

Methodological Approach for Classifying Typical Recurrent Urban and Peri-Urban Configurations

Chiara Di Dato(✉)

Department of Civil, Building-Architecture and Environmental Engineering, University of L'Aquila, Via Giovanni Gronchi 18, 67100 L'Aquila, Italy
chiara.didato@univaq.it

Abstract. Qualitative characterization of urban and peri-urban areas is widely studied in literature and definitions varies by geographic areas and specific characteristics. The paper aims at presenting a methodology to distinguish urban and peri-urban representative configurations by the means of artificial soil data, satellite images and qualitative interpretation of urban elements. The obtained classification covers 6 classes of 2 square-km recurrent configurations that are functional to the purposes of the integrated project LIFE IMAGINE Umbria, which aims at protection of habitats, biodiversity and local communities related to the Natura 2000 Network in Umbria region (Italy). The case study area is composed of two Functional Urban Areas: Perugia and Terni. The obtained results have already been supportive of planning strategies related to the project's outputs. The paper aims to approach and discuss the methodological approach in relation to its main scope in the LIFE IMAGINE Umbria project and to future developments and applications.

Keywords: peri-urbanization · urban morphology · Natura 2000 Network

1 Introduction

In the globalized world, cities are pole of economic growth, job and a variety of services and activities. The interest around cities and their expansion is even vivid because urban settlements have never stopped growing [1].

Increasing urbanization affects multiple fields related to the living and quality of spaces. Often, such process of urbanization consists in creating new peri-urban areas that deeply impact also on landscape fragmentation. Peri-urban areas can relate with socio-economic processes [2] and with quality of life [3] and quality of morphological configurations [4]. Also, peri-urbanization is directly related to processes that impact on ecological connectivity and environmental fragmentation. Ecological functions within adjacent natural and semi-natural areas can be highly compromised when they are "cut off" by new settlements and infrastructures [5].

The LIFE IMAGINE Umbria (LIFE19 IPE/IT/000015) [6] integrated project is devolved to implement the environmental continuity in Umbria region (central Italy). It

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024
O. Gervasi et al. (Eds.): ICCSA 2024 Workshops, LNCS 14817, pp. 18–31, 2024.
https://doi.org/10.1007/978-3-031-65238-7_2

is 7 years long LIFE project started in 2020. The main object is the Natura 2000 (N2K) Network as established by the "Habitat" Directive 92/43/EEC [7]. The main goals are divided per actions, and they aim at the biodiversity conservation due to the creation of an integrated management system.

The Umbria region is around 8500 km^2 wide, whereas the extension of N2K network is around 1275 km^2 (around 15% of the regional territory). Then, the A2 action "Preliminary analysis of urban and peri-urban areas" has been focused on analyses of types of settlements for evaluating their role in conservation goals [8]. The action has been conducted with steps that included description and recognition of different recurrent urban and peri-urban areas; the analysis of existing and potential relationships with N2K networks' sites and then to the definition of guidelines devolved to evaluation processes of programs, plans and projects.

To this extent, classifying various types of settlement and defining proper differences between urban and peri-urban areas can be fundamental to assess environmental continuity with proper actions and projects.

In the fields related to management of cities no one approach can fully describe the nature of peri-urban dispersed configurations [9]. Researchers found out diverse methods and instruments for delimiting and classifying peri urbanization producing a multitude of contributions and prospectives [10, 11].

In many studies the peri-urban areas consist of very variable low-density urban morphology, multifunctional territories, and long commuting distances [12, 13]. Some analyses are focused on developing models and indicators for configuring and parametrize urban dynamics. The phenomenon's measure is considered crucial for having awareness of the problem. In the European context, settlement spread studies are associated with urban sprawl and urban sprinkling models, which are studied both for the state of the art [14–16] and for implementing techniques, tools, and simulations for reversing the tendence [17–19].

Some studies have focused on definitions of peri-urban, from the studies on the 'Diffuse city' which aimed at describing the tendence of a dispersive structure in urban space derived by dynamics and social-economic processes [20]. In the late 1990s in Europe, such construction trends have generated many local parceling out, that were characterized by single constructed interventions scattered around the territory including both historical tissue and new settlements. Such dispersal structure of the city has been described in various ways which emphasize the morphology changes, such as 'Metropolitan archipelago' [21] and enclaves [22].

The present work presents a methodology that has been used in the LIFE IMAGINE Umbria project. The aim of the paper is to deal with urban areas' classification starting from the specific necessity to recognize and schematize the complex reality with the aim of approaching the issue of environmental continuity.

The paper is organized in five paragraphs. Paragraph 2 explains the methodology exploring used data and the classification process. Paragraph 3 focuses the obtained results which consist in 17 recurrent configurations of urban and peri-urban areas. Then, paragraph 4 explores some main limits and considerations derived from the study. In conclusion, the author expresses the general overview on the findings of the methodology and the developments to be implemented in future (paragraph 5).

2 Materials and Methods

The paragraph is articulated in two sub-paragraphs. It presents the methodology following the presentation of material and methods and then the process of analysis that leads to the classification of urban and peri-urban configurations (Fig. 1).

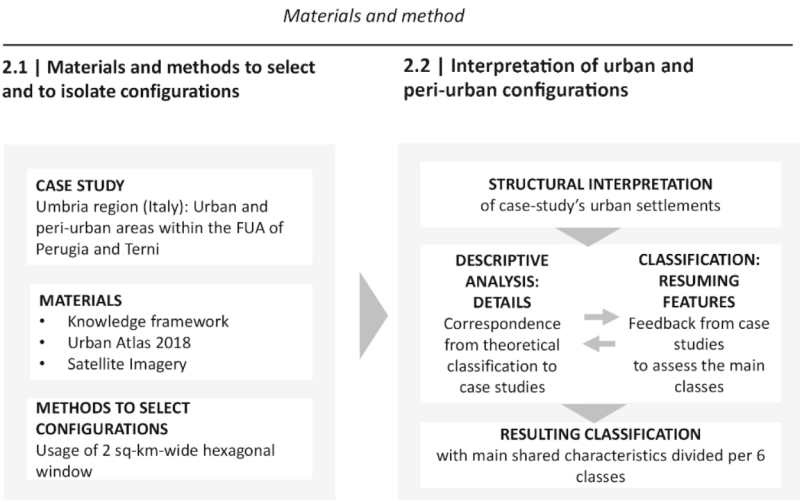

Fig. 1. Flowchart of the methodology. Source: Own elaboration.

2.1 Materials and Methods to Select and to Isolate Configurations

The proposed approach is comparative and qualitative. It is based on a comparative analysis considering the existent literature on the urban gradient and the land cover/ land use data and satellite imagery available for the case study. The land cover and land use information (LULC) are based on the Copernicus Land Monitoring Service (CLMS) [23]. Specifically, the focus is on the section of pan-European component (CORINE Land Cover) and the local component (Urban Atlas) composed of main Functional Urban Areas (FUA) [24]. In Umbria region, the areas that present such data are the FUAs of Perugia and Terni (Fig. 2). Then, satellite images are used for the high-resolution and wide coverage of data for the detailed analysis of urban settlements.

For giving substance to the comparison among different settlement then is introduced a figure of reference in order to frame the selected configurations with one dimension and shape. The hexagonal shape is considered suitable as it refers to the hexagonal cell used in urban grids. The use of hexagonal shape has advantages derived both from the equal distance between the centre and each edge, and the relationship among grids' cells. (Fig. 3) [25, 26]. As instance, spatial accessibility analyses use these characteristics for having a better representation of connectivity and neighborhood relations [27, 28]. Such properties are considered useful for developments of the research [29].

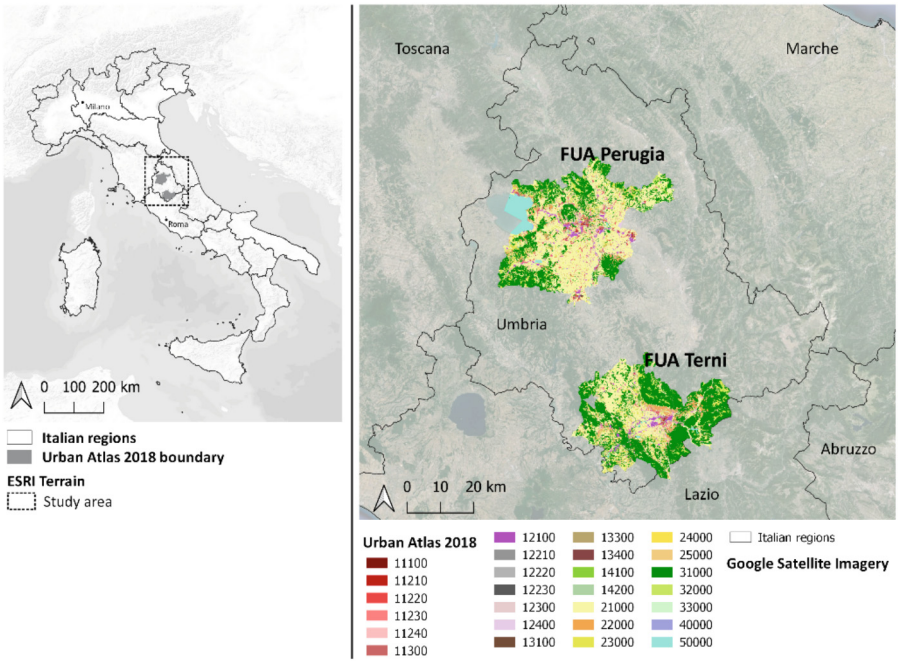

Fig. 2. Case study area. General framework of Italy (on the left side) and Umbria region with the two selected FUAs considered in the present work (on the right side). Source: Own elaboration. Data from Google Map, Copernicus data.

The use of such shape-window is here released from any grid system. For the present analysis, the use of a free shape is proposed as solution for identifying recurrent areas in every position they are, differently from what would have happened with the use of grids that are randomly located [16]. As one hand lens, the hexagonal window is "moved" on the case study area, and it is arbitrarily stopped where it frames one recurrent configuration.

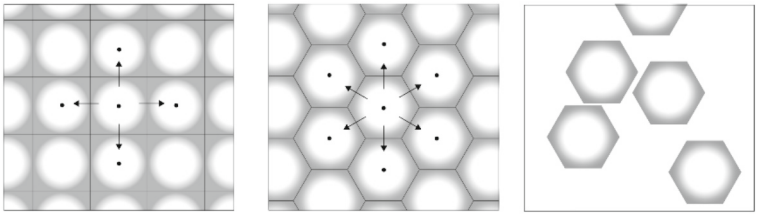

Fig. 3. General properties of grids compared to the singular window that is used for the present methodology. Source: Own elaboration.

Window's dimension then must be settled to frame significant portions of the urban and peri-urban configurations. To this extent, the window's dimension is chosen as the

doubled data of the average CLC urbanized areas in the case study. The layer of artificial surfaces (classes from 1.1 to 1.4) is considered for fitting the average dimension of one urbanized area and its surrounding. According to this data, the medium value of single polygons of artificial surfaces as mapped in the CLC is about 100 ha (86,5 ha). Considering the double of the data, the dimension results equal to 200 ha/2 km^2.

As further tool, a visual isolation of the area is elaborated using six adjacent empty cells around the window. This is functional to isolate only the analyzed area from external elements (such as other parts of the settlement, infrastructures, or other settlements) (Fig. 4).

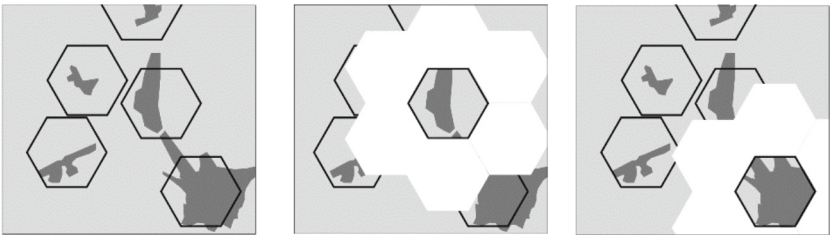

Fig. 4. Windows and isolation of the configuration. Source: Own elaboration.

2.2 Interpretation of Urban and Peri-Urban Configurations

Given the framework of tools, critical approach is fundamental for distinguishing shapes, level of aggregation and characteristics of urban settlements. How to classify the gradient with its unclear scattered borders, variations, and irregularities [11]? Structural and functional interpretation are possible analyses [30]. However, such work implicates the reduction of complex system (the reality) in different possibilities of settlements (the model) which can be associated to the real gradient (Fig. 5).

The proposed structural interpretation consists in the match between identification of the urban structure and interpretation of quality of the urban environment. The process is based both on the specificities of the case study and on the knowledge framework.

The analysis is carried out through two steps. Firstly, identification of real settlements approaches the local specificities of the case study. Secondly, the definition of the main classes is aimed at giving coherence in one homogeneous classification. The theoretical classification is done in mutual progression with the descriptive analysis of real settlements (Fig. 5).

The descriptive analysis proceeds to frame the recurrent settlements due to the use of the hexagonal window. Then, the descriptive analysis acquires information related to the context, the morphological features that affect distribution of settlements. This aspect includes identification and description of natural elements as mountains, rivers, lakes etc. When urbanized areas are present, the level of occupation of the soil is studied through the sealing soil data (Urban Atlas). Such information is integrated with evaluation of typology of buildings, grades of compact tissues as well as interstitial natural areas as readable in satellite images.

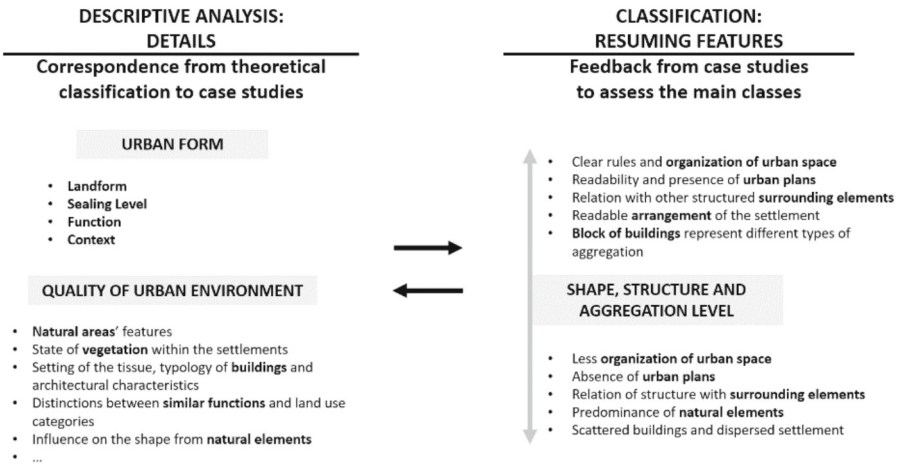

Fig. 5. The process of classification. Source: Own elaboration.

Then, function and uses are useful for understanding specific characteristics of the settlement. Even though the window is ideally isolated in its analysis, the context can be derived from elements in the window that give information on the matrix of reference. The study of the road network is then considered for focusing on the presence and the types of streets (highway, main road, high-speed road, provincial and minor streets) inside the window and the road network that draws the settlement.

There is also the observation of the state of vegetation within the settlements. Vegetation can be mature and full-grown, then it can indicate the co-presence of enduring settlements. On the contrary, youth plants can indicate a recent settlement. At the same time, same species and organizations of the plants can indicate a plan behind the construction. The setting of the tissue, the typology of buildings and architectural characteristics are indicative of properties of settlements. Same typology and same building material suggests a structured unitary plan. On the contrary, great diversity among structures and open spaces' design suggest autonomy in the building process. Extreme diversity with a non-structured design of the streets can indicate spontaneous development of the settlement [31].

Secondly, the classification follows a gradient of main structures and aggregation features. Shape and structure are the primary features in considering the artificial area as it appears at the chosen scale. The classification then moves from the most compact structures (aggregated); to the recognizable aggregations along a main direction (linear); to the undefinable prevalent direction and the general dispersion of the artificial elements (spread).

Six main models then are classified from the most compact and aggregated tissue to the absence of buildings and urban shapes (Fig. 6).

1. Aggregated, compact and dense configuration generally represents portion of the urban area. It is comprehensive of historical centre or in proximity of that. This model has readable, structured, and consolidated urban plan. Tissue can be intricate,

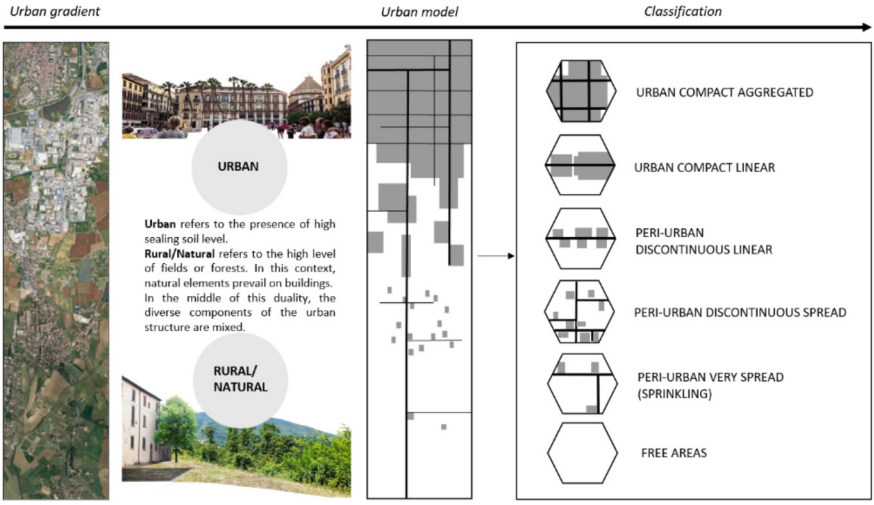

Fig. 6. From the urban and rural extremes to a scheme of the urban gradient. Source: Own elaboration. Data from Google Earth, Copernicus data.

reticular, radio centric or composite. According to the urban zoning, these settlements are included in the A, B, C D and F zones (DM 1444/68).

2. Linear, compact, and dense configuration. Settlement is aggregated along a main path. It can be a provincial or regional road, or a high-speed road. Functions are mixed, often industrial, or commercial units, but also residential areas. Blocks can be sparse or interrupted by empty spaces. These spaces can be marginal or residual areas. According to the urban zoning, these settlements are included in the B, C D and F zones.
3. Linear and discontinuous configuration. Settlement is aggregated along a main path and tissue appears discontinuous. The main path can be a provincial or regional road, a high-speed road or inferior level that connects residential areas. Density varies and structure is porous. Blocks can be organized in wide distances, or they can follow a reticular structure in which empty and residual spaces are present. Also, fragmented parts of farms can be included in the structure. According to the urban zoning, these settlements are included in the B, C, D, and F zones. The main difference with the linear, compact, and dense is the residual space between various settlements. Empty spaces in this scheme weigh as much as sealed areas.
4. Spread and discontinuous tissue. Settlement is discontinuous and scattered with variable density. There is no one path of reference, but some main infrastructures can be present. Blocks can be organized in wide distances, or they can follow a reticular structure, in which empty and residual spaces are present. Also, fragmented parts of farms can be included in the structure. According to the urban zoning, these settlements are included in the B, C, D, and F zones.
5. Very spread tissue in rural context. Settlement is discontinuous and scattered with very low density. In this model rural context is dominant, whereas buildings are spots which follow streets that connect residential areas. Generally, it is located outside and

away from urban centre. Generally, buildings and sealed areas are distant from the main infrastructures. If present, small or medium aggregations form shapes that are not related to the main roads. According to the urban zoning, these settlements are included in the C, D, and E zones.

6. Free areas in rural context. The dominant element is a natural area, such as fields, woods, orchards. Buildings are excluded from this pattern. The class about free areas is a category deprived from artificial land. According to the urban zoning, these settlements are included in the E zones.

3 Results

As a result, the classification matches with 17 windows on the study area. Windows are 9 for FUA of Perugia and 8 for FUA of Terni. The results are divided into 5 recurrent configurations of aggregated compact and dense tissue; 2 Linear, compact, and dense tissues; 2 Linear discontinuous tissues; 3 Spread and discontinuous tissues; 3 Very spread tissue, and 2 configurations of Free areas.

As already prefigured, the development of peri-urban areas follows the proximity of the urban centres [32]. The results highlight that available advantageous morphology (as

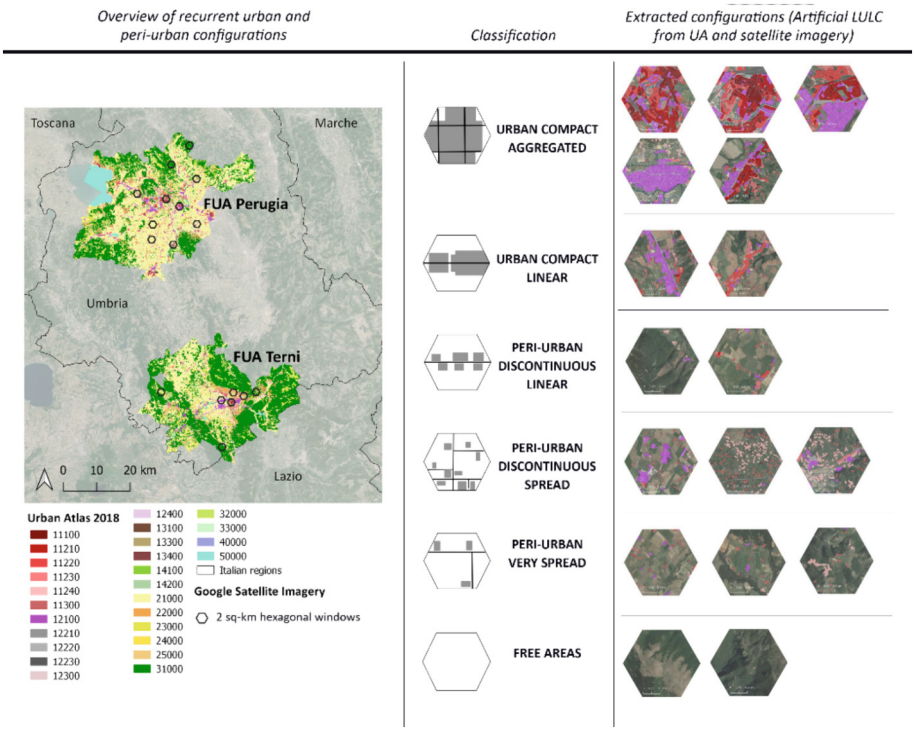

Fig. 7. Results of window classification within the Urban Atlas map and the 17 recurrent configurations selected from the case study. Source: Own elaboration. Data from Google Map, Copernicus data.

agricultural lands) in continuity to the urban core facilitates the presence of heterogeneous peri-urban configurations. Then wider is the rural matrix around the urban centre (as the case of FUA of Perugia), more the urban dispersion may spread in various shapes (from linear to diverse level of dispersion). On the contrary, a mountain environment might limit expansion prospects since the soil available for expansion is limited (as it is partially in the case of FUA of Terni) (Fig. 7) [11].

The considerations done for each configuration converged in single insights realized as worksheets. Each worksheet summarizes the main characteristics derived from the study (Fig. 8). A worksheet corresponds to one configuration, and it indicates the place name, the general overview in the CLC framework and the hexagonal window showing the UA 2018 Land use and land cover information (LULC) with the Google satellite imagery. The illustrating worksheets are comprehensive of satellite imagery at various scales, sketches of the main shapes of the settlement and the main road network. The sum of worksheets give shape to a collection of qualitative detailed presentations of each configuration. Such research products are part of the A2 action's report "Preliminary analysis of urban and peri-urban areas".

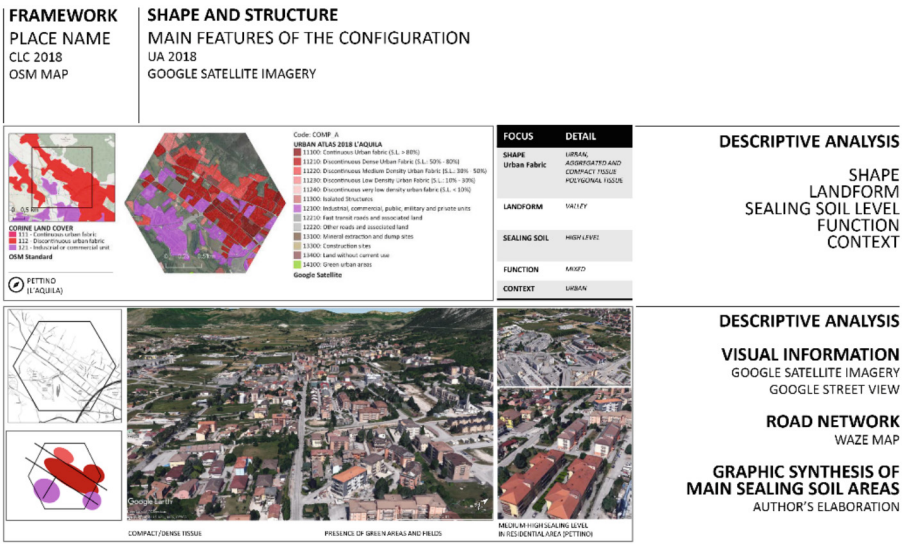

Fig. 8. Summary worksheet that resumes the qualitative investigation on a singular window. Source: Own elaboration. Data from Google Earth Image Landstat/Copernicus, Copernicus data.

4 Discussion

In the present work, the FUA set the perimeter of the analysis, including areas around the urban core and excluding all the areas outside the boarder. Such limit imposes to exclude more peripheral configurations, which would be interested to compare if the Urban Atlas data covered larger areas around the urban cores. Indeed, it seems easier

to find out urban and peri-urban configurations which are denser, whereas uninhabited and building-free areas are present in less quantity. Although the focus of the research is related to urban growth and environmental continuity, other interesting comparisons might regard the welfare-related issues like social services and connections [33].

Then, some general considerations have arisen from the results (Fig. 7).

1. Aggregated, compact and dense tissue are generally part of the historical centres or productive plants. The blocks and the high sealing soil cover almost all the area. The shape might be related to one central point of interest or aggregation.
2. Urban linear, compact and dense tissues are mostly linear productive plants aligned along a main road. Linearization is a typical way of proceeding in urbanization development, and it is highly functional for productive plants and logistic centres. The proximity and the direct access to the main road, services, and resources' infrastructures might be related to economic convenience.
3. Peri-urban Linear discontinuous tissues have varied properties. Settlements are mainly residential areas of small towns. Generally, the low high space between building and the low density is given by a mountain area, impervious or inaccessible areas.
4. Peri-urban spread and discontinuous tissue present mainly scattered configurations which highly depend on the terrain morphology. The configurations are highly variable.
5. Peri-urban very spread tissue is mainly in rural valley context. The vocation of this area is mainly agricultural, and the few scattered buildings are main residential units.
6. Free areas have been found at the borders of the FUA and they mainly share mountainous morphology. The type of involved non-artificial soil is variable (from fields to woods).

In the present work, calibration among different classes has been one of the main discretional choices. For the specific case study, three main choices in terms of distinctions have been done during the classification of the main configurations.

Linear, compact, and dense configuration is one of the most critical categories to define for the case study. The definition of this model dealt with the difficulty in distinguishing different types of compact tissues. A first recognition has included also some aggregated compact tissues because of their main axial development. This has been the case of extended industrial sites that develop on one or two main infrastructures. Then a calibration is made in terms of aggregation. Compact tissues that are more aggregated than linear have been labelled as aggregated compact tissue. On the contrary, compact tissues with strong axial development have remained in the compact linear class (Fig. 9).

Spread and discontinuous configuration is uneasy to identify, and it presents many specificities and variations in each context. Previously, a rough classification of spread/discontinuous tissue included the typical sprawl configuration or mixed discontinuous tissues that might be associated with the sprawl model. However, sprawl model has a defined recognizable configuration which should be considered apart from the general discontinuous tissue (Fig. 9) [14]. Since the typology is not common in the case study, the specific case has been excluded from the classification.

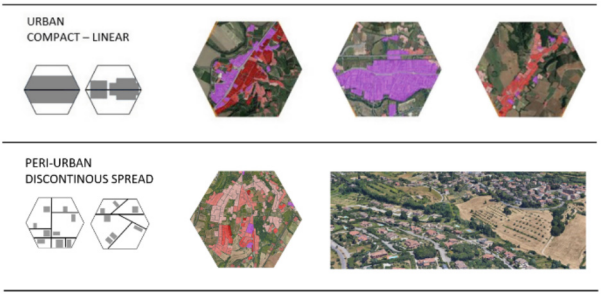

Fig. 9. First classifications of linear compact and dense configurations and example of one (non-recurrent) configuration representative of the sprawl model. Source: Own elaboration. Data from Google Earth Image Landstat/Copernicus, Copernicus data.

Moreover, evident variations in discontinuous tissues have led to the necessity of calibrating two different levels of discontinuous classes. Among the classes, the two discontinuous are the most similar ones. As highlighted in introduction, the discontinuous tissues can vary consistently, and such variations are object of several studies on urban growth models [15].

Furthermore, the selection has been guided by the necessity of coherence inside the classes. Coherence among configurations of the same class is a prerequisite both for the classification itself and for further studies. In fact, the choice of a defined shape (the hexagon) can be also functional to other applications. Phenomena as urban dispersion is studied with methodologies that uses grids. Research have already demonstrated that there is a difference between a grid-base results and an administrative borders' ones [16]. The hexagonal window is part of development lines of research in relation to process of automatic recognition of urban configurations that might cover all the case study area [26]. In the present work, the descriptive and qualitative analysis is a process of reasoning that is not replaceable with software or automatic techniques. However, it has already been used for experimental approach aimed at automating the recognition of recurrent urban and peri-urban configurations given the illustrated classification. In fact, the classification can serve as a dataset, for which the ratio has been defined due to the study of the territory and it can be supportive of semi-automatic machine learning models. Given the distinction in classes, the semi-automatic model can automatically implement the classification for a selected area. The implementation produces a combined methodology between descriptive and computational approaches which has given promising results [29].

5 Conclusions

The theme of peri-urbanization is wide, and it is supposed to be a pivotal question in urban studies for a long time yet. This work deals with the opportunity to improve sectorial classifications used for distinguishing urban and peri-urban areas.

Even though urban elements are related to urban dynamics, the classification has been done considering the readable elements in the current situation. Then, the differences

between the 6 configurations are defined by comparisons among the cases present in the case study and the knowledge framework. Moreover, the methodology may represent a step towards the use of a qualitative to a more computational approach due to the use of the selected window. The role of the author in the present work is relevant for developing the classification. However, the same approach on different case studies might bring to variations to the classification. Although the produced classification is considered suitable for recognize most urban settlements in Italy, next steps of the research include the study of new FUAs in Italy and Europe.

Also, the worth stands in the practical application that the study had within the LIFE IMAGINE Umbria project. The presented approach has in the project its real field of application, as the worksheets have already converged in the implemented project's methodology and in the guidelines of the Action A2 [8].

Among the goals of the project, modelling the urban growth is fundamental both for analyze the present state and for forecasting future scenarios in relation with the protection of Natura 2000 Network. The classification then is a crucial node for defining guidelines for restoring environmental continuity because it permits to give differential responses to different areas. In fact, study of configurations can serve for targeted interventions to implement, in line with the assumption that urban and peri-urban configurations may need different approaches to the urban project [34]. As instance, de-sealing methods can be the prevalent goal for a compact dense area. Conversely, reconfiguration should be the best solution for spread tissues. Peri-urban areas may be also involved in reconfiguration of the territory for including green infrastructure and protection of existent interstitial open spaces [35]. In this sense the classification of urban and peri-urban configurations is a tool for studying targeted projects. At the design level, each configuration can fit a series of interventions and projects then can give specific solutions to configuration-related issues. In perspective, sustainability and performance of settlements should be evaluated through the classification of configurations. Ultimately, configurations might be usable for defining planning strategies as implementation of regeneration and resilience policies [36].

Acknowledgments. The analysis is developed within the Integrated Project LIFE IMAGINE UMBRIA (LIFE19 IPE/IT/000015 – Integrated MAnagement and Grant Investments for the 2000 Network in Umbria).

References

1. UN-Habitat: World Cities Report 2020. The Value of Sustainable Urbanization (2020)
2. Serra, P., Vera, A., Tulla, A.F., Salvati, L.: Beyond urban-rural dichotomy: exploring socioeconomic and land-use processes of change in Spain (1991–2011). Appl. Geogr. **55**, 71–81 (2014). https://doi.org/10.1016/j.apgeog.2014.09.005
3. Sargolini, M.: Urban Landscapes: Environmental Networks and Quality of Life. Springer, Heidelberg (2013). https://doi.org/10.1007/978-88-470-2880-7/COVER
4. Carta, M., Gisotti, M.R., Lucchesi, F.: Settlements and urban morphological quality in landscape planning. Analytical models and regulating tools in the landscape plan of Regione Toscana. Sustainability (Switzerland). **14** (2022). https://doi.org/10.3390/su14031851

5. Romano, B.: Rete ecologica del Veneto. Analisi delle interferenze ambientali e linee di pianificazione. Rapporto finale (2006)
6. LIFE IMAGINE. https://www.lifeimagine.eu/. Accessed 12 Apr 2023
7. European Commission: The Habitats Directive. https://environment.ec.europa.eu/topics/nature-and-biodiversity/habitats-directive_en. Accessed 03 Mar 2023
8. Di Dato, C., Pierantoni, I., Fiorini, L., Marucci, A., Sargolini, M.: Characterization of urban and peri-urban areas in Umbria region to identify their possible role in the conservation of Natura 2000 network. In: Marucci, A., Zullo, F., Fiorini, L., Saganeiti, L. (eds.) INPUT 2023. LNCE, vol. 463, pp. 659–668. Springer, Cham (2024). https://doi.org/10.1007/978-3-031-54096-7_57
9. Ravetz, J., Fertner, C., Nielsen, T.S.: The dynamics of peri-urbanization. In: Nilsson, K., Pauleit, S., Bell, S., Aalbers, C., Sick Nielsen, T. (eds.) Peri-Urban Futures: Scenarios and Models for Land use Change in Europe, pp. 13–44. Springer, Heidelberg (2013). https://doi.org/10.1007/978-3-642-30529-0_2/COVER
10. Cattivelli, V.: Delimiting rural areas: evidence from the application of different methods elaborated by Italian scholars. Land **11**, 1674 (2022). https://doi.org/10.3390/LAND11101674
11. Sahana, M., Ravetz, J., Patel, P.P., Dadashpoor, H., Follmann, A.: Where is the peri-urban? A systematic review of peri-urban research and approaches for its identification and demarcation worldwide. Remote Sens. **15**, 1316 (2023). https://doi.org/10.3390/RS15051316
12. ISTAT: FORME, LIVELLI E DINAMICHE DELL'URBANIZZAZIONE IN ITALIA (2017)
13. Piorr, A., Ravetz, J., Tosics, I.: PERI-URBANISATION IN EUROPE Towards European Policies to Sustain Urban-Rural Futures SyNThESIS REPORT (2011)
14. Egidi, G., Cividino, S., Vinci, S., Sateriano, A., Salvia, R.: Towards local forms of sprawl: a brief reflection on mediterranean urbanization. Sustainability **12**, 582 (2020). https://doi.org/10.3390/SU12020582
15. Romano, B., Zullo, F., Fiorini, L., Ciabò, S., Marucci, A.: Sprinkling: an approach to describe urbanization dynamics in Italy. Sustainability (Switzerland). **9** (2017). https://doi.org/10.3390/su9010097
16. Saganeiti, L., Favale, A., Pilogallo, A., Scorza, F., Murgante, B.: Assessing urban fragmentation at regional scale using sprinkling indexes. Sustainability (Switzerland). **10** (2018). https://doi.org/10.3390/su10093274
17. Marucci, A., Fiorini, L., Zullo, F., Di Dato, C., Tomei, V., Romano, B.: Vision and project to retrofit the "urban dust" scenario: simulation in the region of Umbria, Central Italy. J. Urban Plan. Dev. **147** (2021). https://doi.org/10.1061/(asce)up.1943-5444.0000722
18. Romano, B., Zullo, F., Marucci, A., Fiorini, L.: Vintage urban planning in Italy: land management with the tools of the mid-twentieth century. Sustainability (Switzerland). **10** (2018). https://doi.org/10.3390/su10114125
19. Romano, B., Fiorini, L., Zullo, F., Marucci, A.: Urban growth control DSS techniques for de-sprinkling process in Italy. Sustainability (Switzerland). **9** (2017). https://doi.org/10.3390/su9101852
20. Indovina, F.: La città diffusa: cos'è e come si governa. Daest IUAV, Venezia (1990)
21. Indovina, F., Doria, L., Fregolent, L., Savino, M.: Dalla città diffusa all'arcipelago metropolitano. Franco Angeli (2009)
22. Petti, A.: Arcipelaghi e enclave. Architettura dell'ordinamento spaziale contemporaneo. Bruno Mondadori (2007)
23. Copernicus Land Monitoring Service: CORINE Land Cover. https://land.copernicus.eu/pan-european/corine-land-cover. Accessed 14 Apr 2023
24. Copernicus Land Monitoring Service: Urban Atlas. https://land.copernicus.eu/local/urban-atlas. Accessed 14 Apr 2023

25. Burdziej, J.: Using hexagonal grids and network analysis for spatial accessibility assessment in urban environments - a case study of public amenities in Toruń. Miscellanea Geographica. **23**, 99–110 (2019). https://doi.org/10.2478/MGRSD-2018-0037
26. Fiorini, L., Falasca, F., Marucci, A., Saganeiti, L.: Discretization of the urban and non-urban shape: unsupervised machine learning techniques for territorial planning. Appl. Sci. (Switzerland) **12** (2022). https://doi.org/10.3390/app122010439
27. Levine, A.S., Feinholz, C.L.: Participatory GIS to inform coral reef ecosystem management: mapping human coastal and ocean uses in Hawaii. Appl. Geogr. **59**, 60–69 (2015). https://doi.org/10.1016/J.APGEOG.2014.12.004
28. Birch, C.P.D., Oom, S.P., Beecham, J.A.: Rectangular and hexagonal grids used for observation, experiment and simulation in ecology. Ecol. Modell. **206**, 347–359 (2007). https://doi.org/10.1016/J.ECOLMODEL.2007.03.041
29. Di Dato, C., Falasca, F., Marucci, A.: Machine learning techniques for the semiautomated recognition of urban and peri-urban configurations. In: Gervasi, O., et al. (eds.) ICCSA 2023. LNCS, vol. 14109, pp. 16–29. Springer, Cham (2023). https://doi.org/10.1007/978-3-031-37120-2_2
30. Gottero, E., Cassatella, C., Larcher, F.: Planning peri-urban open spaces: methods and tools for interpretation and classification. Land (Basel). **10** (2021). https://doi.org/10.3390/land10080802
31. Romano, B., Zullo, F., Fiorini, L., Marucci, A.: Illegal building in Italy: too complex a problem for national land policy? Cities **112**, 103159 (2021). https://doi.org/10.1016/J.CITIES.2021.103159
32. European Environment Agency: Land take and land degradation in functional urban areas (2021)
33. Di Dato, C., Marucci, A.: Fragile territories around cities: analysis on small municipalities within functional urban areas. In: Gervasi, O., Murgante, B., Misra, S., Rocha, A.M.A.C., Garau, C. (eds.) ICCSA 2022. LNCS, vol. 13378, pp. 427–438. Springer, Cham (2022). https://doi.org/10.1007/978-3-031-10562-3_30
34. Cutini, V.: La Forma del disordine. Tecniche di analisi e progetto urbano ai tempi dello sprawl. Materiali di architettura e di urbanistica 2016 (2016)
35. European Environment Agency: Green infrastructure and territorial cohesion. The concept of green infrastructure and its integrationinto policies using monitoring systems (2011)
36. OECD: Italy's National Action Plan for Policy Coherence for Sustainable Development. OECD (2022). https://doi.org/10.1787/54226722-EN