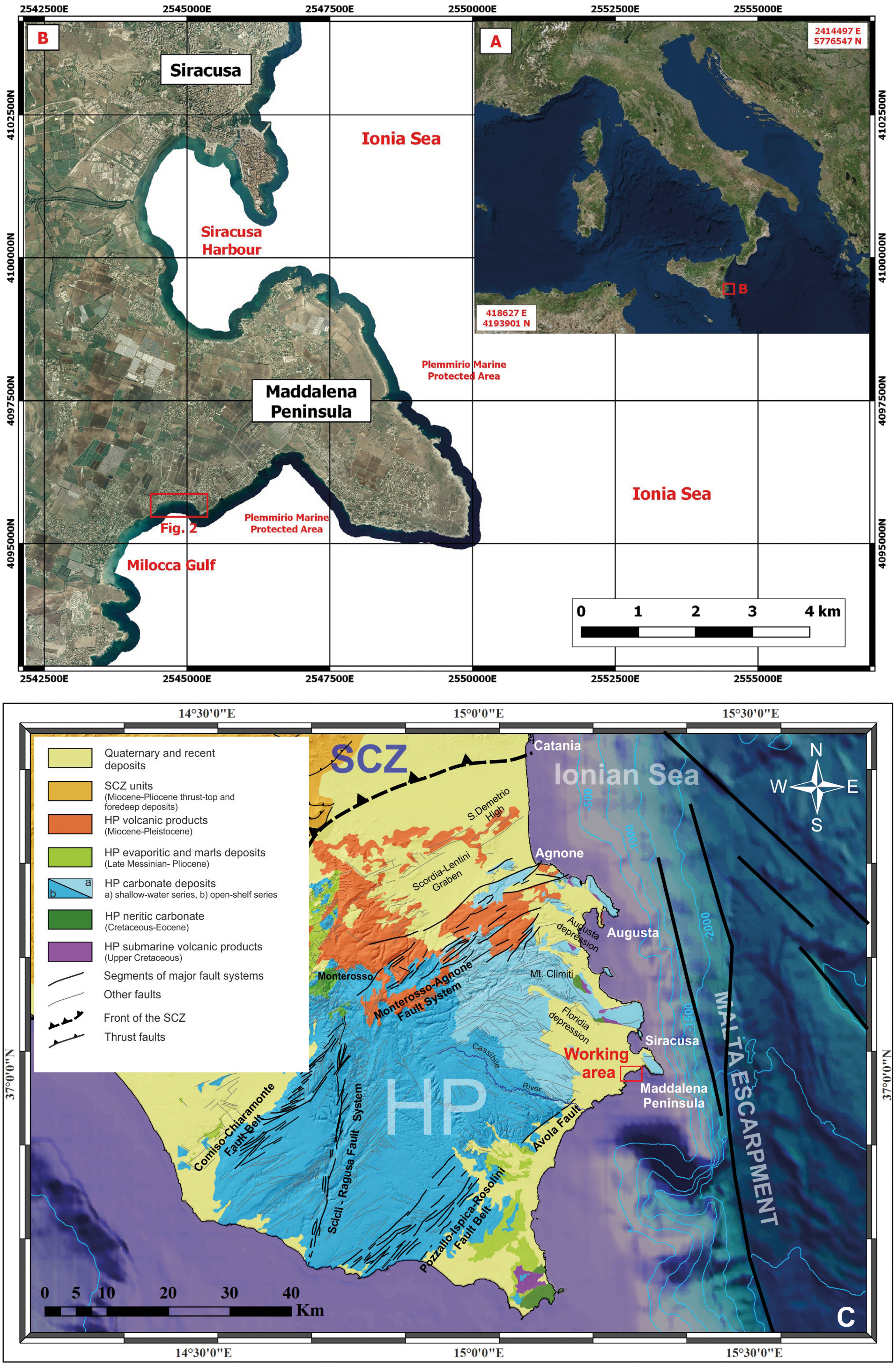

FIG. 1 - A) Map of Italy with B) the location of the Maddalena Peninsula and the investigated area (red rectangle); C) Seismotectonic and geological features of South-eastern Sicily (HP=Hyblean Plateau, SCZ=Sicilian Collision Zone).

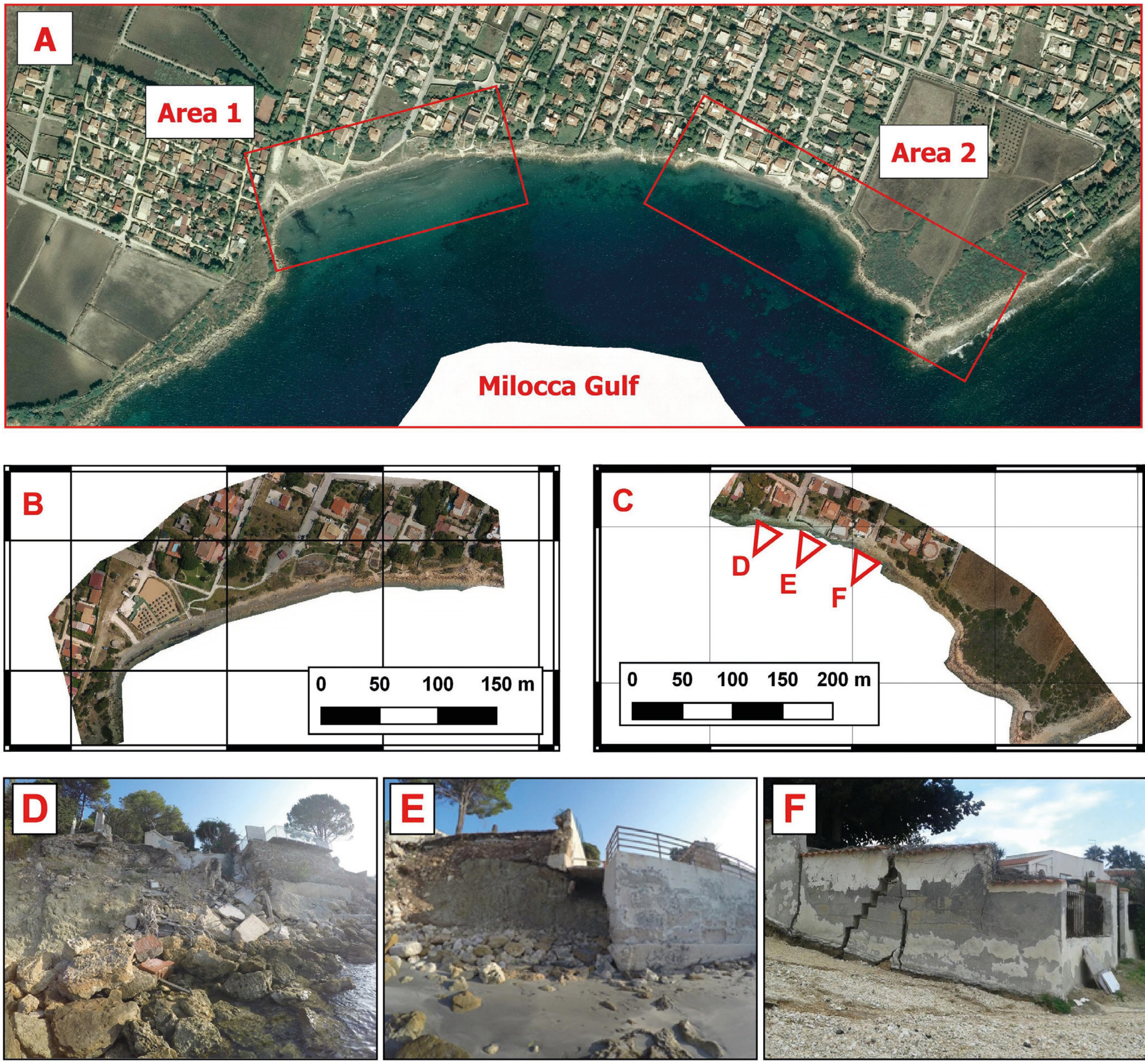

Fig. 2 - A) UAV survey area; B) Area 1; C) Area 2; D) Collapsed houses along the shoreline; E and F) Details of the collapses caused by coastal erosion.

erosion since the beginning of this century. In consequence of this phenomenon, beaches have severely retreated and almost disappeared while storm waves have increased their impacts on the coast. This results in an accelerating erosion of the cliffs on which are standing building and infrastructures since the beginning of 1970. We focus on two tiny areas that stretch for about 2 km along the coast of Milocca Gulf, in the Plemmirio Marine Protected Area, where several houses and the coastal road have been damaged and part of them collapsed on the coast (fig. 2). Based on the climatic scenarios provided by the IPCC AR5 Report, that estimate a sea level rise close to 1 m by the year 2100 AD (IPCC, 2014) or more, depending on different estimates (Arns & *alii*, 2017; Rahmstorf, 2007), this area will be severely exposed to marine flooding and erosion in the next years, like elsewhere in Italy (Antonioli & *alii*, 2017; Anzidei & *alii*, 2017; Mastronuzzi & *alii*, 2017).

High resolution Digital Elevation Models (DEM), represent a main tool for hazards analysis and landscape morphology evolution. During the past years DEMs have been traditionally generated by aerial photogrammetric surveys from aircrafts, providing accurate but high cost results. The recent developments of ultra-light Unmanned Aerial Vehicles (UAV) open new opportunities on the acquisition of high resolution topographic data from low altitude flights. Therefore, acquisition and mapping activities are more cost effective compared to traditional aerial vehicles for airborne based surveys. In order to apply the IPCC scenarios to this coastal area, adjusted for local land subsidence, we conducted aerial photogrammetric surveys by Unmanned Aerial Vehicles (UAV). To calibrate the aerial surveys and reconstruct a very high resolution Digital Elevation Model (DEM), were also measured a number of Ground Control Points (GCPs) by GPS/RTK technique. To account for a realistic flooding scenario, we included in the analysis the vertical land movements that affect this area by using long term estimates from geological records (MIS 5e) and instrumental data from geodetic estimates obtained from available GPS stations located in the investigated area. We also included in the analysis the Glacial Isostatic Adjustment (GIA) contribution from Lambeck & *alii* (2011) and Peltier (2004) models. Finally, we provided a flooding scenario and extension of the beach retreat for 2100 AD for this coast.

GEOLOGICAL SETTING

Southeastern Sicily represents the emerged sector of a larger foreland domain of the Sicilian Collision Zone (Grasso & Lentini, 1982). This area, locally known as Hyblean Plateau (HP), is a fault-controlled rigid block formed by Mesozoic shallow to open-shelf carbonate sequences, thick a few thousand meters, with levels of volcanic products. Top-sequences consist of Quaternary series preserved at the edges of the HP mainly within fault-bounded extensional basins. As a whole, the HP represents the footwall-block of a large normal fault system located in the near-offshore of the Ionian Sea, the Malta Escarpment, which is a Mesozoic boundary originally separating the Hyblean continental domain from the oceanic crust of the Ionian basin (Scandone & *alii*, 1981; Sartori & *alii*, 1991; Hirn & *alii*, 1997). The HP is also internally deformed by variously oriented extensional fault systems, the major of these are NE-SW trending and bordering the HP to the north and south respectively. Further, minor fault arrays trending NW-SE occur in between the major ones along the eastern part of the HP and consist of normal faults generally forming horst and graben associations (e.g. Cultrera & *alii*, 2015). Among these the Floridia Graben, where the study area is located, consists of a ~10 km-wide, NW-SE striking structural depression filled by Quaternary clayey and clastic sediments (fig. 1C).

The occurrence of several orders of middle–upper Pleistocene marine terraces and palaeoshorelines (Di Grande & Raimondo, 1982; Bianca & *alii*, 1999), located above and under sea level (Scicchitano & Monaco, 2006), witness that HP is a tectonically active region that experienced vertical land motion and sea level changes. Flights of marine terraces along the eastern coastal domain of the HP generally indicate a non-homogenous uplift rate in the area (e.g. between Augusta and Siracusa) with a regional signal progressively decreasing toward the south (Ferranti & *alii*, 2006; 2010). The elevation of the marine terraces support long-term uplift rates at ~0.4 mm a^{-1} in the last 400 ka for the area of Siracusa (Dutton & *alii*, 2009) whilst recent studies on coastal archaeological sites located between Augusta and Siracusa, proposed an uplift rate of the same order also for the Holocene (Scicchitano & *alii*, 2008; 2017). Similar rates are also inferred from borehole data collected between Siracusa and Marzamemi (Spampinato & *alii*, 2011).

This value compared with the sea level rise during the Holocene (Lambeck & *alii*, 2011 and references therein), resulted into marine ingression in the area that together with anthropogenic and natural contributes (i.e. anthropic morphological variations, decrease of continental sediments supply, tectonic subsidence and increasing of storm surges), caused coastal retreat and erosion along cliffs of Maddalena Peninsula and the Floridia Graben, south of Siracusa.

During the last 124 ka BP, this coast has been tectonically stable along the vertical as inferred from the elevation of the MIS 5.5 terraces but lightly uplifting in the Holocene. Anyway, during the last decades GPS data and GIA models indicate a current weak subsidence at rates close to 1 mm a^{-1}. This is relevant considering that the area is undergoing to a heavy coastal retreat and exposed to severe storms associated with high-waves, also in consequence of the global sea level rise (Le Cozannet & *alii*, 2017; Arnell & *alii*, 2015).

METHOD

We applied a multidisciplinary approach using coastal topography, geodesy and sea-level rise estimates to provide relative sea level-rise projections and maps of flooding scenarios for the coast between Plemmirio and Ognina, to the year 2100 AD. Our approach consists in three main steps: 1) realization of a DTM by UAV surveys, to obtain an ultra-high-resolution 3D model of the coastal area and coastline position; 2) estimate the rates of vertical land movements from the analysis of local geodetic CGPS network; 3) combine these data with the regional IPCC-AR5 projections using two Representative Concentration Pathways (RCPs): the stringent mitigation scenario RCP2.6 and the scenario with very high anthropogenic greenhouse gas (GHG) emissions RCP8.5 (IPCC, 2014), to estimate upper bounds of the expected sea levels for 2100 AD for this area and the expected inland extent of related marine flooding. To define the retreat of the cliff, a diachronic analysis of coastline has been performed trough Remote Sensing and GIS analyses by means of aerial photos provided by the Italian Military Geographic Institute (IGMI) for 1955 and 1986; IGMI maps (1970), regional technical maps (CTR) for 2008 and 2012; ortophotos provided by Regione Sicilia (2008, 2012), Google Earth Database (2001, 2002, 2003, 2004 epochs), UAV ortophotos (2015, 2016, 2017).

DIGITAL TERRAIN MODEL RECONSTRUCTION

The changes of a coastal area affected by sea level rise and erosion can be successfully evaluated by high-accuracy Digital Surface Models (DSM) and Digital Terrain Models

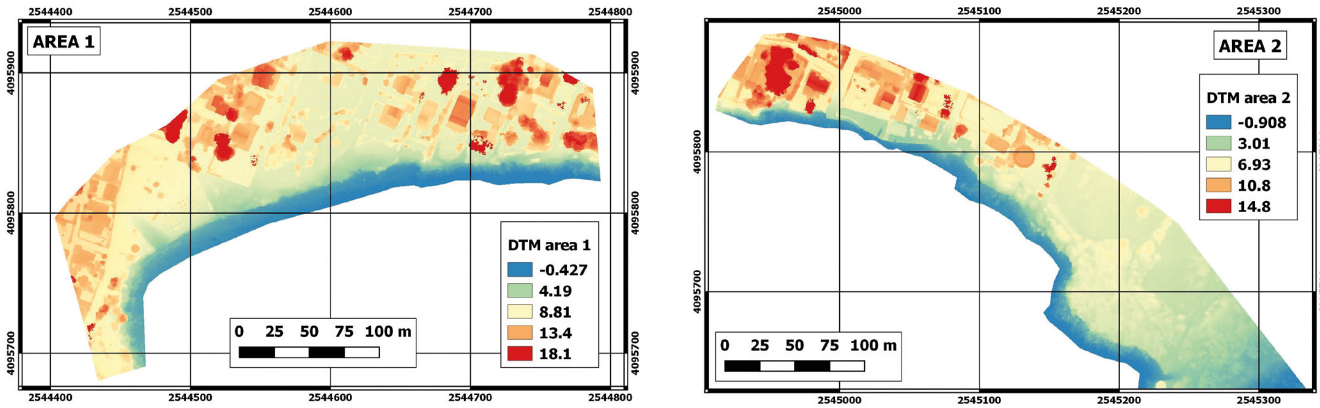

FIG. 3 - Reconstructed DTM of the study areas.

FIG. 4 - Position of the Ground Control Points (GCPs) measured in the investigated area.

(DTM). A DSM represents the Earth's surface and includes all natural or anthropic features on it, while a DTM represents only the ground surface without any features. Aerial photogrammetry is a powerful technique to produce DSM and DTM in different environments (Achilli & *alii*, 1998; Anzidei & *alii*, 2017; James & Robson, 2012). To this goal, we used UAV for aerial photogrammetry to realize DSM/DTM of small areas at low costs and in short time. Images collected by UAV analyzed by Structure-from-Motion photogrammetry (SfM) technique, can provide high resolution and accurate three-dimensional spatial data. SfM employs overlapping images acquired from different viewpoints

(VPs) providing 3D reconstructions by automatically estimation of camera position and orientation even without the use of Ground Control Points (GCPs).

Based on this technique, we carried out UAV surveys on the coastal zone of Maddalena Peninsula (Siracusa, Sicily), on June 2016 and January 2017. Data have been collected by more than repeated 20 flights to provide very high-resolution digital models of land topography (fig. 3).

In this way, we obtained land topographical data co-registered and georeferenced into the same UTM (Zone 33) WGS84 projection frame. Shoreline position was determined at the time of the surveys by aerial photogrammetry. Then, it was relocated for the local mean sea-level using tidal data from the nearby station of Catania (www.mareografico.it).

The aerial photogrammetric surveys were performed using a radio-controlled multi-rotor Airvision NT 4C UAV system, equipped with a high resolution lightweight nadiral digital camera, to capture a set of multiangle images of the investigated area. The UAV was controlled by an autopilot system using waypoints previously planned on a Ground Control Station system. To optimize the photogrammetric spatial resolution and coverage of the surveyed area, a constant altitude of 70 m was maintained during the flight and 80% partly overlapping aerial digital photos were acquired. To scale the aerial images, we used a dual-frequency geodetic GPS receiver to measure the coordinates of a set of reference Ground Control Points (GCPs) falling in the investigated areas (fig. 4). GCPs positions were estimated in real time by the RTK technique with 1-2 cm accuracy, with respect to the reference GPS station.

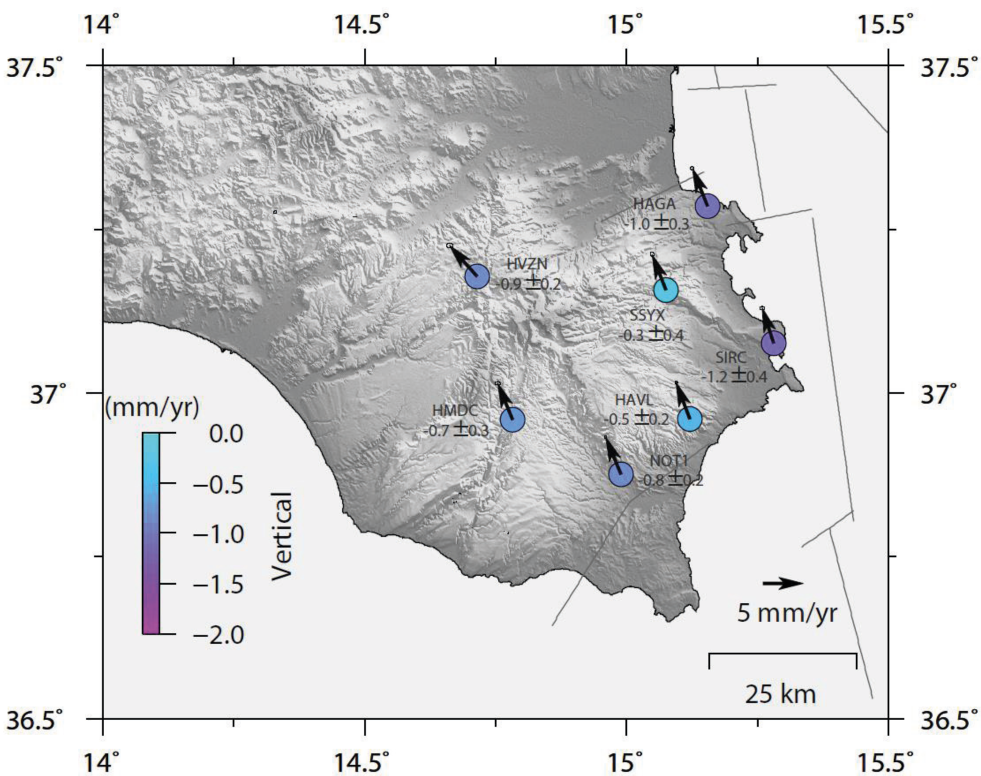

Fig. 5 - The CGPS stations belonging to the INGV-GNSS network, located in the surroundings of the studied area. Arrows are the horizontal motion at the individual stations, while in colour are the vertical velocities with related values and uncertainties (see color palette for scale).

Table 1 - Vertical rates of land movements from GPS data and isostatic models for the investigated area. See fig. 5 for location of the GNSS stations. The mean UP velocity is a subsidence at -0.77 ± 0.28 mm a^{-1}.

Current vertical rates of land movements				
Instrumental			Isostatic model	
CGPS station	GPS UP mm a^{-1}	Err GPS UP mm a^{-1}	ICE G5 mm a^{-1}	KL05 mm a^{-1}
HAGA	-1.0	± 0.3	-0.52	-1.01
HAVL	-0.5	± 0.2	-0.52	-1.02
SIRC	-1.2	± 0.4	-0.52	-1.01
HMDC	-0.7	± 0.3	-0.52	-1.01
HVNZ	-0.9	± 0.2	-0.52	-1.01
NOT1	-0.8	± 0.2	-0.52	-1.01
SSYX	-0.3	± 0.4	-0.52	-1.01

We used the Agisoft PhotoScan Pro software package (http://www.agisoft.com) based on the Structure-from-Motion photogrammetry technique (Ullman, 1979) to process the acquired georeferenced images. The analysis includes: (1) camera triangulation with image position and orientation; (2) generation of a dense points cloud and (3) generation of an orthomosaic photo and DSM extraction by GCPs. A mean dense cloud point separation at a resolution of 1.7 cm was achieved, with a mean error of 3.2 cm. DSM has been post-processed in order to remove vegetation, especially from the coastal area, and obtain a Digital Terrain Model on which apply the sea level rise prediction model.

RELATIVE SEA LEVEL RISE AND FLOODING SCENARIO FOR 2100 AD

To estimate the current vertical land movements, we analyzed the time series of GPS data collected in the time span 1995-2013 from the regional GNSS network. We focus on a set of seven GNSS closely spaced stations located nearby the coast of Maddalena Peninsula and Ognina (Avallone & *alii*, 2010; fig. 5). Data analysis was performed using the Gamit/GlobK software (Herring & *alii*, 2010) and included GPS observations from a set of GNSS stations belonging to the IGS network located in Eurasia. The vertical GPS velocities reveal mean values of land subsidence 0.77 ± 0.28 mm a^{-1} (table 1) that we selected as a representative rate of current land subsidence for this area. We remark that this rate occurs in the absence of significant seismic activity during the last two decades, although this area was struck by large earthquakes in the past centuries (Boschi & *alii*, 1995). In this period, the detected subsidence is dominated by the secular global glacio-hydro-isostatic signal, estimated in this region of the Mediterranean between 0.6 and 1.0 mm a^{-1} (Peltier, 2004; Lambeck & *alii*, 2011), and an eventual weak tectonic contribution (Serpelloni & *alii*, 2013). We also assume this rate of subsidence will remain unchanged up to 2100 AD, in the absence of additional episodes of land movement resulting from a possible reactivation of the tectonic structures and earthquakes with significant magnitude in the area. To estimate the sea level for 2100 AD, we use the regional sea level (SL) projections (spatial resolution: 1° x 1°) discussed in the Fifth Assessment Report

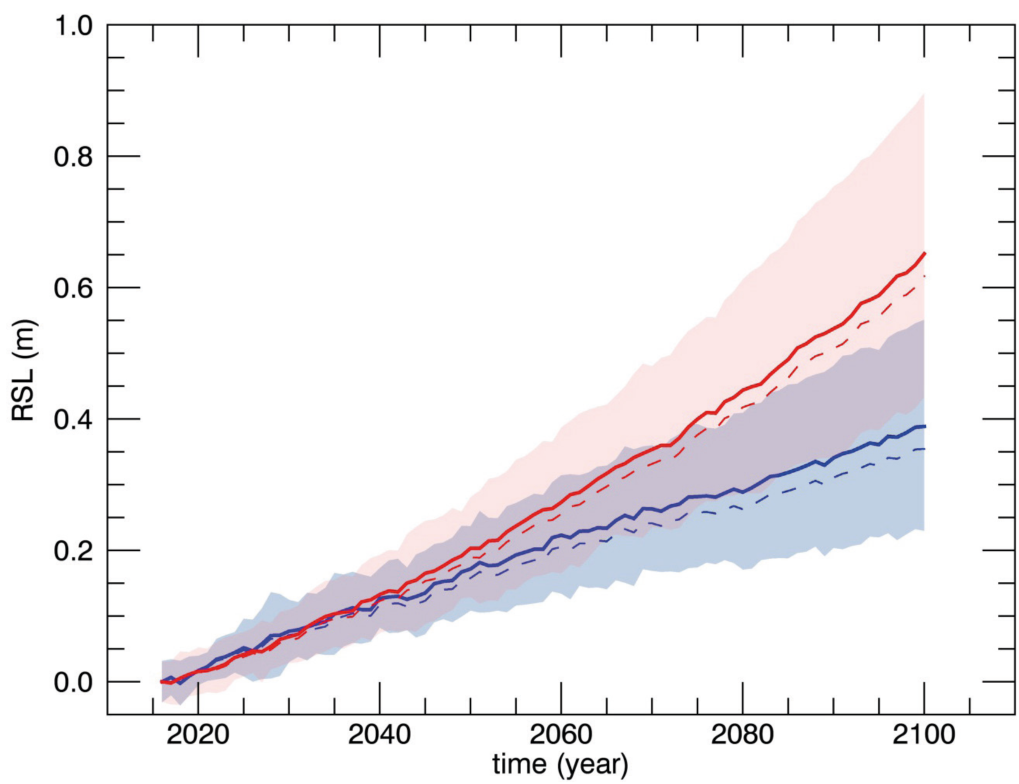

FIG. 6 - Sea level with respect to 2016 epoch, expected for 2100 at the coast between Ognina and Plemmirio, based on the regional IPCC AR5 sea level projections and land subsidence. Blue and red full lines indicate the IPCC sea surface height (SSH) projections, for RCP2.6 and 8.5 respectively, adjusted with the mean GPS rates of land subsidence at 0.77 ± 0.28 mm a^{-1}. Dotted lines correspond to the pure IPCC projections. Colour bands are the estimated uncertainties at 95% confidence level, obtained by combining lower and upper sea level bounds from IPCC projection with the uncertainty from GPS measurements of land subsidence.

Table 2: Amount of estimated subsidence and sea surface height at 2050 and 2100, with respect to 2016, expected at the coast between Ognina and Plemmirio, based on the regional IPCC AR5 sea level projections and land subsidence.

	Amount of land subsidence (m)	RCP 2.6 (m)	RCP 2.6 + land subsidence (m)	RCP 8.5 (m)	RCP 8.5 + land subsidence (m)
2050	0.026 ± 0.003	0.16 ± 0.06	0.17 ± 0.06	0.19 ± 0.07	0.20 ± 0.08
2100	0.065 ± 0.003	0.35 ± 0.15	0.39 ± 0.16	0.62 ± 0.23	0.65 ± 0.23

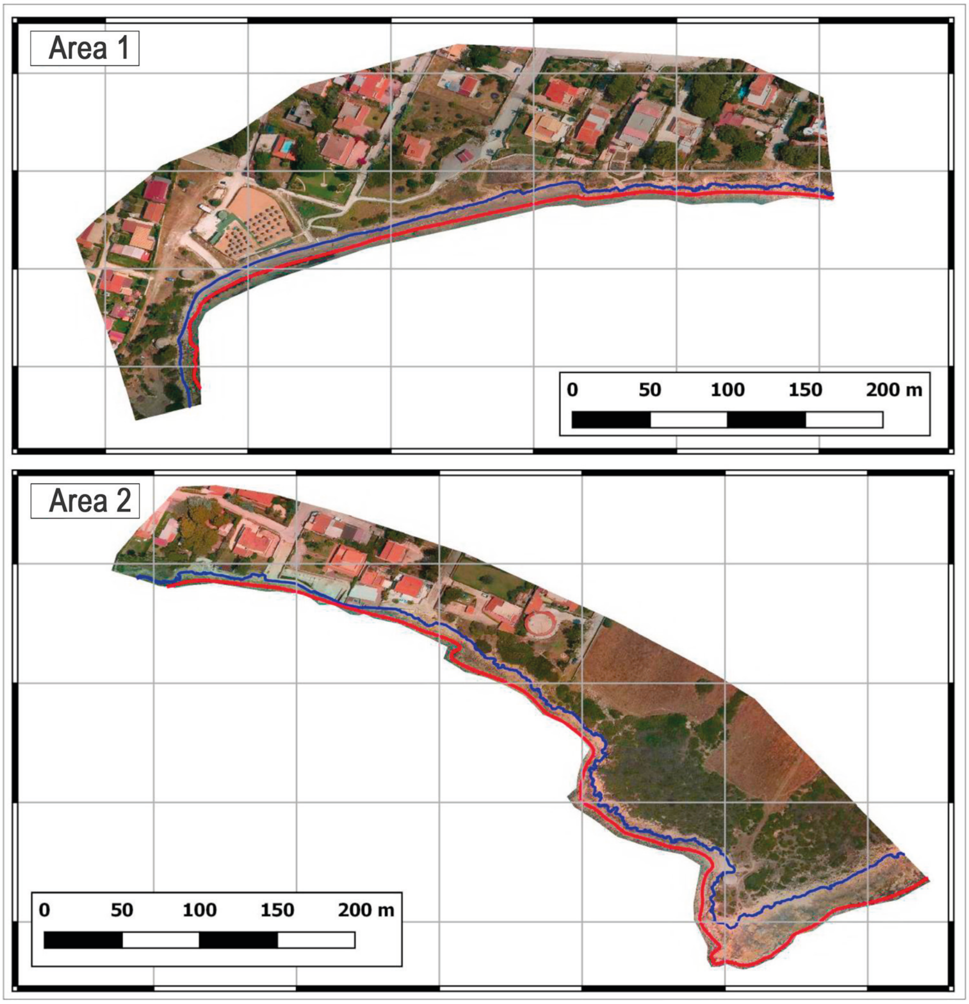

FIG. 7 - Flooding scenario for 2100 AD based on land subsidence estimated from GPS data and projections of sea level rise (RCP8.5 scenario). Red is the current coastline while in blue is the coastline expected for 2100 AD corresponding to a relative sea level rise at 0.65 m higher than 2016. About 7400 m^2 of loss of land is expected in about 2 km of coastline.

of the IPCC-AR5 (Church & *alii*, 2013a, b) and available from the Integrated Climate data Center-ICDC of the University of Hamburg (http://icdc.cen.uni-hamburg.de/1/daten/ocean/ar5-slr.html). These data consist of mean values and upper/lower confidence bounds of the SL obtained by adding the contributions from geophysical sources driving long term sea-level changes. These include the thermosteric/dynamic contribution, obtained from 21 Coupled Model Intercomparison Project Phase 5 (CMIP5) coupled atmosphere-ocean general circulation models (AOGCMs), the surface mass balance and dynamic ice sheet contributions from Greenland and Antarctica, the glacier and land water storage contributions, the glacial isostatic adjustment and the inverse barometer effect (Church & *alii*, 2013a, b).

We built up flooding scenarios for the coast of Plemmirio and Ognina in 2050 and 2100 AD by considering sea level projections based on two different Representative Concentration Pathways, RCP2.6 and RCP8.5 from IPCC AR5 (IPCC, 2014) regional projections have been re-evaluated, at the grid point centered at 15° 16' 40" E and 37° 00' 27" N, by using measured GPS rates to calculate a vertical contribution to sea level, that includes both GIA and subsidence.

Sea levels, relative to 2016 are shown in fig. 6, and corresponding values at 2050 and 2100 AD are reported in table 2. Uncertainties are expressed as the 95% confidence interval. The areal extent of the flooded land at 2100 for the RCP2.6 and RCP8.5 projections, correspond to a maximum relative sea-level rise of 0.39 ± 0.16 m and 0.65 ± 0.23 m for 2050 and 2100 AD, respectively. The position of the coastline in 2016 AD and in 2100 AD is shown in fig. 7. The limiting values of relative sea-level rise imply a maximum expected flooded land of about 7400 square meters, along a coastal strip about 1 km long.

Although the role and effects of waves on marine flooding are outside the scope of this study, we observe that storm waves approaching the coast from the east have major effects on the coast. With a sea-level rise of about 0.65 m, increasing wave energy along the coast is expected (Masselink & Hughes, 2003), leading to accelerated beach erosion and enhanced damage to buildings in the bay. Since flooded areas have been estimated with respect to the local mean sea level, during high tides or extreme waves from storms or tsunamis (Chiocci & *alii*, 2008), the flooding will temporarily affect further areas, exceeding those shown in fig. 7.

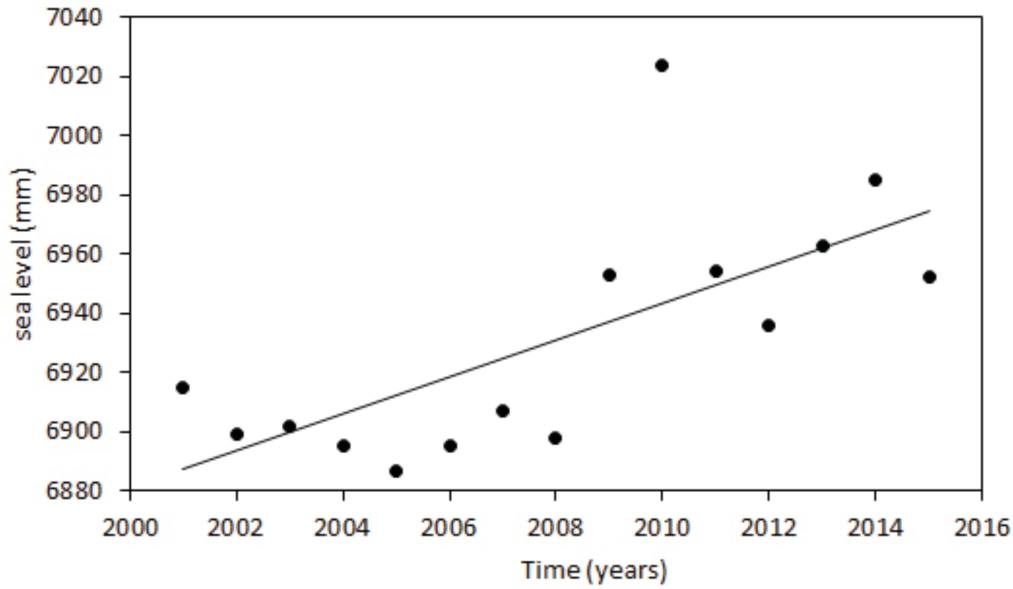

FIG. 8 - Data from tide gauge of Catania, which is the nearest to the Maddalena Peninsula.

DISCUSSION

The investigated sector of southeastern Sicily is affected by relative sea level rise since the last 2100 ± 100 years as inferred by the submerged Roman-Greek constructions of Ognina, presently located at 1.3 ± 0.2 m below sea level (Scicchitano & *alii*, 2008). Between 2001 and 2106, the tide gauge of Catania, which is the nearest to the Maddalena Peninsula, shows a trend at 6.2 ± 2 mm a^{-1}, (fig. 8), that exceeds, the mean rate of sea-level rise for the Mediterranean Sea estimated at ~1.8 mm a^{-1} for the last two-three centuries (Woppelmann & Marcos, 2012; Anzidei & *alii*, 2014). Based on these data it is worth noting that sea level behaviour for this region is of a continuous rise, although the time series of tidal data for the station of Catania is still too short to provide a robust estimation of the current sea level trend.

Based on these observations, the severe coastal erosion and beach retreat affecting since 1986 the southern coasts of Maddalena Peninsula can be then addressed to sea level rise, also in combination with the reduced transport of continental sediments by the river that exit near Ognina Promontory.

Between the end of 1800 and the first half of 1900, the course of the Ognina river was intercepted and its mouth shifted about 5 km northwards. The new course of the river was object of intense exploitation for agricultural, civil and industrial purposes. By the end of 1970 its mouth completely disconnected from the sea, with the exception of alluvial events that occur with a return period of about 2 or 3 years. For this reason, the nearby coastal system has not been fed anymore by continental sediments, thus leading to the progressive reduction of the pocket beaches and the increasing erosion of cliff, dunes, and beaches (fig. 9).

The southern coasts of Maddalena Peninsula show Late Pleistocene calcarenites up to 10 m thick, gently sloping seaward standing on Pleistocene silt and mud deposit up to 20-30 m thick. Where calcarenites and muds do not outcrop, the coastal retreat is mitigated and the erosion process is mainly related to the mechanical action of waves on the rocky cliff. Where the limit of calcarenites and muds outcrop, then the action of waves combined with sea level rise, become responsible of the intense erosion of muds that trigger the land fall of the above calcarenite blocks. Diachronic analysis of coastline show that this phenomenon was mitigated by 1980, due to the presence of pocket beaches that contributed to dissipate the wave energy before they get the base of the calcarenites, where Pleistocene clays occur. From a hydrological point of view a small river mouth is present along the coast located between the southeastern corner of Maddalena Peninsula and Ognina Promontory, although it is not natural. The analysis of ancient cartography (Spannocchi in 1578, Gambino 1890) and old aerial photos provided by the IGMI (1955, 1966, 1986, 1995) outlined as the natural course of a river was intercepted (likely in 1895 during the construction of the railway), and its mouth was shifted about 2 km north of the Ognina Promontory to the Arenella Promontory, inside the Mortellaro channel. Evidences of the presence of the river along the Ognina Promontory are reported in Scicchitano & *alii* (2010) who describe a deposit outcropping landward the present channel harbour, with a continuous marsh environment. The latter was dated by radiocarbon techniques between the early Roman Age and 1693 AD, when it was flooded by a tsunami related to the 1693 earthquake (Boschi & *alii*, 1995). Detailed morpho-bathymetric surveys (Scicchitano & *alii*, 2017) found new evidences of the river channel also in the tiny offshore of the Ognina Promontory. Here, was found the ancient river mouth at about 20 m below the present sea level, showing how the river should have been active since the beginning of the Holocene.

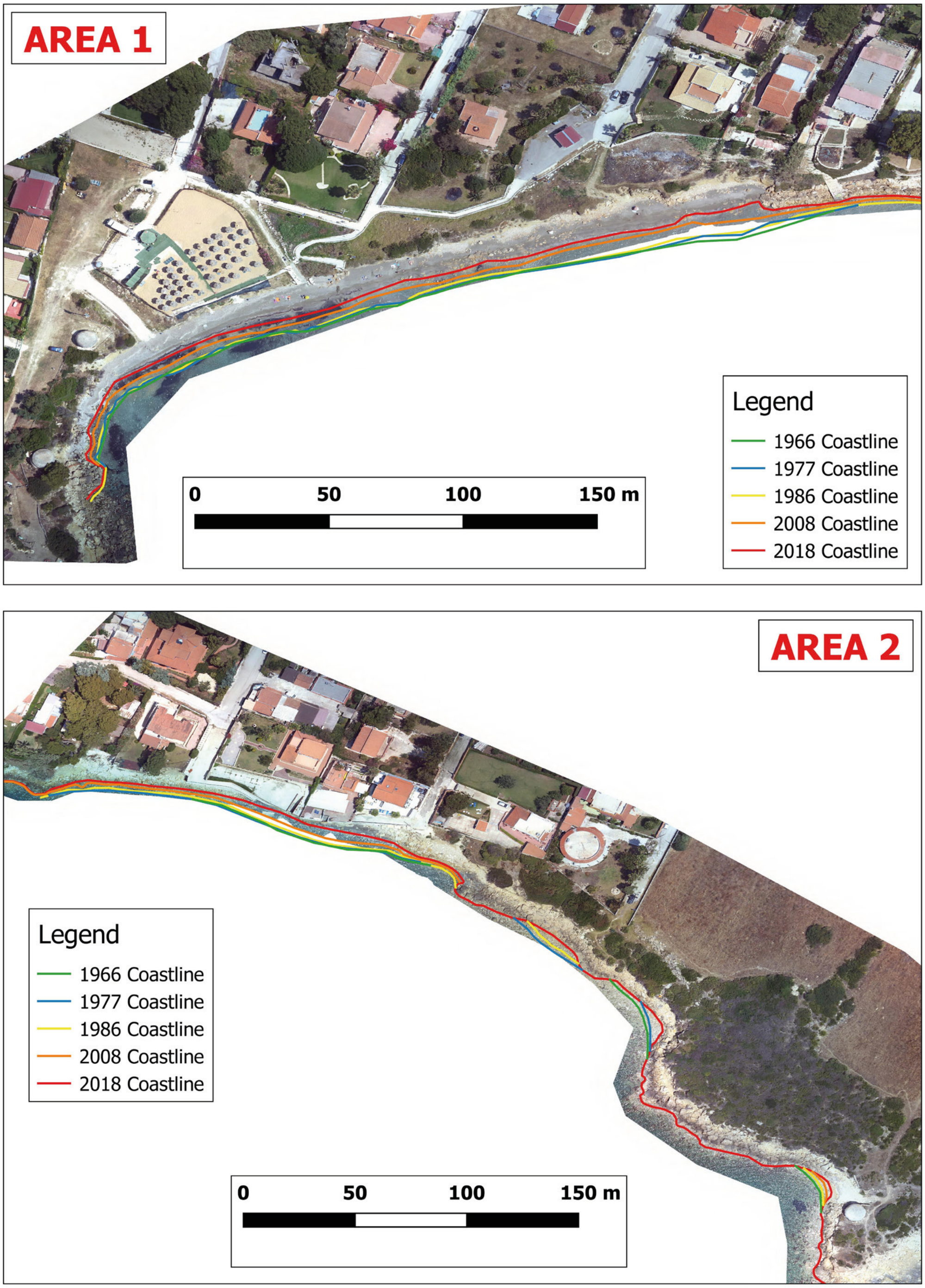

FIG. 9 - Diachronic analysis of the investigated area, with the coastline positions between 1966 and 2018. Data show the continuous retreat of the coastline in time.

The retreat of the coast implies a heavy erosional impact on the Pleistocene clays, triggering rock fall on the calcarenites lying at the top. Recently, rock falls are involving also house foundations and infrastructures with related hazards implications and people safety. In addition, sea level rise may induce the amplification of coastal protection systems (Arns & *alii*, 2017).

CONCLUSIONS

The realistic high-resolution flooding scenario for 2100 AD for the investigated area is caused by the combined effects of regional land subsidence and sea level rise as consequence of climate change.

The relative sea level rise projection by 2100 AD for the coast of the Maddalena Peninsula (Siracusa, Sicily), shows that this area could be largely flooded by sea up to 0.65 m above the 2016 mean sea level. The possibility of having a very high resolution DTM, allowed to estimate the extension of the interested area, corresponding to a potential loss of land of 7400 m^2 and a maximum beach retreat of 27 m. Our scenario does not consider the still unknown process of sediment transport that may contribute to slightly increase or reduce the flooded area.

For the above reasons, this area is highly prone to be affected by severe environmental impacts and loss of economic value. Although in this zone the low rates of land subsidence are not critical for relative sea-level rise, they can be roughly estimated at about 0.1% and 13% for the upper bounds of the IPCC-AR5 RCP2.6 and RCP8.5 scenarios, respectively.

Land planners and decision makers should take into account these scenarios for cognizant coastal management to protect coastal infrastructures and people living along these shores.

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