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Publisher:
Springer Science and Business Media Deutschland GmbH

Published
DOI:10.1007/978-3-031-59925-5_13

(Article begins on next page)

Preprint. Version of Record: https://doi.org/10.1007/978-3-031-59925-5_13

On the Role of Geomatics and Official Regional Cartography in the Interconnected Nord-Est Innovation Ecosystem

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Abstract. The paper presents the role played by geomatics within the *Interconnected Nord-Est Innovation Ecosystem* (iNEST), a research and innovation project funded by the Italian National Recovery and Resilience Plan and involving universities, companies and territorial institutions of the Triveneto macro-region. The iNEST ecosystem aims to extend the beneficial effects of digitalization to the key specialization areas of *Nord-Est*, including technologies for the marine and mountain environment, smart agri-food, architecture, tourism and cultural heritage. In fields such as these, where knowledge of the territory is paramount, up-to-date regional cartographic products are essential. Therefore, this work also gives us the opportunity to provide a comprehensive overview of the cartographic products available for Friuli Venezia Giulia, one of the regions included in the iNEST project.[1]

Keywords: Geomatics · Official Cartography · Interconnected Nord-Est Innovation Ecosystem · Italian National Recovery and Resilience Plan · Friuli Venezia Giulia region.

1 Introduction

As outlined in the National Recovery and Resilience Plan (NRRP), Italy's post-pandemic recovery from COVID-19 is based on the digitalization of products, processes and services, and requires measures to improve the quality of life and environmental safety. It is clear that this is a multidisciplinary challenge that can be tackled by bringing together different skills and technologies, with a key role for data of various kinds, including geographic information.

[1] This preprint has not undergone peer review or any post-submission improvements or corrections. The Version of Record of this contribution is published in Borgogno Mondino, E., Zamperlin, P. (eds) *Geomatics for Environmental Monitoring: From Data to Services.* ASITA 2023. Communications in Computer and Information Science, vol 2088, and is available online at https://doi.org/10.1007/978-3-031-59925-5_13

In this context, geomatics can support other disciplines by providing up-to-date, complete and accurate three-dimensional geometric and semantic data of both the natural environment and artificial objects, which could serve as a basis for the simulation, understanding and monitoring of complex phenomena [1]. The role of official cartography produced by public administrations seems to be essential, especially for projects covering large areas: the spatial information accessible through regional geoportals can be one of the starting points for institutions, companies and researchers to carry out the activities envisaged to achieve the objectives of the NRRP. In addition, NRRP projects are expected to be implemented in a very short time frame, so the immediate availability of regional cartographic products is another strength of these data sources.

The aim of this paper is two-fold. In Sect. 2, we present the *Interconnected Nord-Est Innovation Ecosystem* (iNEST), a project funded within the NRRP to extend the advantages of digitalization to the main specialization areas of Northeast Italy, and highlight the activities that significantly benefit from geographic data and surveying technologies. Some of the topics addressed by iNEST and its interregional nature make the importance of public cartographic products evident. We therefore describe in Sect. 3 the ambitious cartographic program launched by the Friuli Venezia Giulia (FVG) region in 2017, whose features place it at the forefront of Italian regional databases.

2 Interconnected Nord-Est Innovation Ecosystem

Funded under the NRRP within the Mission 4 – "Education and research", Component 2 – "From research to business", innovation ecosystems are local research and development leaders, born to strengthen the cooperation among universities, businesses and territorial institutions, with the aim of involving also the local community in digitalization and sustainability issues. The iNEST ecosystem is one of 11 financed projects, built on the Smart Specialization Strategies of the northeastern Italian territory, in compliance with the industrial and research missions of the Triveneto macro-region. The territory, that includes the Regions of Friuli Venezia Giulia and Veneto and the two Autonomous Provinces of Trento and Bolzano, is characterized by a variety of vocations, from industry to agri-food, from tourism to cultural heritage. This wealth of key sectors has been transferred to the project by setting up nine interconnected spokes, each led by one of the nine universities of Northeast and devoted to a different theme (Fig. 1). The planning of the activities carried out by each spoke is detailed in [2].

The iNEST project can be considered as an opportunity to establish synergies not only between different partners (universities, companies, local authorities), but also between disciplines and technologies. Within this framework, geomatics techniques can assist in carrying out many activities, as they can be used in different application contexts. In particular, the role of geomatics is most significant within spoke 1 and 8, which deal with mountain and marine ecosystems, respectively.

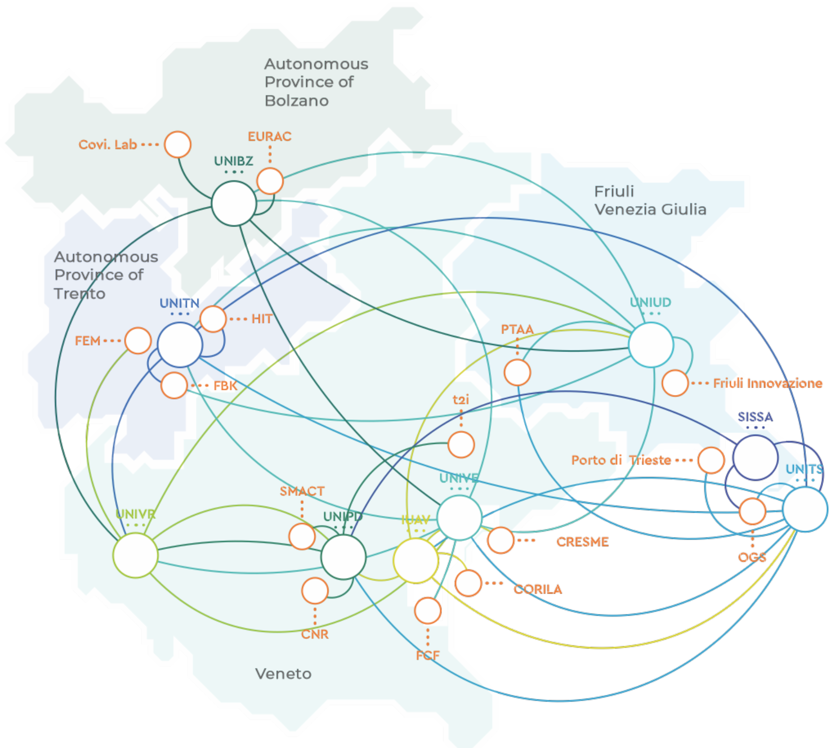


Fig. 1: Partners of the iNEST ecosystem [2].

Improving the resilience of mountain areas to the risks of climate change and geo-hydrological hazards is one of the research and technology transfer actions carried out in spoke 1, led by the Free University of Bolzano. The *Topography, remoTe sensing, and Mobile mapping systems* (ToTeM) Laboratory of the University of Udine, together with the *HydroLab uniUD* group, is currently involved in the development of a reference framework aimed at optimizing the effectiveness of risk prevention measures and structures in mountain basins. The activities employ both current and legacy cartographic data, to monitor the evolution of torrents and sediment-related phenomena at a regional scale, as well as high-resolution topographic surveys (mainly based on photogrammetry and laser scanning techniques) to locally assess the interaction between sediment dynamics and channel control works. The overall goal is to define a protocol of operational techniques for remote sensing surveys and geographic data processing, that allows quantifying the problems at different scales and could be profitably applied in the future not only by researchers, but also by practitioners and local authorities.

The aim of spoke 8 (led by the University of Trieste) is the creation of the North Adriatic Digital Twin, in cooperation with spoke 9 (coordinated by the

International School for Advanced Studies – SISSA). Among the activities currently carried out, we can find the production of high-quality, certified, harmonized, accessible and reusable georeferenced data.

The survey and assessment of existing buildings, as well as the realization of Building Information Models (BIM), can be one of the inputs for some of the actions carried out by spoke 4, led by Iuav University of Venice and focused on the construction and design sectors. The activities related to the sustainable development and management of the territory also benefit from topographic geodatabases and Geographic Information System (GIS) tools.

On the other hand, geomatics techniques, from laser scanning to photogrammetric 3D modeling, are supportive technologies in the field of culture and creative industries (spoke 6, led by the University Ca' Foscari of Venice), especially for realizing virtual experiences involving heritage sites, allowing also the collection of 2D and 3D data for precision agriculture (spoke 7, coordinated by the University of Verona).

Although less prominent, geomatics methods and surveying techniques can provide metrology solutions to support disciplines such as robotics and artificial intelligence, which are crucial in the areas of digital health (spoke 2, coordinated by the University of Trento), advanced manufacturing (spoke 3, led by the University of Udine), and Industry 5.0 (spoke 5, supervised by the University of Padova).

The topics and activities described above require to resort to regional cartographic products. Therefore, the following section provides a comprehensive overview of the recent mapping program developed by the Autonomous Region of Friuli Venezia Giulia, one of the territories involved in the iNEST project.

3 Friuli Venezia Giulia Regional Cartography

The history of regional cartography in Friuli Venezia Giulia dates back to 1970, when the production of the first technical map at a scale of 1:5,000 started. Although limited in size (it is the fifth smallest region of Italy, covering an area of approximately 7,900 km^2), the region is characterized by a great variety of landscapes, ranging from coastal plains to hilly and mountainous alpine terrain. Moreover, Friuli Venezia Giulia has been subject to intense seismic and hydrological events in the last decades. In such a scenario, an accurate knowledge of the changing territory is essential, which has led the regional administration to carry out partial updates of the technical map over the years [3].

The breakthrough came in 2017 when, after a successful test in some municipalities of the Isonzo area, a major and ambitious program was launched to completely renew the regional geodatabases [4]. Thanks to the use of state-of-the-art instruments and advanced processing methods, new cartographic products are now freely available and can be accessed via the geoportal *Eagle.fvg* [5].

According to the Ministerial Decree 10.11.2021, "Adoption of the National Geodetic Refence System", all the data are expressed in the RDN2008 reference system, which is the Italian realization of the ETRF2000 frame, and the cartographic coordinates are represented according to the UTM system, Zone 33N. It is worth mentioning that the cartographic products are distributed both in GRS80 ellipsoidal heights and in othometric heights, the latter referring to the mean sea level and computed according to the geoid undulation model provided by the Italian Military Geographic Institute (IGM). The adoption of such technical specifications promotes the interoperability with European datasets.

3.1 Laser scanning data

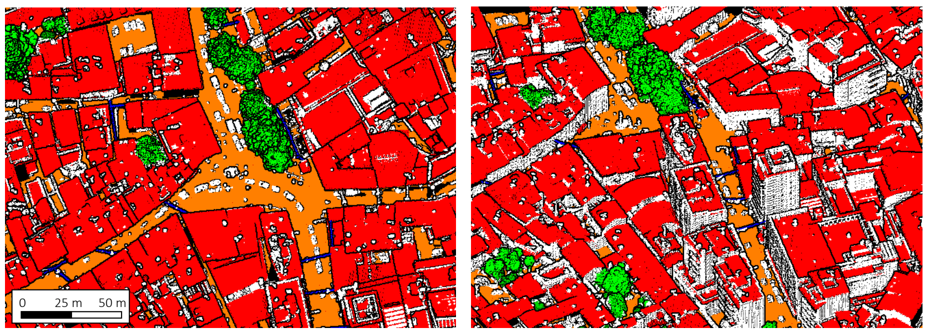
The first product delivered was the airborne laser scanning survey. The entire region was mapped using a Riegl LMS-Q780 Light Detection and Ranging (LiDAR) sensor, able to register the full-waveform of the backscattered signal. Up to 9 echoes for each emitted pulse could be retrieved by the instrument, maximizing ground point density and vegetation penetration. The flights were planned to ensure an average density of 16 points/m^2 in areas below 1,000 m above seal level (asl), and 10 points/m^2 for higher altitudes. A flight altitude of 500 m above ground level (agl) was thus used, also guaranteeing a 30% overlap between adjacent strips. As a result, more than 300 billion points were acquired, with an accuracy of better than 10 cm in elevation.

To associate semantic information with the point cloud, useful also for data interpretation and the subsequent generation of digital elevation models, a novel deep learning algorithm was implemented to efficiently and accurately classify the data [6, 7]. Figure 2 shows some examples where points are colorized in accordance with the identified classes: *ground*, *low, medium and high vegetation*, *building roof*, *power line*, *water* and *other* (e.g., walls and cars). As can be seen in the figure, the high density of the survey allowed the reconstruction of thin objects such as low-voltage electricity network, chimneys, and fences.

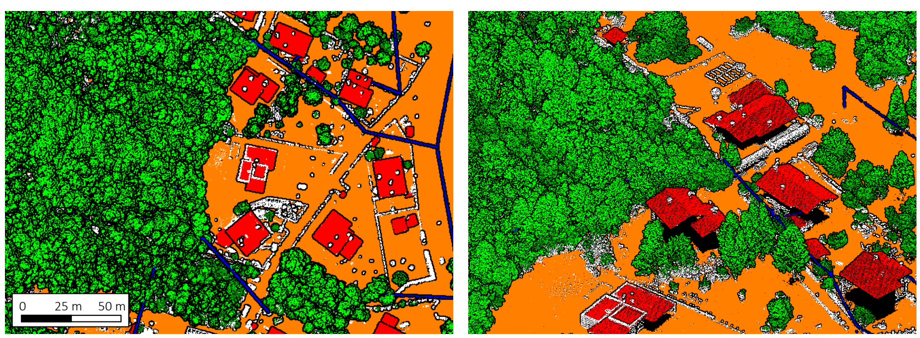
The labeled point cloud was then used to derive raster maps at 0.5 m/pixel resolution, including the Digital Terrain Model (DTM), obtained from the *ground* class (Fig. 3a), and the Digital Building Model (DBM), in which *ground* and *roof* points are considered (Fig. 3b). The Digital Surface Model is derived from all the first returns (i.e., the first echoes registered by the instrument for each pulse emitted, corresponding to the higher points), obtaining the so-called DSM*first* (Fig. 3c), whereas the DSM*last* (Fig. 3d) takes into account all the last returns (i.e., the last echoes registered by the instrument for each pulse emitted, corresponding to the lower points).

3.2 True orthophoto

The 3D LiDAR point cloud is complemented by a high-precision orthomosaic of the entire region, characterized by a resolution of 10 cm/pixel and a planimetric accuracy of better than 20 cm. To obtain these results, a large-format Vexcel UltraCam Eagle digital camera was used (panchromaic image size of 20,010 × 13,080 pixel, color image size 6,670 × 4,360 pixel), capturing 4 bands (RGB and NIR channels) at an average flight altitude of 1,300 m agl. The strips were

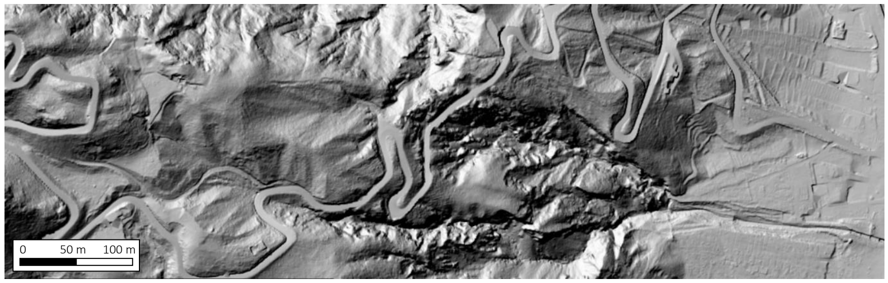


(a) Udine city center.

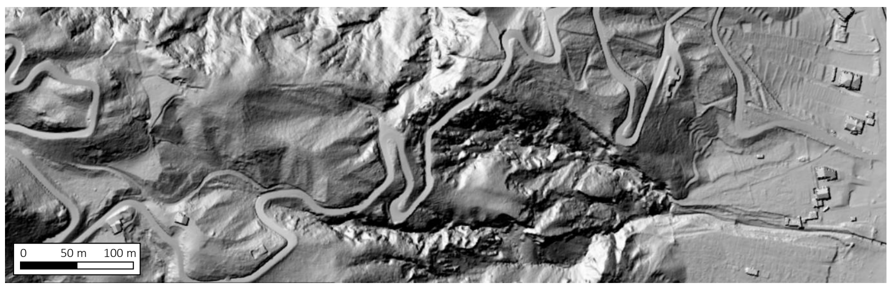


(b) Mountain village.

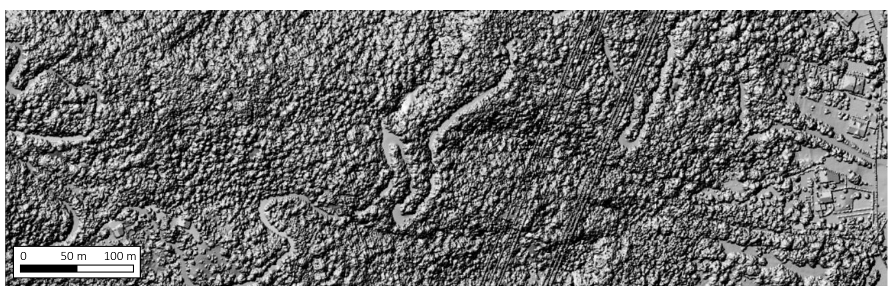
Fig. 2: Top view (left) and 3D view (right) of classified airborne LiDAR point clouds. Classes: *ground* (orange), *low and medium vegetation* (dark green), *high vegetation* (light green), *roof* (red), *power line* (blue), *other* (white).



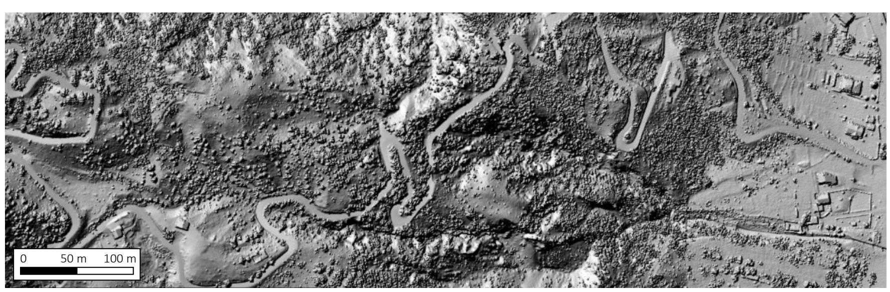
(a) Digital Terrain Model.



(b) Digital Building Model.



(c) Digital Surface Model (first returns).



(d) Digital Surface Model (last returns).

Fig. 3: Digital models at 0.5 m/pixel resolution, obtained from the airborne LiDAR survey.

planned to ensure a frontal overlap of 80% and a side overlap of 60%, values that allowed the subsequent precise orthorectification process.

It is worth underlying that the result produced is a *true* orthophoto, i.e., a highly detailed and accurate photogrammetric-derived DSM was used in the rectification process, rather than a DTM. The differences and advantages over a traditional orthophoto are clearly shown in Fig. 4: the accurate planimetric position of all objects can be measured in the true orthophoto (Fig. 4a), whereas in the standard orthophoto there is a significant displacement of tall structures (Fig. 4b).

3.3 Hyperspectral images

Hyperspectral images of entire regions are usually acquired using satellite platforms. Instead, the Friuli Venezia Giulia administration commissioned an airborne survey at an average flight altitude of 1,500 m agl to reduce the radiometric distortion caused by the atmosphere and increase the spatial resolution compared to satellite imagery. Hyperspectral rectified images were obtained with a resolution of 1 m/pixel, covering the spectral range 400–1000 nm. For the area of the Province of Trieste, hyperspectral data were acquired with a CASI 1500H sensor from ITRES, characterized by a radiometric resolution of 125 bands at 14 bits. The rest of the region was surveyed employing a HySpex VNIR-1800 sensor from NORSK Elekto Optikk, which collected 186 bands at 16 bits.

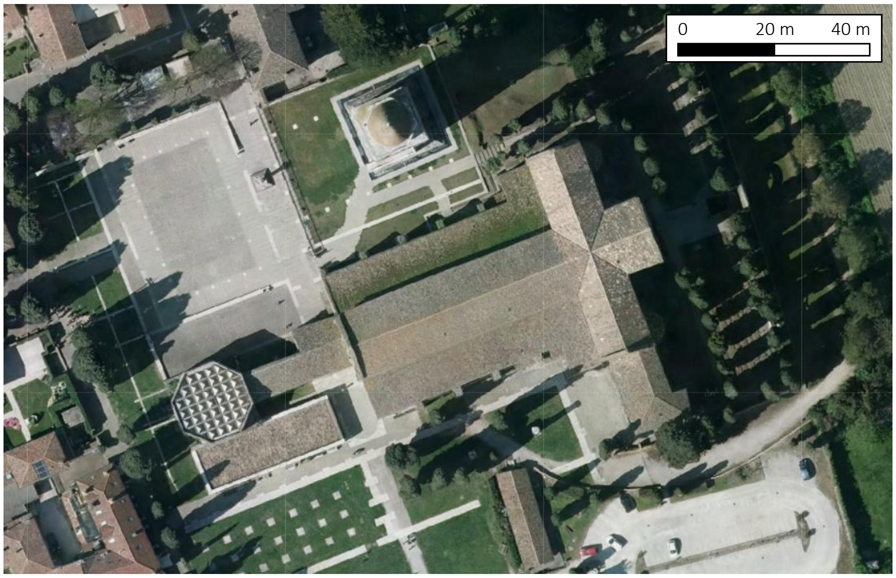
3.4 Topographic database

The previously described datasets were the basis for the creation of the Topographic Database (DBT*fvg*) of the main municipalities of the FVG region, a valuable tool for its geometric structure, semantic content and metric quality. Following the requirements of the INSPIRE Directive (Directive 2007/2/EC of the European Parliament) and of the national Ministerial Decree 10.11.2021, “Technical rules for the definition of the content specification of the geotopographic databases”, the DBT*fvg* is structured according to the GeoUML standard, based on ISO specifications.

The reference element is the *class*, which contains objects that share common properties and is associated with a predefined number of strictly coded attributes. Classes of similar objects are grouped into *themes*, which in turn are organized in *layers*. For instance, the classes *natural water course*, *channel* and *water pipeline* belong to *hydrographic network*, that is one of the four themes grouped in the *hydrography* layer.

It should be noted that most of the objects were obtained from photogrammetric restitutions, while each roof was modelled in 3D using the LiDAR point cloud as a reference. The complexity and high level of detail of the novel DBT*fvg* can be seen in Fig. 5a.

The geometric features of the DBT*fvg* make it a GIS-oriented product, since each object is fully defined and topological consistency is guaranteed. On the contrary, in the previous digital regional technical cartography (CTRN), some



(a) True orthophoto.

(b) Traditional orthophoto.

Fig. 4: True orthophoto (a) of the Basilica of Aquileia (Udine) compared to a traditional orthophoto (b). Significant displacement of tall structures (bell tower and church walls) is visible in (b).

(a) DBT*fvg*.

(b) CTRN.

Fig. 5: (a) The DBT*fvg* for an area of the city of Trieste. (b) Representation of the corresponding CTRN.

elements are implicitly defined by the geometry of adjacent objects, making spatial analyses far more complex.

The first experiment of the DBT*fvg* was carried out in the years 2012-2014 for the area of Monfalcone (scale 1:2,000), and then it was realized at a scale of 1:1,000 for the city of Trieste, and of 1:5,000 for extra-urban areas of the nearby province. In 2021 the DBT*fvg* was extended to the municipalities of Udine, Gorizia and Pordenone, adopting a scale (and, thus, the corresponding nominal tolerance) of 1:2,000. In the near future, the DBT*fvg* will cover also the remaining municipalities with more than 15,000 inhabitants.

Fig. 6: Simplified version of the DBT (DBT*sped*), obtained directly from the true orthophoto. Only the most interesting classes are retrieved.

Due to the difficulties and long lead times required to produce a map as detailed as the DBT*fvg*, the regional administration is adopting a cost-effective solution for updating the regional cartography in the remaining areas. A simplified version of the DBT (called DBT*sped*, Fig. 6) is currently being developed, taking into account only the classes of major interest (i.e., *building*, *road*, *bare soil*, *green or agricultural area*, *forest*, and *water courses*) and directly using the true orthophotos as input data to localize the footprints of the desired object classes. As with the classification of LiDAR data, the use of artificial intelligence algorithms proves essential to automate the process.

4 Conclusion

In this work, we analyzed the role of geomatics within the topics covered by the iNEST project, underlining at the same time the need of up-to-date spatial data in order to carry out the planned activities. The inter-regional nature of the iNEST consortium highlights the importance of standardizing and harmonizing the data produced by each region, so that the methodologies developed by a regional research group can be applied across the ecosystem.

Finally, it should be emphasize that the project started in September 2022 and the activities described are still at an early stage of development. At the end of the project, which is scheduled for December 2025, it will be interesting to analyze what role geomatics has actually played. It will also be useful to understand which cartographic data have been most commonly used, and to point out any difficulties that have arisen in integrating data provided by different regions.

Acknowledgement

This study was carried out within the Interconnected Nord-Est Innovation Ecosystem (iNEST) and received funding from the European Union Next-GenerationEU (Piano Nazionale di Ripresa e Resilienza (PNRR) – Missione 4 Componente 2, Investimento 1.5 – D.D. 1058 23/06/2022, ECS00000043). This manuscript reflects only the authors' views and opinions, neither the European Union nor the European Commission can be considered responsible for them.

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