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DARE VALORE AI VALORI IN URBANISTICA
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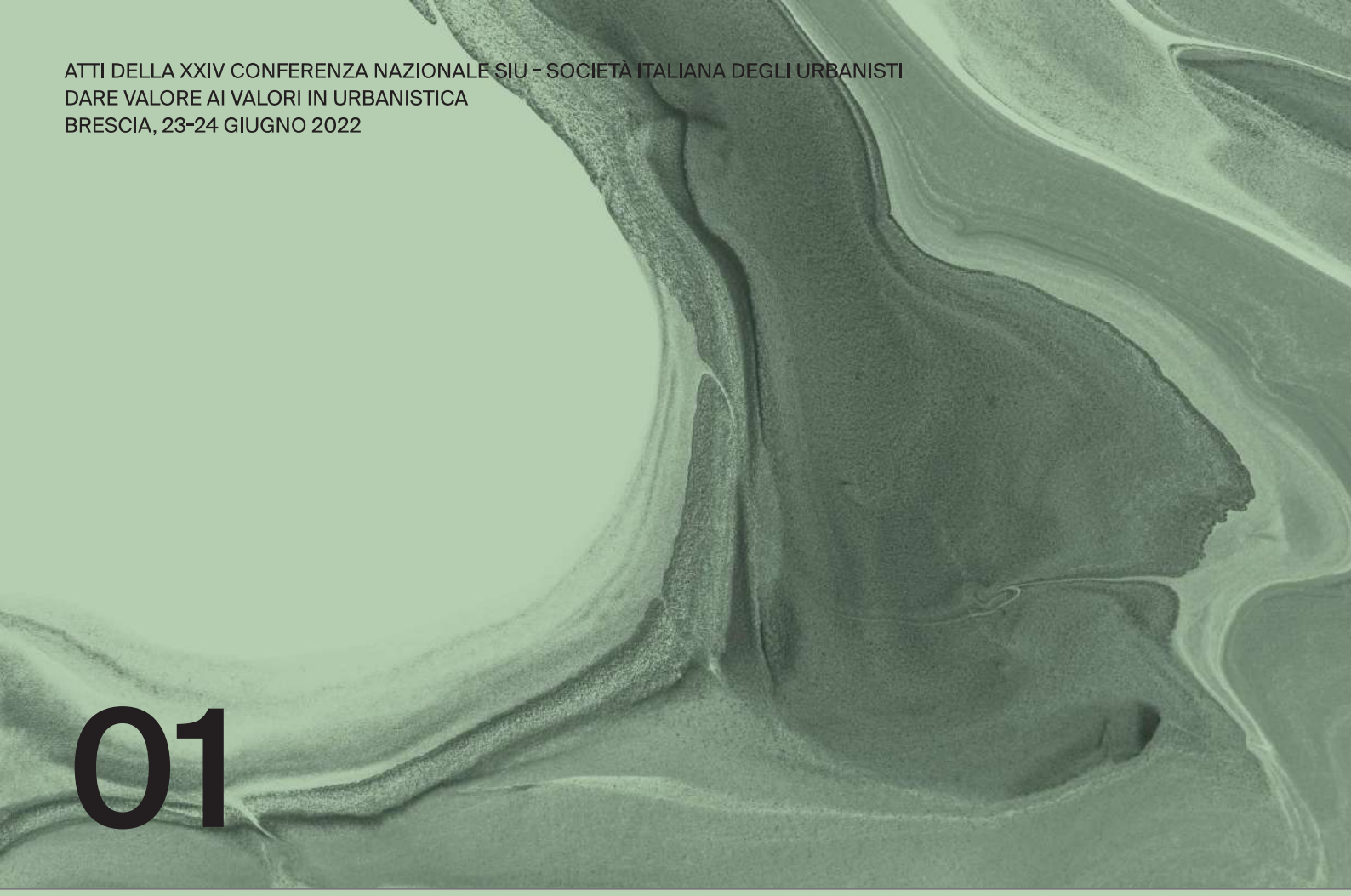

01

Innovazioni tecnologiche e qualità urbana

A CURA DI ROMANO FISTOLA, LAURA FREGOLENT, SILVIA ROSSETTI, PAOLO LA GRECA

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Emerging models for landscape digital representation: comparing experiences towards the Digital Twin of an Italian inner alpine valley

Chiara Chioni
University of Trento
DICAM - Department of Civil Environmental and Mechanical Engineering
Email: *chiara.chioni@unitn.it*

Sara Favargiotti
University of Trento
DICAM - Department of Civil Environmental and Mechanical Engineering
Email: *sara.favargiotti@unitn.it*

Abstract
Nowadays, the urban design, planning and environmental management of areas suffering territorial imbalances (namely the "peripheral", "marginal" and "inner" areas) require exploiting the ever-increasing availability of real-time data about the natural and built environments, while promoting stakeholder engagement and empowering local communities, towards a network of truly "smart" systems. In this framework, the contribution briefly presents ongoing research projects and emerging practices that develop multidimensional models of urban and landscape systems, combining technological innovations and embedding socio-ecological perspectives. The goal of this overview is to explore the transferability of the idea of a territorial Digital Twin to the case of the Italian inner areas, conceptualising a dynamic and responsive model of the landscape, fed by an updated stream of open data, to support policy decision-making and participative planning. The case study for this experimentation is the Val di Sole, an Italian inner mountain valley in the Trentino-Alto Adige region, where to enhance the social-spatial resilience and the capacity to respond more sustainably to hazards.

Keywords: fragile territories, information technology, digitalization

1 | Introduction

Unprecedented climate change impacts on economies, environment and society occur on various spatial and temporal scales, in relation to both rapid and slow onset events: such dynamic phenomena require resilient and sustainable approaches from the practice of urban and landscape management, planning, and design, especially in terms of operational digital tools taking advantage of new technologies and techniques (Semeraro et al., 2019). With this respect, during the last thirty years, the digital and information revolution has offered effective multi-level, multi-scale, dynamic, and n-dimensional mapping/modelling approaches (Juan Gutiérrez and Marcos Alba, 2019): the ever-increasing availability of (almost) real-time data about the natural and built environments could be translated into design-relevant information, represented understandably, and integrated into territorial planning and management processes to valuably support decision-making, promote stakeholder engagement and public empowerment (Fricker and Munkel, 2015; Hermansdorfer et al., 2020).

Nevertheless, in the field of digital landscape architecture, several researchers (Ervin, 2001; Nessel, 2013; Zhang, 2021) have identified a gap between landscape design tools and industry-standard mapping/modelling technologies for producing meaningful information at different scales and levels of detail. Indeed, landscape planning tools in Europe – and specifically in those countries that have adopted the principles of the European Landscape Convention – reveal that the prescriptions of the Landscape Plans are represented in static documents such as the Landscape Charters (Sala et al., 2014). Even if the current "charters" are no longer drawn on paper, they still take the form of bidimensional maps, although digital, in compliance with cartographic symbolization and generalisation conventions, and are costly to update. Moreover, these representations rarely embed the qualitative features of the landscape assets – such as sensorial perception, cultural values, or evolution in time – that are fundamental elements for the landscape comprehension and for its care, management, and design.

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This contribution adds to the debate around the integrated application of digital tools, technologies and techniques in the responsive and people-centred landscape and town design, planning and management by exploring the transferability of the concept of a distributed Digital Twin (Moshrefzadeh et al., 2020) to the case of the Italian so-called "inner areas" (DPS, 2013). Such emergent models for landscape digital representation may be used to deliver "a networked technological service system providing better services to the local community and businesses" (Rotondo et al. 2020: 203), enabling a multi-scale and multidimensional understanding of territorially imbalanced areas to increase their social-spatial resilience. Given that applications of resilience concepts are bound to territorial specifics, an Italian case study is selected to demonstrate the potential benefits of the proposal: the Val di Sole, an inner mountain valley in the north-west of the Trentino-Alto Adige region, very rich in natural capital, but exposed to severe man-made and natural hazards.

2 | Background: Smart Systems and Digital Twins

The smart development and digital twinning of natural and built environments could be divided into two sets of frameworks, at different levels of advancement: the urban, already well established, and the intermediate, rural or mountain, recently emerging, but lagging technical innovations. Indeed, even with the awareness that "smart landscape" is a broader concept "careful of social cohesion, creativity and quality of life" (Cerreta and Fusco, 2016: 490), the technological and digital components are still critical aspects. Several on-going theoretical and applied experimentations in the field of urban planning offer the opportunity to reflect on how to cope with the gap between landscape design tools and emergent technologies towards more dynamic and responsive territorial digital models.

In connection with several Smart City projects (i.e., Helsinki's 3D city models, Rotterdam 3D, Virtual Singapore), Industry 4.0 technologies have been exploited to transfer the concept of Digital Twin (DT) – originally born in the field of production engineering as a digital representation of systems enriched with real-time data and capable of autonomous operations (Grieves, 2014) – to towns (Dembski et al., 2020), cities (Batty, 2018; Ketzler et al., 2020), and even nations (i.e., the Netherlands' 3D Baseregister Addresses and Buildings, the Switzerland and Liechtenstein's swissTLM3D), according to different levels of "maturity" (Kim et al., 2022: 109-122). With regard to the urban scale, moving from the MIT's Senseable city and the New York University's Urban Intelligent Lab, researchers from the Italian National Research Council together with the Italian National Institute of Urban Planning are attempting to operationalise the paradigm of "Urban Intelligence" towards the development of an urban community DT (Framework Agreement, 2019). The long-term goal is to develop a tool capable of learning, replicating, and dynamically predicting the behaviour of an urban system, offering multi-source real-time data aggregation and analysis abilities for decision-making.

Regarding the territorial scale, even if the idea of a "smart", "responsive", "sensory" landscape is still in its infancy (Ervin, 2018; Ervin, 2020), latest conceptualizations include that of a distributed DT for landscapes: Moshrefzadeh et al. (2020) developed an organised and integrated network of information models and systems testing it in an agricultural landscape research environment. The uptake of similar solutions would allow to embrace and mirror the complex and polycentric structure of intermediate, rural and mountain areas, but currently there are at least two main challenges to be addressed (Moshrefzadeh et al., 2020): networking distributed data and information resources, which raises questions about interoperability in all its multidimensional aspects (Chioni et al., 2022); and integrating them in real-time in raw environmental conditions such as poor Internet connectivity, lack of sensors, digital divide, etc.

3 | Areas suffering territorial imbalances as laboratories for "innovability": the Val di Sole case study

The scientific literature on territorially imbalanced areas is mainly concentrated in Asia and in Europe with Italy resulting the second most active country globally (after China) in researching practices (Oppido et al., 2020). Among the strategic objectives of the last (2014-2020) and current (2021-2027) European Cohesion Policies is to foster the smart, sustainable, and inclusive growth of these areas – which often overlap with intermediate, rural and mountain territories – recognised as critical reservoirs of resilience because of their richness in environmental resources, vernacular knowledge, cultural artefacts, and potential uses. More generally, recalling the concept of "innovability" (from the two terms "innovation" and "sustainability), the idea of a distributed DT for landscapes fits well the European goal of accelerating the digital and green transitions towards a more sustainable, resilient, and human-centric industry (namely Industry 5.0 which complements and extends Industry 4.0).

In this framework, the Val di Sole case study appears to be particularly suitable to experiment an innovative cross-sectoral approach, towards a virtual-physical system supporting landscape planning and design, for a subsequent technology transfer to other national and international areas with comparable characteristics (Fig. 1). Indeed, this Alpine valley is comprehended in the Italian National Strategy for Inner Areas (SNAI), a territorial cohesion policy – which has recently benefited of new funds from the 2021 National Recovery and Resilience Plan (PNRR) – that aims to counteract the marginalisation and demographic decline of the Italian so-called "inner areas". Since such contexts are not residual, but account for about 60% of the entire national territory (DPS, 2013), they require a sensitive, respectful, and sustainable design-driven approach.

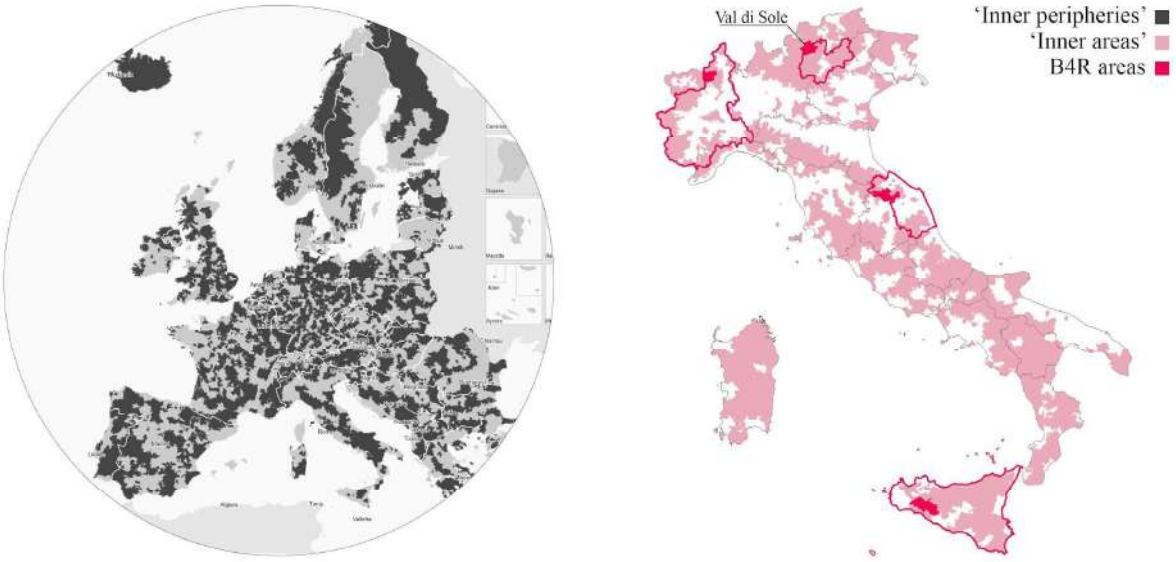

Figura 1 | In the circle, the European "inner peripheries" (from ESPON, 2017); on the right, the Italian "inner areas" (from DPS, 2013) with the location of the four B4R focus areas. Data collection and elaboration: Chiara Chioni (2022).

The authors are investigating the Val di Sole and its thermal landscapes in two on-going research projects, "B4R Branding4Resilience"[1] and "MedWays Le Vie del Mediterraneo"[2], to develop a methodological approach for the understanding and valorisation of water resources from a landscape perspective (Pasquali et al., 2022). In particular, the first project asks if integrated infrastructure can help the development of small settlements in rural-urban contexts "to foster new polycentric settlement models" (Ferretti et al., 2021: 347). The research activities – shared by all the four B4R research units, each focusing on a different Italian inner territory (Fig. 1) – are organised in three main phases, according to as many methodological aspects: the exploration, based on a collaborative and incremental collection of data with a focus on spatial interactions; the co-design, with local actors; and the co-visioning, oriented to the formulation of strategic guidelines for policymakers and local communities. In this framework, the quali-quantitative exploration of the Val di Sole, besides a photographic campaign and a stakeholder analysis, was conducted by the UniTrento research unit via the collection, categorisation, and spatialization of open-source and collaborative data from different databases at various geographic scales and levels of detail to create a digital multi-domain information profile for the valley, developed in a Geographic Information System (GIS) environment. The resulting identification of the landscape heritage values and assets, so-far synthesised and visualised in an under-construction atlas of thematic maps, diagrams, and cross-cutting indicators, was addressed during the co-design phase to support planning-oriented information management activities specifically caring for the widespread natural capital and careful to the hydrogeological risk (Figure 2).

[1] "B4R Branding4Resilience. Tourist infrastructure as a tool to enhance small villages by drawing resilient communities and new open habitats" is a research project of national interest (PRIN 2017 – Young Line) funded by the Ministry of Education, University and Research (MIUR) with a three-year duration (2020-2023). The project is coordinated by Prof. Maddalena Ferretti (Università Politecnica delle Marche) and involves as partners the Università degli Studi di Palermo (local coordinator Prof. Barbara Lino), the Università degli Studi di Trento (local coordinator Prof. Sara Favargiotti), and the Politecnico di Torino (local coordinator Prof. Diana Rolando). The UniTrento research unit consists of Prof. Sara Favargiotti (local coordinator), Prof. Alberto Nucciarelli, Margherita Pasquali, Chiara Chioni, and Angelica Pianegonda. For more information: www.branding4resilience.it.

[2] "MedWays Le Vie del Mediterraneo" is a three-year research cluster (2019-2022) awarded by the Accademia dei Lincei Centro Interdisciplinare Beniamino Segre and coordinated by Prof. Mosè Ricci with Silvia Mannocci and Margherita Pasquali. The research group consists of Prof. Sara Favargiotti, Margherita Pasquali, and Chiara Chioni.

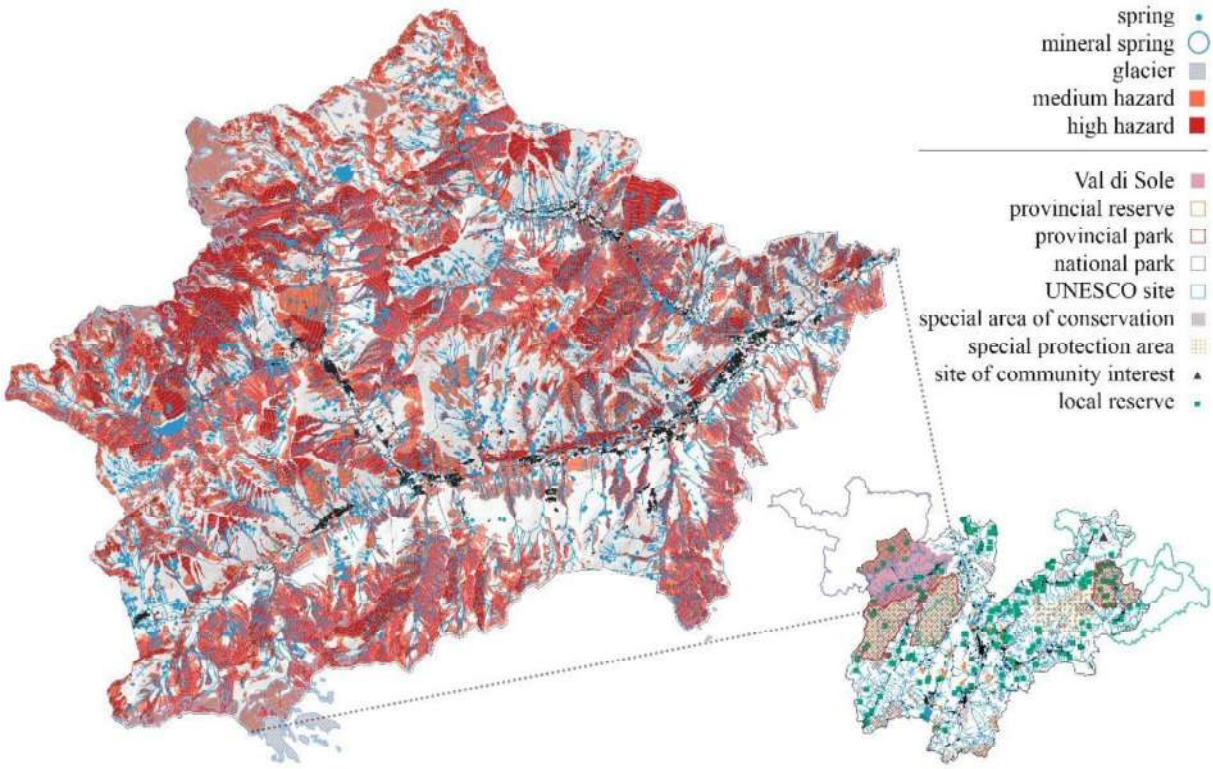

Figure 2 | The Val di Sole map, on the left, shows the medium-high hazard (synthesis of the hydrogeological, avalanche, seismic and forest fire hazards, from Protezione Civile, 2020) with its hydrological resources (from Provincial Urban Plan, 2019); on the right, the valley (in pink) within the Trentino autonomous province, with the identification of the protected natural sites (from Provincial Urban Plan, 2019; Provincial Geo-Catalogue, 2018). Data collection and elaboration: Chiara Chioni (2022).

4 | Towards a territorial Digital Twin

An on-going PhD research funded via B4R Branding4Resilience identifies opportunities for increasing the usability of the bidimensional maps' information content towards the development of multidimensional design support tools, also in view of the concluding co-visioning phase. Indeed, in parallel to the spatial database creation, efforts have been made to construct a 3D landscape model of the Val di Sole which would embed all the collected information: to this end, some image-based geometric modelling workflows from data accessible via ®Google Earth and imagery acquired in situ from UAV, have been tested for reconstructing portions of the valley. Although these techniques were originally developed for photogrammetric applications, this research focuses primarily on their ability to support the 3D documentation of the Val di Sole to improve the visualisation of information from existing databases and available sensors for better decision-making. It would represent a step towards the development of a territorial Digital Twin serving both as a three-dimensional queryable repository of knowledge and as a simulator of resilient futures for the valley.

In this investigation, landscape design and planning, civic innovation, and hacking are considered as key parts of the social and infrastructural webbing of the territory in order to address the main challenges for the uptake of a DT for the landscape (pointed out in Section 2). Volunteered, crowdsourced and social media geographic information have proven to valuably provide useful data about opinions, needs, perceptions and movement patterns of local communities, both in urban and rural environments, towards the definition of design requirements and strategies (Nikšič et al. 2017; Witanto et al., 2018). With particular regards to multiscale 3D reconstructions, images collected and shared by tourists and citizen-scientists can be used (Grun et al., 2004; Agarwal et al., 2011; Wahbeh et al., 2016; Bshouty et al., 2020) to improve results obtained using remotely sensed images by integrating point-cloud models from collaborative photogrammetry. Indeed, the global availability of smartphones, cameras and drones has transformed non-professionals citizens into "prosumers" (i.e., both consumers and producers) of data and information useful for landscape and urban design.

Since the requirements of quality and metric precision for the output are more relaxed in territorial planning and design applications, the actualisation of information technologies' affordances in intermediate, rural and mountain areas may rely on citizen participation. Within these contexts, civic hacking initiatives would

ensure extra data and information (even if raw, unstructured, or semi-structured) are in place for large-scale digital processing (Kelly et al., 2017) and the use of more or less expeditious techniques for 3D reconstructions would enable monitoring places of greatest tourist concentration, with particular regard to local resources exposed to hazards. In particular, the data updating would be more economically and temporally sustainable than carrying out extensive and resource-consuming survey campaigns, e.g., using airborne LiDAR technologies.
Indeed, while combining crowdsourced street-level and/or aerial imagery with other data sources requires further research on integrating citizen science inputs into data collection and elaboration processes, cloud-based photogrammetric processing mobile apps promise to significantly reduce the future costs of 3D digital documentation campaigns (Nocerino et al., 2017).

5 | Outlook

Adopting a whole system approach to the resilient and sustainable planning and design of inner territories requires reformulating high-level objectives for tactical interventions to ensure that local resources are protected, and risks connected to the exposure of population, infrastructures and enterprises are reduced. To this end, the elaboration of a dynamic and responsive 3D model of the landscape can support the envisioning of future territorial design at different levels of engagement, being used by stakeholders to assess situations as it unfolds, proposes, and tests alternative ideas.
In the Val di Sole case study, mapping/modelling processes were oriented at sensitising about the responsible use of environmental resources: the feedback of local actors, involved at various levels in the governance of the territory, will allow the ongoing research to further conceptualise and develop a territorial Digital Twin of the thermal landscape. The additional enrichment with real-time and site-specific data would enable an agile decision-making tool towards the management and design of complex territorial transformations from a truly holistic and integrated perspective.
In complex and infrastructurally raw systems such as inner areas, the feedback from the virtual realm to the physical world – because of the lack of adequate technological tools, networks, and structures – might come from people, involved not only as sensors, but also as actuators in automatic or semi-automatic decisional models. Supporting operative actions in collaborative decision-making sessions, possibly facilitated by experts, would contribute to closing gaps in strategic planning and process management, also overcoming issues connected to the digital divide.

Author Contributions

Conceptualization, CC and SF; methodology, CC and SF; investigation, CC; data curation, CC; writing—original draft preparation, CC; writing—review and editing, CC and SF; visualisation, CC; supervision, SF. All authors have read and agreed to the published version of the manuscript.

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Note

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