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# Maintenance Management of Infrastructure Systems: Organizational Factors in Territorial Planning

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**Abstract**. The issue of the maintenance of the infrastructure systems (e.g., viaducts, roads, bridges and highways), built some decades ago, is increasingly becoming a central argument. Within this topic, the safety assessment represents a fundamental as well as basic analysis that underpins a sustainable territorial management of the infrastructure systems. In fact, many structures are often affected by functionality, aging or safety problems and need specific interventions to avoid undesirable impacts in terms of social implications. In addition, the reference stakeholders, in terms of institutions and public actors, play an important role in relation to both the administrative and economic planning procedures. The present study has the preliminary aim to illustrate some possible contributions and improvements to achieve a more sustainable territorial planning, especially for the maintenance of the infrastructure systems. In detail, the present preliminary investigation highlights the possible advantages deriving from the use of the technology (i.e., remote sensing technique by means of satellite data - Differential Interferometry Synthetic Aperture Radar "DInSAR") within an analysis at territorial scale. Indeed, the activity of monitoring all the overall infrastructure system can represent a useful approach to have a territorial vision of the safety of the infrastructures and can lead to a more sustainable planning. In fact, the involvement of all the reference stakeholders, in relation to this specific territorial issue, can lead to a more organised administrative and economic process. Some preliminary results, shown through thematic maps using the Geographic Information System (GIS), are described for a case study in a sample area in Italy.

## 1. Introduction

Nowadays, it is very central the issue of the maintenance of the infrastructure systems (e.g., roads, viaducts, bridges and highways), built some decades ago. To this aim, the safety assessment represents a fundamental and basic analysis to define, successively, a sustainable territorial management of the infrastructure systems. In point of fact, many structures are often affected by functionality, aging or safety problems and need specific interventions to avoid undesirable effects on the society as commented in [1]-[5], also in accordance with more stringent safety requirements provided by the technical codes.

Furthermore, the reference stakeholders, such as institutions, public actors, road companies and agencies (i.e., private and public stakeholders), has an important role regarding both the administrative and economic processes and planning procedures.

Concerning the management planning activities developed by public actors, recent proposals and examples of policies (e.g., [6]-[7]) have been oriented to defend urban communities including the main infrastructures from natural hazards due to climate changes, and from geological events like liquefaction

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as a consequence of earthquake events [8]. Similarly, other studies (as an example, [9]-[13]) have dealt with innovations for the planning in territorial areas affected by natural hazards through surveys or risk-based frameworks by employing also the GIS (Geographical Information System) technique. In [14], a systemic and integrated management methodology for security and safety of road infrastructures is explained.

Regarding the specificities of the maintenance management to ensure a satisfactory and adequate safety level of infrastructures, private and public stakeholders have also proposed different strategies known as Bridge Management Systems (BMSs), usually, jointed to the Structural Health Monitoring (SHM) techniques [15]-[16]. All the proposals are aimed at detecting the occurring anomalies and/or damages to select the intervention typology.

The description of these approaches and studies highlights the requirement of risk analyses and/or technology techniques combined with in-situ or remote monitoring technologies. Along the time, there has been a high interest for the satellite remote sensing, principally the Differential Interferometry Synthetic Aperture Radar (DInSAR) [17]-[18].

The present research has the preliminary aim to illustrate some possible improvements to delineate a more sustainable territorial planning, especially, for the maintenance of the infrastructure systems. Precisely, the present preliminary investigation highlights the possible advantages attainable from the implementation of the technology (i.e., remote sensing technique through satellite data - Differential Interferometry Synthetic Aperture Radar "DInSAR") to carry out territorial analyses. Indeed, the activity of monitoring all the infrastructure systems together can be a useful approach to have a territorial vision of the safety of the infrastructures leading to a planning able to respect the sustainability principle. In such a way, the infrastructure systems can be monitored for multi hazards (e.g., earthquakes, season phenomena, slow landslides, soil-structure interaction effects, temperature effects, subsidence phenomena, structural degradation phenomena) at territorial scale. Moreover, the involvement of all the reference stakeholders, concerning this specific territorial issue, can give rise to a more organized administrative and economic process. Some preliminary results, shown through GIS maps, are described as an example for an Italian area.

## 2. Territorial planning and (BMSs) strategies

As already discussed, the presence of existing infrastructures is large in any region of the world with the consequential increase of the costs for engineering maintenance works to guarantee a satisfactory and adequate safety level. This aspect makes this issue very relevant for the public and administration actors to select the best policies through territorial plans or management strategies.

### *2.1. Territorial planning and policy*

This sub-section described some proposals and examples of the territorial governance and administration policies referred, especially, to the specific issue of the maintenance of the infrastructure systems.

An in-depth content analysis is described in [6]-[8] examining the documents, rules, guidelines, goals, tools and plans produced by the different levels of policy to ensure a satisfactory protection of the urban communities including the main infrastructures from some natural hazards.

In [9], they are commented the outcomes from surveys with the scope to estimate, in qualitative terms, how the citizens perceive the risk concerning natural hazards (i.e., landslides). Although the qualitative nature of the information, these outcomes are a useful contribution to the territorial planning. Also in [19], within the territorial planning, the choice of the best political or institutional actions

finalised to decrease the risk is founded on collaborative interaction between the citizens and stakeholders (e.g., institutions, public administrators).

The investigation of [10] develops a territorial planning analysis by using the GIS technique and explaining an improved framework to estimate the risk specific for the industrial activities in opposition to accident hazards as also recommended by (Seveso II Directive by the European Council). The research also highlights the importance and need to adopt specific methodologies, procedures and techniques in the planning activity.

Other researches [11]-[13] have discussed risk maps or methodologies, also in GIS environment, for a safety-based planning taking into account different infrastructure systems. Precisely, the study by [13] focuses on the location of some typologies of plants. The one of [12] examines the most appropriate location concerning the industrial park.

The work of [14] proposes an integrated approach for management of infrastructure security and safety, modifying the perspective into a general analysis of a system in which interdependent agents influence the system performance.

*2.2. Management strategies – BMSs*

This sub-section illustrates some proposals and examples of management strategies delineated by companies and agencies, authorities to guarantee that structures are serviceable and safe during their service life. These strategies are based on inspections, numerical evaluations, testing, maintenance and replacement.

Many countries have delineated as many BMSs explained below.

Two BMSs have widely been adopted in the U.S. and are denoted, respectively, as PONTIS [20],[21] and BRIDGIT [22]. In detail, PONTIS is, maybe, the most innovative strategy, characterised by a top-down approach, which can be finalised to better select funding for rehabilitation, maintenance and repair of a bridge or a network of bridge structures conditional to a pre-assigned budget [23].

In Europe, many countries (e.g., Slovenia, Norway, Germany, France, Spain and United Kingdom) have instituted a program defined as BRIME (i.e., Bridge Management in Europe) to revise and propose a complete BMS functional for the needs specific for the European Infrastructures [20].

In Italy, beyond the different BMSs developed by the different agencies, the “Italian Infrastructure and Transport Ministry (MIT)” disciplined the combined use of SHM and BMS as delineated in Security Management System [16]. The SHM of a structural system, over a timeframe of interest, typically involves appropriate devices and sensors (e.g., displacement transducers, thermometers, strain gages and accelerometers) and analysis of the measurements to estimate the current safety condition of the structure [24].

The abovementioned approaches (i.e., policies and strategies), often delineated by different actors, are not perfectly homogenous and present some limitations at the territorial scale for the costs of the SHM sensors. As recently stood out, the technology of the DInSAR image processing could be a good instrument able to give some improvements to solve some of the abovementioned limitations.

## 3. The contribution of the DInSAR technology to infrastructure territorial planning

The remote sensing technique, the DInSAR [25]-[30], has been widely employed to achieve measurements of displacements (or deformations) on the topographic surface over the timeframe of

interest for many hazards (e.g., slow landslides, earthquakes, season phenomena, subsidence phenomena, soil-structure interaction effects, structural degradation phenomena, temperature effects). Indeed, the DInSAR technique, using data achieved by the Italian COSMOSkyMed satellite constellation, permits to monitor the infrastructure systems including also the territorial context. In such a way, the data time series may be elaborated in GIS environment to define thematic maps and achieve a vision of the overall territory.

The advantages of the DInSAR technique are certified by its increasing diffusion through many research and technical projects [31],[32] by reason of both the territorial analysis and lower costs in comparison to the conventional monitoring techniques.

The DInsAR technology permits also to enhance the institutional organization in the administration of the territory ensuring an appropriate maintenance management of the infrastructure systems with a better territorial planning. Indeed, the DInSAR-based territorial analysis, involving multidisciplinary experts, can represent a technical instrument to increase the synergy among the different institutions, public actors and the different levels of the administration. Many aspects concerning planning, decisions and economic investments can be approached by all the reference stakeholders with a global vision of the territorial safety of the infrastructure systems.

In detail, using the GIS technique, it is achievable to define a thematic map representing the territory with its administrative boundaries overlapped to another thematic map showing the infrastructure systems. Therefore, the main stakeholders can be easily recognised.

Then, the DInSAR data can be reported in the GIS environment to compute and show the trend of the measurements of the monitored points within the timeframe of interest. The infrastructure systems are divided in specific “cells” to calculate the velocities and, hence, the displacements in each “cell”.

After that, an expert engineering judgment is decisive to evaluate if the displacements are dangerous and can cause important effects on the infrastructure systems.

Finally, all the reference stakeholders can analyse the criticisms and elaborate an investment planning organised on the basis of the various administrative competences concerning the specificity of each criticism. In addition, they can also modify the territorial planning to prevent other risks and future emergencies.

Some preliminary results of the application of this DInSAR-based territorial analysis are illustrated in Section 4, through a case study in Italy.

## 4. Case study in Italy

Considering some main highways (i.e., infrastructure systems) of the Municipality of Rome in Italy, in accordance with [32], some preliminary results achieved from the the DInSAR-based territorial analysis are described as follows.

Figure 1 shows, in GIS environment, the Municipality of Rome overlapped to the thematic map corresponding to the infrastructure systems. Table 1 summarises the main stakeholders of the infrastructure systems under investigation: specifically, “AutoStrade Per l’Italia - ASPI”, “ANAS S.p.A.”, “Strada dei Parchi S.p.A.”, Municipality and Province.

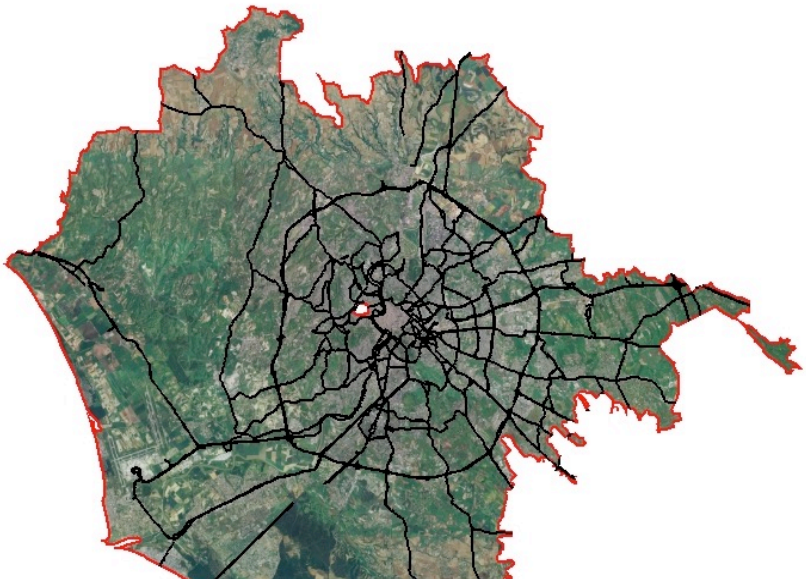


**Figure 1.** The infrastructure systems.

**Table 1**. Main infrastructures with the relative stakeholders.

| Roads | Stakeholders |
|---|---|
| "A12 - Autostrada Azzurra" | "AutoStrade Per l'Italia – ASPI" |
| "A1 - Autostrada del Sole" | "AutoStrade Per l'Italia – ASPI" |
| "A24" | "Strada dei Parchi S.p.A." |
| "A91" | "ANAS S.p.A." |
| The orbital motorway that encircles Rome, denoted as "Grande Raccordo Anulare" | "ANAS S.p.A." |
| "SP 216 - Maremmana" | Province |
| "Circonvallazione" | Municipalility |
| "Lungotevere" | Municipalility |

On these GIS thematic maps, the DInSAR data have been implemented and processed, considering the SAR sensor images (COSMO-SkyMED) corresponding to the ascending orbit and for a timeframe equal to the last 8 years. Adopting a coherence value of 0.6 according to [33], more than 6 millions of monitoring points are available, as painted in Figure 2. This figure depicts the average velocities: specifically, increasing velocity values present a more and more dark colour. In the elaboration, the authors divided the territory and the infrastructure systems into "cells" having a size equal to 50x50m [25],[34] to calculate the displacements. Successively, the time series data have been processed to achieve the computation of the vertical displacements, represented in Figure 3, according to [25],[34].

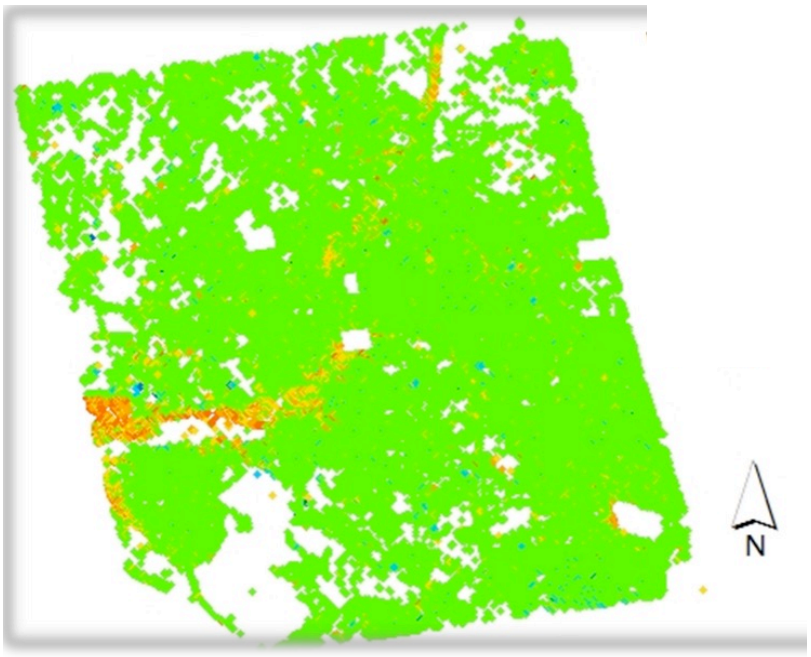



**Figure 2.** Monitoring points.

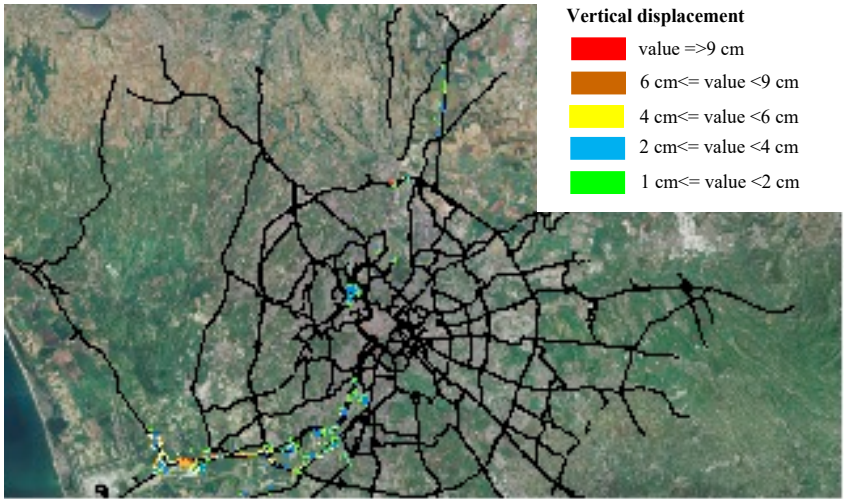



**Figure 3.** Vertical displacements.

The results show the necessity to investigate, through more detailed analyses, some specific infrastructure systems affected by high values of the vertical displacements. In fact, these results have to be compared to appropriate limit state thresholds [5] to judge the safety level but represent preliminary indicators of the potential damage.

Although these results are preliminary, thanks to their strong correlation to the stakeholders, the useful potentialities of this technology-based territorial analysis can be easily deduced. Indeed, this territorial analysis should give rise to an administrative process involving all the stakeholders to delineate the most pertinent investments jointed to territorial planning in accordance with the

sustainability principle, focusing the attention on the infrastructure systems affected by larger displacements (i.e., potential damage).

## 5. Conclusions

The study aims to give some preliminary and useful innovations to the important issue of the maintenance of the infrastructure systems. Since many infrastructure systems were built some decades ago, their maintenance is required in accordance with the sustainability principle. In fact, many structures are often affected by functionality, aging or safety problems and need specific interventions to avoid undesirable effects on the society.

In this argument, they are relevant the reference stakeholders, institutions and public actors, due to their central role concerning both the administrative and economic processes and planning procedures.

With this purpose, the present research is a preliminary investigation that highlights the possible advantages attainable from the employment of the technology (i.e., remote sensing technique through satellite data - Differential Interferometry Synthetic Aperture Radar "DInSAR") to carry out territorial analyses.

As highlighted in the explanation of the preliminary results referred to the case study in Italy, the activity of monitoring the overall infrastructure system can be a useful approach to have a territorial vision of the safety of the infrastructures with a more sustainable planning. Actually, the involvement of all the actors, concerning this specific territorial issue, can give rise to a more organised administrative and economic process in accordance with the sustainability principle.

## References

[1] B. Blochl, and B. Braun, "Economic assessment of landslide risks in the Schwabian Alb, Germany - research framework and first results of homeowners and experts surveys," *Nat Hazards Earth Syst Sci*, vol. 5, pp. 389-396, 2005.

[2] V. Cotecchia, "The Second Hans Cloos Lecture. Experience drawn from the great Ancona landslide of 1982," *Bulletin of Engineering Geology and the Environment*, vol. 65, pp. 1–41, 2006.

[3] G. Iovine, O. Petrucci, V. Rizzo and C. Tansi, "The March 7th 2005 Cavallerizzo (Cerzeto) landslide in Calabria – SouthernItaly," *Proceedings of the 10th IAEG Congress*, Nottingham, Great Britain, 6–10 September 2006, 785, pp. 1–12, 2006.

[4] M. F. Mansour, N. R. Morgenstern, and C. D. Martin, "Expected damage from displacement of slow-moving slides," *Landslides*, vol. 7, pp. 117–131, 2011.

[5] P. Castaldo, M. Calvello, and B. Palazzo, "Probabilistic analysis of excavation-induced damages to existing structures," *Computers and Geotechnics*, vol. 53, pp. 17-30, 2013.

[6] W. McWilliam, R. Brown, P. Eagles, and M. Seasons, "Evaluation of planning policy for protecting green infrastructure from loss and degradation due to residential encroachment," *Land Use Policy*, vol. 47, pp. 459-467, 2015.

[7] C. Kubal, D. Haase, V. Meyer, S. Scheuer, "Integrated urban flood risk assessment – adapting a multi-criteria approach to a city," *Nat. Hazards Earth Syst. Sci.*, vol. 9 (6), pp. 1881–1895, 2009.

[8] R.B. Olshansky, "Land use planning for seismic safety: the Los Angeles county experience 1971-1994," *J. Am. Plann. Assoc.*, vol. 67 (2), pp. 173–185, 2001.

[9] M. B. de Mendonca, and F. T. Gullo, "Landslide risk perception survey in Angra dos Reis (Rio de Janeiro, southeastern Brazil): A contribution to support planning of non-structural measures," *Land Use Policy*, vol. 91, pp. 104415, 2020.

[10] Z. Török, R. M. Petrescu-Mag, A. Mereuță, C. V. Maloș, V. I. Arghiuș, and A. Ozunu, "Analysis of territorial compatibility for Seveso-type sites using different risk assessment methods and GIS technique," *Land Use Policy*, vol. 95, pp. 103878, 2020.
[11] B. Claudia, M. M. N. Jeroen, Z. Sisi, and A. Ben, "Risk-maps informing land-use planning processes: a survey on the Netherlands and the United Kingdom recent developments," *Journal of Hazardous Materials*, vol. 145 (1/2), pp. 241–249, 2007.
[12] A. Zucca, A. Sharifi, and A. Fabbri, "Application of spatial multi-criteria analysis to site selection for a local park: a case study in the Bergamo Province, Italy," *Journal of Environmental Management*, vol. 88 (4), pp. 752–769, 2008.
[13] Y. Hossein, and E. Sachio, "Geothermal power plant site selection using GIS in Sabalan area, NW IRAN/Natural Resources and Environment (NRE)," In: *Proceedings of 6th Annual International Conference on Geographical Information Technology and Applications*. GIS Development Press, Kuala Lumpur, pp. 1–18, 2007.
[14] R., Troisi, and G. Alfano, "Towns as Safety Organizational Fields: An Institutional Framework in Times of Emergency," *Sustainability*, vol. 11(24), pp. 7025, 2019.
[15] E. Figueiredo, I. Moldovan, and M. Barata Marques, "Condition Assessment of Bridges: Past, Present and Future. A Complementary Approach," Universidade Católica Editora, Unipessoal, Lda ISBN: 978-972-54-0402-7, 2013.
[16] Italian Infrastructure and Trasport Ministry (MIT) "Guidelines for classification and management risk, security assessment and monitoring of existing bridges," 2020.
[17] M. Crosetto, E. Biescas, and J. Duro, "Generation of advanced ERS and Envisat interferometric SAR products using the stable point network technique," *Photogramm. Eng. Remote Sens.*, vol. 4, pp. 443–450, 2008.
[18] M. Crosetto, O. Monserrat, M. Cuevas-González, N. Devanthéry, and B. Crippa, "Persistent scatterer interferometry: a review," *ISPRS J. Photogrammetry Remote Sens.*, vol. 115, pp. 78–89, 2016.
[19] B. Wisner, "Vulnerability as Concept, Model, Metric, and Tool," *Oxford Research Encyclopedia of Natural Hazard Science*, 2016.
[20] BRIME, "Bridge management in Europe. Final Report D14, IV Framework Programme," Brussels, 2001.
[21] P. D. Thompson, "PONTIS: the maturing of bridge management systems in the USA," In J. E.Harding (Ed.); G. A. R. Parke (Ed); M. J. Ryall (Ed), Bridge Management 2: inspection, maintenance, assessment and repair (pp971-978). London: Thomas Telford, 1993.
[22] H. Hawk, "BRIDGIT: User-Friendly Approach to Bridge Management," Transport Research Circular No 498, pp E:7.1-15, 1999.
[23] M. S. Khan, "Bridge Management Systems: Past, Present, and Future," *Concrete International*, 2000.
[24] A. C. Tan, M. Kaphle and D. Thambiratnam, "Structural health monitoring of bridges using acoustic emission technology," *8th International Conference on Reliability, Maintainability and Safety*, Chengdu, 2009, pp. 839-843, doi: 10.1109/ICRMS.2009.5269952, 2009.
[25] D. Peduto, L. Cascini, L. Arena, S. Ferlisi, G. Fornaro, and D. Reale, "A general framework and related procedures for multiscale analyses of DInSAR data in subsiding urban areas," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 105, pp. 186-210, ISSN 0924-2716, 2015.
[26] P. Berardino, G. Fornaro, R. Lanari, and E. Sansosti, "A new algorithm for surface deformation monitoring based on small baseline differential SAR interferograms," *IEEE Trans. Geosci. Remote Sens.*, vol. 40 (11), pp. 2375–2383, 2002.
[27] O. Mora, J.J. Mallorquı´, A. Broquetas, "Linear and nonlinear terrain deformation maps from a reduced set of interferometric SAR images," *IEEE Trans. Geosci. Remote Sens.*, vol. 41, pp. 2243–2253, 2003.
[28] U. Wegmuller, C. Werner, T. Strozzi, and A. Wiesman, "ERS-ASAR Integration in the

Interferometric Point Target Analysis," In: Proceedings Fringe 2005 Workshop, Frascati, Italy, 28 November–2 December, 2005.

[29] B. M. Kampes, and N. Adam, "The STUN Algorithm for Persistent Scatterer Interferometry," *Fringe 2005 Workshop*, Frascati, Italy, 2005.

[30] G. Fornaro, A. Pauciullo, and F. Serafino, "Multipass SAR Processing for urbanized areas imaging and deformation monitoring at small and large scales," In: *Proceedings of the Urban Remote Sensing Joint Event*, Paris 11–13 April, pp. 1– 7, 2007. http://dx.doi.org/10.1109/URS.2007.371879.

[31] MATTM, "Piano Straordinario di Telerilevamento Ambientale (PSTA), Linee guida per l'analisi dei dati intereferometrici satellitari in aree soggette a dissesti idrogeologici," Italian Ministry of the Environment and Protection of Land and Sea (MATTM), 108 pp., 2010.

[32] ReLUIS, "Research project between the Italian Civil Protection Department and the Italian Universities: WP 11 – Task 11.4: Monitoring and satellite data", 2019-2021.

[33] Y. Yang, A. Pepe, M. Manzo, M. Bonano, D. N. Liang, and R. Lanari, "A simple solution to mitigate noise effects in time-redundant sequences of small baseline multi-look DInSAR interferograms," *Remote sensing letters*, vol. 4(6), pp. 609-618, 2013.

[34] M. Calvello, L. Cascini, and S. Mastroianni "Landslide zoning over large areas from a sample inventory by means of scale-dependent terrain units", *Geomorphology*, vol. 182, pp. 33-48, 2013.