iSUB Gruppo Italiano Studio Subsidenza
Italian Working Group Land Subsidence

LaSII LAND SUBSIDENCE UNESCO

La Subsidenza in Italia: dal confronto tecnico scientifico alla creazione di un gruppo di lavoro (iSUB-I)
Padova, 17-18 Febbraio 2026

Modificazioni del Paesaggio, Architettura Stratigrafica e Subsidenza nella Pianura Alluvionale e Deltizio-Costiera del Fiume Volturno (Campania Settentrionale): Stato delle Conoscenze

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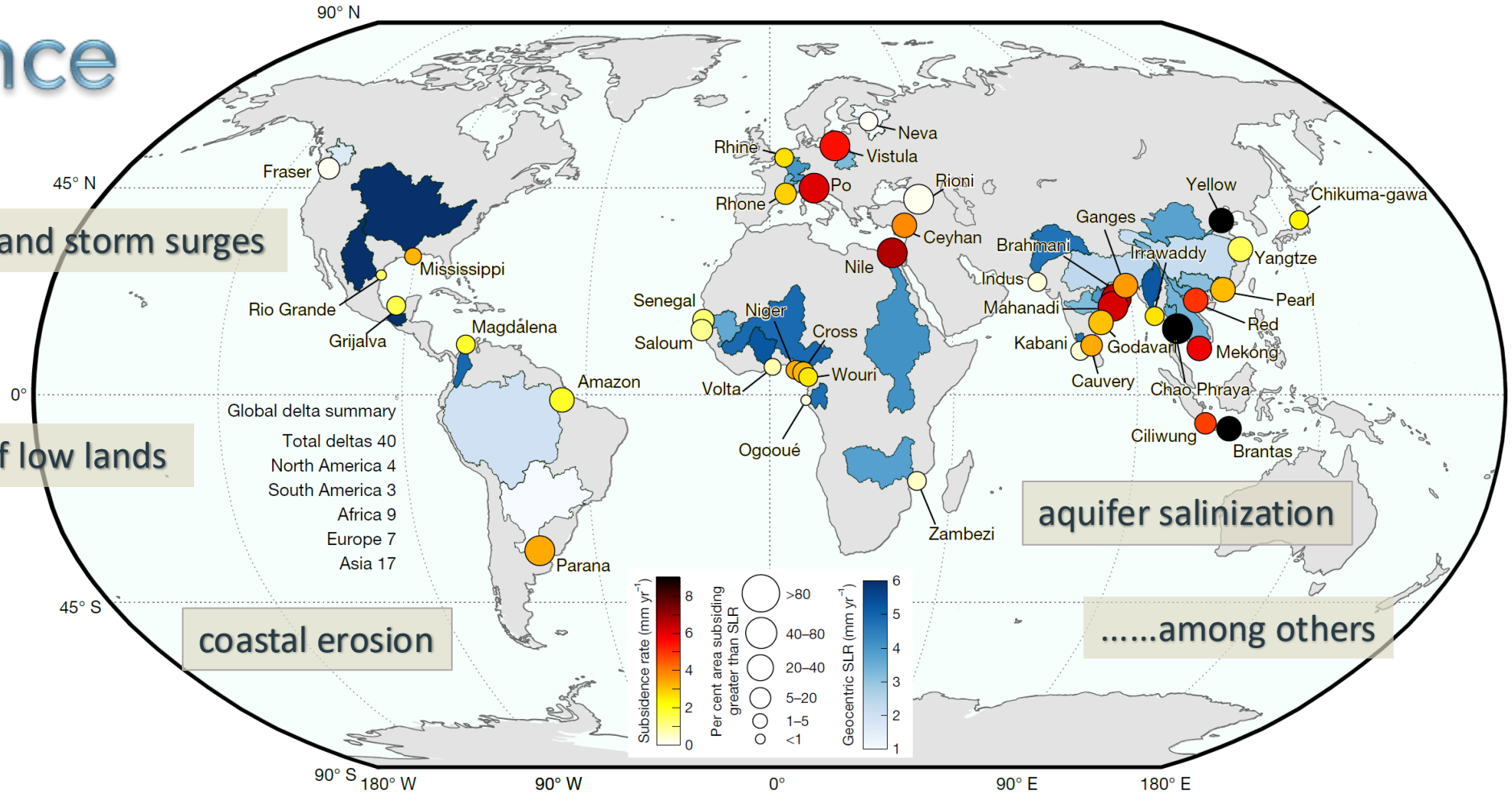
Subsidence

vulnerability to flooding and storm surges

inundation of low lands

coastal erosion



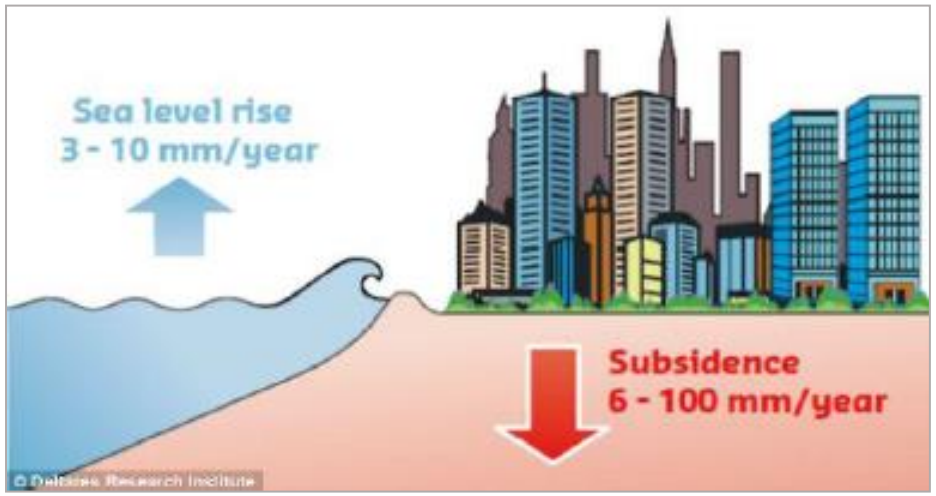
aquifer salinization

.....among others

Most of the world's major river deltas and related alluvial coastal plains are sinking due to both acceleration in global sea level rise and subsidence of human and natural origin.

Herrera-García et al., 2021. Science
Ohenhen et al., 2026, Nature

In exploring the potential drivers of subsidence, *over-exploitation of groundwater resources* was regarded as the major cause of this phenomenon.



Average SLR and land subsidence for a few coastal cities (after Deltares, 2016)

In spite of this, in coastal and delta areas subsidence can also have *natural causes* related to the natural compaction of alluvial/coastal plain deposits, mostly consisting of alternating layers of sand, clay and peat, still compacting under their own weight.

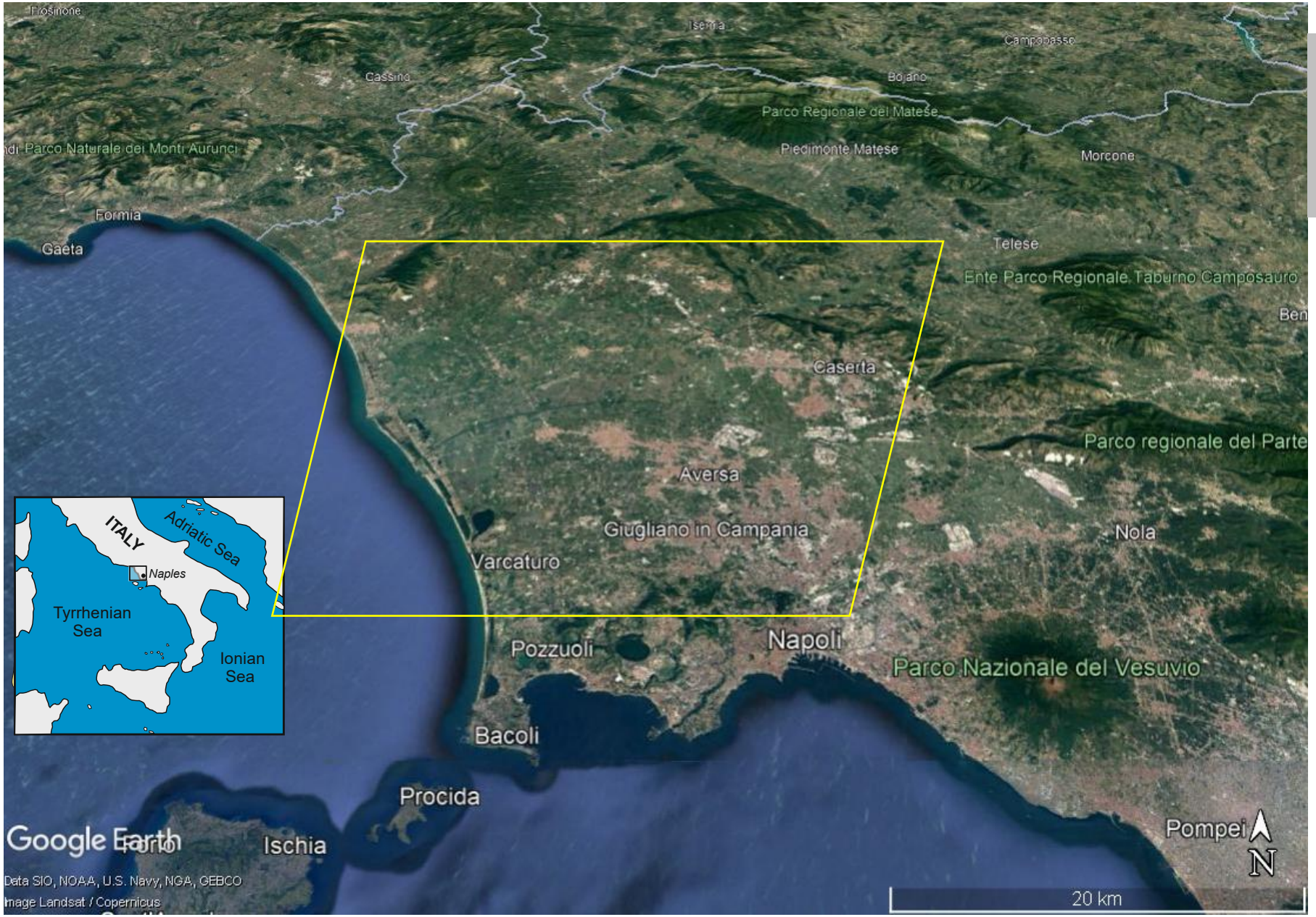
AIM OF THE RESEARCH

- Detect the major causes of the land subsidence in the Volturno River Plain

- Assess the contribution to land subsidence of:
  - the stratigraphic framework
  - the land use changes
  - reclamation

- Assess the major geomorphological modification in the deltaic-coastal area

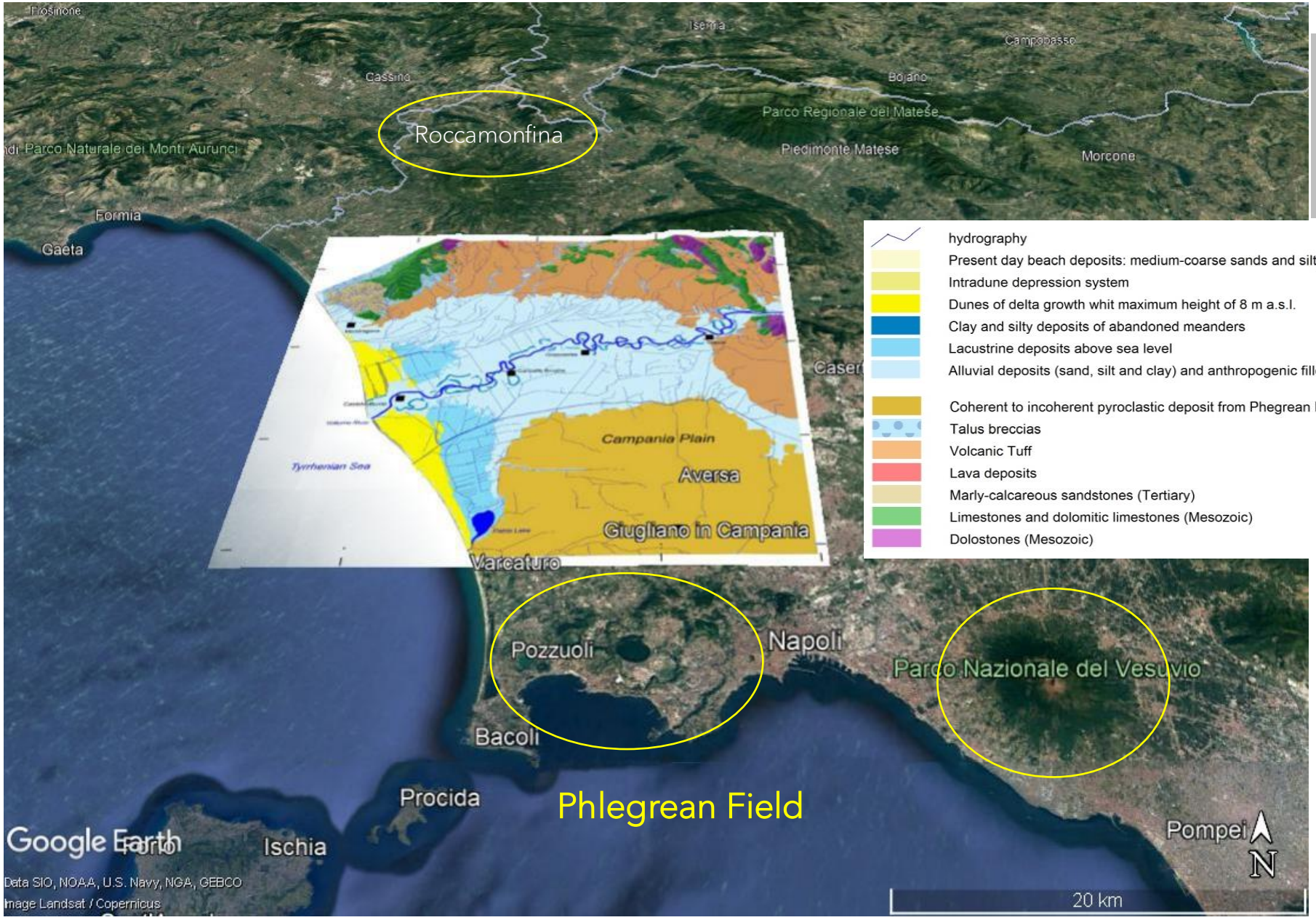
Geological setting



Southern Italy

Northern Campania

Geological setting



- hydrography
- Present day beach deposits: medium-coarse sands and silty sands
- Intradune depression system
- Dunes of delta growth whit maximum height of 8 m a.s.l.
- Clay and silty deposits of abandoned meanders
- Lacustrine deposits above sea level
- Alluvial deposits (sand, silt and clay) and anthropogenic filled deposits
- Coherent to incoherent pyroclastic deposit from Phegrean Fields
- Talus breccias
- Volcanic Tuff
- Lava deposits
- Marly-calcareous sandstones (Tertiary)
- Limestones and dolomitic limestones (Mesozoic)
- Dolostones (Mesozoic)

Southern Italy

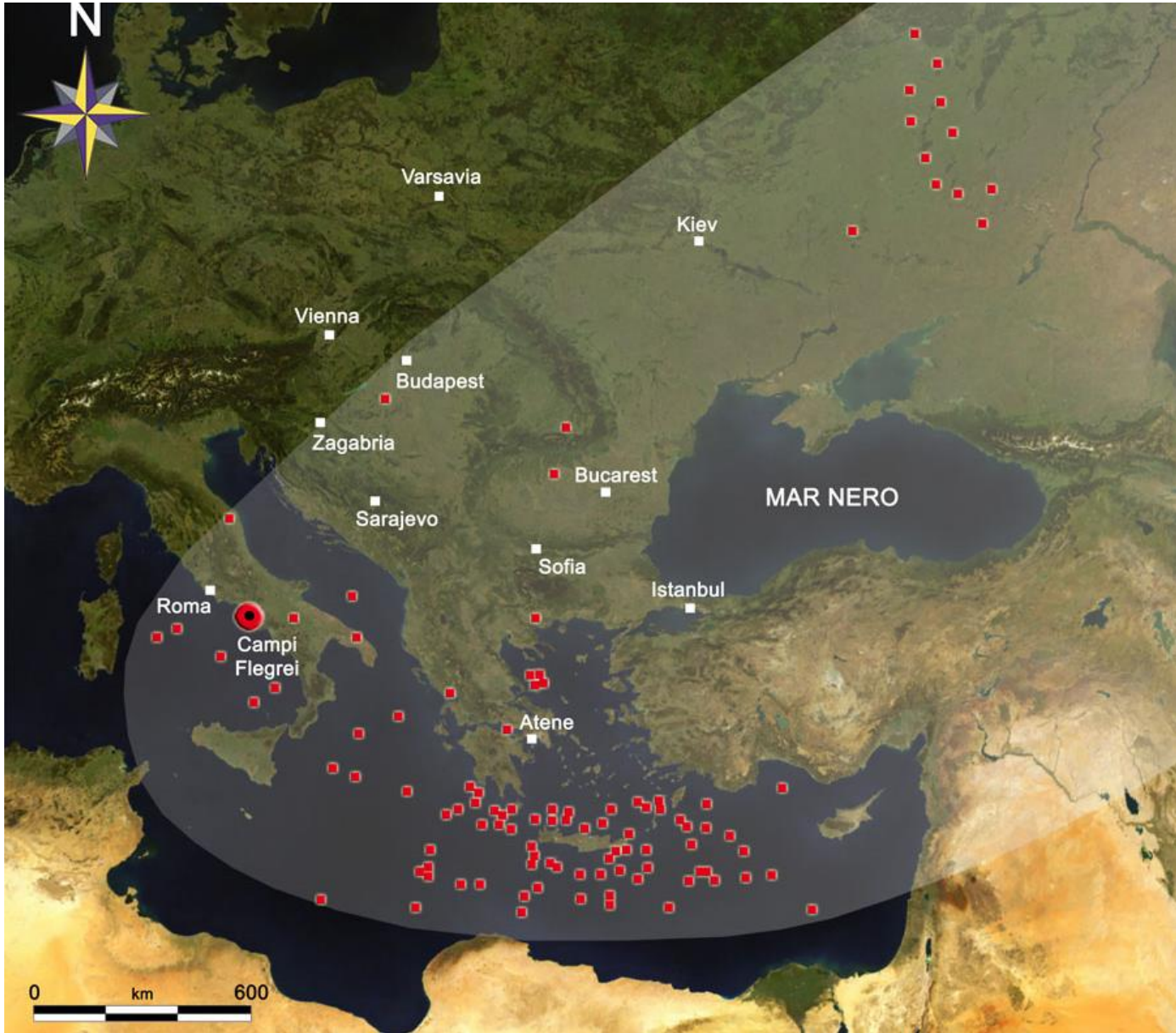
Northern Campania

STUDY AREA

During the eruption of the Phlegraean Fields – 39 ky:

- 50 km^3 of magma was released
- the ashes spread over an area of about 5 million km^2

Campania Ignimbrite

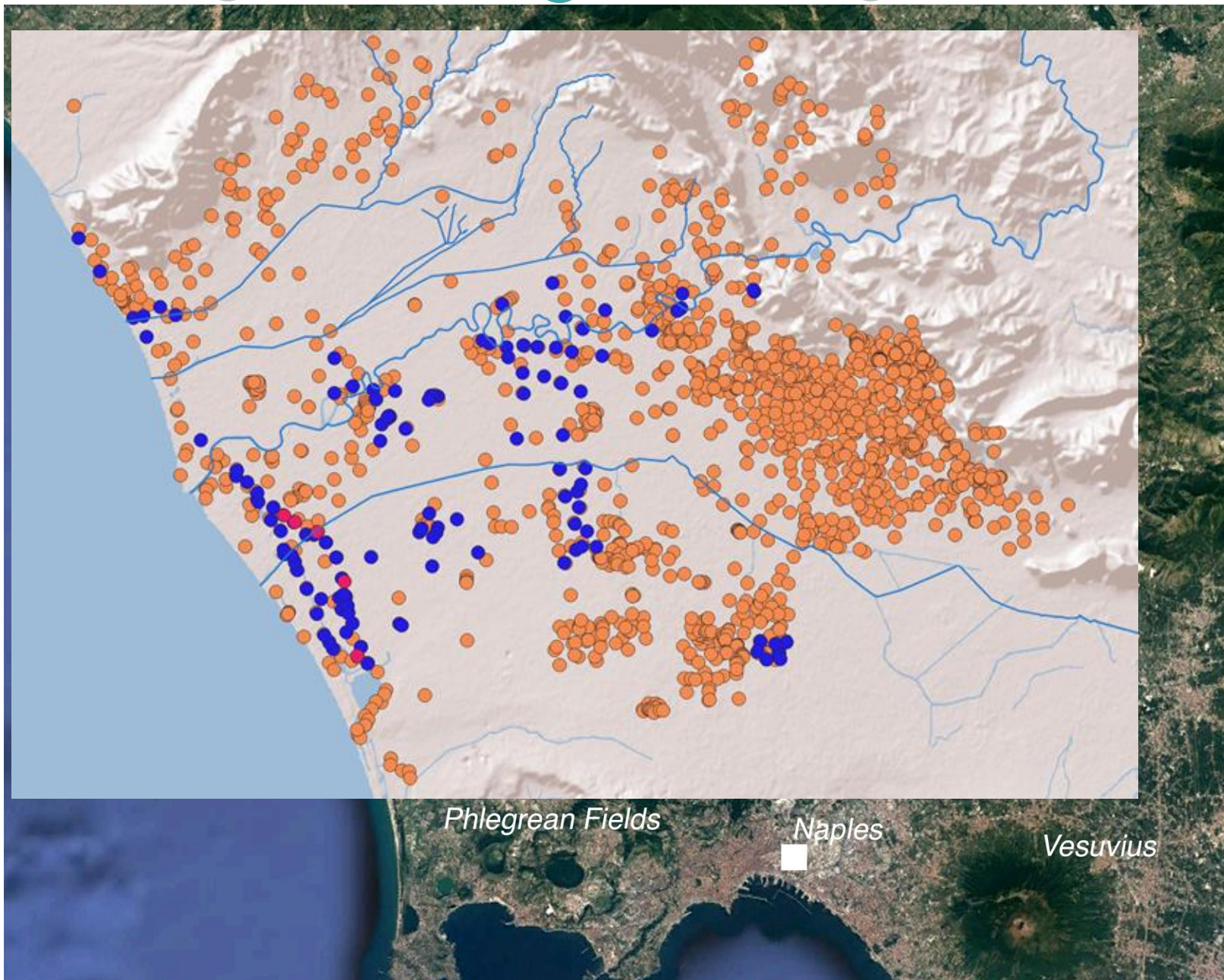


https://www.ov.ingv.it/

SUBSOIL DATA

- Boreholes
- Cone Penetration Test
- Cone Penetration with pore water pressure measurement

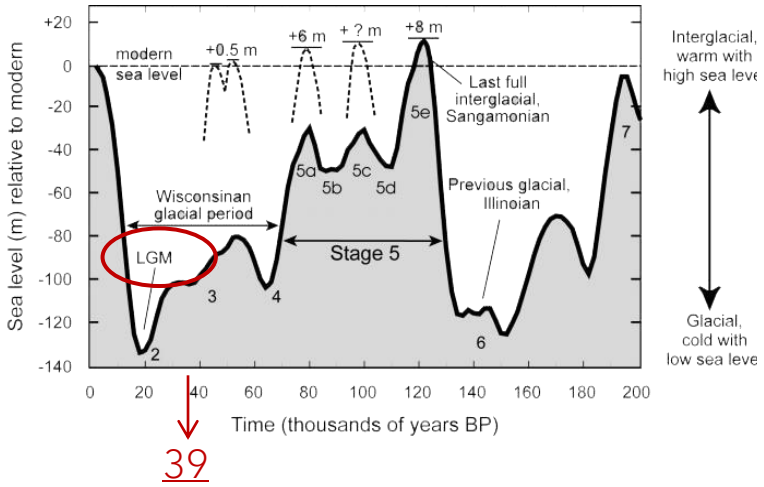
The data have been selected, interpreted, homogenized and georeferenced



CARTOGRAPHIC ANALYSES

TUFF SURFACE RECONSTRUCTION

A palaeovalley is recognized, about 15-20 km wide and up to 30 m deep



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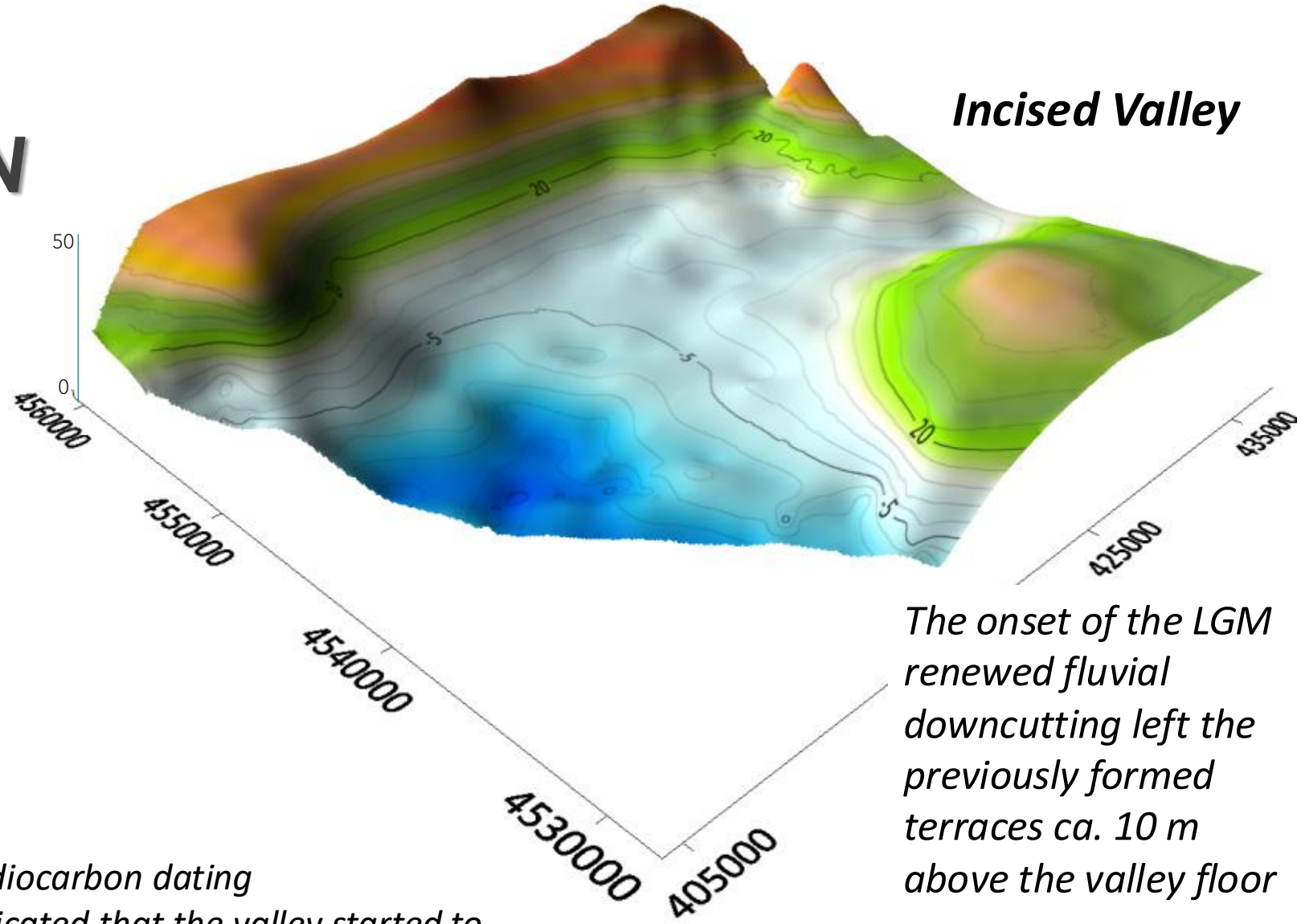
Campania Ignimbrite



Incised Valley

The onset of the LGM renewed fluvial downcutting left the previously formed terraces ca. 10 m above the valley floor

Radiocarbon dating indicated that the valley started to form at ca. 37 ka B.P.

Ruberti D. et al., 2022. Quaternary International.
Buffardi et al., 2025. Frontiers in Earth Sciences

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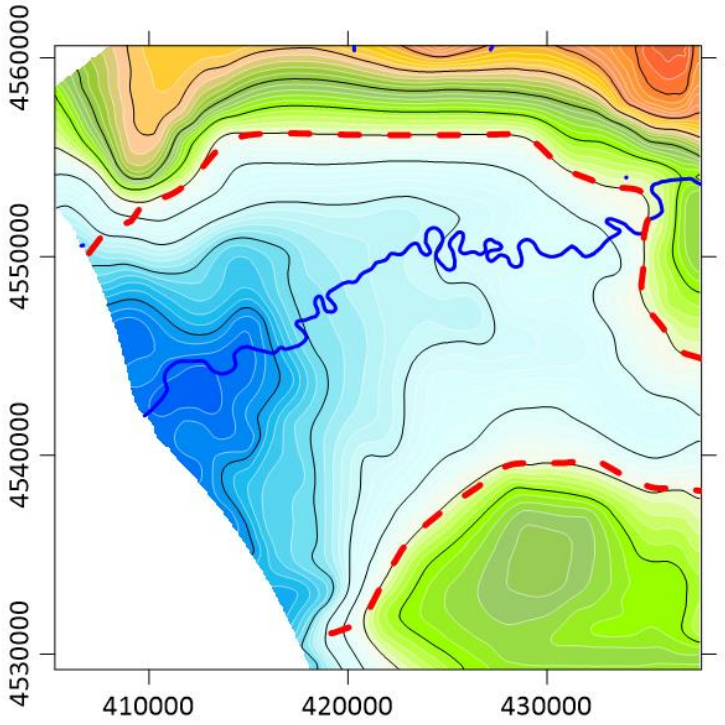

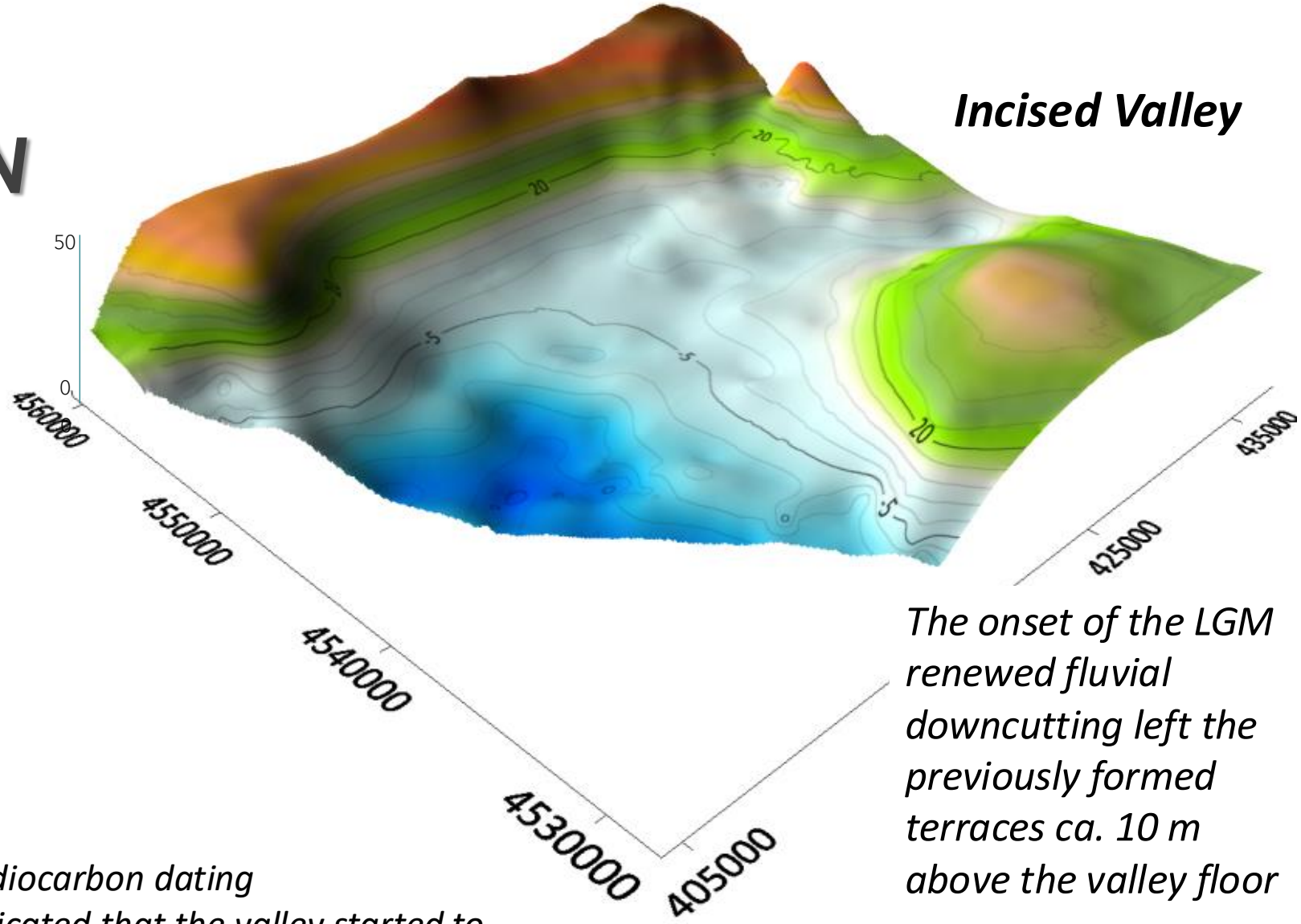

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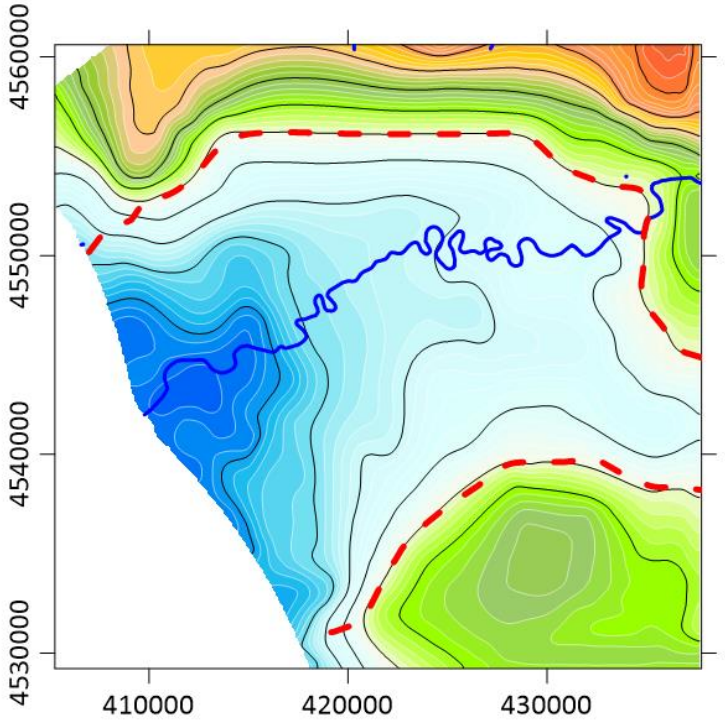

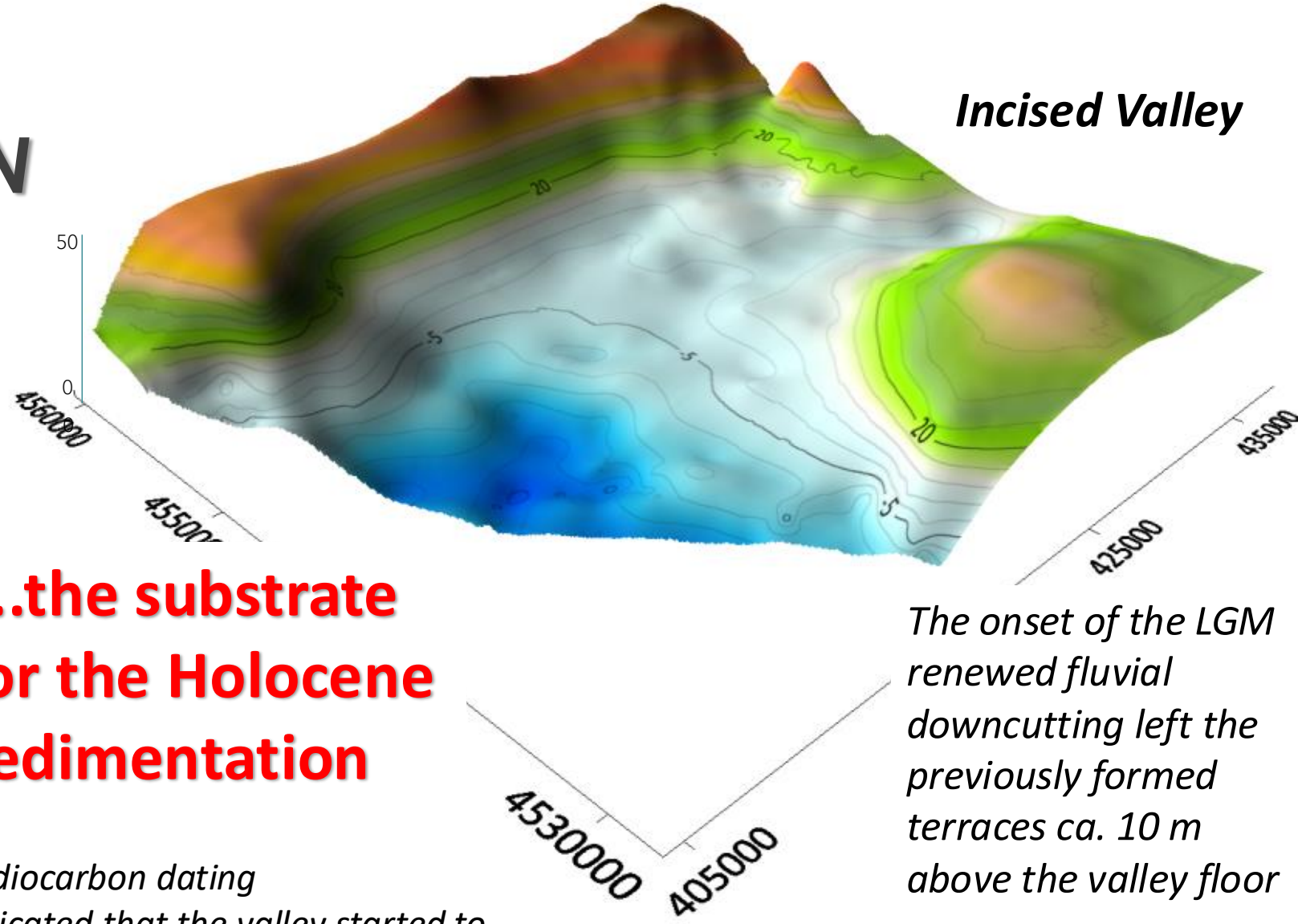

Incised Valley

….the substrate for the Holocene sedimentation

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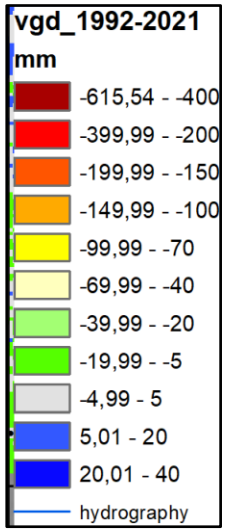
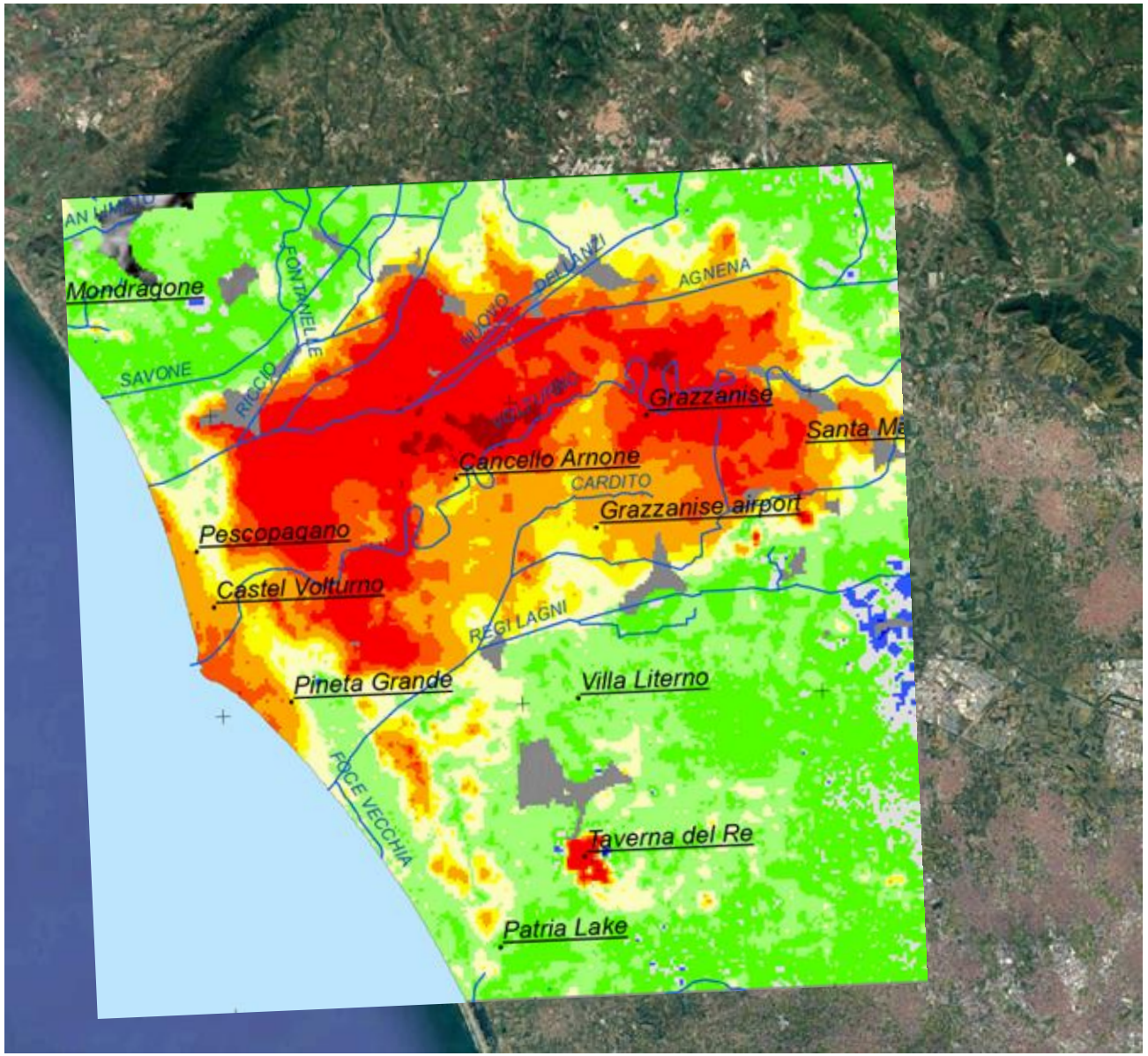
Buffardi et al., 2025. Frontiers in Earth Sciences

SUBSIDENCE MAP

Map of the cumulative subsidence during 1992-2021

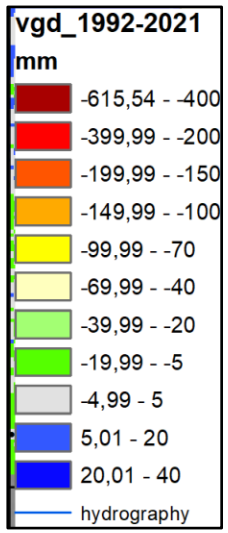
(Vertical Ground Deformation expressed in mm)

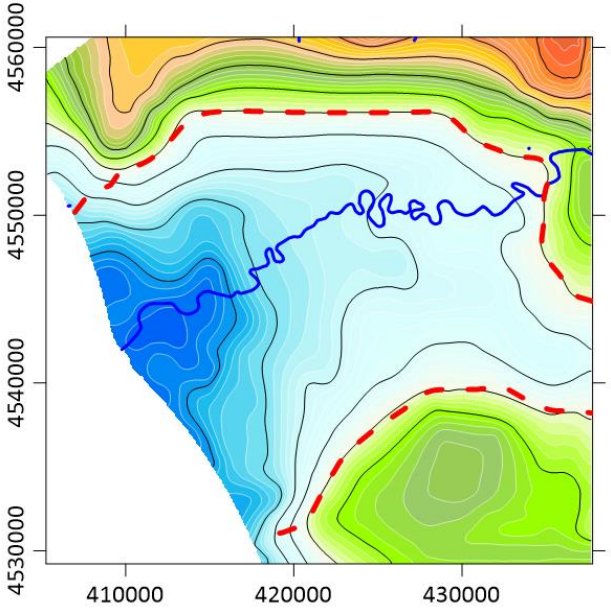


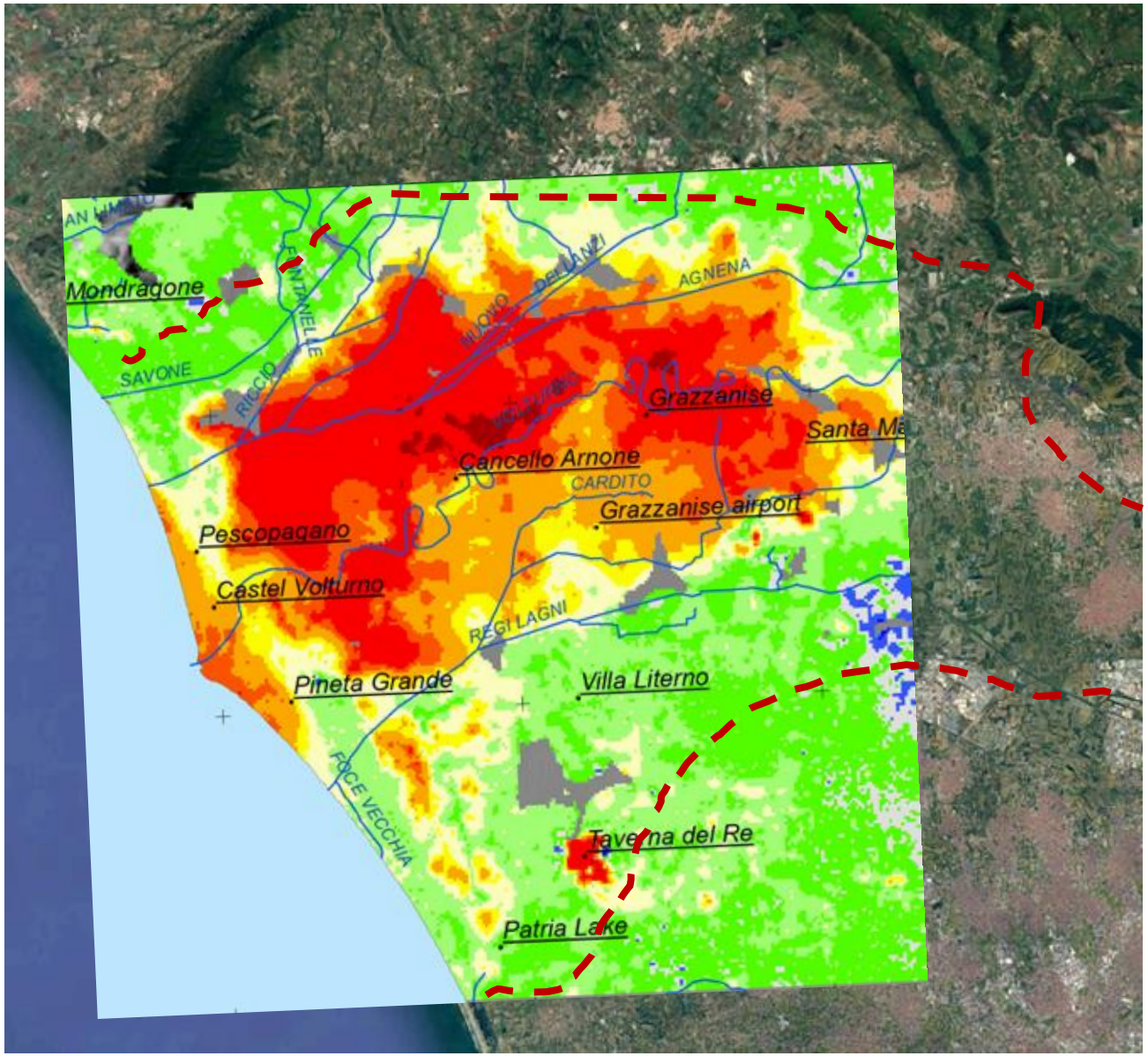


Alberico & Matano et al., 2024. Quaternary International, 712.
Based on ERS, ENVISAT, RADARSAT and SENTINEL 1 data

SUBSIDENCE MAP







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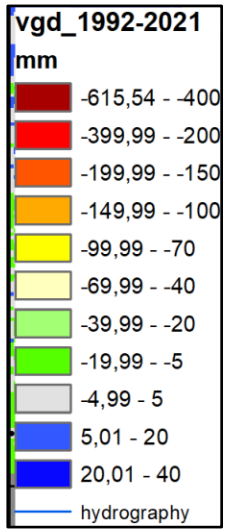
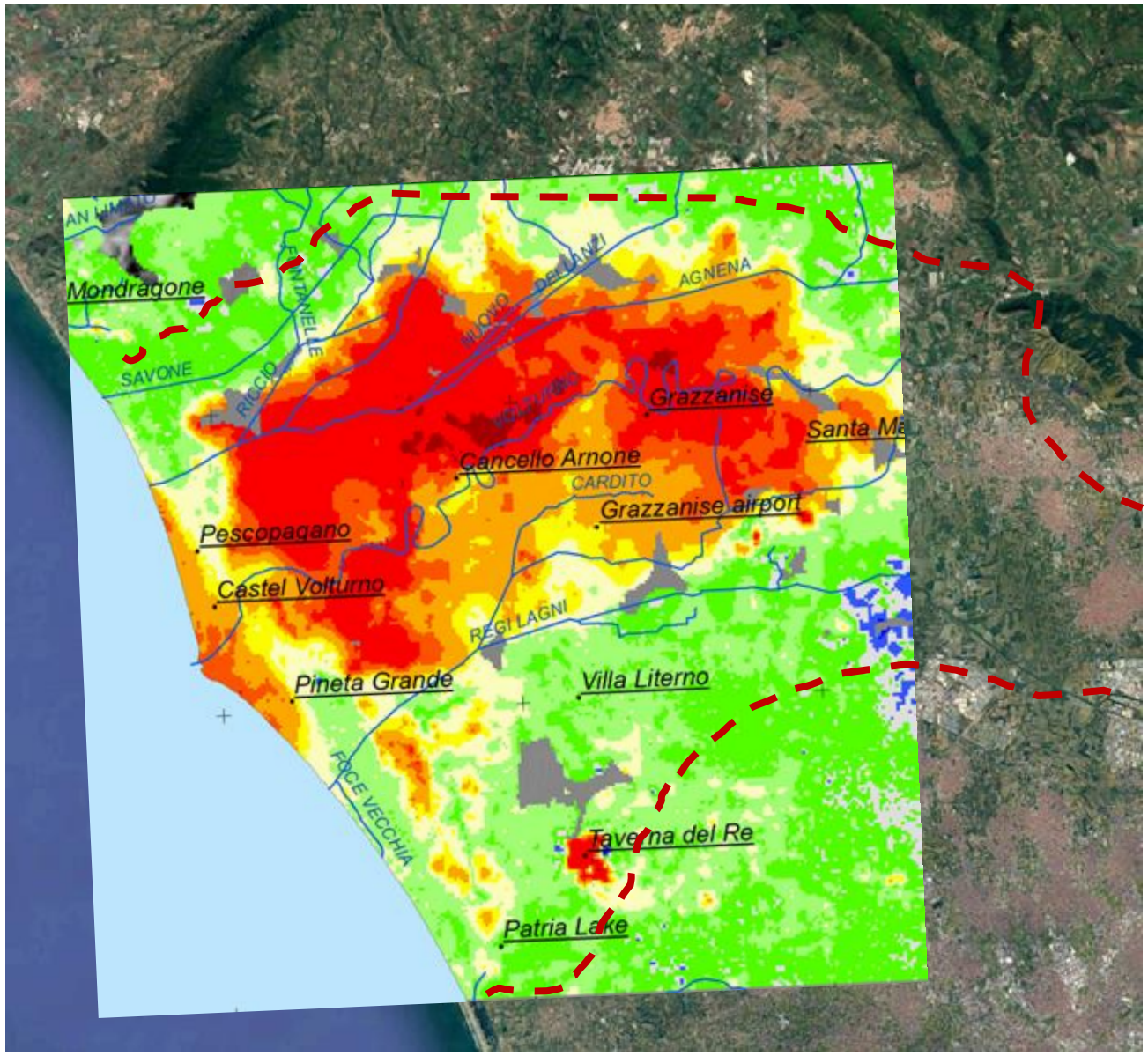
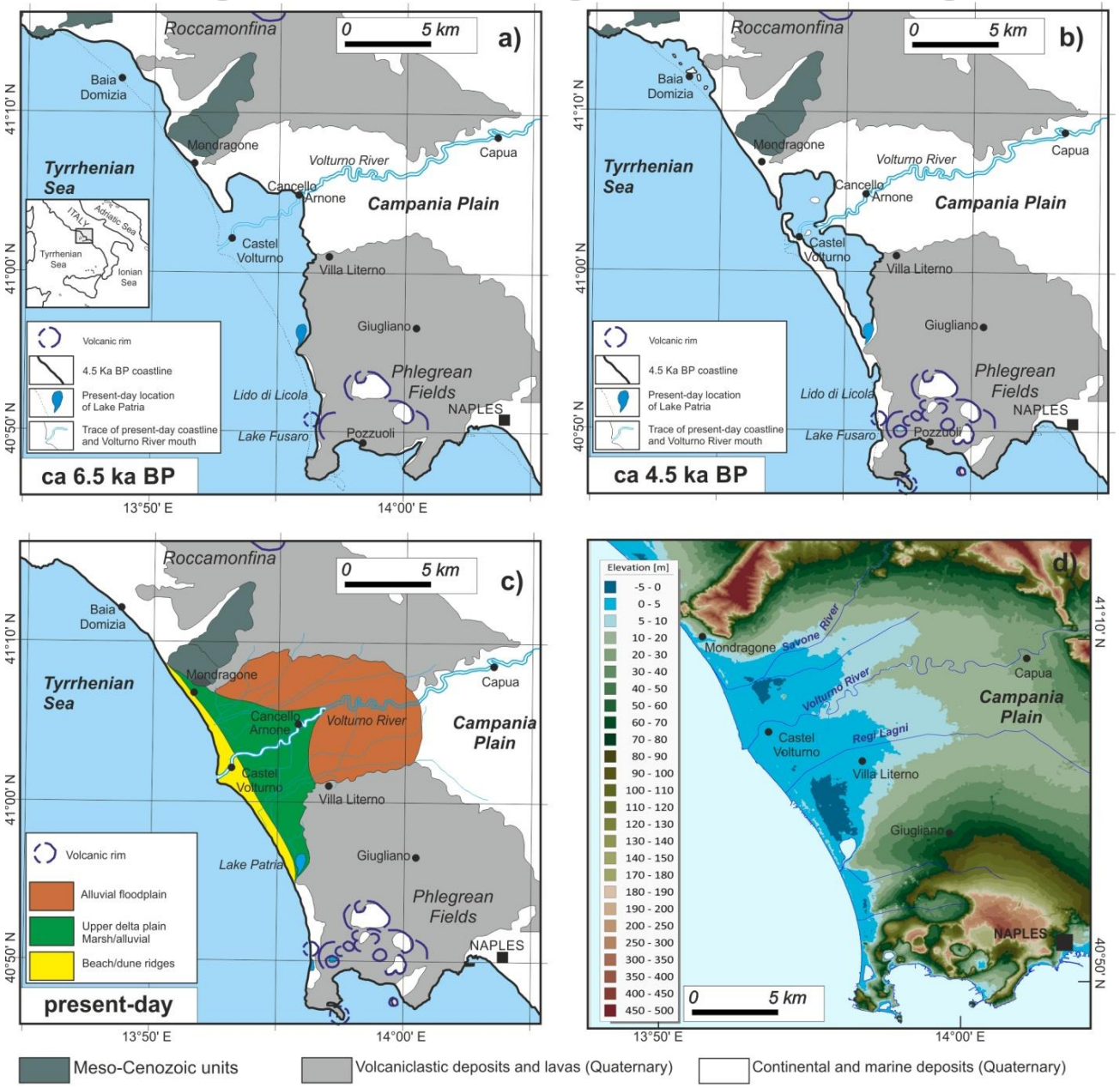




incompressible substrate → tuff

compressible filling → Holocene

Buffardi et al., 2021. Water



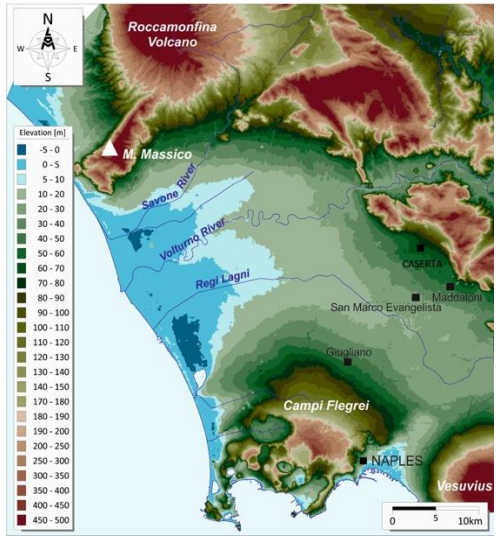
THE VOLTURNO DELTA FORMATION

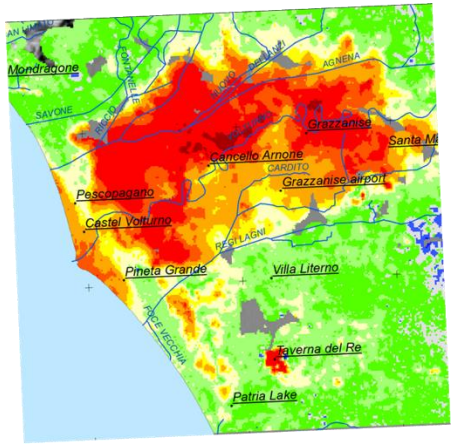
a) during the maximum marine ingression a wide embayments is recognized;
b) the onset of back-barrier lagoonal environments is documented at the mouth of the Volturno River, as a response to coastal aggradation and sand bar development by littoral drift;
c) present day setting of the Volturno delta plain;
d) DTM with 70-m cell: morphological setting largely inherited by the late Quaternary sedimentary evolution of the plain

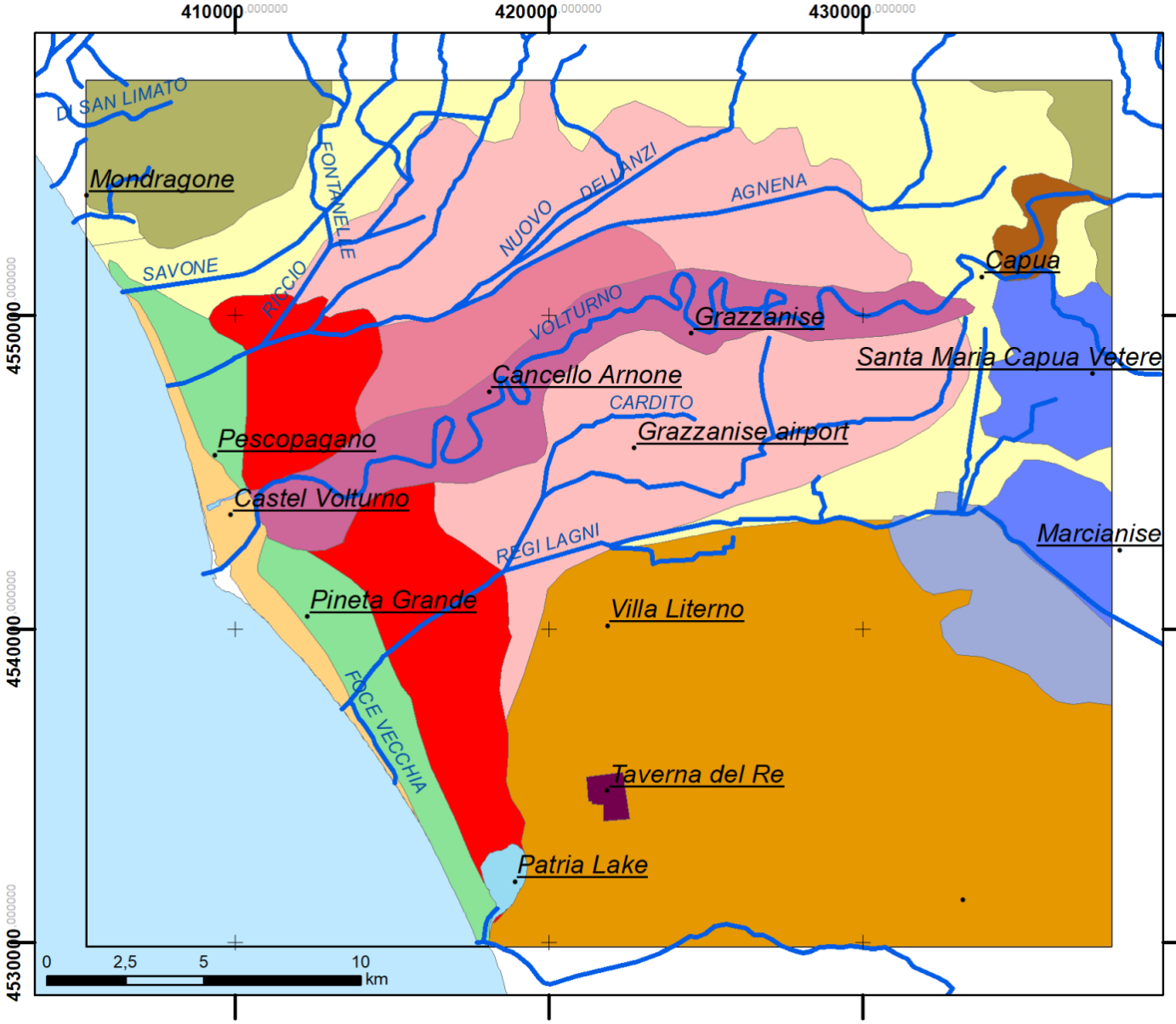
After *Amorosi et al., 2012. Sedim. Geol.,*
Sacchi et al., 2014. Glob. Plan. Change
Ruberti et al., 2022. Quaternary International

SUBSIDENCE ZONING MAP

- lake
- slightly uplifing plain
- slightly uplifing Phlegrean caldera outer slope
- stable dunal and retrodunal sector
- post-1800 river mouth and beach
- slightly subsiding Phlegrean caldera outer slope
- slightly subsiding mountain slope
- slightly subsiding plain
- slightly subsiding river course abandoned meander
- subsiding river course and abandoned meander
- subsiding plain
- highly subsiding plain
- subsiding lowlands
- waste disposal site
- hydrography

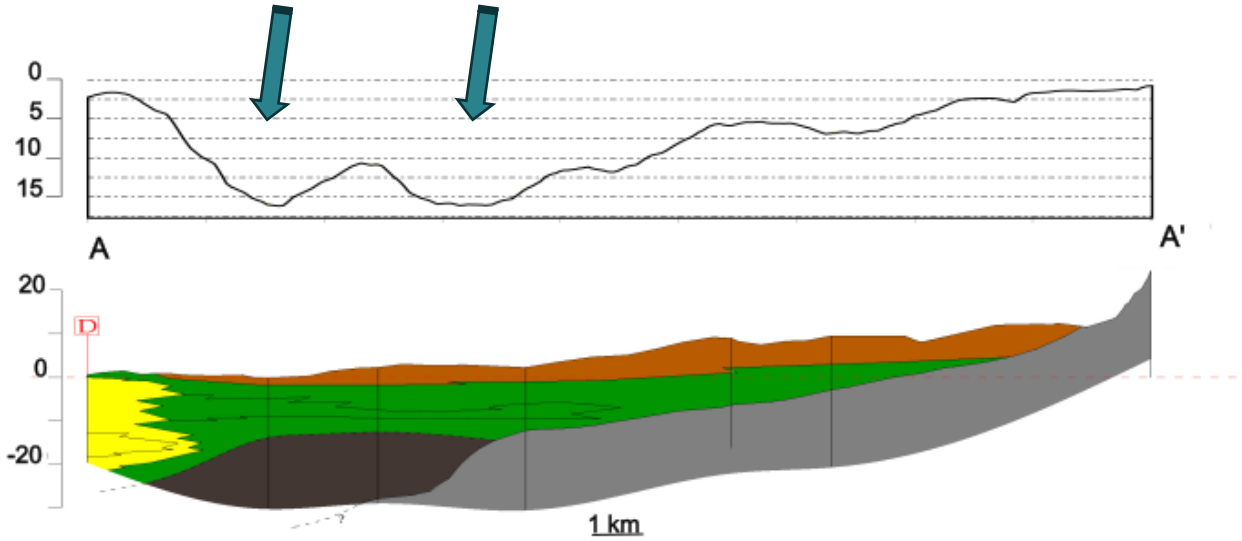


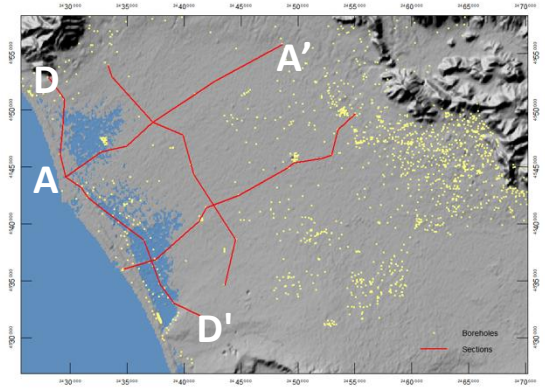


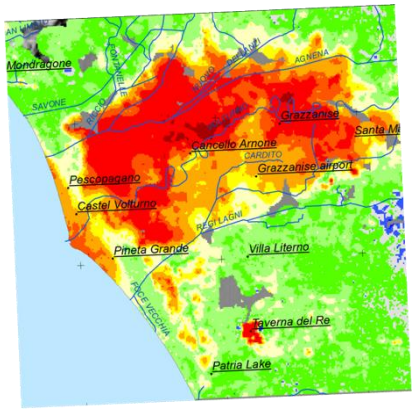


Alberico & Matano et al., 2024. Quaternary International, 712.

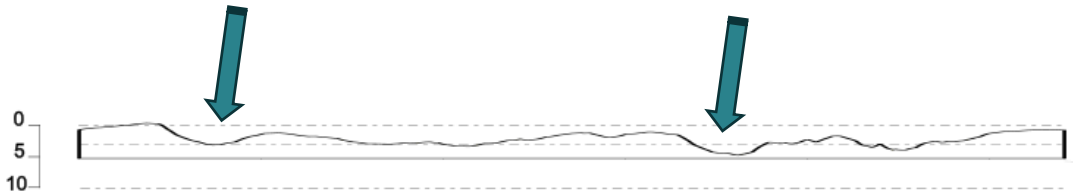
HOLOCENE DEPOSITIONAL SYSTEMS VS. SUBSIDENCE







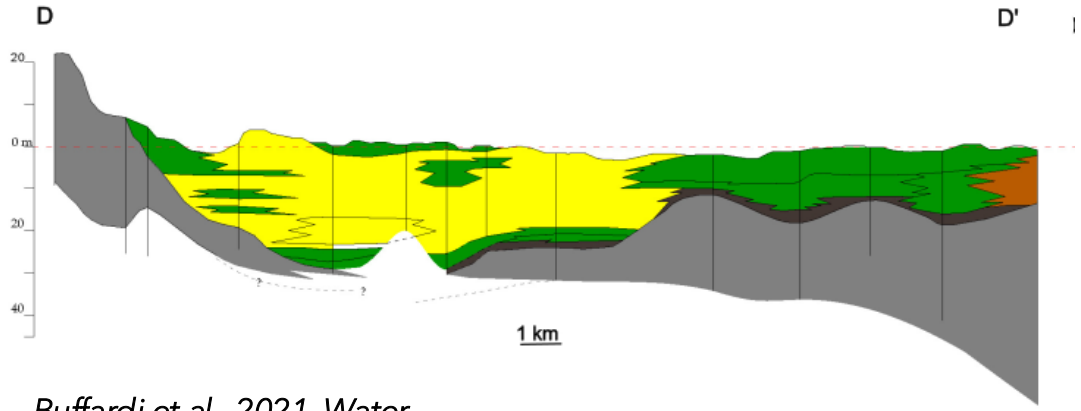
[(Σ Thickness Peat + Thickness Clay) *vs.* (post-IC Thickness)] *vs.* [LS rates]



Differential compaction was detected, with the **highest values of subsidence** corresponding to **high thicknesses of peat and clay** but **low post-Ignimbrite thickness**, proceeding from the coastal zone towards the interior.

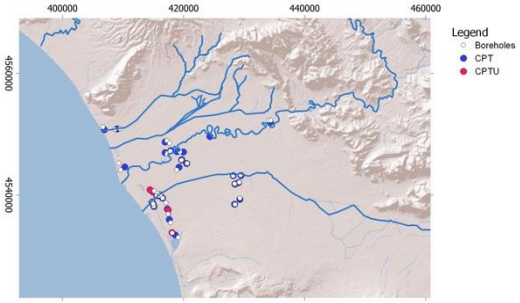
The most superficial sediments, i.e. the youngest ones

Primary and secondary consolidation



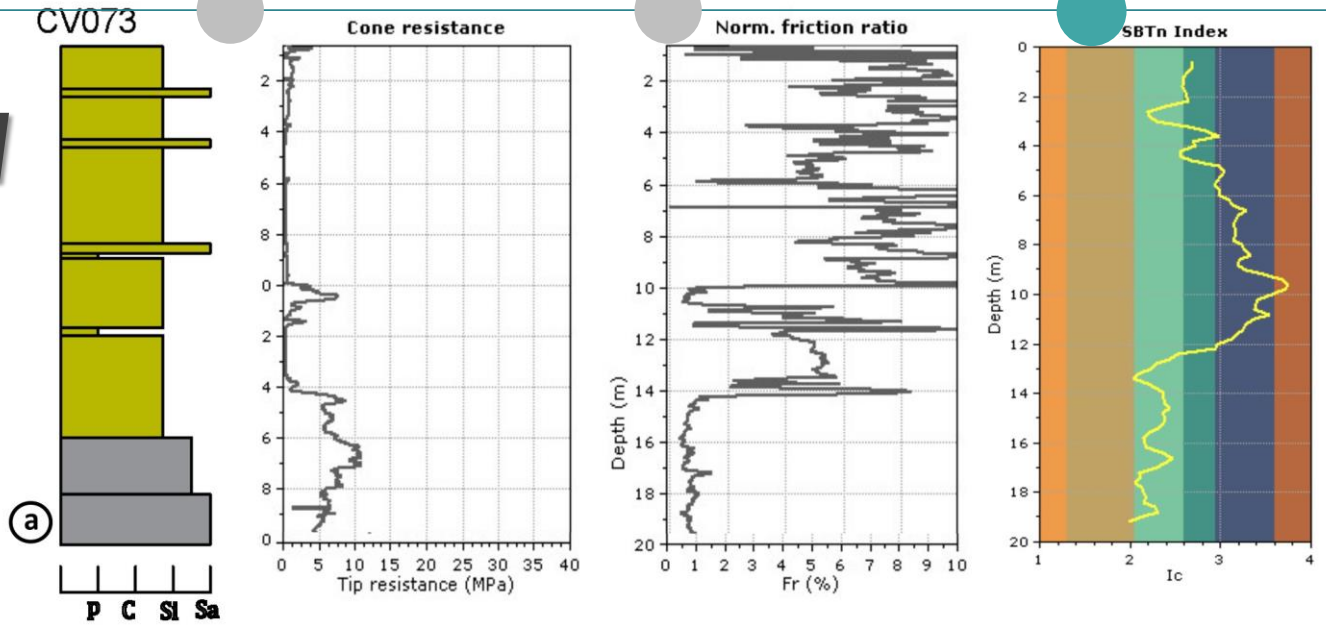
Buffardi et al., 2021. Water

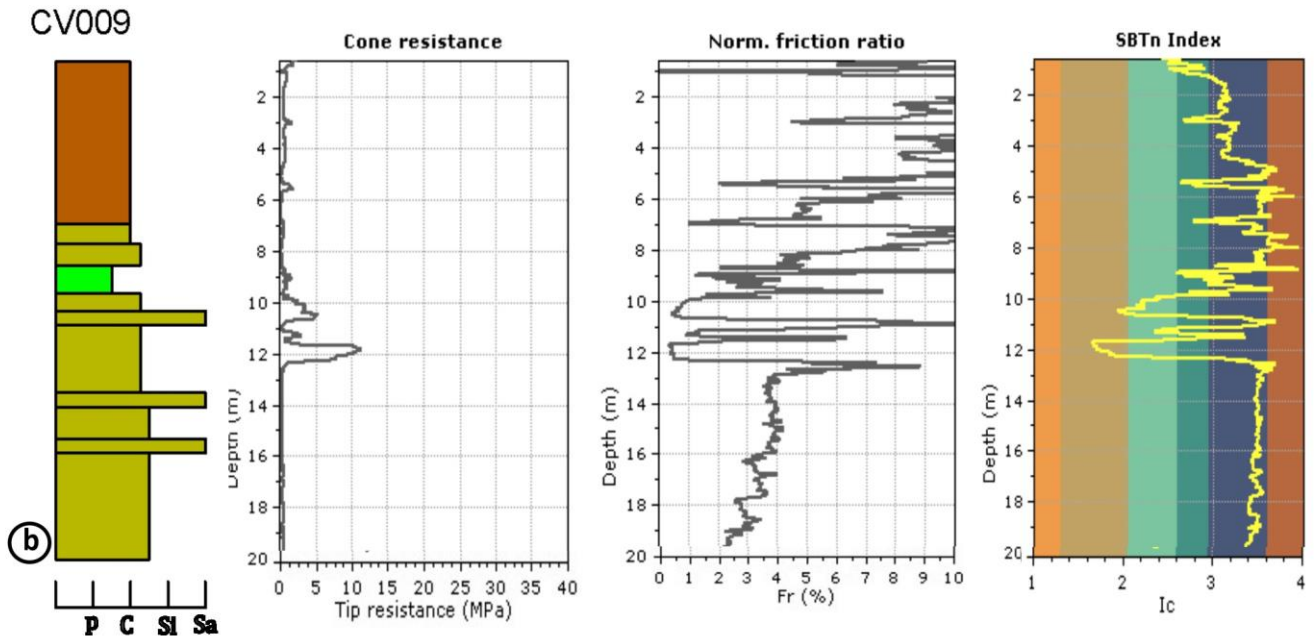
CPT INTERPRETATION



Zone	Soil Behavior Type
1	Sensitive, fine grained
2	Organic soils - clay
3	Clay – silty clay to clay
4	Silt mixtures – clayey silt to silty clay
5	Sand mixtures – silty sand to sandy silt
6	Sands – clean sand to silty sand
7	Gravelly sand to dense sand
8	Very stiff sand to clayey sand*
9	Very stiff fine grained*

Several stratigraphic logs are characterized by different lithologies and significant changes of geotechnical parameters, even in the presence of the same depositional environment…..





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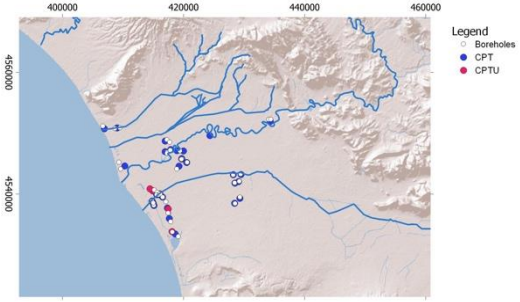

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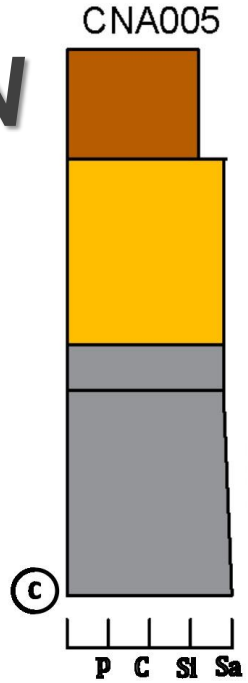
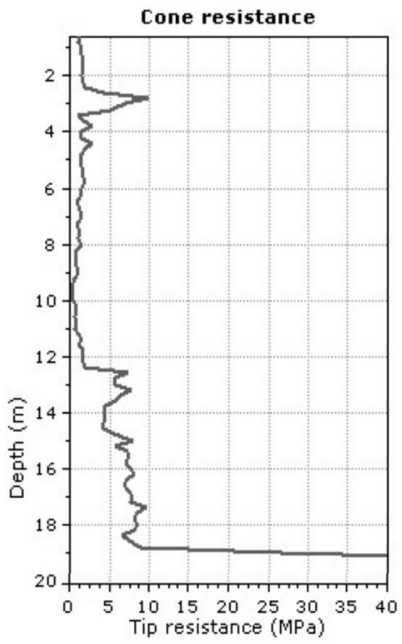
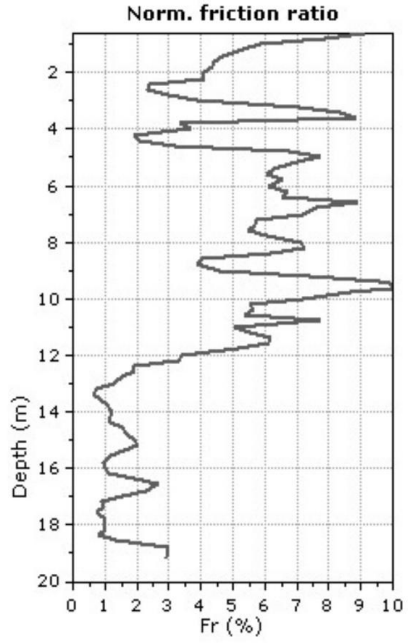
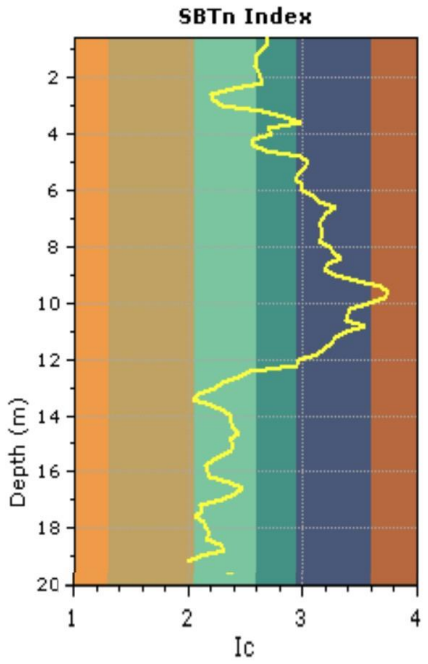
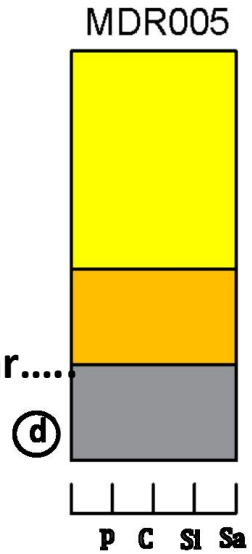
….in other cases, lithologies remain relatively uniform throughout the log while depositional environments change significantly and their geotechnical behaviors may be strikingly dissimilar….

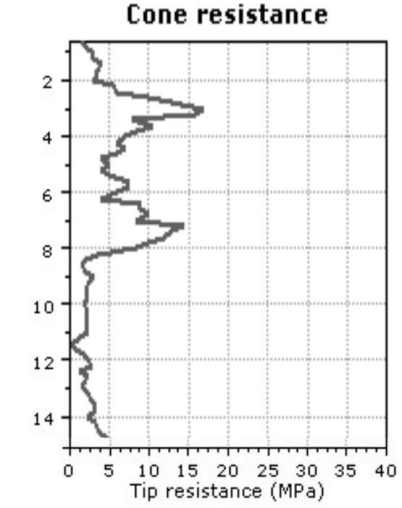


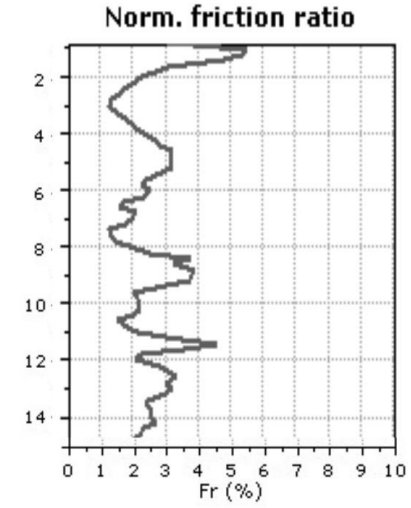


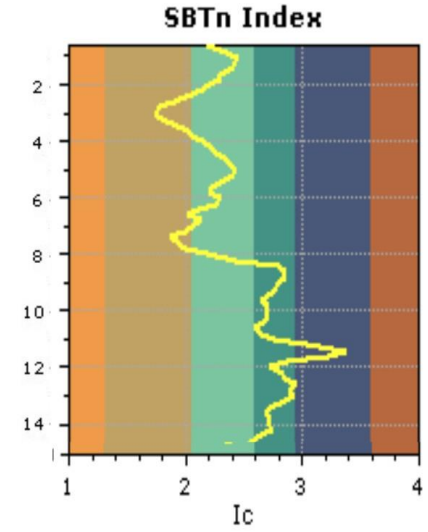












CPT INTERPRETATION

SBTn charts

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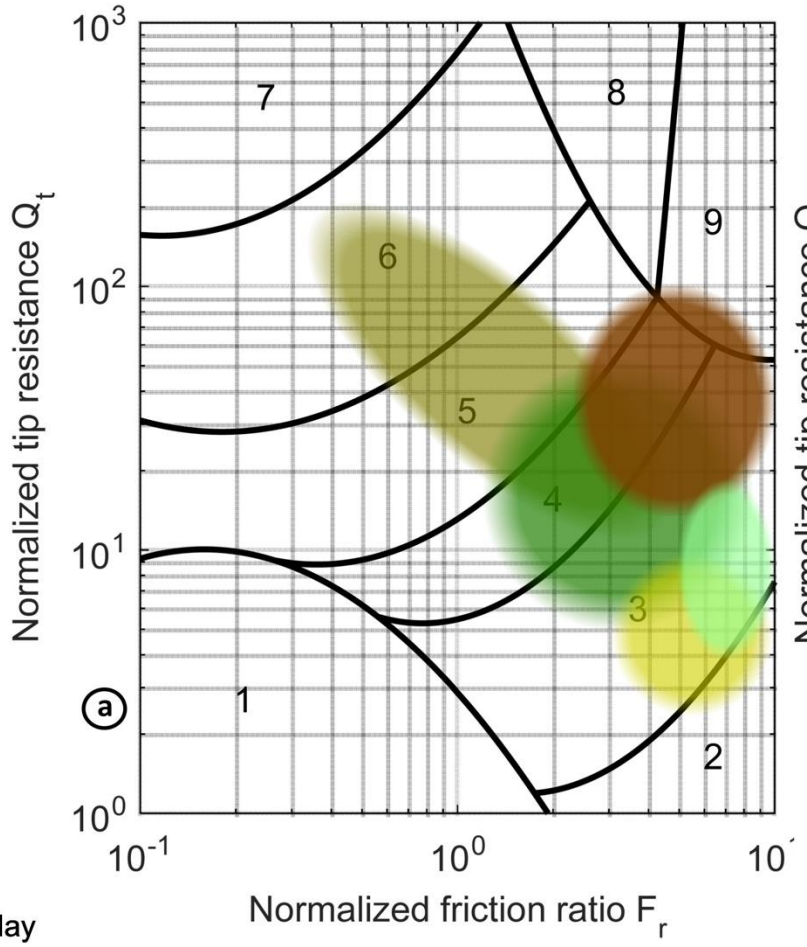
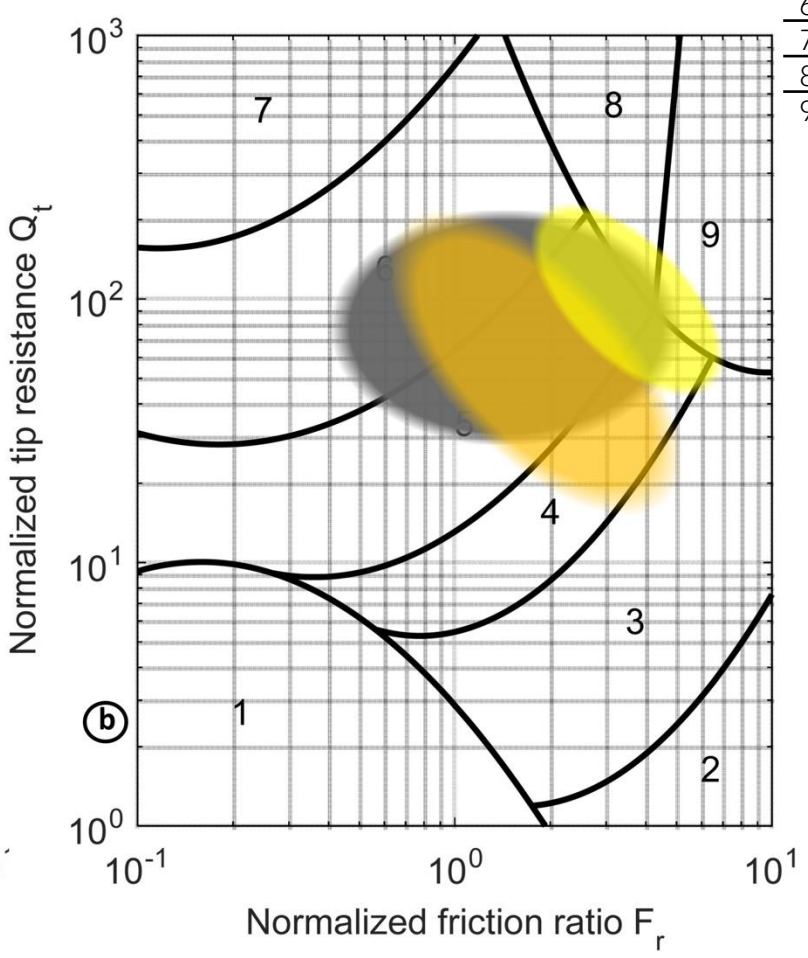
Fine grained materials



Coarse grained materials



Homogeneous lithologies may not represent a single facies…..
these differences are highlighted by geotechnical testing and analysis

- Floodplain
- Coastal Plain
- Swamp
- Lagoon/Peaty clay
- Lagoon/Silt
- Pyroclastic sands
- Fluvial Channel
- Beach- Dune

CPT INTERPRETATION

SBTn charts

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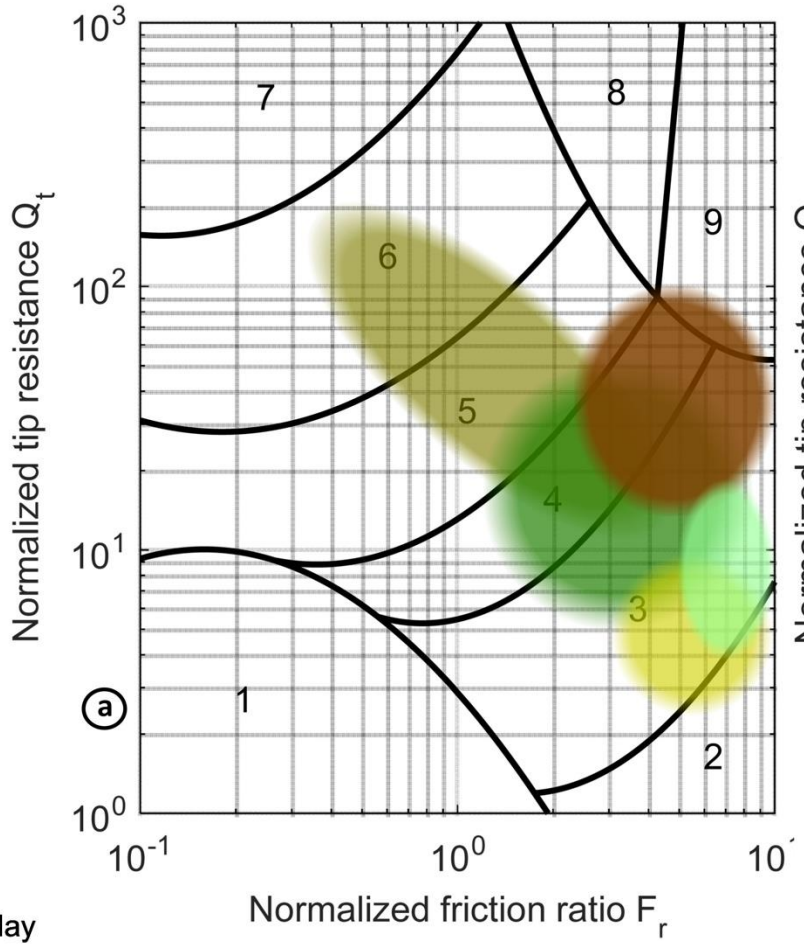
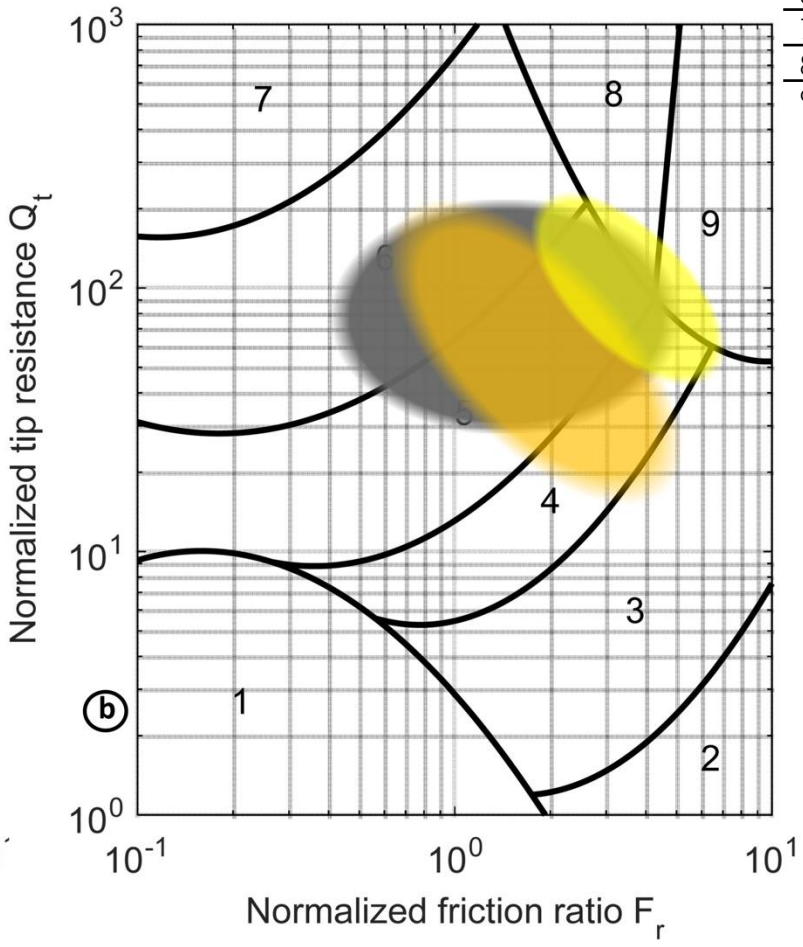
Fine grained materials



Coarse grained materials



The discrepancy can be attributed to:

- **the age of the sediments**
- **the post-depositional processes**

Floodplain
Coastal Plain
Swamp
Lagoon/Peaty clay
Lagoon/Silt

Pyroclastic sands
Fluvial Channel
Beach- Dune

RECENT EVOLUTION AND ANTHROPIC IMPACT

RECLAMATION INTERVENTIONS

Part of the river's water was diverted and canalised, with the aim of elevating the land surface by filling the marshy areas with alluvial sediments.

The canals branched into other diversion canals reaching the inner parts of the sedimentation tanks.

Ruberti & Vigliotti, 2018. Environm. Earth Sc.

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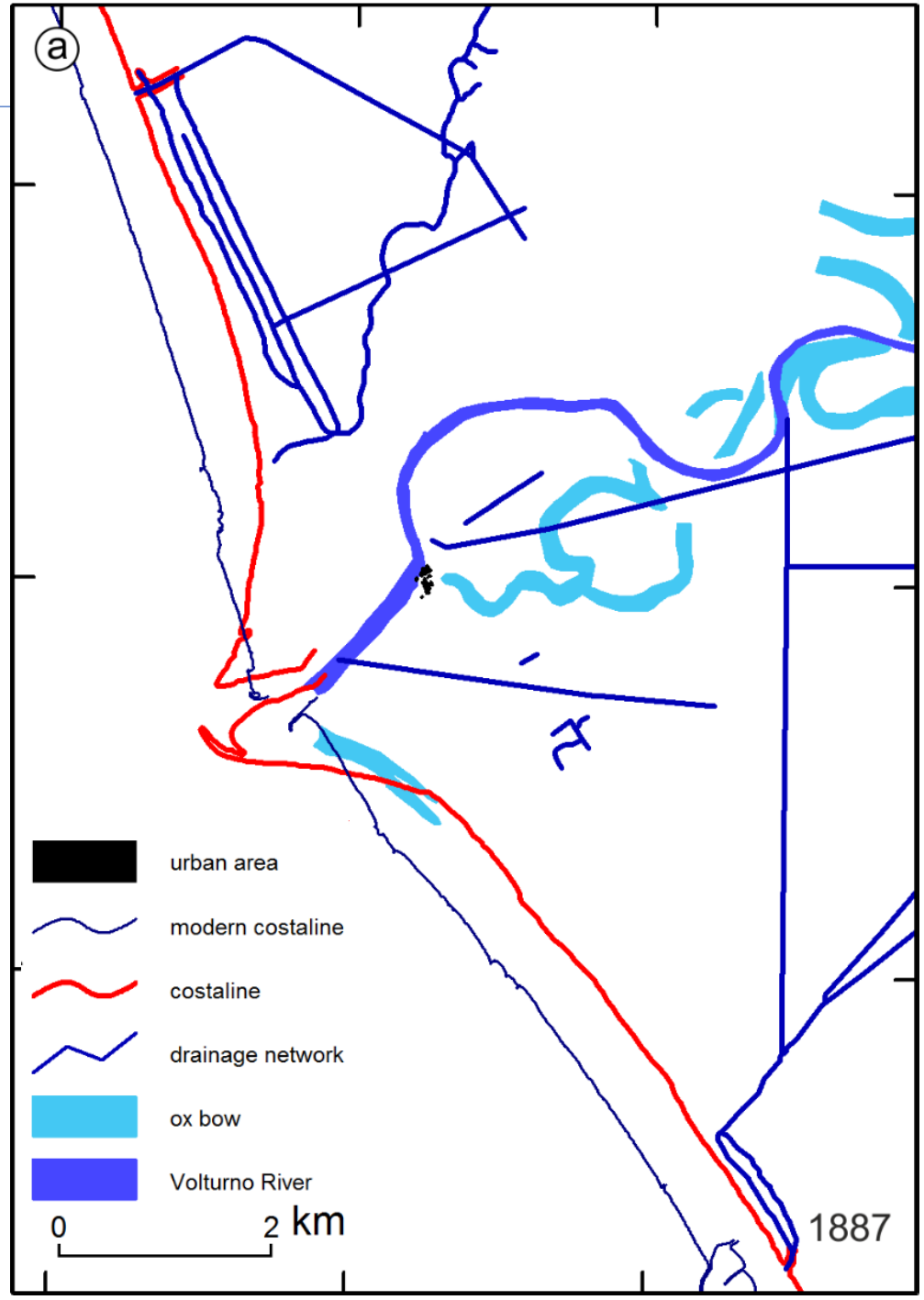
DRAINAGE EVOLUTION

Evolution of the drainage system pattern following land reclamation work between 1880 and 2010 in the Volturno River delta plain.

Analysis of the drainage network characteristics through time (based on Horton 1932; 1945)

Year	Total stream	Total stream lenght (km)	Area (km^2)	Drainage density (km/km^2) (Horton, 1932)	Stream frequency (Horton, 1945)
1887	89	125,916	99,812	1,26	0,89
1957	1338	525,054	103,986	5,05	12,87
1987	1223	489,579	103,218	4,74	11,85



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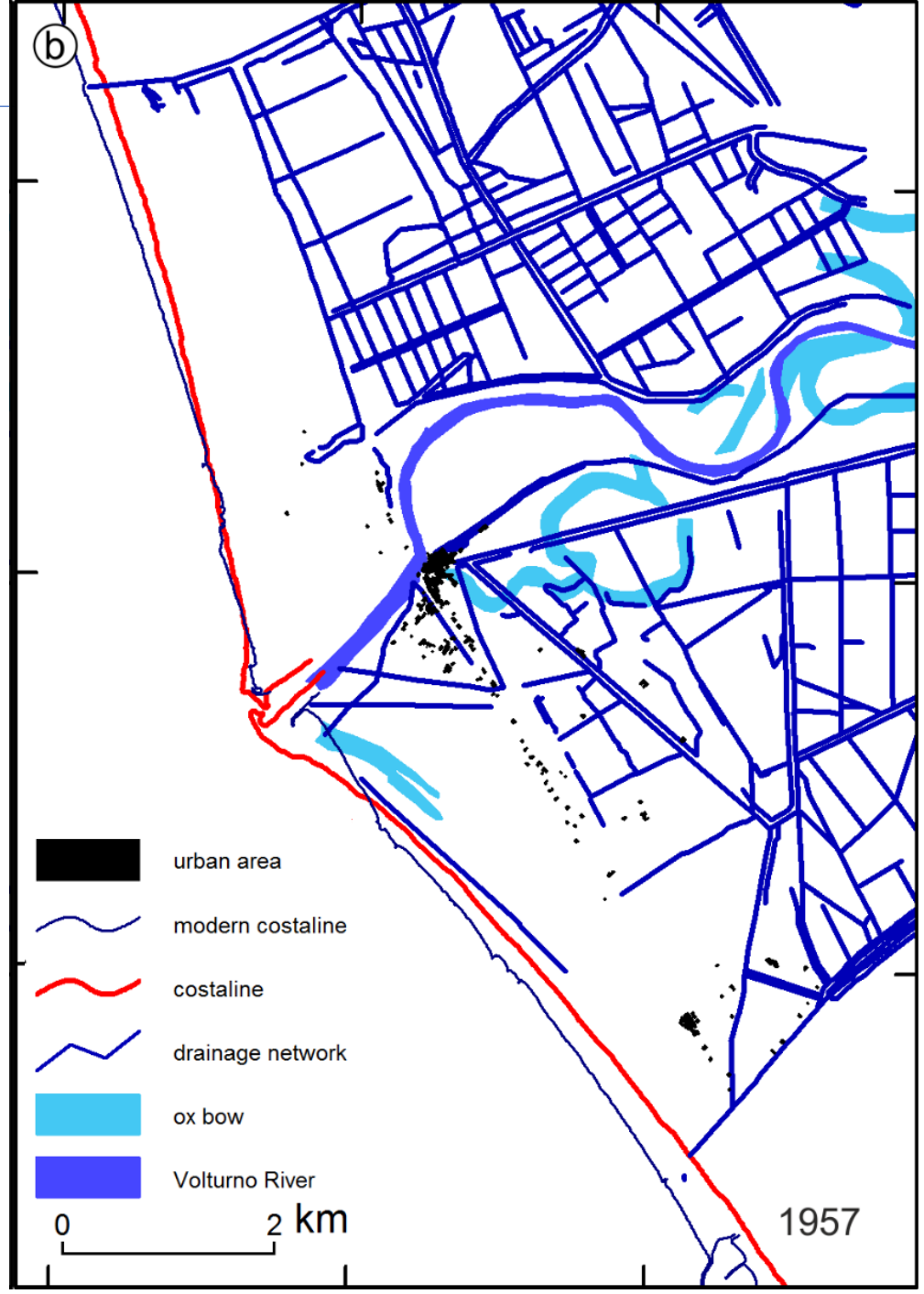

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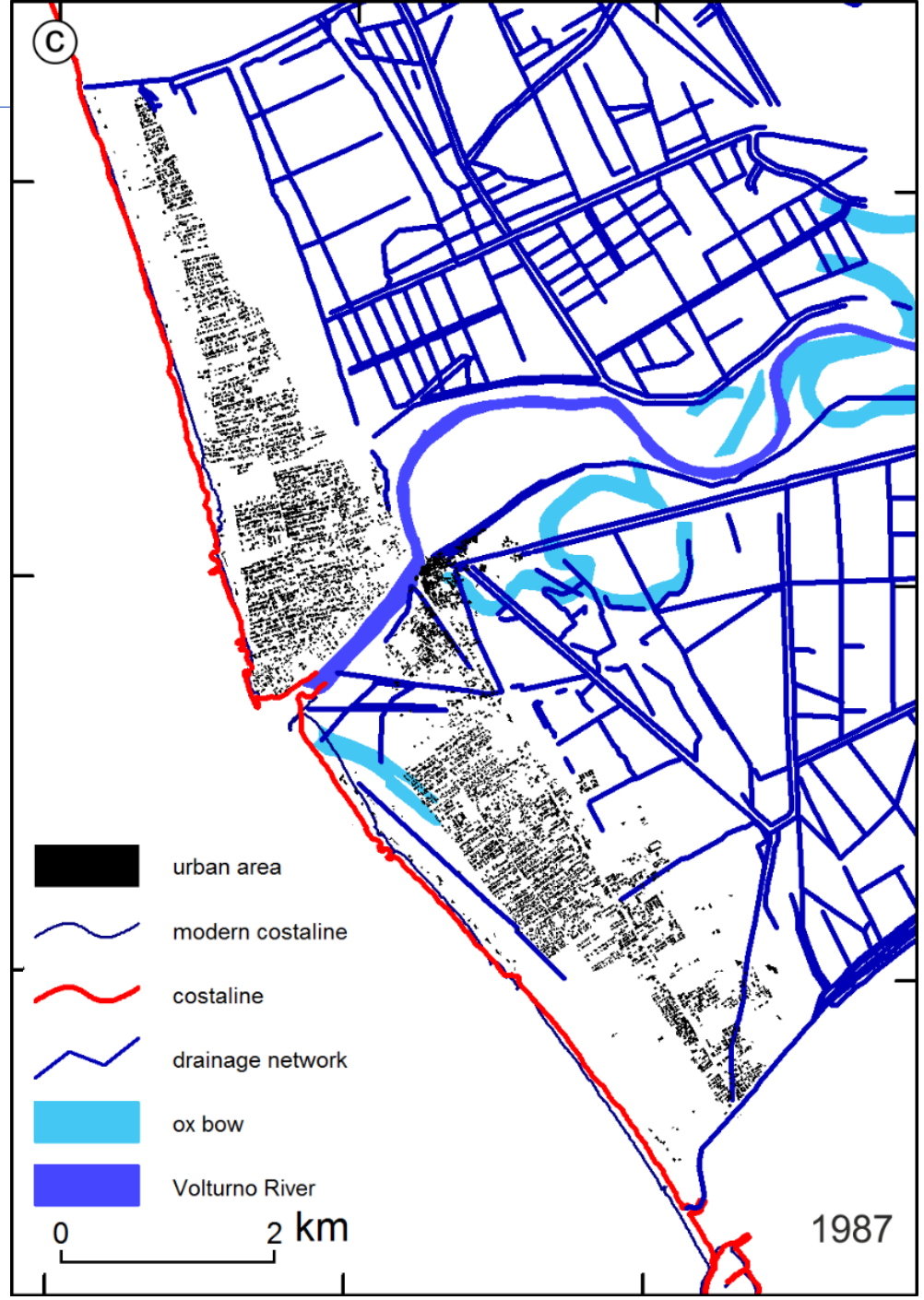

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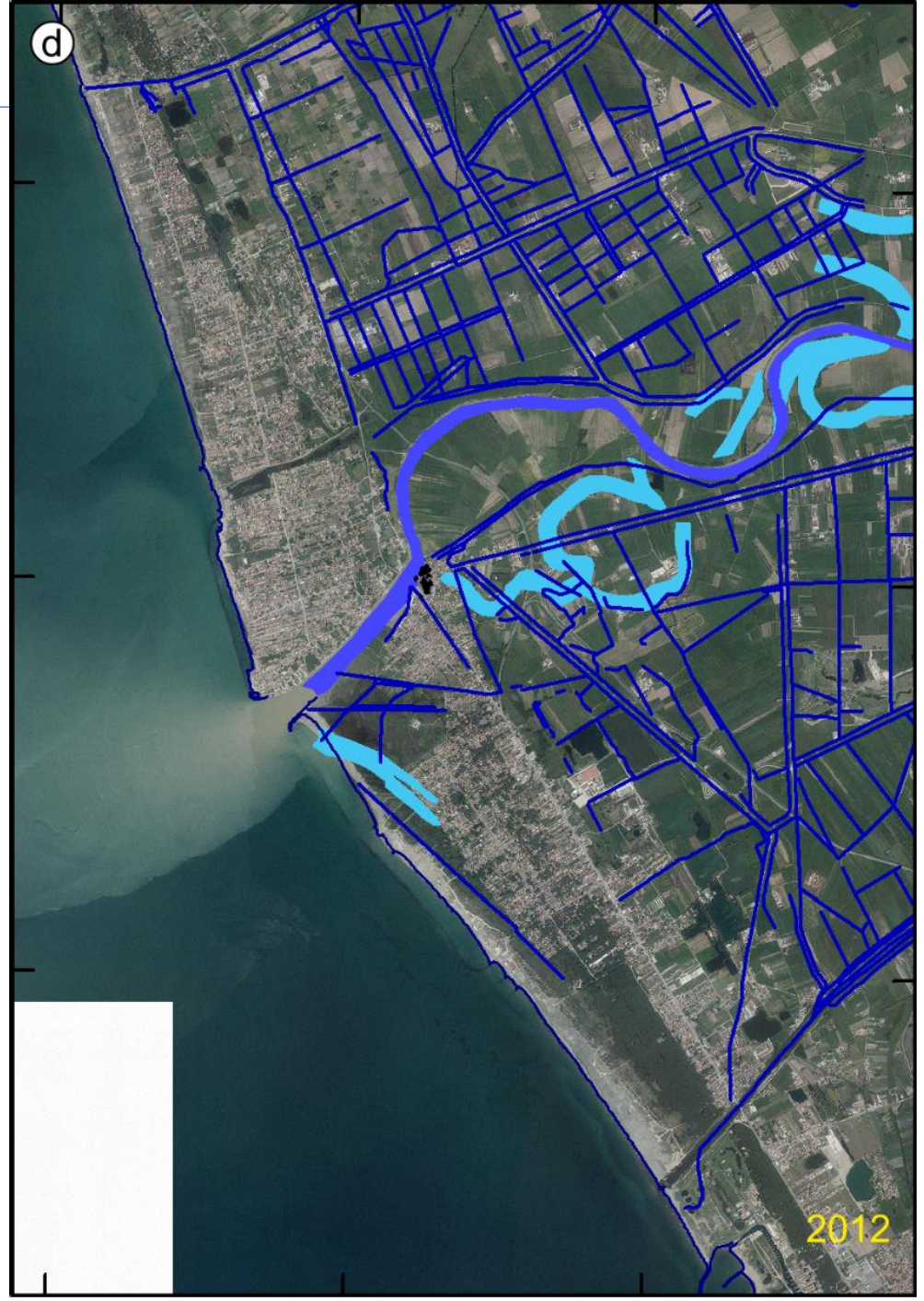
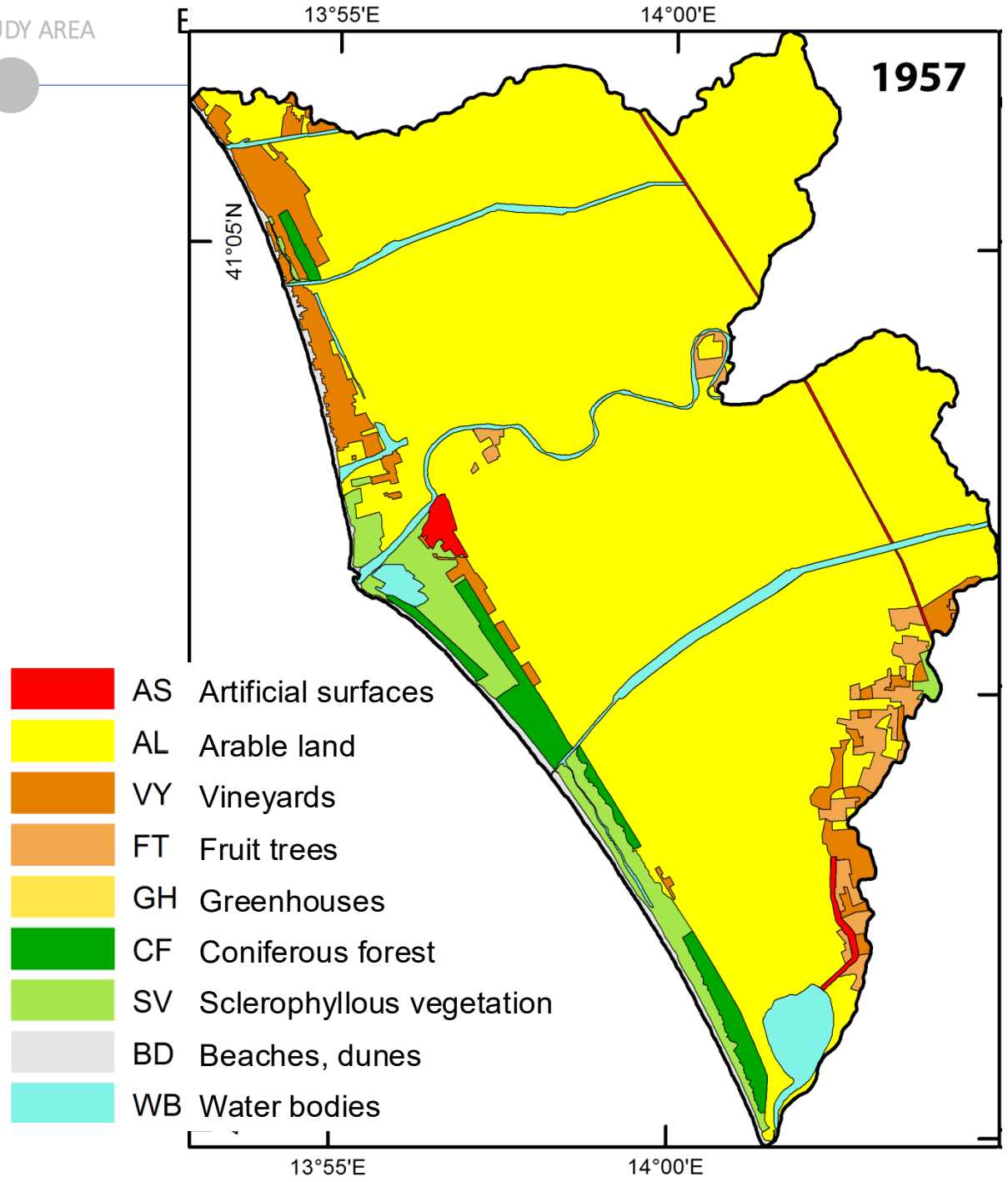


LAND USE CHANGES

Most of the marshy areas were reclaimed for agriculture and other human activities from the beginning of 1800s until the early 1900s.

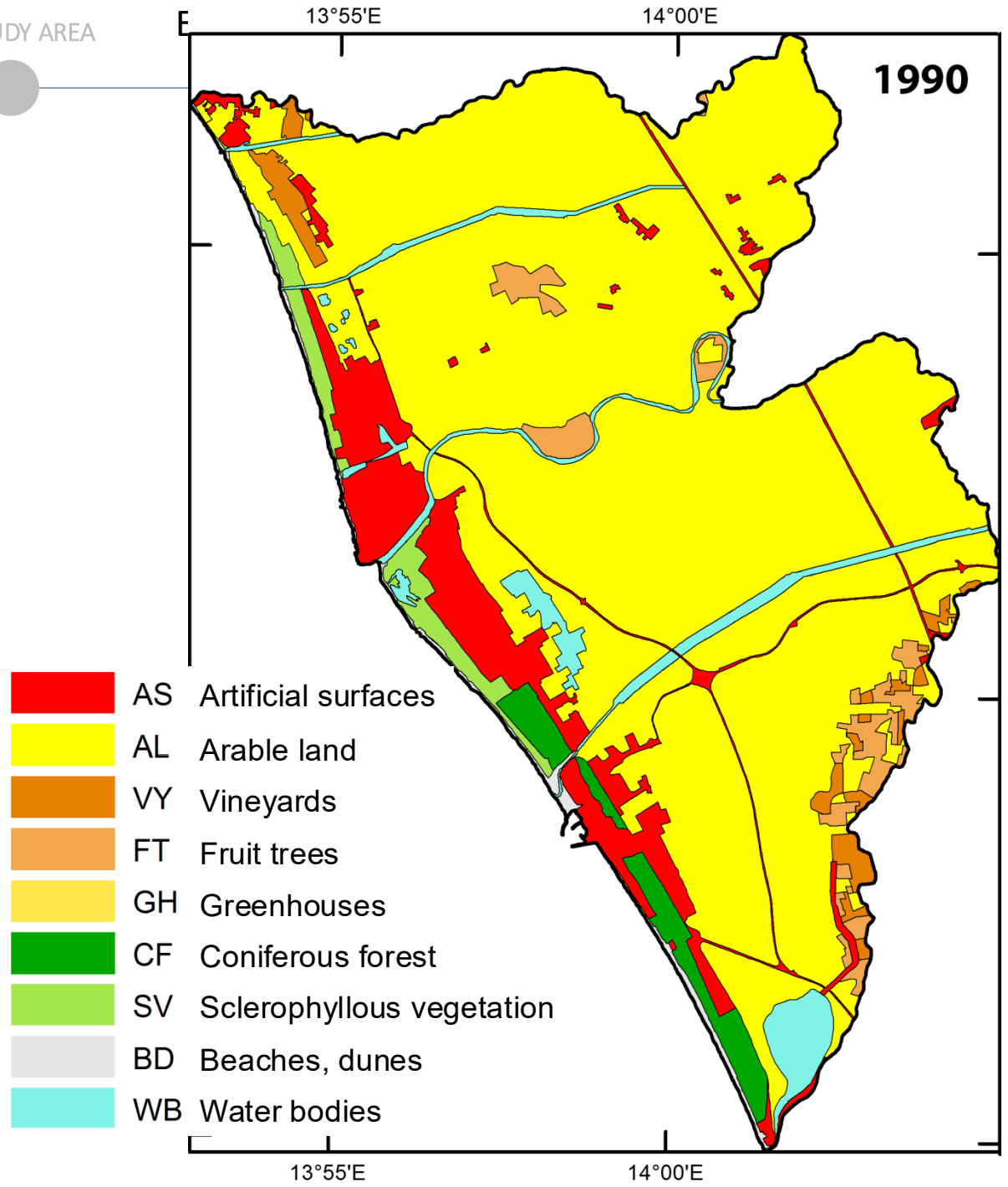
In 1957 Arable lands (81%), Sclerophyllous vegetation (3,7%) and Vineyards (4,%) were the predominant land cover types.



LAND USE CHANGES

A reduction of beach-dune land was recorded up to 1990.
The Artificial Surfaces were the land use type, with the largest rate of increase at the same time.

Among other things, the great fragmentation of the landscape, the increase in urbanization, especially along the coast, the destruction of many coastal habitats are evident.

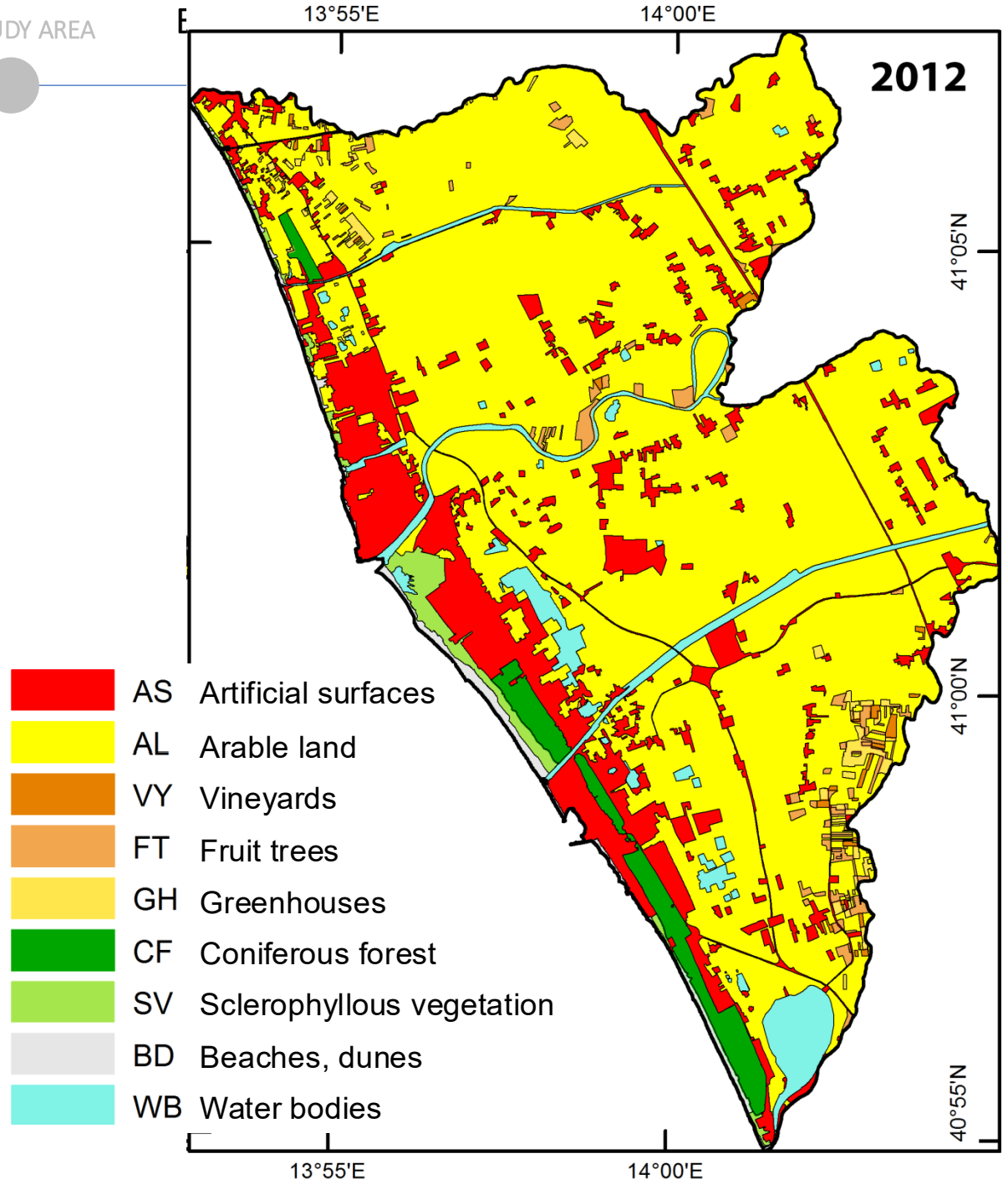


LAND USE CHANGES

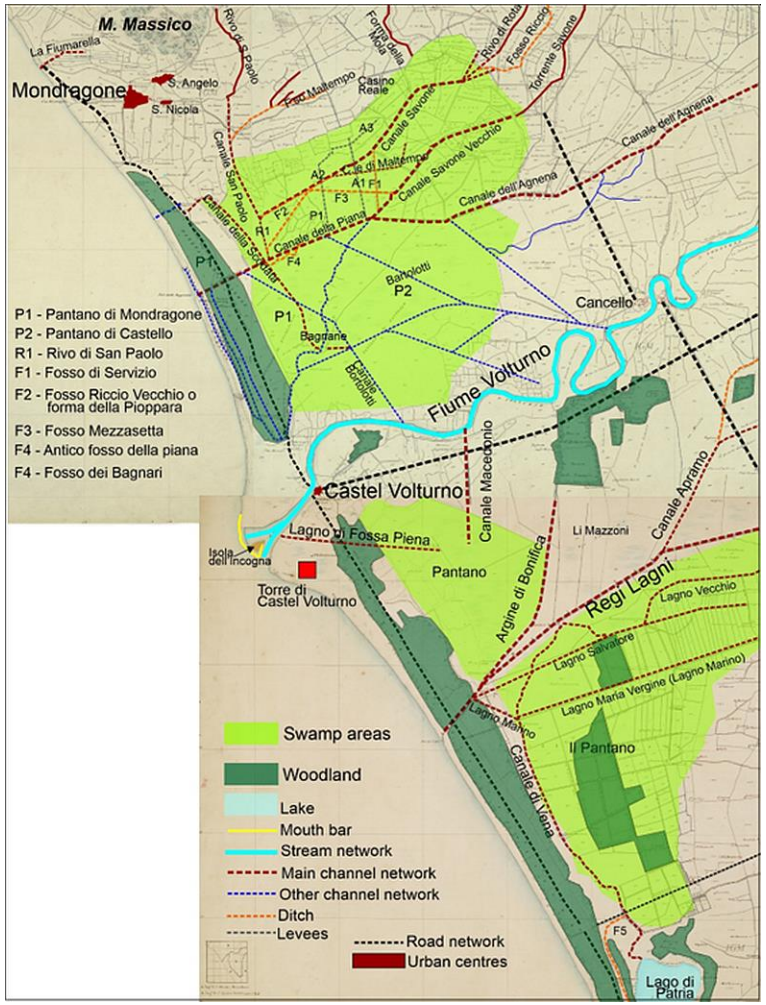
- **Urbanization & Infrastructure**: Building heavy structures and infrastructure compresses underlying soft sediments, while growing populations demand more groundwater, leading to aquifer depletion and land sinking.

- **Groundwater Extraction**: Pumping water from aquifers for cities, industry, and agriculture (like aquaculture) removes support, causing significant land loss, as seen in Jakarta and Tokyo.

- **Agricultural Practices**: Drainage of peat soils for farming causes oxidation and shrinkage, while high freshwater demand for irrigation (e.g., in aquaculture) depletes aquifers, contributing to subsidence

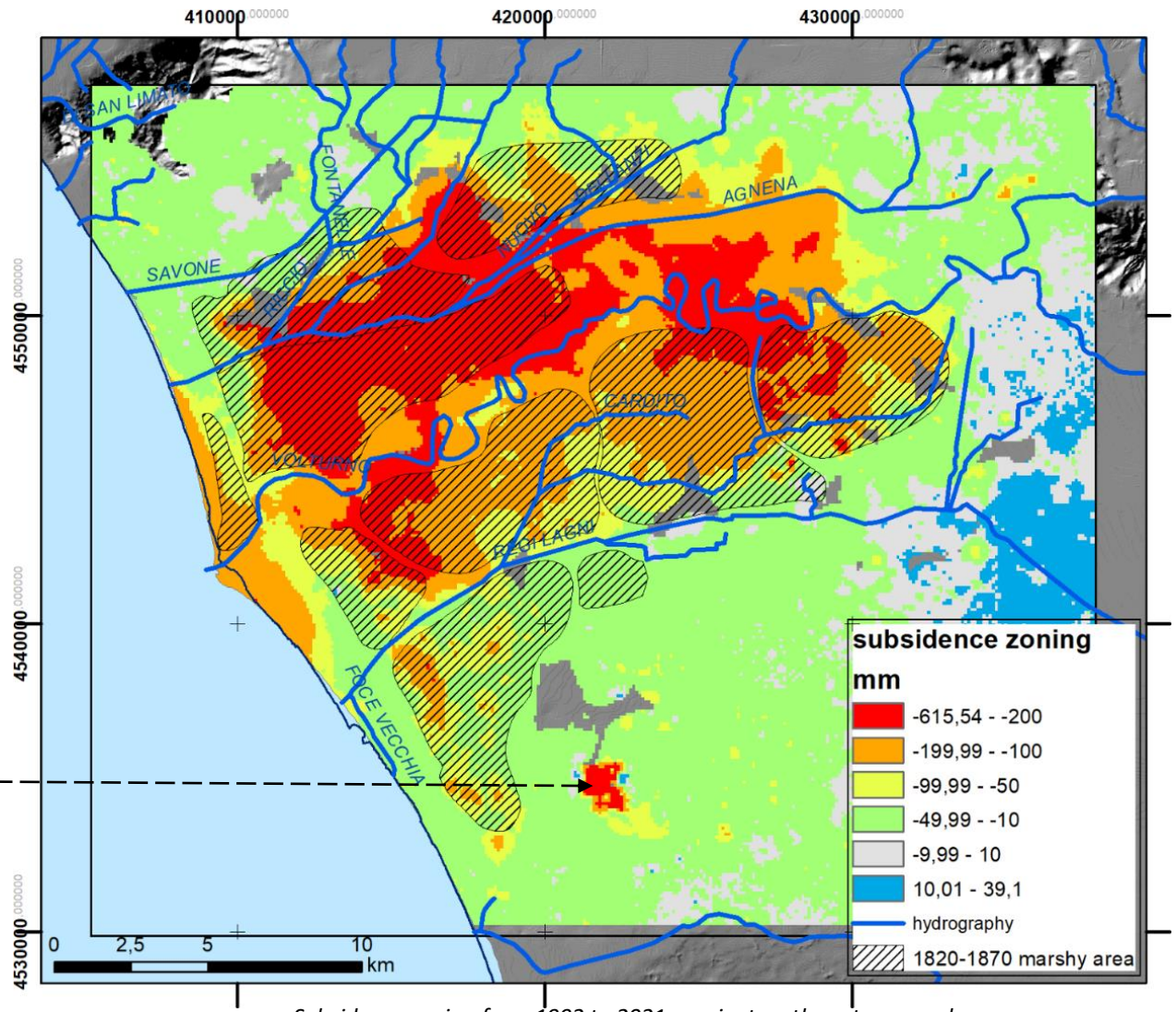


SUBSIDENCE PROCESSES AND COASTAL LANDSCAPE EVOLUTION



Topographic map of 1834-1860, 1:20,000 scale (Italian Geographic Military Institute). The woodlands were outlined from Topographic and Hydrographic Map of the surrounding areas of Naples 1817-1819 at 1:25,000 scale.

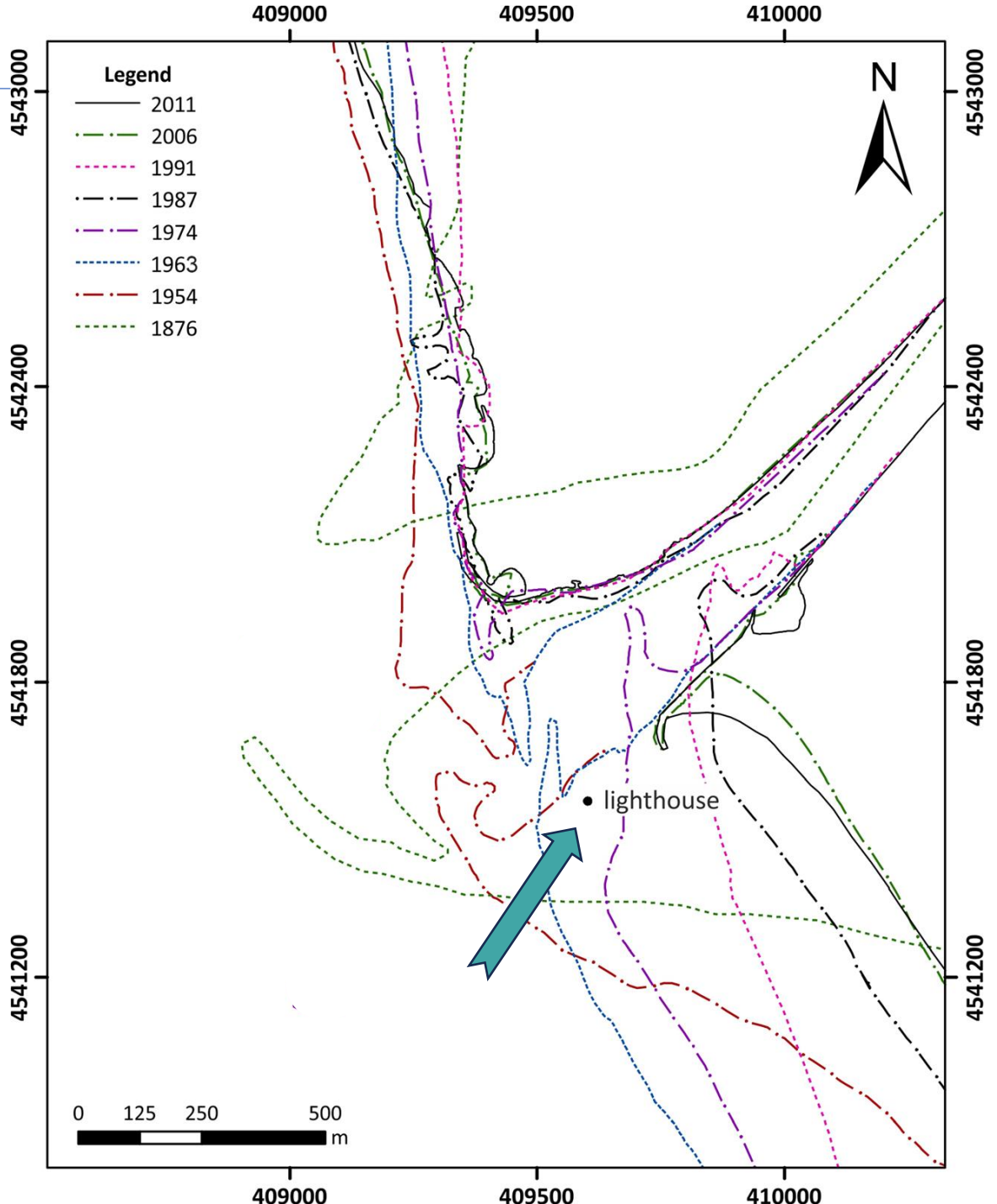
Taverna del Re "ecoballe" waste disposal site



Subsidence zoning from 1992 to 2021 vs. nineteenth century marshy areas.

Coastline erosion……

- Strong retreats are registered between 1954 and 2013, with variation of mouth orientation and morphology.
- The lighthouse was on mainland in 1954 and 1968, then gradually remained isolated in the sea due to shoreline retreat and was destroyed by sea storms.




Coastline erosion……

CONCLUSIVE REMARKS

The natural processes have an important role in the Volturno delta plain subsidence

The subsidence appears to be related to the characteristics of the most compressible deposits and their age.

Anthropogenic impacts may be significant in terms of the local variability of the subsidence rates

CONCLUSIVE REMARKS

An integrated approach to the study of the geological and anthropogenic processes in these delicate environments offers a clear understanding of the processes and provides insights for mitigation interventions.


Thanks for your attention

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Session *S_195* - From Sediments to Cities: Unravelling Subsidence in Coastal and Alluvial Environments

Theme – Anthropocene

Sub-theme - 4. Records of anthropogenic impact on landscape and sustainability

Session description

Subsidence in coastal and alluvial landscapes is a dynamic process driven by both natural and anthropogenic forces. During the Quaternary, interactions among sedimentation, tectonics, and climate variability have shaped the evolution and habitability of low-lying environments. Today, these settings face intensified challenges from human-induced stressors, including land reclamation, groundwater extraction, rapid urbanization, and infrastructure loading, which exacerbate land subsidence and relative sea-level rise.

This session aims to explore the multifaceted nature of subsidence, ranging from sedimentary basins to urbanized floodplains, integrating insights from sedimentology, geotechnics, hydrogeology, geomorphology, remote sensing, and geodesy to enhance our knowledge of past and present deformation processes. We encourage studies that address multidisciplinary and innovative approaches, including advanced monitoring techniques, numerical and AI-based modeling, and decision-support frameworks to mitigate risk and support adaptive planning for densely populated coastal zones and deltas.

Conveners

- Daniela Ruberti, Università della Campania "Luigi Vanvitelli" – Dept. Engineering
- Wei-Chia Hung, Green Environment Engineering Consultant Co. LTD
- Ashwani Raju, Dept. of Geology, Institute of Science, Banaras Hindu University
- Pietro Teatini, UniPD – ICEA
- Luigi Tosi, National Research Council – Institute of Geosciences and Earth Resources
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