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Indicators for fragile territories and classification of urban and peri-urban configurations: a methodological approach

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INDICATORS FOR FRAGILE TERRITORIES AND CLASSIFICATION OF URBAN AND PERI-URBAN CONFIGURATIONS: A METHODOLOGICAL APPROACH

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FOREWORD

Since 2019, the PhD activities have developed through the study of urban characteristics to improve the sustainability of urban transformations.
The PhD activities are contextualized in a framework of projects which have guided the develop of the addressed topics. The methodology was developed within the framework of the Project SostEn&Re (2020-2022). The project has aimed at improving the sustainability, resilience, and adaptation for the protection of ecosystems and physical reconstruction in central Italy. The interest in the territorial context went deeper with the analysis on urban and peri-urban areas thought the use of Functional Urban Areas. Such work is developed within the Integrated Project LIFE IMAGINE UMBRIA (LIFE19 IPE/IT/000015 - Integrated MAnagement and Grant Investments for the N2000 NEtwork in Umbria) that gives a framework for the in-depth qualitative analysis on urban structure.
Such analysis has led to the most innovative part of the present work. The classification of urban and peri-urban configurations is the result of qualitative analysis and discretization of real multifaceted urban gradient.

Abstract

The thesis research develops a multi-scalar planning process from the general (strategic asset) to specific (project solutions). The process describes an integrated methodological approach focused on fragilities of urban settle-ments and the proposed methodologies are devolved to comprehend and to analyse the Italian territory. The research is developed through 4 passages of scale (in 3 main chapters). The first chapter aims at introducing some macro-criteria that can characterize the fragile conditions of Italian small municipalities (less than 5000 inhabitants). Levels of fragile conditions are computed through the combination of indicators that represent some main territorial issues (hydrogeological instability, economic backwardness,...). Results highlight the possible distinction of three macro-regions that can represent different clusters of priority for future allocation of funds. Results also highlight territorial gradient of differential measures of fragility in the same territorial context. Then, the investigation focuses on the physical structure of the urban envi-ronment for understanding if macro-criteria s fragility is related also to ur-ban structure. The object is the urban gradient (studied by means of Urban Atlas artificial land data) which generally expands from the main compact city to the surrounding rural areas. Then, the second chapter proposes a classification of main recurrent configurations (from aggregated, compact, and dense tissue to free areas in rural context) found in three Functional Urban Areas in central Italy. The methodology introduces both the role of the author as the Subject Matter Expert in the process of qualitative evaluation and a possible implementation of Supervised Machine Learning techniques in accelerating future processes of recognition. Lastly, the de-sign project is introduced for deepening the study on urban configurations structure. The further change of scale is an exercise of in-depth analysis which serves to contextualize the previously modelled configuration within the real urban context. Specific urban fragilities (such as lack of green connections and inadequacy of open spaces) can be associated with the in-dicators of fragility that have been computed at the macro-scale level. As conclusion, the overall relevance of results is framed within the op-portunity to produce high-performance and replicable planning tools for cities and territory management, implementing decision support systems and sustainable urban transformations.

Abstract

La tesi sviluppa un procedimento multi-scalare tipico dei processi di pianificazione, dalla piccola scala (assetto strategico) a quella grande (soluzioni progettuali). Il procedimento descrive un approccio metodologico integrato focalizzato sulle fragilità degli insediamenti urbani e le metodologie proposte sono devolute alla comprensione e all'analisi del territorio italiano. La ricerca si sviluppa attraverso 4 passaggi di scala (in 3 capitoli principali). Il primo capitolo si propone di introdurre alcuni macro-criteri che possono caratterizzare la condizione di fragilità dei piccoli comuni italiani (meno di 5000 abitanti). I livelli di fragilità sono calcolati attraverso la combinazione di indicatori che rappresentano alcune principali problematiche territoriali (dissesto idrogeologico, arretratezza economica,...). I risultati evidenziano la presenza di tre diverse macroregioni che possono rappresentare diversi cluster di priorità per future allocazioni dei fondi. I risultati evidenziano anche la presenza di un gradiente di livelli di fragilità nello stesso contesto territoriale. L'indagine si concentra poi sulla struttura fisica dell'ambiente urbano per indagare se la fragilità evidenziata dai macrocriteri può essere rilevata anche nella struttura urbana. L'oggetto di analisi è il gradiente urbano che generalmente si espande dalla città compatta alle aree rurali circostanti (nello specifico, i suoli artificiali del database Uban Atlas). Quindi, il secondo capitolo propone una classificazione delle principali configurazioni ricorrenti (dal tessuto aggregato, compatto e denso alle aree libere in contesto rurale) riscontrate in tre Aree Funzionali Urbane dell'Italia centrale. La metodologia introduce sia il ruolo dell'autore come giudizio esperto nel processo di valutazione qualitativa, sia una possibile implementazione di tecniche di apprendimento automatico supervisionato per accelerare futuri processi di riconoscimento. Viene infine introdotta un elaborazione progettuale per esaminare ulteriormente la struttura delle configurazioni urbane. L'ulteriore cambio di scala è, infatti, un esercizio di approfondimento che serve a contestualizzare la configurazione, precedentemente modellata, all'interno del proprio contesto urbano reale. È quindi riscontrabile come alcuni specifici fattori di fragilità urbana (come la mancanza di connessioni verdi e l inadeguatezza degli spazi aperti) possano essere associati agli in-dicatori di fragilità che sono stati calcolati alla scala dei piccoli comuni.

In conclusione, la rilevanza complessiva dei risultati si inquadra nell'opportunità di produrre strumenti di pianificazione che siano replicabili ed altamente performanti per la gestione della città e del territorio, implementando sis-temi di supporto alle decisioni e sostenibilità delle trasformazioni urbane e territoriali.

INTRODUCION

The awareness of the complexity of land as object of analysis is at the heart of this research. Urban settlements are centres of economic growth, employment, and a wide range of services and activities and they have never stopped growing. This is still true for developing countries and for the Mondial population growth ([1]). Previsions from United Nations confirm that "the future growth of the human population can be accounted for almost entirely by a growing number of city dwellers" because "by mid-century, roughly two thirds of the world's population will be living in urban areas" ([2]). At the same time, cities consume land faster than they grow in population: urban sprawl and peri-urbanization are becoming more common ([3]; [4]; [5]).
Actual trends confirm this tendence. All the research refers mainly to the European legislation, but it is focused on the Italian state of the art. In Italy, 56,7 km2 of soil has been lost in 2019-20 ([6]) and such land take trend has lasting from fifty years ([7]; [8]). The most recent estimations show that in 2022 net land take has been equal to 63,3 km2, with a percentage of 13,6 km2 permanently occupied ([9]). Such data seems to be insufficient for the goal of no net land take settled at European level ([10]). This tendence comes with consequences, such us impoverishment of natural resources, increase of average temperature and worsening of living conditions in urban areas ([11]). Climate change and extreme weather events then may have a significant impact on biodiversity and less resilient ecosystems due to urbanisation and related pressure on land resources.
In fact, sustainability and resilience of urban settlements are part of vocabulary of international policies and guidelines as Agenda 2030. The 17 Sustainable Development Goals (SDGs) adopted in 2015 from 193 United Nation member States are a set of global action goals that address environmental, social, economic, and institutional issues ([12]; [13]). European Union is involved in the implementation of the Agenda 2030 and in the realization of SDGs. The Goal 11: "Make cities and human settlements inclusive, safe, resilient and sustainable" aims at inverting actual trends related to land consumption and unsustainability of urban environments. In accordance with the 2019 OECD Recommendation on Policy Coherence for Sustainable Development (PCSD), in Italy has been developed the

Italy's National Action Plan for Policy Coherence for Sustainable Development (NAP) for "enhancing co-ordination in the public administration to more effectively and inclusively mainstream sustainable development across policy sectors and levels of government" ([14] p.3). Even if strategies are drawn, the main issues are often operating instruments available. Not all actual regulations for urban planning appear to be prepared for such challenges which implicate long term strategies. In Italy, land transformations are readable mainly due to European Standard Products (i.e., CORINE Land Cover) and many local database (i.e., regional database DBTR). Not updated local plans, uneven data and procedures for planning and monitoring tools are the main issues in Italy ([15]; [16]). Urban management should need more performative and efficient instruments. Monitoring land transformation would be effective if strategies implemented integrated approaches and decision support systems (DSS) that incorporate more approaches, multiple and accurate dataset to maximize efficacy ([17]). Cities can be seen as systems that interact with the territory and analytical methods can already support the process of comprehension and prevision of complex dynamics of urban settlements ([18]). Artificial Intelligence (AI) techniques and new approaches enable researchers to approach both physical and socioeconomic environments ([19]). Also, fields of implementations are transportation, security of streets and air quality monitoring and in general the concept of smart cities ([20]; [21]). Other AI implementations regard the accelerations of procedures and analyses that would take hours or days for same results. Studies related to AI and recognition of images have started in half nineties, but it has been highly developed in recent years. Image recognition is also one of the multitudes of uses made today. Recognition of images has started to interest the studies related to urban geography and urban planning ([22]; [23]; [24]).

The present research is permeated by the idea that efficient systems and tools can considerably implement efficacy in urban planning: can integrated approach and advanced techniques help in better managing territories and implementing sustainability goals? Urbanization, unsustainability of land transformations and related socio-economic issue affect some territories more than others? Are there any areas and territories more involved in such processes? In this research objectives are macro-level condition of territorial fragility and the diverse configurations of urban structure that compose the urban environment, in Italy and central Italy. Are the existent methods useful in classifying such territories and different configurations?

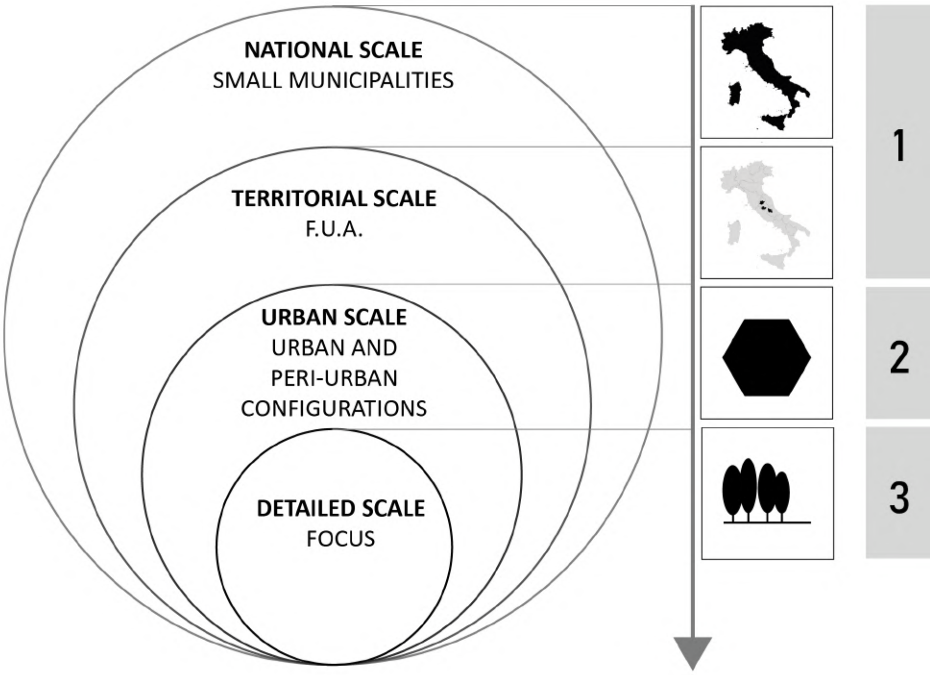
In literature, both fragility and peri-urbanization are inflected in various ways. Definition of fragility refers to the peripheralization that large part of the Italian Country is facing as the European trend ([25]). Inner Areas are the most affected from issues related to peripheralization because they are the most remote municipalities in terms of essential services ([26]; [27]).

The issues can be extended also to Less Favoured Areas ([28]; [29]) and areas that are generally minor centres. All these areas share some main characteristics as the abandonment of buildings and places ([30]; [31]) and socio-economic decline. Such issues determine the general abandonment of the territory and then the probability of extreme events increases. For example, the abandoned territory increases the exposition to natural risk and loss of biodiversity ([32]; [33]).

As far as concern urban structure, it is approached considering the actual condition of the urban environment. One of the most significant urban tendence of the 21st century is peri-urbanization ([34]). In many fields and especially in Urban Planning, many approaches are used to comprehend nature of peri-urban and dispersed configurations and achieve better management practices. Studies are extensive because researchers dealt with the topic working on different subjects, scale, methodologies, and purpose. The lack of one singular definition reveals the complexity of associate one singular term to a broad concept. Moreover, as every process which involves land, peri-urbanization is a site-specific issue, and it varies depending on characteristics of geographical context. The uncertainty is given by the genesis of these areas which can be uncontrolled and scattered. Generally, it refers to areas of transition and interaction between urban and rural, which are hybrid landscapes with dispersive urban growth. Peri-urban areas are characterised by an extensive use of the space and low-density settlements ([35]).

Some analyses are focused on the permeation of peri-urbanization with other fields that affect other aspects of living and quality of spaces. Definitions descend from the main studies on the field, such as the 'città diffusa' ([36]). Qualitative investigations through geographic and architecture vocabulary assess definitions ([37]; [38]) in the field of landscape studies and assessments of relation with quality of life ([39]), and morphological studies ([40]). Some analyses are focused on developing models in urban dynamics. In this area are included many analytical approaches with indicators and models of urban growth, such as urban sprawl and urban sprinkling ([41]; [42]; [43]; [44]; [45]) and analytical approaches with remote sensing, forecasting models and machine learning implementations ([46]; [47]; [48]; [49]). Such studies dealt with the study of urban models on territorial scales. Some approaches dealt with various methods for applying methodological classifications to the theme of peri-urbanization ([50]; [51]; [52]) Researches try to define and compare the hybrid spaces, studying the non-homogeneous configurations ([53]) and the relation with grades of the issue ([54]; [55]; [4]).

In this framework, the research develops a multi-scalar and multi-level process, from general to specific, that is from the strategic configuration to project solutions. The research describes an integrated approach on fragilities of urban settlements. It has delimited and balanced various possible scales of analysis. In fact, proposed methodologies are devolved to comprehension and then the analysis of territory. The research is developed through 4 passages of scale (in 3 main chapters).



Firstly, fragile areas are investigated through the national perspective of the Italian territory. The object are small municipalities with populations of up to 5000 inhabitants. Substantially, main and bigger cities are excluded, and the selection focuses on the 70% of municipalities, that includes also Inner Areas (52% of municipalities). The National Strategy for Inner Areas (SNAI) is one of the strategic lines of intervention of the European Structural Funds of the 2014-2020 programming cycle. It is a reference point for innovative national policy of development and territorial cohesion ([56]; [57]). Inner Areas are defined as mainly dependent on hubs: main urban districts which offer a range of services, such as more than one upper secondary education, at least one hospital and one train station. Municipalities that are less than 20 minutes distant from the nearest hub are called belt. Then, according to growing distance from hubs, inner areas can be intermediate, peripheral, or ultra-peripheral. In recent years, SNAI policies have addressed these areas. More recently, specific funds from National Recovery and Resilience Plan (PNRR) have been allocated to 21 selected villages to support sustainable development in small municipalities with a recognisable historical centre ([58]). In fact, most of small Italian villages (borghi) have great potential for their historical, cultural,

and natural heritage. PNRR intends to sustain such fragile areas for socio-economic development areas aimed at cultural regeneration and touristic relaunch as places for alternative tourism ([59]). The plan includes financial support and requalification of public open spaces and building heritage.
Similarly, Law 158/2017 was born to give ”Support measures for promotion of small municipalities and regulations for redevelopment and restoration of their historical centres” ([60]). The support is given depending on certain fragility criteria. The Law definition provide the basis for the present research, which computes a set of indicators to assess territorial fragilities. As a result, the analysis identified potential serviceable clusters for the intervention in these areas, based on a set of indicators related to fragile conditions and local vulnerabilities.
Secondly, 39 small municipalities among the previous selection are chosen, in the context of Functional Urban Areas (FUA) of Perugia, L'Aquila and Terni. The context of FUA is interesting because land take occurs primarily in and around urban areas, where land is most required for housing, transportation infrastructure, or economic development ([61]). Also, the choice has been oriented by the ongoing research projects, such as the LIFE IMAGINE UMBRIA Integrated Project ([62]). This LIFE Integrated Project aims to sustain integrated strategies for management of Natura 2000 Network in Umbria Region. Strategies are focalised on management and conservation of habitat and species and connections between sites in Natura 2000 Network ([63]). The framework of two FUA in Umbria Region (Perugia and Terni) is opened with the FUA of L'Aquila, in Abruzzo Region. In the present work, the LIFE Integrated Project is more than a methodological framework. It has practical values by the virtue of applicative repercussions implied in the project itself. Such second focus then permits to make comparisons and to evaluate causes of fragility that emerge in small municipalities at national level.
For the same case study, the third passage investigates if one more parameter of potential fragility can be related to the material structure of the urban settlements. Assuming the existence of an urban gradient from urban to rural, a qualitative analysis based on morpho-typological recognition provides a classification of recurrent urban configurations. The classes are representative of the main structures and shapes of the gradient. Classes are recognised in selected configurations from the case study, in a process of validation of the classification using a hexagonal window of selection. A dimension is settled, and it is the same for each area of the case study. The result of the recognition phase is a set of 22 selected configurations, divided for 6 classes. Classification from predominant urban to predominant rural extremes of the gradient is divided in 6 classes: urban aggregated configuration, urban linear configuration, peri-urban linear configuration, peri-urban spread configuration, and very spread peri-urban and the non-

urban configuration which is composed of free areas.
For such classification, the urban scale is combined with the detailed scale. Observation at detailed scale is the base of the urban scale classification. This is because specificities of each singular configuration are both things that characterise it as unique, and characteristics that have contributed to its selection and then in its position within the classification. The results obtained are the base for more than one further study. One regards a design project proposed for one among the configurations classified and the other puts the classification inside the broad subject of automation modelling in urban planning. Then, an experimental approach deals with application of ML techniques in the process of configurations' recognition. The process has been tested with one first application, but it opens to the use of images in AI techniques applied in urban studies. The study opens to faster urban dynamics study and easier generation of models related to spatial distribution scenarios that will be discussed in the conclusions.
The last passage of scale is a design application. It regards the design focus in Pettino, L'Aquila. The area is classified as compact urban configuration, but it presents also relevant natural configurations if seen at local level. In fact, the design scale is deepened at this further scale focus. Such exercise of in-depth analysis serves to contextualize the configuration previously modelled within the real urban context. Detailed scale is even deepened with a project of de-sealing and urban forestry on one selected area, part of the University Campus. The design project is relevant for its feasibility as urban regeneration project. It is aimed at providing multifunctional benefits derived by maintained and improved ecological functions ([64]). The qualitative analysis on the configuration also provides identification of proper strategies of reconfiguration for open spaces. Promoting a valuable green reconnection with the natural surroundings should be one more aim of the design application. In fact, the eventual sum of more qualifying urban transformations can affect characteristics of urban configurations increasing resilience and the ability of habitats to provide various ecosystem service ([65]; [61]).
Future works aim at extending the classification on other urban areas in Italian or European territory, as they are included in the Urban Atlas database. One other future development concerns design project for each specific urban or peri-urban configurations classified. From urban forestry (implementation of forests in cities) to defragmentation (intervention of removal or mitigation from barriers that penalize areas of natural connections – Local ecological network) ([66]). As conclusion, the overall relevance of results is framed within the opportunity to have faster and replicable instruments useful for sustainable urban transformations ([67]).
The research thesis also comprehends an illustrative appendix which is composed of the Atlas of urban and peri-urban configurations. The case study

from classification of urban and peri-urban areas is composed of 22 windows. This extensive textual description deepens the characteristics studied for the classification. Descriptions are divided for single configuration. The selected configurations are also outlined with their main characteristics, in a brief overview contained in worksheets. The appendix C is focused on the first five classes, from Aggregated, compact, and dense tissue to Very spread tissue in rural context. The sixth class with free areas is excluded from the elaboration.

FRAGILE AREAS: INDICATORS FOR PRIORITY CLUSTERS

Chapter abstract

The chapter aims at introducing some macro-criteria that can characterize the fragile conditions of Italian small municipalities. Levels of fragile conditions are highlighted through the combination of indicators that represent territorial issues, i.e., from hydrogeological instability to economic backwardness. The chapter develops on two levels: the national perspective on all the 5482 small municipalities and then the specific territorial context of central Italy Apennines. The latter consists of around 40 small municipalities part of the FUA of Perugia, Terni, and L'Aquila. Results highlight the presence of three macro-regions that can represent clusters of priority. Results also highlight territorial gradient of differential conditions of fragility in the same territorial context.

FRAGILE AREAS: INDICATORS FOR PRIORITY CLUSTERS

Il capitolo si propone di introdurre alcuni macro-criteri che possono caratterizzare le condizioni di fragilità dei piccoli comuni italiani. I livelli di fragilità vengono evidenziati attraverso la combinazione di indicatori rappresentativi delle problematiche territoriali, ovvero dal dissesto idrogeologico all'arretratezza economica. Il capitolo si sviluppa su due livelli: la prospettiva nazionale su tutti i 5482 piccoli comuni e poi il contesto territoriale specifico dell'Appennino centrale. Quest'ultimo è costituito da circa 40 piccoli comuni facenti parte della FUA di Perugia, Terni e L'Aquila. I risultati evidenziano la presenza di tre macroregioni che possono rappresentare cluster prioritari. I risultati evidenziano anche il gradiente territoriale di condizioni differenziali di fragilità nello stesso contesto territoriale.

1.1 Introduction

The first analysis aims at contextualizing territorial dynamics related to territorial fragility that will be deepened through two parts in the present chapter. The global-scale analysis serves also for guiding and contextualizing the passages of the next chapters. Fragile territories are here studied in the context of national level in Italy, a south-central European country. If at the global scale the gap between big cities and the rest of territory is growing ([2]), the tendence for Italian territory is the same ([68]). Italian territory is characterized by multi-faceted and inter-dependent polycentric territorial model ([56]). The counterpart of main cities is a network of towns, villages, and other territories. Such minor centres occupy about two thirds of the national territory ([69]). Many researchers have studied such variegated subaltern configurations which generally refer to the dependence on bigger or richer urban centres. Alps ([70]) and Apennines are part of this areas ([71];[72]). Some studies found out definition for characteristics of subaltern configurations that match with other issues, such as shrinking territories ([73]) for the demographic and economic causes related to depopulating urban regions. Then, adjectives as fragile, marginal, and distressed are generally related to Inner Areas ([26]). Inner Areas are the most observed configurations because of a classification made by the Cohesion Agency which launched the SNAI ([57]). The National Strategy for Inner Areas provide a classification in six categories based on distances from urban poles and consequent limited access to essential services when the distance increases (i.e., education, health, mobility) ([57]). Shared characteristics of inner areas are also depopulation, abandonment, and high potentiality of the territories because of relevant environmental and cultural resources. Also, such areas are highly diversified ([56]). The present methodology is framed inside the actual Italian legislation for these areas. In fact, the SNAI is considered a benchmark for local development of the minor centres. It gives definition and spatialization to marginal centres providing a classification ([74]). However, many other issues take part in the structural distress condition of minor centres. Previous studies have highlighted how housing distress is not only related to very marginal areas. It has started to regard other areas and even bigger municipalities (up to 10000 inhabitants) ([75]). Then, the framework of Italian fragile territories is extended over the definition of SNAI's Inner Areas with the intent of reaching a more comprehensive overview on territorial fragilities. A defined area is the starting point of the present analysis. Starting with a population-based selection of 5000 inhabitants, the large territorial scale frames the issue of territorial fragility which includes Inner Areas, minor centres and marginal areas which are comprehended in the Italian small municipalities. Municipalities serve as the foundation for comparisons based on specific indicators. Therefore, the results are used to compare a subset of 39 small municipalities from the specific geographical area of Central Italy (Perugia, Terni, L'Aquila). The selection uses the definition of Functional Urban Areas ([76]). The change in scale enables the reading of specific urban environment factors of single municipalities, allowing a more comprehensive comparison. For such analysis, data elaborated refer to the specific framework of Italian regulation (Law 158/2017). Such Law has not been revised or proposed again. In the same way, data are updated at the years 2017-2020, which are the years of the Legislation under consideration and the first formulation of the research. However, the analysis is considered adequate for testing the methodology, which is also suitable for updates. The methodology then elaborates the issue while also demonstrating a replicable methodology. The scope of the chapter is to give a framework of a generalized condition of fragility which is not only related to inner areas definition. In this sense, the attempt is to compute conditions to give the sense of various levels of fragility and disadvantage. Computing various criteria that impact on fragility, the results give the idea of which places have more disadvantaged conditions. This is devolved to the eventual assignment of funds. In fact, the research uses parameters given from a Law for demonstrating that too large selections may not lead to focused and efficient fund distribution. Small municipalities in Italy have up to 5000 inhabitants and they are 5522 out 7904 (2022), whereas in 2017 they were 5482 out 7998. Generally, small municipalities are towns or small cities, due to the medium-low range of population. In fact, most municipalities have between 1000 and 3000 residents. The high quantity of small municipalities in Italy have already been studied for implications on planning strategies because it produces high fragmentation in administrative procedures ([77]). In detail, small municipalities are around 3100 in the north, 650 in the center, 1700 in the south and the major islands. The medium dimension of municipalities is 29,46 kmq (1.1). This area can vary from less than 5 kmq to more than 200 kmq.

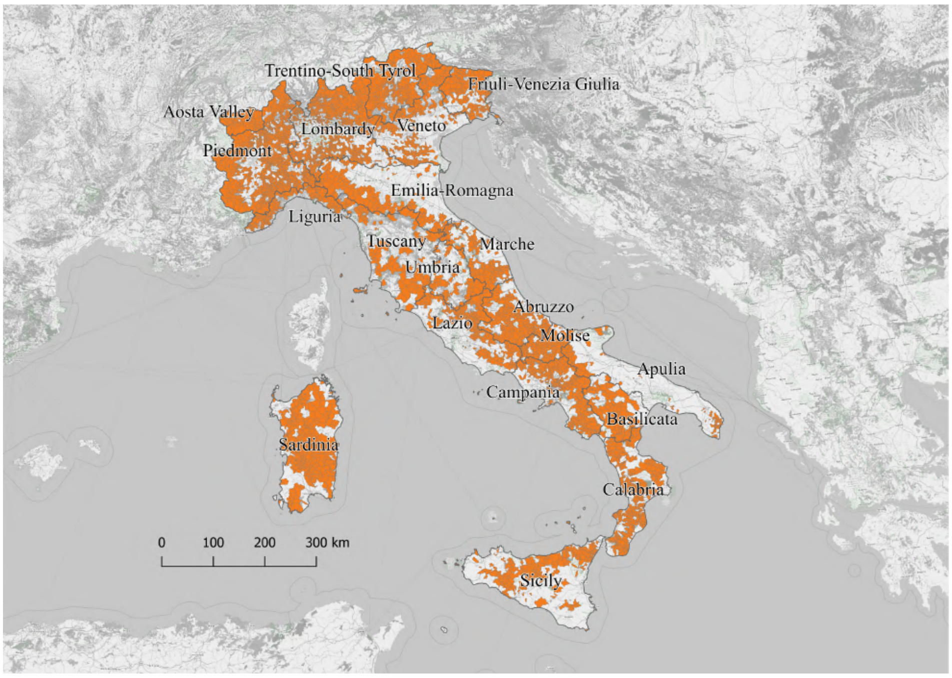


Figure 1.1. Small municipalities

Small municipalities are around the 70% of Italian municipalities (7998 in 2017) and they cover 54% of the national area. About 11 million of inhabitants live in small municipalities, which means approximately 18% of Italian population. The remaining 82% live in 46% of the territory that mainly consists of metropolitan cities and surrounding areas ([77]). Conversely, taxable income data from the Italian National Institute of Statistics (ISTAT) show disparities between metropolitan areas and small municipalities. Small municipalities represent only 15% of national taxable income. The economic disadvantage is only one of a set of problems. These municipalities are evenly distributed, with more presence on mountain areas, the Appenines and the Northern Regions. They are missing in some areas of Apulia and Emilia-Romagna Regions. The National Association of Italian Municipalities (ANCI) analysed their population variations between 2011 and 2017 compared to the national trend. On 5500 municipalities, ANCI assesses negative, neutral, and positive population variation and the study provides results distinguished per altitude ranges and in case of Inner Areas. Positive population variation occurs in 965 municipalities only, which are mostly in valley or coastal areas and outside of perimeter of inner areas. On the contrary, around the 75% of 2159 small municipalities in the most inner mountains are facing negative population variations. Moreover, around 80% of 3402 small municipalities in the inner areas are facing negative population variations. Depopulation then is one of the main issues for inner mountain areas and inner areas ([78]). Such phenomenon is deeply related to other issues such as reduction of services and interest in investing in these areas. Finally, these issues are related to the general abandonment of the overall territory. Within this framework, the analysis identifies some clusters related to different levels of fragility. These clusters are analysed in two steps (the national level and then with a selected number of 39 municipalities). Then some considerations rise from the comparison between results obtained and national supportive strategies (as SNAI) and with the Law 158/2017 itself, which has released the precise composition of criteria in 2021.

1.2 Materials and methods

Parameters from Law 158/2017 are the main reference for the analysis of fragilities in most Italian municipalities ([79]). Law 6 October 2017 n. 158 is an implementation decree that introduces "Support measures for promotion of small municipalities and regulations for redevelopment and restoration of historical centres of the mentioned municipalities". The funds of 160 million go to structural, economic, and social development of small municipalities up to 5000 inhabitants ([60]; [80]), which are 5482. Eligible municipalities should be:
(a) municipalities included in areas affected by hydrogeological instability;
(b) municipalities affected by strong economic backwardness;
(c) municipalities affected by strong population decrease compared to the general census of 1981;
(d) municipalities affected by housing distress. Data computed on a series of indicators such as aging index, percentage of employed compared to local

population and rurality index;
(e) municipalities affected by inadequacy of essential welfare services;
(f) municipalities located in areas characterised by communication distress and remoteness from urban centres;
(g) municipalities characterised by a residential density lower than 80 inhabitants per km2;
(h) municipalities that include fractions with conditions of criteria (a), (b), (c), (d), (f) or (g). In this case, according to art.3, funds address the fractions only;
(i) municipalities that are part of a mountain community (as mentioned in art.14, comma 28, legislative decree 31 May 2010, n. 78, later converted with amendments as Law 30 July 2010, n. 122) or municipalities that implement together the basic functions (as specified in comma 28);
(l) municipalities partially or totally included in a national park, a regional park or other protected areas;
(m) municipalities created by fusion;
(n) municipalities included in peripheral or ultra-peripheral areas, as defined by National Strategy for Inner Areas (SNAI) (according to art.1, comma 13, Law 27 December 2013, n. 147).

According to the Law, meeting just one criterion is enough to apply for funding. The analysis aims to evaluate each of the mentioned criteria. Then, to apply the criteria in the analysis, corresponding available data is searched. Due to the complexity of criteria, various datasets need to be matched for formulating the indicators needed. First requirements are data availability for each Italian municipality and the maximum the number of inhabitants (5000). A spatial layer of Italian municipalities from 2017 then has been used. The dataset also contains demographic information. Then, due to heterogeneity of parameters, data show to be available and testable for calculate 8 criteria only. The remaining 4 criteria are not computable. They refer to parameters which should need a given precise formulation, such as welfare-related criteria. Also, they may refer to unclear construction, unavailable or partial data, such as distress-related criteria. The selection of criteria then comprehends (a), (b), (c), (g), (i), (l), (m) and (n). Respectively, composition of each dataset come from the following

datasets (figure 1.2).
(a) Municipalities included in areas affected by hydrogeological instability. Data on Hydrogeological Configuration Plan (PAI) of Italian municipalities are provided by the inventory of Italian landslide phenomena ([81]), which is the official national database on landslides ([82]). Database is product by the Italian Institute for Environmental Protection and Research (ISPRA), Regions and Autonomous Provinces (art. 6, comma g, in Law n. 132/2016). Municipalities affected by hydrogeological instability have been selected if involved in one landslide event at least. At least one landslide event is sufficient for assigning the criteria. The dataset is used for indicators IndA and IndA2.
(b) Municipalities affected by strong economic backwardness. Data come from the Ministry of Economy and Finance website ([83]). The total income is discarded because comprehensive of deductions (security and healthcare) and other incomes (i.e., maintenance payments for separated partners and supplementary pension scheme). Instead, data on taxable income are comprehensive of all diverse incomes (i.e., building, employment work, pension, self-employment). As a further analysis, percentage incidence of retirement income is considered. Then, this analysis is done on retirement incomes and number of retired people. Fiscal years 2012 and 2017 are considered in the analyses. The dataset is used for indicators IndB and IndB2.
(c) Municipalities affected by strong population decrease compared to the general census of 1981. Population trend of municipalities is calculated for 1981-2017 using population census data from the Italian National Institute of Statistics ([84]). Since no thresholds are given for "strong" decrease, percentages of -10% and -25% are set as significant thresholds for the two simulations (as described later in the chapter). The dataset is used for indicators IndC and IndC2.
(g) Municipalities characterised by a residential density lower than 80 inhabitants per km2. Residential density data come from population census of 2017 in the area of municipality. ISTAT database provides the data. The dataset is used for indicator IndG.
(i) Municipalities that are part of a mountain community (as mentioned in art.14, comma 28, legislative decree 31 May 2010, n. 78, later converted

with amendments as Law 30 July 2010, n. 122) or municipalities that implement together the basic functions (as specified in comma 28). The law specifies characteristics of unions in art.32 (part of legislative decree 18 August 2000, n. 267 and successive amendments). Municipalities are selected as specified in the mentioned law. ISTAT database provides the data. The selection considers years 2010 and 2017. Then, the selection concentrates on unions included in mountain municipalities (Law n. 1102/1971). The dataset is used for indicator IndI.
(l) Municipalities partially or totally included in a national park, a regional park or other protected areas. The Ministry of Environment, Land and Sea Protection (today Ministry of Environment and Energy Security) provides the data on National Geoportal, through the Open Geospatial Consortium Service (OGC). The dataset gathers all protected areas, both marine and terrestrial. It is part of the sixth update approved with deliberation of the State-Region Conference on 17 December 2009, published on the official bullet n. 125 on 31 May 2010. The dataset is used for indicator IndL.
(m) Municipalities created by fusion. The main reference is the mentioned law about unions of municipalities (art.14, comma 28, legislative decree 31 May 2010, n. 78, later converted with amendments as Law 30 July 2010, n. 122). ISTAT database provides the data. Then, the selection considers years 2010 and 2017. The dataset is used for indicator IndM.
(n) Municipalities included in peripheral or ultra-peripheral areas, as defined by SNAI (according to art.1, comma 13, Law 27 December 2013, n. 147). Territorial Cohesion Agency provides the data. Database consists of classification from main hubs to ultra-peripheral areas. The dataset is used for indicator IndN.

In most cases, thresholds are required for the analysis. Given such heterogeneous indicators, thresholds should be needed for setting weighs where needed. For points (g), (i), (l), (m) and (n), no thresholds are needed because results are binary variables (0 or 1). Points (a), (b) and (c) have results in ranges such as percentage, and then thresholds should be set. Each of the three indices has proper range and then proper thresholds. So, a set of three thresholds combined may give an acceptable response. However, two groups of thresholds can implement more truthfulness in results.

	CRITERIA AND INDICATORS FROM LAW 158/2017	AVAILABILITY OF DATA	SOURCE	CONTENT OF DATA	TYPOLOGY OF DATA	YEAR OF REFERENCE
A	IndA and IndA2	Available or computed	Hydrogeological Asset Plan (PAI) ISPRA	Inventory of national landslide phenomena Area of municipalities	Vector	2015
B	IndB and IndB2	Available or computed	MEF	Taxable income Retirement income Number of retired people	Table	2012 2017
C	IndC and IndC2	Available or computed	ISTAT	Population census Area of municipalities	Table Vector	1981 2011
D		Not available				
E		Not available				
F		Not available				
G	IndG	Available or computed	ISTAT	Population census Area of municipalities	Table Vector	2017
H		Not available				
I	IndI	Available or computed	ISTAT	Italian municipalities Mountain municipalities	Table Vector	2010 2017
L	IndL	Available or computed	MASE data from NATIONAL GEOPORTAL	Area of municipalities Area of parks and protected areas	Vector	2017
M	IndM	Available or computed	ISTAT	Italian municipalities Unions of municipalities	Table Vector	2010 2017
N	IndN	Available or computed	Territorial Cohesion Agency	Italian municipalities	Table	2020

(grey cells) For the time period considered, data are not available or they are partial.

Figure 1.2. The table resume the availability of dataset for each criterion from the Law 158/2017.

Then, in two parallel simulations, two scenarios of findings are explored (figure1.3). The simulation is based on critical thresholds on average, and it comprehends:

- (a) Selection of municipalities affected by hydrogeological instability matches with territories involved in one landslide event at least.
- (b) Selection of economic backwardness matches with municipalities with decreasing income trend between 2012 and 2017.

- (c) Variation of population considered significant is equal to -10%.

Later, Simulation Data 1 (S1). Indicators for S1 are IndA, IndB, IndC, IndG, IndI, IndL, IndM and IndN, The second simulation includes more critical conditions (in terms of natural risks and more disadvantaged socio-economic conditions):

- (a) Selection of municipalities affected by hydrogeological instability considered territories that arise with at least one event in hazard classes P3 or P4 and that run into urban areas or infrastructure.

- (b) Selection involved municipalities with both negative income trend and negative contribution from pension income between 2012 and 2017.

- (c) Variation of population considered significant is equal to -25%.

Later, Simulation Data 2 (S2). Indicators for S2 are IndA2, IndB2, IndC2, IndG, IndI, IndL, IndM and IndN.

	S1	S2
a	Selection of municipalities affected by hydrogeological instability matches with territories involved in **one landslide event** at least.	Selection of municipalities affected by hydrogeological instability considered territories that arise with at least one event in hazard classes **P3** or **P4** and that run into urban areas or infrastructure.
b	Selection of economic backwardness matches with municipalities with **decreasing income trend** between 2012 and 2017.	Selection involved municipalities with both **negative income trend** and **negative contribution from pension income** between 2012 and 2017.
c	Variation of population considered significant is equal to **-10%**.	Variation of population considered significant is equal to **-25%**.

Figure 1.3. Differences between the two simulations.

Given the two simulations' parameters, all data presented are combined through the open-source software QGis. The instrument allows to combine spatial and tabular databases. Indicators' datasets are collected in one.

Global comparison of all indicators is possible through the unique database, which comprehends IndA, IndA2, IndB, IndB2, IndC, IndC2, IndG, IndI, IndL, IndM and IndN (Figure 1.4).

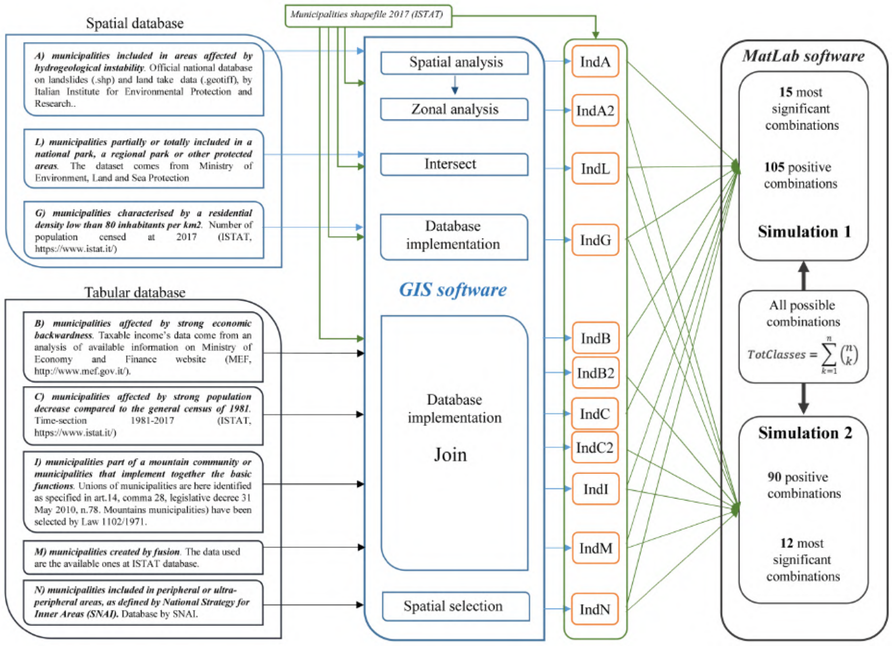


Figure 1.4. Flow chart of methodology. Collection of dataset, analysis, and elaboration of results is provided by QGis and MatLab.

Each indicator has the same weigh of the others. The 5482 Municipalities with up to 5000 inhabitants are selected from the dataset of Italian municipalities from 2017. The elaboration considers each municipality as the object on which associate all the indicators. Then, each municipality is associated with 1 (Positive) if a related indicator is present or 0 (Negative) if it has no correspondence (figure1.5).

The classification is provided by a MATLAB analyses (2019a) (The MathWorks, Inc., Natick, MA, USA) ([85]; [86]). MATLAB is a proprietary multi-paradigm programming language and numeric computing environment developed by MathWorks. It is a programming platform designed specifically for engineers and scientists to analyze and design systems and products. The heart of MATLAB is the MATLAB language, a matrix-based language allowing the most natural expression of computational mathematics. MATLAB allows data analysis, algorithms development, creation of user interfaces, and creation of models and applications ([87]). Therefore, each municipality gets a sort of score. Moreover, each

Municipalities	IndA	IndB	IndC	IndG	IndI	IndL	IndM	IndN
Municipality 1	0	0	1	0	0	0	1	1
Municipality 2	1	0	0	0	0	0	1	0
……	……	……	……	……	……	……	……	……
Municipality i	0	1	1	0	0	1	0	0

Figure 1.5. Hypothetical example of results from using binary variable for Simulation S1. Negative correspondence (0) if the Municipality does not meet the reference criterion. Positive correspondence (1) if the Municipality meets the reference criterion.

municipality may have a different combination of indicators (combination) and a different number of indicators related (class). Two datasets of results are obtained (S1 and S2). They include each municipality's satisfaction with the computed indicators and all the possible combinations (or classes) are computed avoiding repetitions. The total number of combinations is obtained (Equation 1.1), where the total number of indicators (n = 8) for each simulation is taken in groups of k = 1,2, … 8. Then, 255 classes are identified.

$$TotClasses = \sum_{x=0}^{n} \binom{n}{k} \tag{1.1}$$

Subsequently, a scan of all the municipalities present in the databases is performed. Among the 255 combinations identified, each municipality is assigned to a class of combination composed of its related indicators. A count of municipalities included in each class allows to:

- exclude all empty classes. i.e., those for which no one municipality satisfies the combination of indicators;
- automatically determine the number of municipalities for each class;
- select only the municipalities that satisfy the criteria of belonging to single classes of combinations of indices.

Finally, the script allows to plot a graph showing distribution of the number of municipalities for each class, with also the possibility of filtering and excluding those that have a minimum number of municipalities that can be set as a threshold, by entering it as input. In the worst case (i.e., plot all 255 classes), the total computation time is on average less than 4 s using a commercial computer (Apple Macbook Pro equipped with processor 2.6 GHz Intel Core i7, 6 core and 16 GB of RAM).

1.3 Results

The analysis enables knowledge of the prevalence of criteria on the national territory. Main results comprehend the evaluation of numerical incidence of criteria for each municipality and the distribution of different criteria. A first level of results is related to the location of municipalities that have a certain number of criteria. Figure 1.6 shows the results for S1 and S2, which are expressed as the sum of all considered indicators for each municipality. The analysis highlights clustering in specific geographic areas. This result also confirms that there is a significant settling of some typical issues of the small municipalities. According to a preliminary qualitative analysis, in some areas the number of criteria for each municipality is equal to 0. On the contrary, other areas are strongly defined by the coexistence of numerous criteria. The most affected areas are the central Apennines: Marche, Abruzzo, and Molise regions, as well as Basilicata, Calabria, and the northern part of Sicily. In northern Italy the most affected areas are the Tuscan-Emilian Apennines, the remote areas of the Alps and the eastern part of Friuli-Venezia Giulia region.

The graph below (Figure 1.7) shows results for the two simulations. It is divided into sections from 1 to 8. Each section corresponds to groups of classes composed by the same number of indices (i.e. class 1 = 1 index, class 8 = 8 indices). Bars inside each section refer to each single index and show how many municipalities they are a part of. Bars then show the frequency of each index for each class, or in other words, the various classes in which one or more criteria are present. Hydrogeological instability (IndA in S1 and IndA2 in S2) has very high values in all classes. As a result, it seems to be a generalist indicator and expresses a nationwide issue, which does not significantly contribute to the identification of urban distress hotspots.

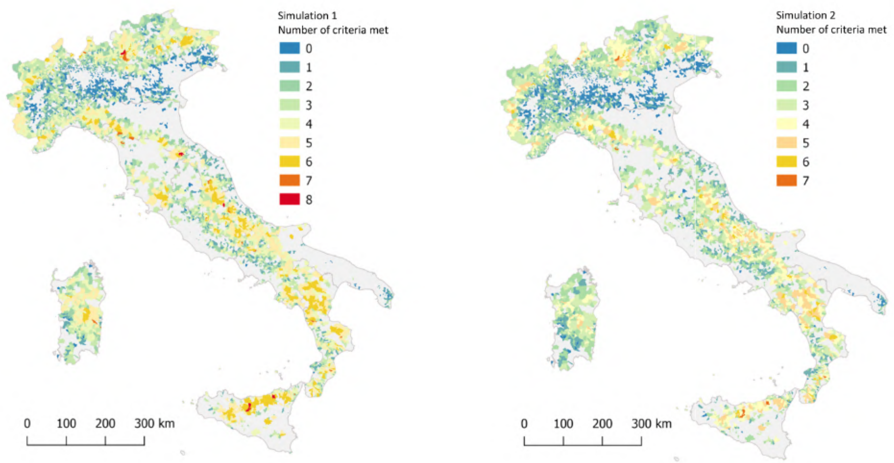


Figure 1.6. Number of criteria met in simulation data S1 and S2.

Also, IndG (low population density, d < 80 inhab/km2) is a recurring index of distress, except for municipalities belonging to the class with a single criterion (class 1). Then, if excluded the indices mentioned (IndA-IndA2 and IndG), the essential critical range is concentrated in classes 3 to 5 (Figure 1.7). Moreover, due to the stricter thresholds, S2 returns clusters which are more defined and significant for geographical locations. The critical range (dotted box in Figure 1.7) then is interesting to examine. In these areas, strategies and adjusted extent of actions should be evaluated to try to change the current trend, assuming a scale of interventions for support local communities based on their actual requirements.

Then, after quantification of criteria and definition of the critical range, a deeper analysis is carried out with the MATLAB software to optimize the process of classifying the degree of disadvantages of the municipalities. Then, the procedure (as described in Methodology chapter) allows to extract 105 values for S1 and 90 for S2. These results represent the combinations of existing criteria, excluding null results. Plots in Figure 1.8 show the combinations with frequency values greater than 100. Such a threshold is chosen because the average number of municipalities for each class is 45 for S1 ($avg(S1)$) and 51 for S2 ($avg(S2)$) and for this reason the most significant combinations have been identified through Equation (1.2), as the double of the previous average numbers:

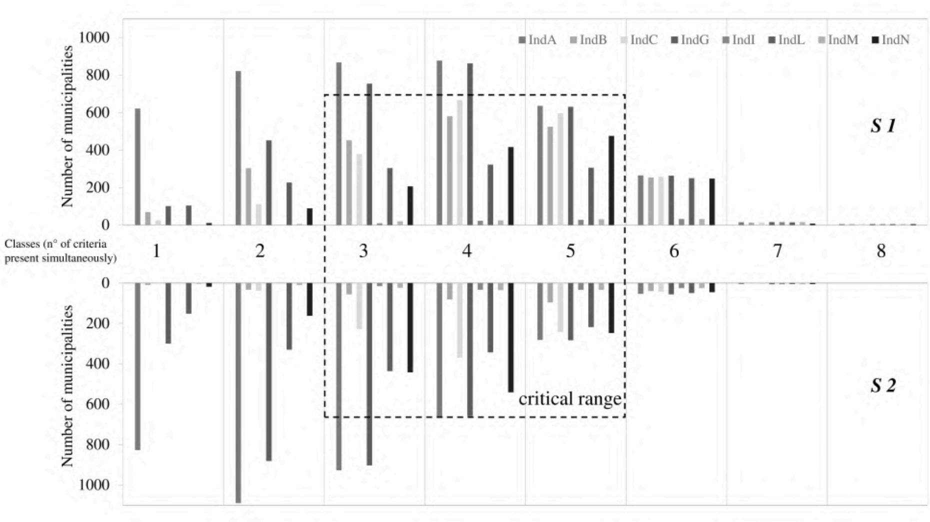


Figure 1.7. Comparative analysis of the simulation results.

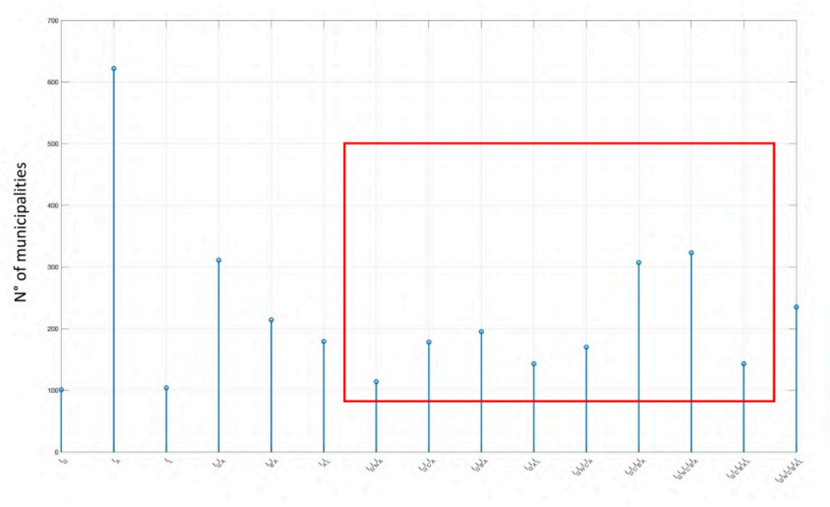
$$Threshold = 2 * max(avg(S1), avg(S2)) \tag{1.2}$$

Among the 5482 eligible municipalities, the result is the selection of 15 combinations for S1 and 12 combinations for S2. Such combinations represent 70% of municipalities for S1 (3339 out of 4816) and 82% of municipalities for S2 (3760 out of 4626) (Figure 1.9).

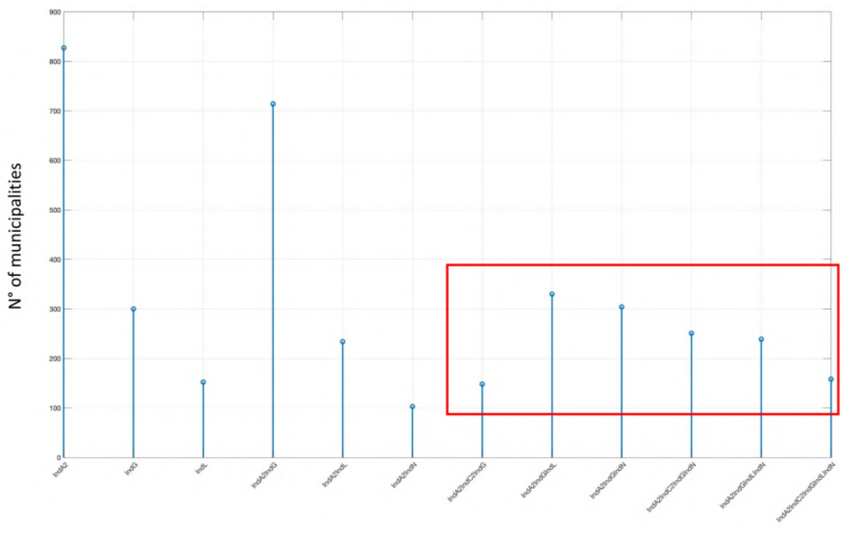
The sequences shown in Figure 1.9 (b) are all the configurations found considering the 8 criteria and the threshold of 100 for both simulations (S1 and S2).

By reducing the selection, it is possible to extrapolate eight combinations for S1 and six combinations for S2, considering only the critical range (i.e., combinations of 3, 4 and 5 indices). Figure 1.10 shows the aggregated data at the national level. In this way, 1808 Municipalities are selected for S1 and 1430 Municipalities for S2, which represent, respectively, 22% and 18% of all Italian municipalities. Values of the area vary from 70 to 75 km2, which corresponds to 23.5% and 25% of the national territory (Figure 1.11). In terms of population data, the percentage swings between 3.3% and 3.5% for both simulations, with roughly 2 million inhabitants.

Results collected at the regional level are shown in Figure 1.12 and



(a)



(b)

Figure 1.8. Plot of significant sequences for S1 (a) and S2 (b).

1.13. Some other parameters are included: Number of municipalities, Municipality surface, Percentage of regional area, Inhabitants and Percentage of regional population.

Results obtained for the two simulations underline that about one-fifth of the country faces demographic and economic distress. Results of S2

Table 2. Degree of representativeness for Simulation 1 (S1) and Simulation 2 (S2) (a). Sequence configuration for S1 and S2 (b).

(a)	
Municipalities with Populations Less than 5000 Inhabitants	**5482**
Total selected Municipalities for S1	4816
Total selected Municipalities for S2	4626
Number of Municipalities S1 with threshold 100	3339
Number of Municipalities S2 with threshold 100	3760
Threshold 100 for S1	70%
Threshold 100 for S2	82%

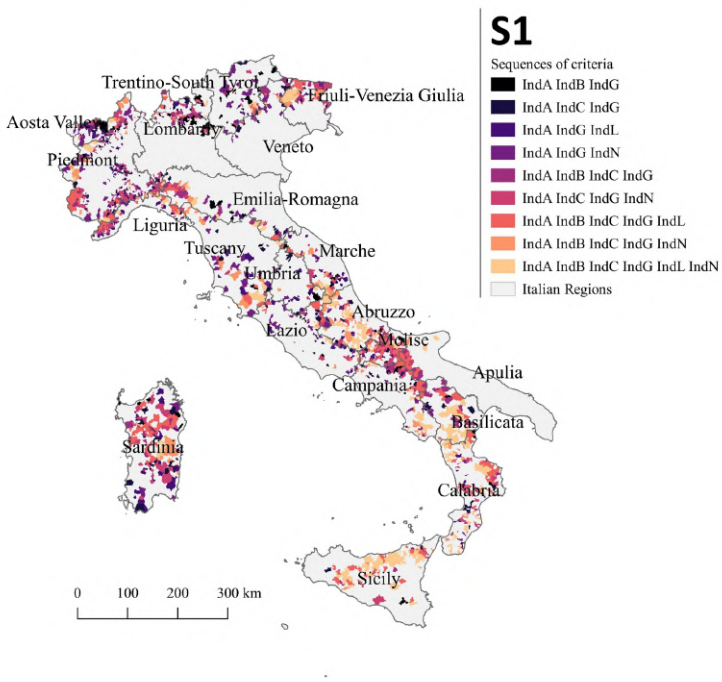
(b)	
Simulation 1	**Simulation 2**
IndA IndG IndL	IndA2 IndG IndL
IndA IndB IndA IndG IndA IndL	IndA2 IndG IndA2 IndI IndA2 IndN
IndA IndB IndG IndA IndC IndG IndA IndG IndL IndA IndG IndN	IndA2 IndC2 IndG IndA2 IndG IndL IndA2 IndG IndN
IndA IndB IndC IndG IndA IndC IndG IndN IndA IndB IndC IndG IndL	IndA2 IndC2 IndG IndN IndA2 IndC2 IndI IndL IndM IndA2 IndC2 IndG IndL IndN
IndA IndB IndC IndG IndN IndA IndB IndC IndG IndL IndN	-

Figure 1.9. Degree of impact and characteristics of S1 and S2.

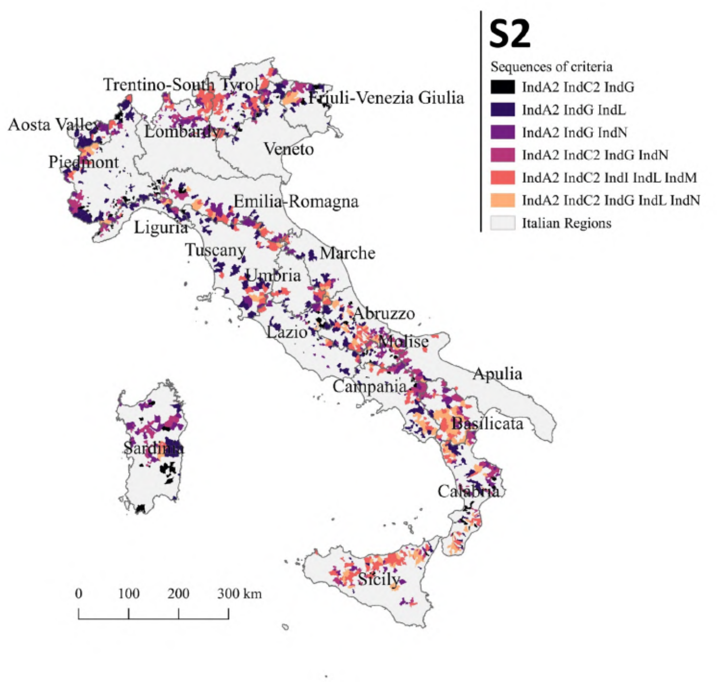
Simulation	Number of Municipalities	Municipalities Surface (Km^2)	% National area	Inhabitants	% National Population	Population Change in the Last 20 Years	Population Change in the Last 50 Years
S1	1808	75,886	25	2,158,831	3.5	−13%	−30%
S2	1430	70,839	23,5	1,992,370	3.3	−11%	−27%

Figure 1.10. Aggregated results at national level.

express the distribution of local governments that are highly economically distressed. Compared to S1 (IndB), the S2 simulation purposefully imposes the economic parameter (IndB2). Molise, Basilicata and Aosta Valley regions have the highest percentage of regional population involved in the less-favoured condition as expressed in Law n. 158/2017. For S1, Molise's inhabitants involved (90,042) represent 29% of the regional population. This percentage is comparable to Lombardy's result, even though the same number of inhabitants represents only 1% of the regional population. Then, Abruzzo and Trentino-South Tyrol are involved with 10% of regional population. Observed in numbers, Sardinia and Calabria show more than 210,000 inhabitants involved. On average, the parameter about



(a)



(b)

Figure 1.11. Frequencies for S1 and S2.

regional inhabitants involved does not exceed 5%. Considering parameter of regional areas in percentage, the same observations remain valid.

Simulation 1 Italian Regions	Number of Municipalities	Municipalities Surface (Km^2)	% Regional Area	Inhabitants	% Regional Population
Piedmont	352	8516	34%	200,702	5%
Aosta Valley	39	1783	55%	34,489	27%
Lombardy	136	3464	15%	101,216	1%
Trentino-South Tyrol	61	2697	20%	87,523	8%
Veneto	38	1611	9%	48,263	1%
Friuli V.G.	49	2914	37%	46,642	4%
Liguria	78	2159	40%	53,581	3%
Emilia Romagna	48	3363	15%	96,925	2%
Tuscany	59	5134	22%	122,966	3%
Umbria	19	1247	15%	37,525	4%
Marche	54	2314	25%	71,564	5%
Lazio	75	3263	19%	101,624	2%
Abruzzo	121	4314	40%	114,080	9%
Molise	94	2796	63%	90,042	29%
Campania	102	3572	26%	159,093	3%
Apulia	26	1513	8%	46,837	1%
Basilicata	69	4413	44%	121,094	21%
Calabria	148	5184	34%	210,050	11%
Sicily	86	5381	21%	179,859	4%
Sardinia	154	10239	42%	234,756	14%

Figure 1.12. Aggregated results at regional level, S1.

Simulation 2 Italian Regions	Number of Municipalities	Municipalities Surface (Km^2)	% Regional Area	Inhabitants	% Regional Population
Piedmont	175	6639	26%	105,711	2%
Aosta Valley	27	1594	49%	29,369	23%
Lombardy	124	4211	18%	122,720	1%
Trentino-South Tyrol	85	3966	29%	122,495	12%
Veneto	37	1871	10%	56,914	1%
Friuli V.G.	36	2213	28%	38,127	3%
Liguria	52	1889	35%	45,220	3%
Emilia Romagna	55	4033	18%	119,064	3%
Tuscany	57	5524	24%	125,754	3%
Umbria	15	1254	15%	31,659	4%
Marche	34	1720	18%	512,86	3%
Lazio	66	2975	17%	84,804	1%
Abruzzo	110	4016	37%	120,597	9%
Molise	60	1917	43%	57,771	19%
Campania	98	3921	29%	171,652	3%
Apulia	21	1219	6%	39,393	1%
Basilicata	78	5004	50%	140,077	25%
Calabria	128	5424	36%	211,412	11%
Sicily	82	5232	20%	184,659	4%
Sardinia	90	6218	26%	133,685	8%

Figure 1.13. Aggregated results at regional level, S2.

The two simulations are interesting to compare. A general contraction of the examined values in S1 and S2 results from comparing them. Exceptions are Lombardy and Veneto, where results are stable in both simulations. In these regions, small municipalities in a less-favoured condition have low incidence in the regional system. Here, variations are assimilated from territorial contexts, which excel for advanced socio-economic conditions compared to the national level. Against the trend, some other regions such as Basilicata and Trentino-South Tyrol show raised parameters in S2. In general, these contexts should be explored in depth to understand causes of such diversities and their correlation to marginality. From the results obtained, it is possible to identify some critical districts with territorial continuity (Figure 1.14). Then three districts, or Macro Regions, are analysed singularly for both simulations. The first area includes Abruzzo, Molise, Campania, Basilicata, and Calabria, which constitute a macro region (Macro Region 1). The Macro Region 1 covers 27,000 Km2 in S1 (21,500 Km2 in S2) and it involves around 920,000 inhabitants (741,000 inhabitants in S2). The most evident results are various. Firstly, the quantity of intercepted inhabitants is high, around the half of the total population considered in the simulations. Secondly, municipalities involved are around half of those initially selected based on Law 158/2017. In addition, a major part of the areas in the Macro Region 1 concerns peripheral and ultra-peripheral areas. These areas are the most affected by persistent distress in accessing services and in lack of energy in economic processes. The Macro Region 2 is composed of Piedmont, Aosta Valley, Liguria and Emilia Romagna. Although the surface covered is smaller (around 15,000 Km2), here the quantity of population involved is significantly less than the previous, which corresponds to 8-9% of the entire macro region's population. The Macro Region 3 is composed of Friuli-Venezia Giulia, Veneto, Trentino and Lombardy. This case provides a clear gap compared with the previous two. Results from both simulations do not produce relevant variations in terms of involved inhabitants and implicated municipalities. Values analysed remain nearly the same, despite any criteria variation, and a lower level of territorial marginality should represent a reason. In fact, the third district is composed of a larger number of municipalities in the intermediate areas, which are the less disadvantaged (Barca & Lucatelli, 2014). Intermediate areas are the nearest to urban cores. These areas have evidently peculiar characteristics, and they can be subject of a further study (See paragraph 1.4). Most probably, the regional driving force of economic growth (macro and micro economies) serve to partially balance the issue of territory's progressive abandonment.

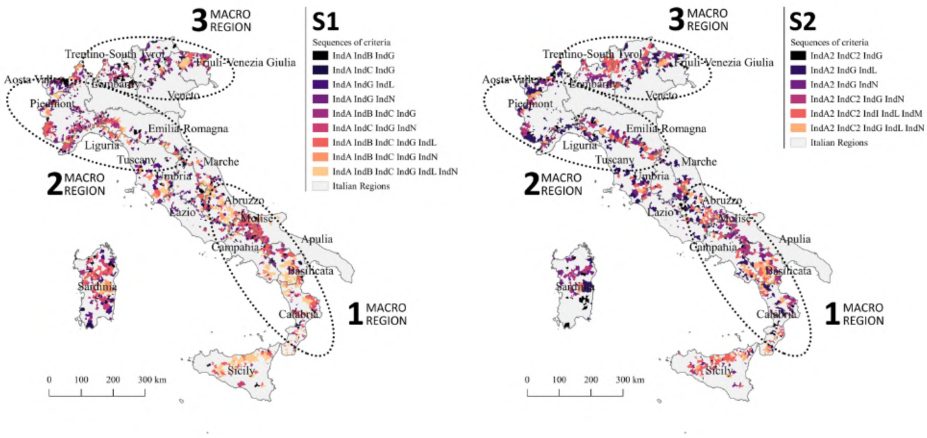


Figure 1.14. Spatial distribution of sequences for Macro Regions.

Macro Region	Simulation	Number of Municipalities	Municipalities Surface (Km^2)	Inhabitants	% Population	% Municipalities Sn/Municipalitie Law 158
Macro region 1	S1	646	27,173	921,055	14%	54%
	S2	495	21,500	740,902	13%	48%
Macro region 2	S1	517	15,821	385,697	9%	42%
	S2	309	14,155	299,364	8%	31%
Macro region 3	S1	284	10,686	283,644	4%	21%
	S2	282	12,261	340,256	4%	21%

Figure 1.15. Aggregated results for Macro Regions.

Other considerations are useful for analysing the three Macro Regions (Figure 1.15). One main factor is the territorial heterogeneity that affects the three Macro Regions. Also, it has a high-impact role in funds management and then it influences the common agricultural policy's effects on local socio-economic development ([88]; [89]). With equal Utilised Agricultural Area (UAA), intermediate areas spend in CAP (Common Agricultural Policy) 33% per hectare more than peripheral areas and 92% more than ultra-peripheral areas ([90]). It should be emphasised also that peripheral and ultra-peripheral areas in the first district are located in less developed regions (Basilicata, Campania, Calabria, Sicily, and Apulia, with Gross Domestic Product (GDP) per person less than 75% of the EU-27 average) and regions in transition (Abruzzo, Molise and Sardinia, with GDP per person between 75% and 90% of the EU average). The results suggest that some areas are more critical than others. According to the criteria of Law n. 158/2017, the attempt to quantify disadvantages represents a first analytical approach to evaluate the intervention priorities of regulatory instruments and national strategies. This approach involves a profound change of attitude that requires the transition from the equality-based model to an equity-based one. To apply this approach to the simulations and therefore considering the municipalities in the critical range as a priority, it could be assumed to allocate to the selected municipalities the entire budget of 2017-2020, which is equal to euro 85 million. If considered the 1430 municipalities resulting from S2, the same economic support would be around euro 60,000 in five years for each municipality. Then, a priority model could permit to concentrate resources and to increase the economic availability for each municipality selected. However, this action cannot be the only solution. In fact, the economic support does not guarantee municipality's wealth. If local resources (management, people, competences in local administrations) continue to be insufficient, the ideal maintenance of minimum wealth functions and proper regulations for the settlement structure would remain out of reach. An ideal management of minimum wealth functions need small interventions. Small interventions need approaches on different scale and small municipalities' disadvantage also depends on this (See chapter 2). Generalized forms of economic support have already demonstrated to be insufficient, if considering the large gap between increasing urban growth and depopulation caused by strong internal migratory flows happened in 1960-70.

1.4 Differential levels of fragility. Intermediate areas: Central Italy FUA

The two simulations on Italian small municipalities have highlighted that critical ranges should be functional to frame fragility conditions and then useful for directing funds. The three Macro Regions shows that location matters in assessing conditions of an area. Economic growth drivers or demographic trends have a significant impact. However, the study has not shown how municipality's local condition relates to these parameters. If excluded the definition of extreme distance as the IndN, middle situations of closeness to urban poles are not considered. Intermediate areas represent the expanding territory surrounding urban centres often interested by urban growth phenomena. For approaching such areas, the paragraph introduces the Functional Urban Area (FUA). FUA provides urban areas that are comprehensive of both urban poles and their next commuting municipalities. Although the area definition is different from the administrative boundaries used so far, FUA is a European standard (Urban Atlas). Moreover, FUA provides data on urban spatial distribution that will be used in the next chapter.

1.4.1 Study area. Cross-sectional case studies

This paragraph aims at comparing three areas around urban centres in central Italy. Perugia, Terni and L'Aquila constitute three municipalities and they are over parameters considered (municipalities up to 5000 inhabitants). Respectively, inhabitants are 164880, 110003 and 70019 ([84]). The three urban cores are classified by SNAI as "Urban Poles", because of the services they offer ([74]). Therefore, they are the starting point for analysing smaller bordering municipalities. All the three cities have a ring of small municipalities (up to 5000 inhabitants) which are reliant on the urban core. The present analysis uses the result from the national level analysis for a zoom in local conditions. Such urban poles and their surroundings are representative of the Central Italy configuration. The geographical setting is Central Apennines: Perugia and Terni are in Umbria Region and L'Aquila is in Abruzzo Region. Between the two regions involved, only Abruzzo region has been considered part of the Macro Region 1. However, territorial continuity and coherence among the three areas permit to consider them together in this further focus. They all represent urban poles on the Central Apennines, and they have been involved in recurring seismic events. The geographic area has been subject to seismic events for the last 30 years. Earthquakes of 2009 and 2016 have stroked this geographical area causing differential grades of damage revealing high local level of fragility ([91]; [92]). Spatial configurations, socio-economic implications and reconstruction processes have influenced actual conditions. Probably, such characteristics will impact also on future development ([93]). Phenomena such as seismic events, in fact, emphasise fragilities related to depopulation and abandonment. Such conditions are shared also around such urban centres and then they involve the surrounding minor centres.

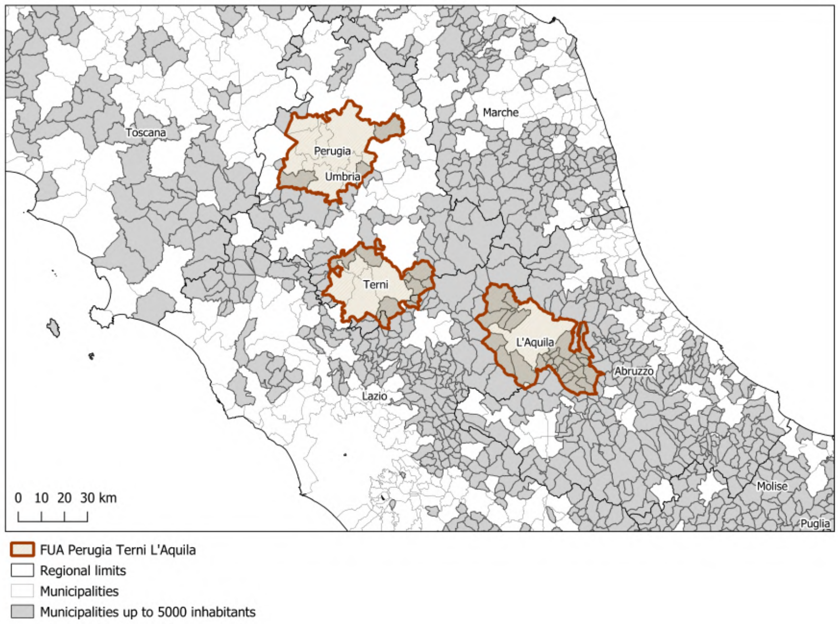


Figure 1.16. Framework of Italian municipalities up to 5 000 inhabitants and the municipalities included in the FUA of Perugia, Terni and L'Aquila. The figure shows the extensive presence of small municipalities in the area considered (Central Italy).

Relation between the three cities and the municipalities surrounding is given by the Urban Atlas database (Urban Atlas - Copernicus Land Monitoring Service). Urban Atlas is part of the Copernicus Land Monitoring Service (CLMS) which offers high-resolution harmonized land use and land cover maps of 788 Functional Urban Areas (FUA) in Europe (Urban Atlas). FUA are composed of one city (urban centre with at least 50000 inhabitants) and its commuting zone (at least 15% of workers, who live in the commuting zone). Evidently, FUA is based on functional links between the city and suburban areas. Urban Atlas data provides a common path for comparisons among FUA in European countries. The study areas then are FUA in which the three cities are included (Figure 1.16). In this chapter the only parameters taken from the Urban Atlas are the borders of FUA. The three areas are comparable in dimensions although they have different numbers in terms of population. FUA of Perugia extends for 1310,59 kmq with 281305 inhabitants, FUA of Terni has 1023,65 kmq for 171877 residents and FUA of L'Aquila extends for 1402,55 kmq with 98186 inhabitants. FUA of Perugia is the densest populated, whereas FUA of L'Aquila has the largest dimensions. FUA of Terni includes also three municipalities belonging to Rieti, in Lazio Region. Then, excluding the three main municipalities and other main municipalities, the analysis is conduct on small municipalities included in the FUA. The analysis focuses on the local scale of outcomes previously reached at the national scale.

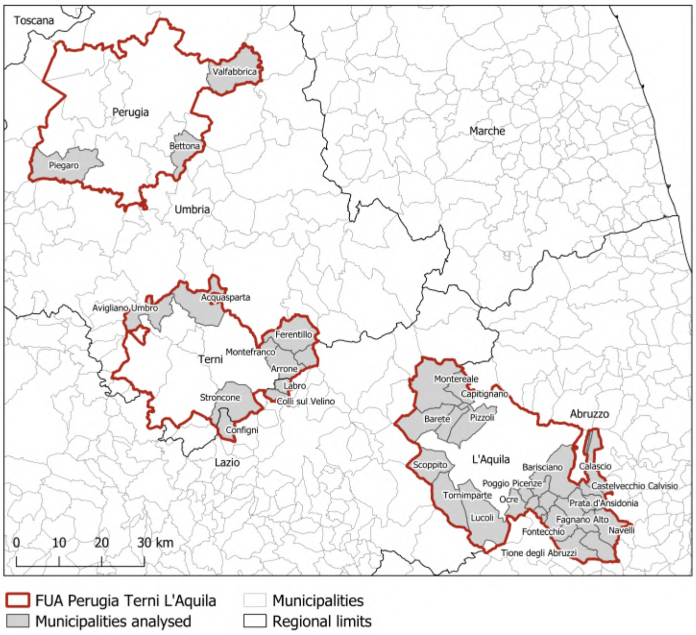


Figure 1.17. Case study: Central Italy municipalities up to 5 000 inhabitants. The figure shows that the three FUA also comprehends municipalities not involved in the analysis.

The study area comprehends 39 municipalities (Figure 1.17). Among these, 3 municipalities are part of FUA of Perugia (Valfabbrica, Bettona, Piegaro); 10 are part of FUA of Terni (Polino, Arrone, Stroncone, Ferentillo, Montefranco, Acquasparta, Avigliano Umbro in Umbria Region and then Configni, Labro, Colli sul Velino which are in Lazio Region) and 26 are part of L'Aquila FUA (San Demetrio Ne' Vestini, Prata D'Ansidonia, Pizzoli, Poggio Picenze, Castelvecchio Calvisio, Montereale, Navelli, Ocre, Barete, Barisciano, San Pio delle Camere, Sant'Eusanio Forconese, Scoppito, Lucoli, Acciano, Villa Sant'Angelo, Tornimparte, Tione degli Abruzzi, Caporciano, Carapelle Calvisio, Capitignano, Cagna-no Amiterno, Calascio, Fagnano Alto, Fontecchio, Fossa). The total area analysed occupies about 1550 kmq. Perugia's small municipalities extend for 236,19 kmq. In the case of Terni, they occupy 391,23 kmq and for L'Aquila they are 929,78 kmq.

1.4.2 Results: frequencies and sequences of Criteria

As evidenced by numerical correspondence of indicators (Figure 1.18), there is a correspondence with criteria related to low residential density (IndG) and hydrogeological instability (IndA) in 33 municipalities out 39. Moreover, more than half of municipalities are affected by strong economic backwardness (IndB). Presence of half of the municipalities inside a national park or other protected areas (IndL) attests environmental relevance of the area considered. Also, population de-crease (IndC) affects almost half of the municipalities. The remaining indicators are less significant. As expected, correspondence with peripheral and ultra-peripheral areas (IndN) affected only few municipalities out 39 (the 3 municipalities Acciano, Tione degli Abruzzi, Calascio, all within the FUA of L'Aquila). In fact, the municipalities analysed are intermediate areas within the FUA perimeter. For this criterion, proximity to urban poles is determinant.

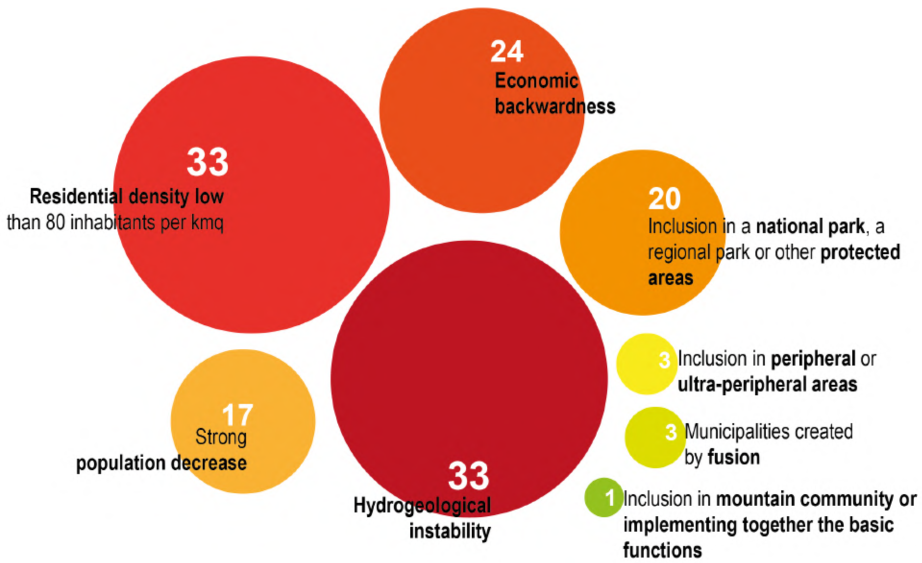


Figure 1.18. Bubble chart of frequencies of each criterion. The chart shows how many times each criterion appears within the case study. Bigger dimensions and darkness colours suggest the prominence of the criteria in the area.

Focusing on singular municipalities, only one municipality (Bettona) results in lack of correspondence to the criteria analysed (Figure 1.19). Indeed, the FUA of Perugia has only three cases of small municipalities.

The other two, Piegaro and Valfabbrica, have respectively 2 and 3 correspondences to the criteria. FUA of Terni presents a mixed result, in which municipalities go from 1 (Labro) to 5 (Polino) criteria met. Instead, municipalities in the FUA of L'Aquila proved to be the most affected by the criteria of disadvantages analysed. 14 municipalities out 26 have correspondence to more than 4 criteria (Acciano, Tione degli Abruzzi, Calascio, Castelvecchio Calvisio, Montereale, Navelli, Barete, Barisciano, Lucoli, Carapelli Calvisio, Capitignano, Cagnano Amiterno, Fognano Alto, Fontecchio). In the worst cases, Calascio and Tione degli Abruzzi have respectively 7 and 6 criteria.

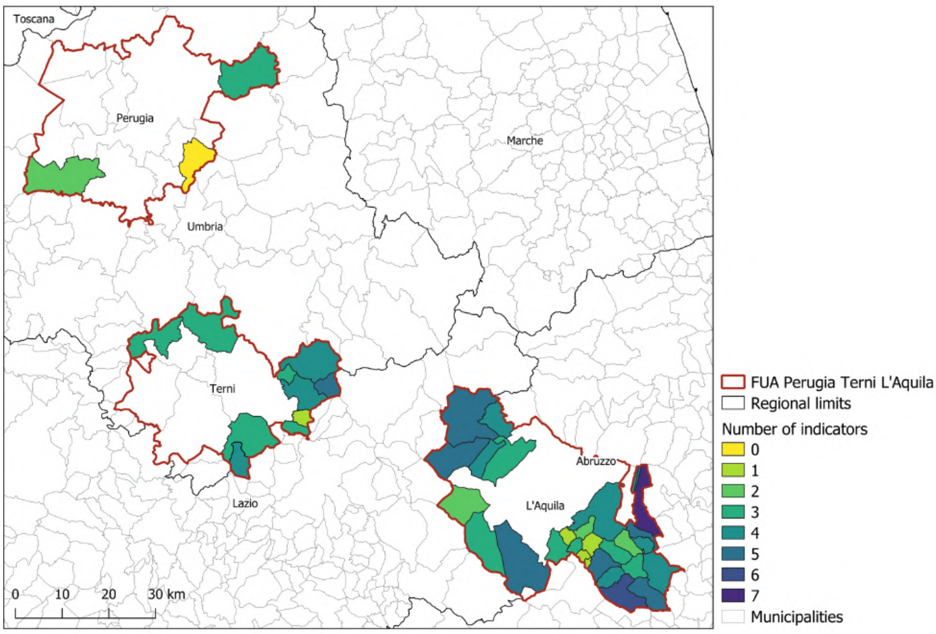


Figure 1.19. Numbers of criteria met for each municipality.

Various combinations occur considering specificity of criteria involved (Figure 1.20). Among all the possible combinations, 19 sequences characterize the 38 municipalities (Bettona excluded). However, the conditions are heterogeneous because about half of combinations are isolated cases (11 combinations are valid only for 11 corresponding municipalities). In other words, a quarter of the total municipalities has a specific condition of disadvantage generated by a singular combination of criteria. However, some sequences are shared by 5 to 6 municipalities. The three main shared sequences are highlighted (Figure 1.21 and 1.22).

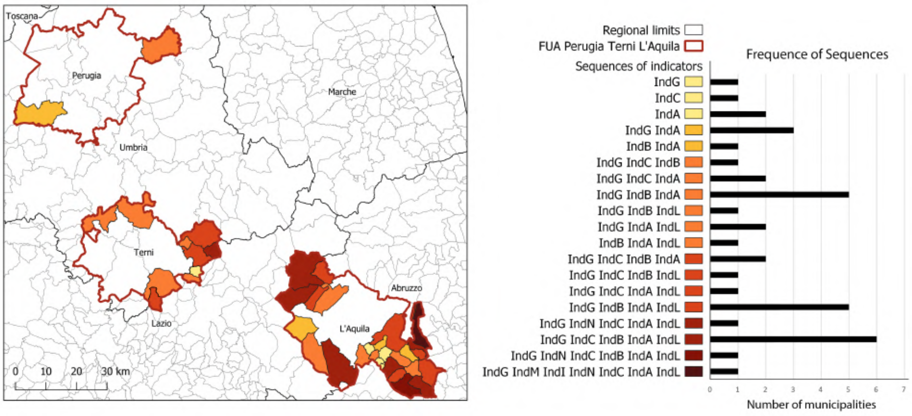


Figure 1.20. Sequences of criteria. Map shows sequences for each municipality, going from less disadvantaged conditions (1 criterion, yellow coloured) to the most disadvantaged condition (7 criteria, dark red coloured). Bar graph shows the frequency of each sequence within the case study. Frequencies goes from 1 municipality to 6 municipalities involved.

Sequences	Criteria		Incidence	FUA
IndG IndB IndA	IndG	Residential density low than 80 inhabitants per kmq	5	1 (20%) Perugia
	IndB	Strong economic backwardness		3 (60%) Terni
	IndA	Hydrogeological instability		1 (20%) L'Aquila
IndG IndB IndA IndL	IndG	Residential density low than 80 inhabitants per kmq	5	0 (0%) Perugia
	IndB	Strong economic backwardness		2 (40%) Terni
	IndA	Hydrogeological instability		3 (60%) L'Aquila
	IndL	Partially or totally included in a national park, a regional park or other protected areas		
IndG IndC IndB IndA IndL	IndG	Residential density low than 80 inhabitants per kmq	6	
	IndC	Strong population decrease compared to the general census of 1981		0 (0%) Perugia
	IndB	Strong economic backwardness		1 (17%) Terni
	IndA	Hydrogeological instability		5 (83%) L'Aquila
	IndL	Partially or totally included in a national park, a regional park or other protected areas		

Figure 1.21. Detail of the three most frequent sequences.

Generally, the three criteria IndG, IndB and IndA are present in the three most shared combination. Low residential density, economic backwardness, and hydrogeological instability are the main causes of disadvantage in the area considered. In particular, hydrogeological instability is among the main shared criteria at the national level. For the first sequence

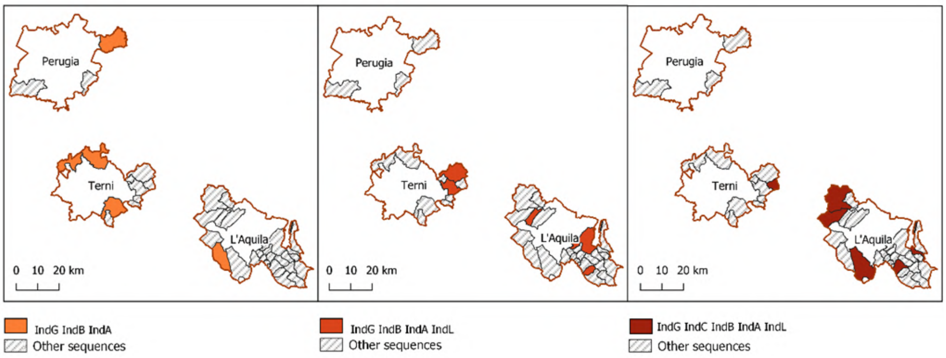


Figure 1.22. The three main frequent sequences

IndG IndB IndA most cases are in FUA of Terni (Stroncone, Avigliano Umbro, Acquasparta), one case is in FUA of Perugia (Valfabbrica) and one other in FUA of L'Aquila (Tornimparte). The second sequence IndG IndB IndA IndL is in FUA of L'Aquila for more than half (Fontecchio, Barisciano, Barete), whereas the other two are in FUA of Terni (Ferentillo, Arrone). FUA of Perugia's municipalities are not involved in the second sequence. The increased fragility condition expressed by the sequence (simultaneity of 4 indicators) is not equally shared by the three areas. Umbria's FUA are more connected to the nearest Regions, such as Lazio and Toscana. They are in a dense road network that crosses Central Italy from north to south. Between the two, Perugia is the highest connected. Moreover, its territory is the most densely urbanized among the three compared. It also presents fewer small municipalities in the FUA area. The sequence which has the highest incidence is IndG IndC IndB IndA IndL (Figure 1.21). The 6 cases are almost in FUA of L'Aquila (5 municipalities: Castelvecchio Calvisio, Montereale, Lucoli, Cagnano Amiterno, Fagnano Alto) and then one case is in FUA of Terni (Polino). The simultaneity of 5 indicators describe the highest level of fragility for the case study. This simulation involved above all FUA of L'Aquila, whereas FUA of Terni is involved marginally. In fact, Terni represents a middle ground among the three areas. It has direct infrastructural connection between Umbria, Abruzzo, and Lazio Regions because of its central position among the regions. The mountainous morphology is typical of all the Central Italy because of the two parallel sub-Apennines ridge and Apennines chain. However, this characteristic tends to accentuate in FUA of Terni and L'Aquila more than in FUA of Perugia. Presence of mountain systems and wide natural areas may implicate the presence of protected areas. In fact, the IndL indicates the presence of protected areas or parks and the only one Terni's municipality involved in the third sequence (Polino) is interested by a Natura 2000 Network ([63]) protect area ([94]). In the same way, L'Aquila's municipalities involved in this sequence are part of parks or protected areas. Protected areas and natural areas are a dominat feature of the territory. Around the 35% of the Abruzzo regional territory is under environmental protection, with four natural parks relevant at regional or national level (Majella National Park, Gran Sasso and Monti della Laga National Park, Silente-Velino Regional Park and Abruzzo, Lazio, and Molise National Park). FUA of L'Aquila can be considered as immersed in a mountain system and this morphological condition deeply impacts on disadvantages ([66]). Difficult connections and absence of diffuse services on territory can cause lack of economic development. Differently for the Umbria's FUA, here the infrastructural network is composed mainly by one axis which is the A24, which connects to Lazio Region at west and to coastal cities at east. Through the years, these aspects have led to concentrate resources in the city centre of L'Aquila at the expense of an even less developed surroundings. Comparing to the other two, FUA of L'Aquila has the highest level of fragility. In fact, although the FUA are in the same central Apennine context, they present different characteristics. A sort of fragility gradient is readable from north (FUA of Perugia) to south (FUA of L'Aquila). The fragile conditions framework is not readable in FUA of Perugia, then it increases in FUA of Terni and then it becomes relevant in FUA of L'Aquila. FUA of L'Aquila is interested in all the three most shared sequences and it has 5 out 6 municipalities involved in the 5 indicators sequence, which is the most critical for the case study. Comparing to the other two, FUA of L'Aquila has the major number of municipalities included in the study but the borders of the study are determined by the FUA standard. In this framework, some municipalities are also part of the highly damaged areas in the recent Central Italy earthquakes. In detail, 9 of them are part of the so-called Seismic Crater: 5 municipalities are in FUA of L'Aquila (Barete, Cagnano Amiterno, Capitignano, Montereale, Pizzoli) and 4 are in FUA of Terni (Arrone, Ferentillo, Montefranco, Polino). Among these municipalities, three are involved in the second sequence IndG IndB IndA IndL (Bareta, FUA of L'Aquila and Ferentillo and Arrone, FUA of Terni), whereas two are involved in the third sequence IndG IndC IndB IndA IndL (Cagnano Amiterno, FUA of L'Aquila and Polino, FUA of Terni). This further criterium of disadvantage weighs on the overall fragile condition of these areas, which presents the highest level of fragility measured in the area. This means also that these municipalities have received extra funds for recovering and that they are involved in plans for reconstructions. Evidently, specific, and different funds are welcome. However, diverse funds focalize on diverse territorial disadvantages, whereas functional planning strategies require organic and long-term vision. A structural assess of all fragilities and then a comprehensive and coherent territorial policy would be preferable.

1.5 Discussion

The first chapter shows the analytical identification of critical ranges of fragile territories, which are comprehensive of mountain areas, inner areas and marginal and disadvantaged contexts. The analysis and the identification of clusters of fragility is intended as useful instrument for a better urban management of resources. Indicators derived from criteria give a computational definition of socio-economically less-favoured conditions for some small Italian municipalities ([79]).

In general, the study is a further confirmation that Italy is a deeply divided country, highly disconnected and lacking a strategic plan of intervention for disadvantaged areas. These areas are largely composed of small municipalities. Municipalities that currently represent the suburban zones of the main metropolitan areas are exceptions and, as has already been verified, they are mainly concentrated in northern Italy. Moreover, both simulations show a significant convergence and show that most of the municipalities, which do not match any of the criteria, are concentrated in northern Italy. This highlights that the definition of "small municipality", i.e., the municipalities with a population less than or equal to 5000 inhabitants, is an unsatisfactory threshold for evaluating the access to public funds for economic support. Figure 1.2 shows that the same considerations

are still relevant also for all municipalities that match a single legal criterion. Despite this intention, some points have remained ambiguous due to the nature of parameters. Hydrogeological instability, as demonstrated, is a problem affecting most of the national territory. Therefore, it is not a real criterion if considered uncritically without any thresholds. Similarly, low residential density does not necessarily correspond to a penalizing factor but can certainly be considered a minor criterion. Furthermore, some criteria are difficult to quantify since the definitions identify a wide range of values, such as strong economic backwardness. Therefore, although 8 out of 12 criteria were considered for the analysis, their ambiguous nature does not allow a precise diagnosis of the problems of small municipalities, inner and marginal areas. In general, the collection of data has been challenging for the quantity of data to harmonize. More specifically, regional datasets are often uneven, with very different representations and structures ([16]). Moreover, most of data collected are very different for composition and ranges. One focus for SNAI is welfare and social-related parameters. Housing distress, inadequacy of essential welfare services and communication distress and remoteness from urban centres are fundamental indicators of fragility. In general, connection is a key factor, but also difficult to compute. Even if calculating connectivity in terms of infrastructures and transportation is simple, pervasiveness of intangible services is more complicated. Instead, four welfare and social-related indicators are out of the analysis because related to data that are unavailable, partial, or unclear in the dataset's components:
(d) municipalities affected by housing distress. Data computed on a series of indicators such as aging index, percentage of employed compared to local population and rurality index;
(e) municipalities affected by inadequacy of essential welfare services;
(f) municipalities located in areas characterised by communication distress and remoteness from urban centres.
(h) municipalities that include fractions with conditions of criteria (a), (b), (c), (d), (f) or (g). In this case, according to art.3, funds address the fractions only; Moreover, criteria computed express negative conditions, as for instance, population decrease or economic backwardness. In general,

Law's criteria base the attribution of funds on municipalities' needs, such as missing conditions or services. Instead, analysing marginality would comprehend positive parameters for a complete overview (i.e., the existence of well-organized social services, environmental points of interest, etc. on the territory).

Thresholds are one other subject of discussion. They are extremely relevant if related to the possibility of fundings. The SNAI defines the same thresholds as fundamental elements for economic development of the country. However, what is the limit beyond which economic measures in favour of a territory are unproductive in view of a possible recovery? This is a reasonable concern given that many funding sources only provide periodic support (such as Law n. 158/2017). In other terms, such measures should instead act on administrative and economic reorganization of small municipalities to trigger some recovery dynamics. The strategies of SNAI focus on an increased centrality of the role of local actors, mediated by the regional and national level in a multi-governance model, simultaneously providing essential services and fostering local development ([95]). Defining a critical range with more accuracy should be a first step towards evaluating different tools (supportive and structural) according to well-defined thresholds of distress. Instead of providing a single solution to a complex policy issue, various sets of reasoning principles should be combined with various designs to produce various sorts of intervention. ([96]). Perhaps more effective methods of identifying fragile areas should be used in conjunction with appropriate intervention measures. Critical range is also related to the time considered. The analysis proposed is strictly related to 2017-2021, which is the timeframe of issuing of the Law 158/2017.

However, the methodology intends to give instruments for defining clusters and then, providing an instrument which can be updated. Updates can be related to various aspects. For example, the selection of criteria-indicators can be update with new data when available. A so-composed instrument then can be a dynamic and even usable tool. For example, it should be suitable for public administrations at local and regional level, in case of studies on territorial and urban policies that must identify strategical areas for regulatory interventions. Also, the related database can keep track of territorial dynamics through the years. Also, if ever the Law would be updated with new criteria, the method can be implemented with additional indicators. A sort of update happened in July 2021, when results from the selection of Law n.158/2017 have been published in the DPCM of July 23, 2021, by the Presidency of the Council of Ministers ([97]). The publication revealed the construction of the 12 criteria, including the 4 which were difficult to define. The publication revealed that the ministry has joined two criteria (F + N). Maybe the match has been moved by the similarity of contents, which are general distress and remoteness (considering or not classification made by SNAI). Moreover, the table excludes the criteria with letter H, because is the one referred to the possibility of small parts of municipalities involved in the criteria (Figure 1.23). Maybe the criterium has been removed because it does not have a specific formulation to explain. Even if the composition was made clear, obtaining the parameters and subsequent data is still challenging, because datasets are not open-access or not aggregated.

The publication also revealed that the municipalities considered are 5522 (compared to 5482 used in the present work) because data considered are the population census of 2011 (and then the municipalities up to 5000 inhabitants) integrated with the updated situation of municipalities created by fusion up to January the 1st 2021. Then, 5518 out 5522 municipalities have been admitted to the fund. In fact, the access to the fund has been opened to each small municipality that meets one criterium out twelve. As the publication has revealed, almost all the municipalities are admitted. However, such modality is not a real selection, and such a large number does not contribute to the concentration of financial resources. The present work has showed that a MATLAB elaboration has computed the most recurrent combinations of fragility indicators finding clusters of fragility. The critical range highlights 1808 (S1) and 1430 (S2) municipalities selected. Between the two, S2 has selected the most critical thresholds. In fact, it includes less municipalities because of the high level of fragility implicated. Such two critical ranges refer to the 22% and 18% of Italian municipalities (1808 or 1430 out 7998 Italian municipalities in 2017). It is fine selection if compared with the around 70% as showed in the DPCM of July 23, 2021 (5518 out

CRITERIA AND INDICATORS FROM LAW 158/2017		Thresholds published 07/2021 by Ministry
A	**Hydrogeological instability**	hydraulic hazard: percetage of the P2 area >= 2% Landslide events P3 and P4>= 2% (01/01/21)
B	**Strong economic backwardness**	taxable income (IRPEF) < National average (20.213,73 euro) (01/01/21)
C	**Strong population decrease compared to the general census of 1981**	Population decrease 1981-2011 >= 20% (01/01/21)
D	**Housing distress.** Data computed on a series of indicators such as aging index, percentage of employed compared to local population and rurality index	Old-age index > 100 National average 173,11 (ISTAT, 01/01/2019)
		Percentage of employed compared to local population
		Rural monucipality (Degree of Urbanization = 3) with over 50% population live in rural cadastral units
E	**Inadequacy of essential welfare services**	Actions and social services for population: expenditure by municipality <= 116,00 euro (National average) (01/01/21)
F + N	**Communication distress** and **remoteness from urban centres, peripheral or ultra-peripheral areas (SNAI)**	Lack of network infrastructure for internet access
		Distance from hubs
G	Residential density lower than 80 inhabitants per km2	Legal population (2011)
		Area of municipality (kmq) (09/10/2011)
		Density per kmq
H	**Fractions with conditions of criteria (a), (b), (c), (d), (f) or (g).** In this case, according to art.3, funds address the fractions only	
I	**Part of a mountain community** or municipalities **that implement together the basic functions**	Union of municipalities, no mountain community considered (01/01/2021)
L	Included in a **national park, a regional park or other protected areas**	EUAP, Area Natura 2000 with surface in protected areas >= 10% (01/01/2021)
M	Municipalities created by **fusion**	Fusion or aggregations (01/01/2021)

Figure 1.23. Conversion from criteria to indices as published in results on Official Gazzette of Italian Republic, DPCM of July 23, 2021, by the Presidency of the Council of Ministers. Own elaboration.

7903 Italian municipalities in 2021) (source ISTAT). Such large number is a direct consequence of the access given to every municipality with at least one criterion and then the lack of any priorities. May a selection be efficient if it comprehends almost all the small municipalities without distinction?

1.6 Conclusion

The chapter highlights some clusters of fragility among the small Italian municipalities. The first elaboration highlights how to define priority compared to the rest national territory. The proposed methodology sets and computes analytical criteria for providing an interpretation of fragile minor centres at the national level. To this extent, MATLAB software has provided the most recurrent combinations of fragility indicators by means of the maximum frequencies. The elaboration provides clusters of high level of fragility. From the database of criteria to the software elaboration, the methodology is feasible to be updated and replicable. It shows how performative instruments (as MATLAB) are usable in urban planning.

The present methodology has various limits related to arbitrary choices. As instance, the partial computation of criteria from Law 158/2017 (8 out 12) and the arbitrarily definition of thresholds (for IndA, IndA2, IndB, IndB2, IndC and IndC2). In general, one weak point may stand in the overall partiality of selected indicators compared to the broad possible conditions of fragility. Despite these points, identification and selection of the most fragile and disadvantaged areas is already a goal of actual cohesion policies ([57];[59]). The analytical methodology could be a supportive instrument for administrations for addressing socio-economic improvement of these areas ([98]). The efficiency of cohesion policy should be improved by the selection of the most distressed territories as first. On the contrary, the funds risk to disperse among too many projects and general fundings. Ultimately, the methodology is proposed as instrument to give a concrete application in contrast to vagueness of definitions around the territorial fragility.

The second elaboration highlights the distribution of fragility and then priority in one territorial context. The analysis is settled inside the perimeters of FUA due to reliability the European standard (Urban Atlas) which provides analytical identification of urban poles and their next commuting areas composed of small municipalities. Also, the context of FUA implicates various processes of land take because land is the most required for housing, transportation infrastructure, or economic development ([61]).

Even if only Abruzzo is part of the Macro Region 1, the present analysis combines it with Umbria region for the territorial continuity between the two regions. This analysis shows that the distribution of fragility in central Apennines is distributed as a gradient. Distribution of sequences increase its incidence along such gradient. Fragility indicators are less present in the FUA of Perugia due to its networks and favourable morphological condition. Then, passing from the middle condition of FUA of Terni, fragility indicators occur mainly in the FUA of L'Aquila, which is more isolated in the mountain context. Small municipalities in FUA of L'Aquila are the most numerous and the frequency of criteria met is higher. Results evidence that small municipalities' ring around the pole of L'Aquila stand without intermediate zones. The mountain morphology has favoured a condensed spatial distribution and the FUA is divided in the main pole and the most fragile small municipalities without any buffer zones. General disconnection and isolation given by morphological configuration then impact also on socio-economic development and then to fragility. The three analysed FUA compose the study area of the further chapters.

URBAN AND PERI-URBAN AREAS: CLASSIFICATION OF TYPICAL RECURRENT CONFIGURATIONS

Chapter abstract

The chapter aims at investigating the physical structure of the urban environment for understanding if macro-criteria's fragility is related also to urban structure. The object is the urban gradient which develops from the main compact urban morphology to the peri-urban areas. The chapter proposes a classification of main recurrent configurations of the complex gradient. The methodology introduces the fundamental role of the Subject Matter Expert in the process of qualitative evaluation and possible implementation of Supervised Machine Learning in urban planning.

URBAN AND PERI-URBAN AREAS: CLASSIFICATION OF TYPICAL RECURRENT CONFIGURATIONS

Il capitolo si propone di indagare la struttura fisica dell'ambiente urbano per capire se la fragilità dei macrocriteri è correlata anche alla struttura urbana. L'oggetto è il gradiente urbano che si sviluppa dalla morfologia urbana compatta principale alle aree periurbane. Il capitolo propone una classificazione delle principali configurazioni ricorrenti del complesso gradiente urbano. La metodologia introduce il ruolo fondamentale del giudizio esperto nel processo di valutazione qualitativa e possibile implementazione dell'apprendimento automatico supervisionato nella pianificazione urbana.

2.1 Introducion

As the national scale investigation has focused on macro-criteria of fragility, this chapter proposes a focus on urban physical structures to investigate the eventual relation to fragility conditions. Urban physical structure is the supporting container of the overall urban environment. If the urban physical structure is a material container, which kind of shapes host fragility? How is the urban structure made? Which elements are there? Does a classification already exist? Instead of administrative boundaries, the chapter proceeds using the FUA (Urban Atlas) already used for assessing local conditions of fragility. The focus is on the three FUA representative of critical context of central Italy. The FUA standard can provide data on urban spatial distribution useful for the purpose. In this chapter the urban environment's structure is analysed approaching the urban configurations in the two main declinations of urban and peri urban areas. Such analysis implicates to include urban poles which have been previously excluded by the macro-criteria of fragility assessment. The peri-urbanization process is critical for framing approaches to urban structures because it has been the most significant urban form and spatial planning problem of the 21st century ([34]). Generally, it refers to the process of rapid creation of new settlements surrounding existent cities and along the main road network. The resulting territory is multifunctional, extensive, with a scattered morphology. It has low-density settlements which requests high mobility and transport dependence longer commuting distances, and it can also imply fragmented communities and degraded landscapes ([99]; [35]). Generally, the causes are articulate and interconnected such as demographic changes, variation in settlement intensity and economic structures ([54]). The phenomenon is related to the well-known sprawl, the low-density urban model of extensive urban areas which creates a mixed use of the territory at the expense of rural areas ([100]). However, the peri-urbanization has been indicated with a multitude of terms from a lexical point of view. The terms refer to transition and interaction of the rural and urban interface, the presence of porous boundaries and the creation of hybrid landscapes ([37]). All the terms refer to a mixed environment, in which the urban-rural dualism

disappear in favour of a complex and uneven gradient from urban to rural. Then, there is not a univocal definition of peri-urban ([101]).
The lack of one definition reveals the complexity of associate one singular term to a broad concept. A part of the uncertainty related to the issue is given by the variegate genesis of these areas. Moreover, as every process which involves land, peri-urbanization is a site-specific issue, and it varies depending on characteristics of geographical context. In fact, a generic approach for peri-urban areas does not exist and local planning should be more incisive than generic policies ([102]). In many fields related to management of cities and especially in Urban studies, no one single approach can be used to comprehend nature of peri-urban dispersed configurations ([103]). Researchers found out diverse methods and instruments for delimiting and classifying peri urbanization producing a multitude of contributions and prospectives ([104];[105]). Some fronts have focused on definitions of peri-urban, from the studies on the 'Città diffusa' which aimed at describing the tendence of a dispersive structure in urban space derived by dynamics and social-economic processes ([36]). The terms indicate the European tendence at the late nineties at local parcelling out given by singular intervention of built spread all over the territory incorporating both historical tissue and new settlements. The term is different from the sprawl model, which refers to singular parcelling plan with a significant area of intervention and it is typical of North American settlements ([106]; [107]). Such dispersal structure of the city has been described in various ways which emphasise the morphology changes, such as 'Arcipelago metropolitano' ([106]) and the study of forms which varies from the archipelago to the enclave ([108]). Terminologies also approach the varied relationship with rural areas that become residential areas as the 'Campagna abitata' and 'Campagna urbanizzata' which are characterized by prevalent low-density settlements with detached and semi-detached houses ([109]; [110]). 'Urban fringe' highlights the disappearance of the rural landscape, but the presence of urban tissue without any shapes ([111]). The definition of 'territories-in between' explicit the lack of a precise collocation in urban or rural categories ([112]; [38]). The terminologies are associated by the difference from the traditional city in which the central aggregation is the main characteristic

together with concentration of jobs and services ([113]). The studies are also focused on the permeation of peri-urbanization with fields that affect living and quality of spaces. Some assessments relate the incidence of peri-urban with socio-economic processes ([52]) and with quality of life ([39]) and quality of morphological configurations ([40]). Some analyses are focused on developing models and indicators for configuring and parametrize urban dynamics. For this front the phenomenon measure is considered crucial for having awareness of the problem. Settlement spread studies are associated with urban sprawl and urban sprinkling models, which are studied both for the state of the art ([3]; [44]; [45]) and for implementing techniques, tools and simulations for reversing the tendence ([17];[16];[114]). Then, remote sensing, forecasting models and machine learning implementations ([46]; [48]) are used for assessing present and future scenarios. Generally, such studies dealt with territorial scales.
Configurations, structures, and connections of urban settlements then are measured with tools such as axial maps and configurational approach. Street networks are seen as complex relational networks ([115]; [116]) which permit to approach themes as mobility patters and densification opportunities ([117]). The environmental fragmentation is a theme of research because of the increasing urban and infrastructural processes impact on ecological connectivity. This is not only given by the adjacency of natural or semi-natural areas cut off by settlements but includes also the connection given by the ecological and functional aspects ([118]). In the overview of knowledge, also intermediate and hybrid approaches are present among the well-defined and structured trajectories. Some approaches dealt with methods for applying methodological classifications to peri-urbanization ([50]; [51]; [52]). Researches then try to define and classify the non-homogeneous urban configurations and the challenging for sustainable planning ([55]; [4]). Among the classifications, macro-categories are assessed per morpho-typological specificities in the Provincial territory of Turin ([53]). The classification identifies dense areas, transitions areas and free areas as they are classified in the Piano territoriale di coordinamento provinciale ([119]). The theme of peri-urbanization is wide and declined in hundreds of ways and it is supposed to remain a pivotal question in urban studies. The current

work begins with the recognition of all these various approaches and outcomes. Then, the first aim is to propose a methodology for overcoming the vagueness which arises from the multitude of definitions around the subject. Starting from the model of urban gradient, the author as the subject matter expert (SME) provides the configuration of reference, which is composed of descriptive analysis and subdivision in 6 classes. The result is the classification of urban structure divided in recurrent urban and peri-urban configurations. Such classification is possible by finding and comparing real examples of the 6 configurations inside the case study. In fact, classes are representative of recurrent configurations in the case study's urban gradient (Figure 2.1).

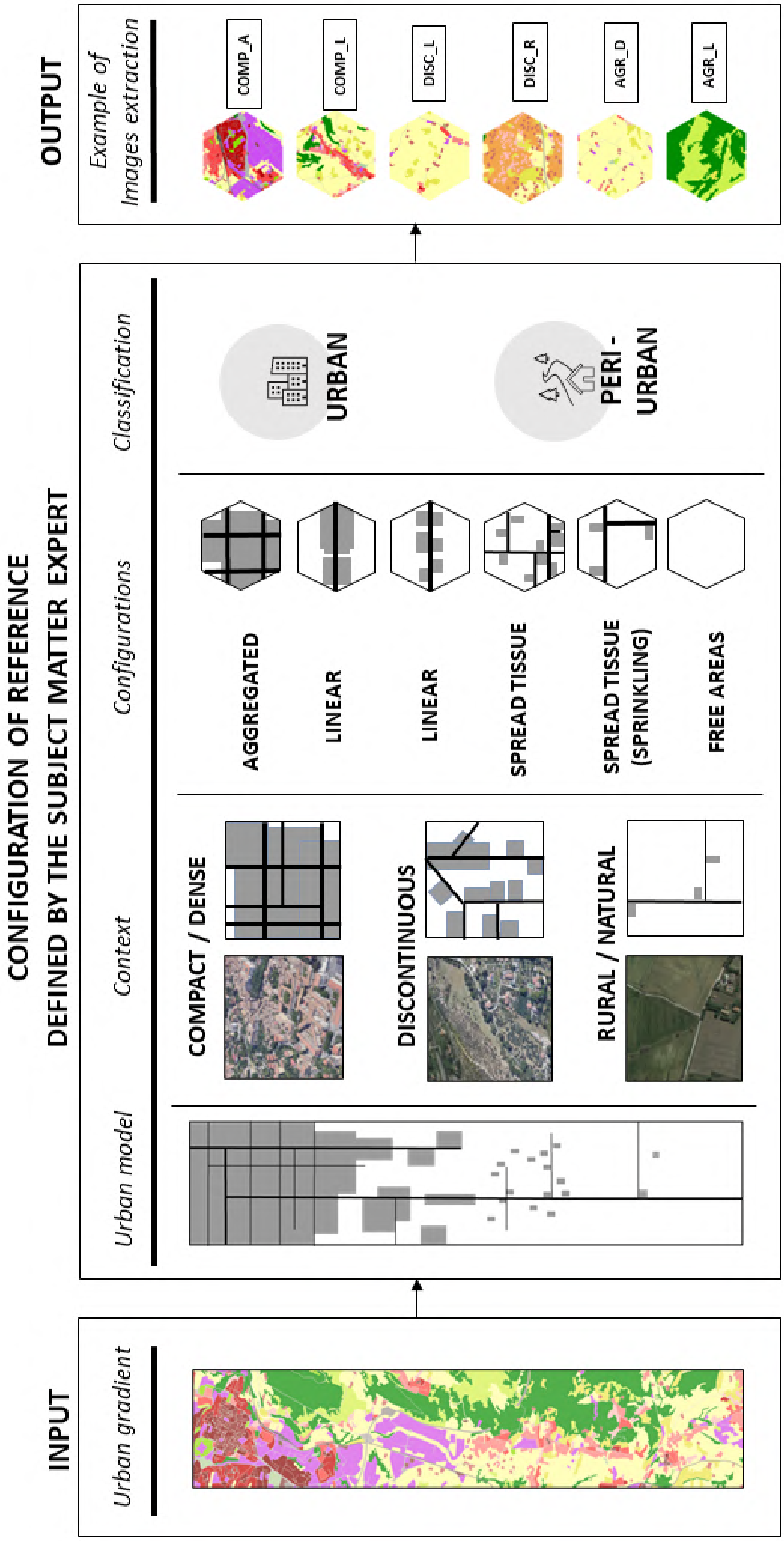


Figure 2.1. The roadmap of the implemented methodology.

The 6 classes are urban compact aggregated configuration, urban compact linear configuration, peri-urban discontinuous linear configuration, peri-urban discontinuous spread configuration, very spread peri-urban and then free areas.
The first result of the analysis is the possibility to extract the configurations as images and then to use them in further processes. One prime example is explained in the paragraph 2.5. The idea is to develop a comprehensive approach which includes the SME's classification and an automatic method of recognition using supervised machine learning techniques. The latter is one of the main future developments of the present work. Such passage is seen in line with progresses in urban studies for implementing new technologies to accelerate responses from planning strategies also in terms of balanced approaches between urban and green components. Ultimately, the aim is reaching a high level of sustainability of the processes which can be efficient, replicable, and ultimately that can deal with actual issues of planning. Therefore, chapter 3 examines in depth one urban compact aggregated configuration to provide an application of urban design project as example of urban quality implementation.

2.2 Materials and methods

The context is the central Italy, and the study area are the three FUA (Perugia, Terni, L'Aquila). Urban and peri-urban spaces are affected by the morphological condition of central Apennines: this leads to the importance of considering the coexistence of the urban settlement in the overall territory ([120]). Material and methods gravitate around the necessity to recognize urban material structures. For so doing, artificial surface and processes for defining the configurations framework are the subjects of the sub-chapter.

2.2.1 Materials

Land cover and land use data and satellite imagery are the main materials of the present analysis. The land cover and land use information (LULC) are based on the the Copernicus Land Monitoring Service (CLMS) ([121]), and specifically on the section of pan-European component (CLC) and the local component (Urban Atlas).

The CLMS provides a wide series of data such as geographical information on land cover, land use, vegetation state, water cycle and earth surface energy variables. The CORINE Land Cover (CLC) ([122]) consists of an inventory of 44 LULC classes ([122]; [123]) with a minimum mapping unit (MMU) of 25 ha and a Minimum Mapping Width (MMW) of 100 m. The source of data are the satellite data: ESA Sentinel-2 dual date Landsat 8, with time consistency: 2017-2018. Urban atlas is described as the instrument which is 'coordinated by the European Environment Agency (EEA) and aims to provide specific and more detailed information that is complementary to the information obtained through the Pan-European component. The local component focuses on different hotspots, i.e., areas that are prone to specific environmental challenges and problems. It will be based on very high-resolution imagery (2,5 x 2,5 m pixels) in combination with other available datasets (high and medium resolution images) over the pan-European area'([124]). The MMU is 0.25 ha (2,500 m^2) and the data for harmonised land cover and land use maps is available for 788 FUA in European Union and EFTA countries ([124]). Artificial surfaces, agricultural and natural and semi-natural areas are the main categories of land considered for the analysis. Artificial surfaces are precisely distinguished in the database with a classification of various levels of sealing soil (Figure 2.2). Then, the Urban Atlas provides pan-European comparable LULC data covering several Functional Urban Areas (FUA).

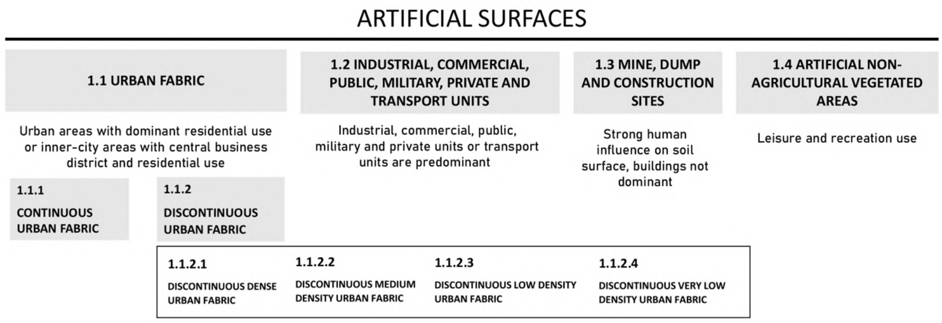


Figure 2.2. Specification in Urban Atlas classification (Source: Urban Atlas 2018).

Surfaces with dominant human influence and without agricultural land use. These areas include all artificial structures and their associated non-sealed and vegetated surfaces. Artificial structures are defined as buildings, roads, all constructions of infrastructure and other artificially sealed or paved areas. Associated non-sealed and vegetated surfaces are areas functionally related to human activities, except agriculture. Also, the areas where the natural surface is replaced by extraction and / or deposition or designed landscapes (such as urban parks or leisure parks) are mapped in this class. The land use is dominated by permanently populated areas and / or traffic, exploration, non-agricultural production, sports, recreation and leisure ([124]).

Then, satellite images are necessary instruments for evaluating urban areas. The high-resolution and wide coverage of data from different sources permit to analyse in detail urban settlements. Qualitative information is fundamental for the descriptive analysis. Google Earth includes many images collected from satellites orbiting the planet. These images come from various satellite companies and are grouped into a mosaic of photographs taken over many days, months, and years. The collected images are then combined into a single image, which is displayed on Google Earth. This RGB collection contains images with three pansharpened, 8-bit bands. The resolution is approximately 0.8m per pixel (closer to 1m for off-nadir images). Streetview tool has been included in the analysis. Other sources of data are Microsoft Bing Map: it is used for comparisons to the other satellite imagery, and Open Street Map. As an open-source map, it provides the structure of the road network.

2.2.2 Methods

2.2.2.1 Process to define the window to select and isolate configurations.

Urban and peri-urban configurations are framed in hexagonal windows. The SME uses such shape for finding recurrent configurations in the case study gradient. The hexagonal shape refers to the hexagonal cell used in urban grids. Generally, in urban studies grids are hexagonal or squared. Phenomena as urban dispersion are well defined with methodologies that uses grids. Research have already demonstrated that there is a difference

between a grid-base analysis and an administrative borders' one ([45]). One of the main differences is that using of grids allows computational spatial evaluation, whereas administrative borders help in contextualizing the subject of study. Between the square and hexagon grids, the hexagonal shape is the most used for various types of research. Differently from squares, in hexagons distance from centre to edges is equal. In case of a grid system, hexagonal shape has the same relationship with all the six adjacent shapes. Moreover, this shape is suitable also for further analyses due to its properties in terms of proximity (Figure 2.3).
The use of hexagonal window is here released from grid system. As one hand lens, such window is moved by the SME. The window is arbitrarily stopped where it frames one recurrent configuration. As explained later, the approach is comparative, qualitative, and visual. It is based on the experience and choices of the SME.

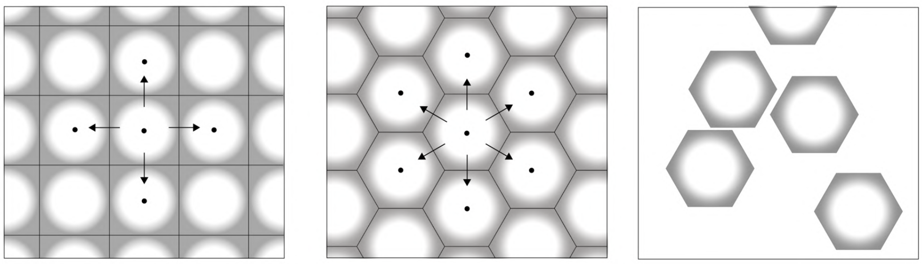


Figure 2.3. Differences in relations and approach in grids and free windows.

However, the arbitrary choice of hexagon shape has other implications. Hexagonal window is part of development lines of the research in relation to process of automatic recognition of urban configurations ([125]).
Therefore, the first problem is to define the window's dimension. The dimension is chosen arbitrarily 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 urbanised 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). Through the GIS software it is possible to dissolve such a result. In other words, the multiple parts are split up in singular parts. Multiple parts are geometries which are related to the same record in the

attribute table. Singular parts are then singular geometries analysable for their single dimension. The groupstats tool (QGis) permits to quantify the medium dimension of geometries of the area considered: the media is 119 ha. Considering the double of the data, the dimension results equal to 200 ha. This dimension is considered useful for framing geometries of artificial surfaces and then framing the urban and peri-urban areas polygons. In other words, such dimension assures to capture and frame the medium size of the settlements or relevant parts of them. For this reason, the dimensions of 200 ha/2 km2 is taken as reference for capturing the recurrent configurations.
As further tool, a visual isolation of the area is defined for proper analysis of the area contained inside the window. This is functional to isolate only the area analysed, instead of being influenced by external elements (such as other parts of the settlement, infrastructures, or other settlements) (Figure 2.4).

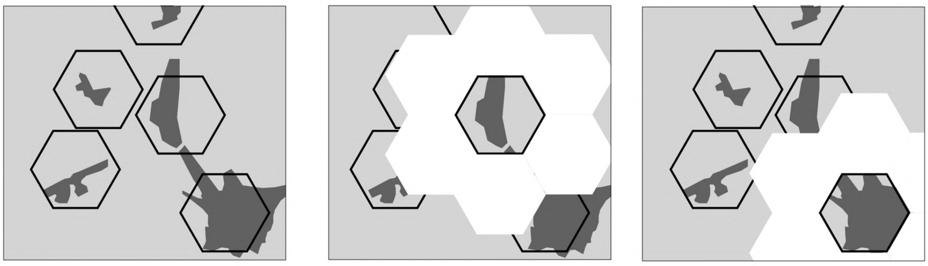


Figure 2.4. Windows and isolation of the configuration.

The two levels of LULC then are used for different scopes. The CLC provides the boundaries because of its law level of detail, but it is significant for the average dimension of urban areas. Then, the UA provides the necessary level of detail for recognizing the configurations.

2.2.2.2 Conceptualize the urban gradient: descriptive analysis and classification of urban and peri-urban configurations.

Instruments and dimensions then give the framework in which to study the phenomenon of urban-peri-urban gradient. How to study the gradient with its unclear scattered borders, unexpected variations, and irregularities? The critical approach is fundamental for distinguishing shapes, level of aggregation and ultimately points of weakness of urban settlements. Such work can be developed by the policy maker or the subject matter expert, who can discretize the real multifaceted reality. In the present work this approach is conducted from the author, which guides the steps from reality analysed to the model (Figure 2.5). This work implicates the reduction of complex system (the reality) in different possibilities of settlements (the model) which correspond to parts of the real gradient. The various parts of the territory then can be analysed in own contexts, but also studied in their own specificity as isolated in one window per configuration.

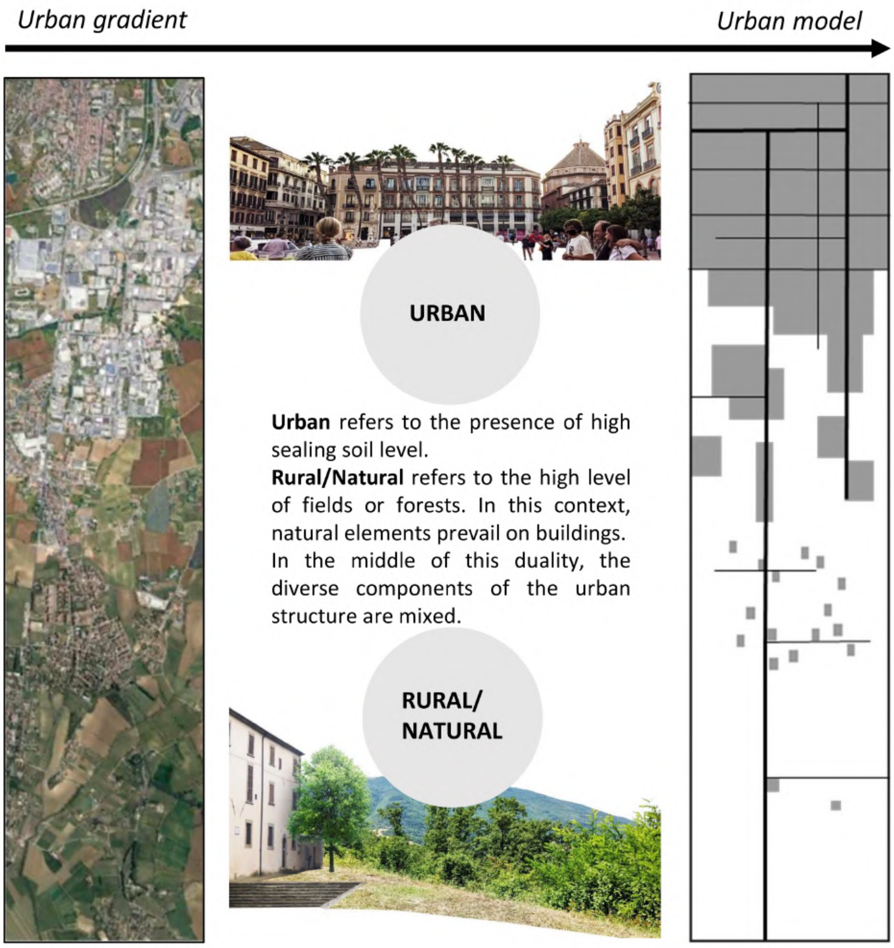


Figure 2.5. From the urban and rural extremes to a scheme of the urban gradient.

The study of territory done by the author as subject matter expert (SME) is the essential step for understanding and interpretating the urban structure of the case study. The match of identification of the urban structure with interpretation of quality of the urban environment is the step that make the classification possible. The SME observes the case study and compares the different configurations. The SME decides where to trace boundaries between one configuration to another. Such work of analysis, comparison and choice is the preliminary phase for the classification of recurrent configurations. In other words, the SME discerns the main variables of urban gradient which characterise the shift from one class to another. Urban gradient is complex and often undefinable, so the SME tries to define the cornerstones which allow to separate different classes. The actual technology and the available tools (such as high-resolution satellite imagery and street view's applications) are fundamental in the process of recognition. However, such analysis requires a process of reasoning that is not replaceable with software or automatic techniques. The process is based both on the specific case study and on the experience of the SME. Knowledge of typical urban forms, understanding of the context and prefiguration of possible cause-effect implications are all instruments based on the experience of SME. Such instruments give the possibility to abstract the theoretical model from various real elements present at the same time. The different composition of the same elements can give rise to different configurations because "The whole is more than the sum of its parts" ([126]). The knowledge of the SME permits to trace connections even when they are not visible. The classification of recurrent configurations then serves as a dataset, for which the ratio has already been defined due to the study of the territory and can be supportive of other techniques (as automatic techniques).

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 guided by the necessity of giving coherence to the specificities in homogeneous classification. As a matter of fact, the two steps are mutual rather than consequential (Figure 2.6). The theoretical classification is done in mutual progression with the descriptive analysis of real settlements.

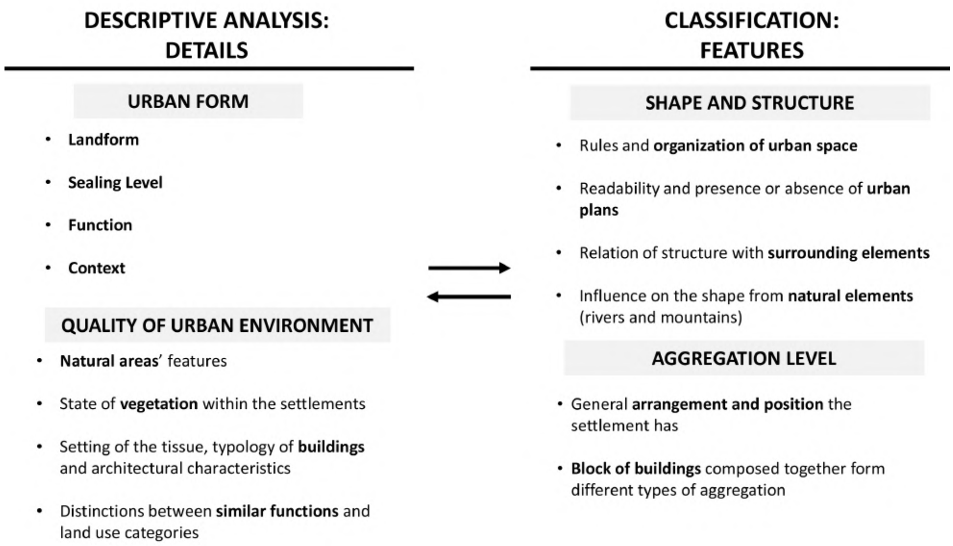


Figure 2.6. The double process of classification.

The first step of analysis considers qualitative aspects. A punctual, visual, and qualitative analysis is necessary together with process of classification. If classification permits to allocate different examples in different categories due to a process of simplification of the reality, qualitative analysis is fundamental for describing specific characteristics that contribute to allocate examples in classes. In fact, each window presents very specific features that have shaped the urban form. They are fundamental for recomposing the urban gradient even though they are set aside during the process of classification. The main fields of analysis are three.
The research begins from the context analysis which provides information such as the place name and the localization. The place name refers to the name of the town or suburb or fraction considered. It permits to identify the specific context from the administrative point of view. Then, the landform regards the morphological features that affect distribution of settlements. This aspect includes identification and description of natural elements as mountains, rivers, lakes etc. Information on percentage of sealing soil present in the dataset of Urban Atlas adds information on settlements. It is a parameter that helps in defining grade of occupation of the soil. It gives quantitative indication in percentage which are useful for having general picture also of typology of buildings, grades both of compact tissues and interstitial natural areas. Then, function and uses

are fundamental in 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. It can be derived from a larger presence of ancient town tissue or a wide area of countryside. Moreover, the comparison can be done the larger framework given from a wider CLC representation, which helps in giving the idea of the place of the window in the urban gradient. The representation of the road network: a focus on the presence, the types of streets (highway, main road, high-speed road, provincial and minor streets) inside the cell and the road network which draws the settlement.

The quality of urban environment can be denoted by mixing the information and due to the powerful satellite imagery. This analysis permit to better distinguishing different spaces which may be identified in the same class from the UA database. As instance, open spaces and non-built areas can be extremely different. Residual, interstitial areas or brownfields can be very different for characteristics and position. Being between buildings or infrastructures may give very different connotations in usage and conservation. The so-called third landscape is included in this category of observations on urban features ([127]). Related to this point, 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 that the settlement is recent. At the same time, same species and organizations of the plants can indicate a plan behind the construction. The setting of the tissue and the typology of buildings and architectural characteristics are indicative of properties of settlements. Same typology and same building material suggest a structured unitary plan, which is built from the same construction company. 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 ([128]). Distinctions between similar functions and land use categories also conditions the analysis. Same function and same coding on the Urban Atlas are not indicative of same conditions and other distinctions are useful. As instance, industrial set-

tlements can be factories, logistics platforms, photovoltaic installations, or bio-gas factories. Even if aggregated in the same typology, such buildings implicate a series of diverse relationship with the territory surrounding.
Secondly, the classification is structure following the main structures and aggregation features. The shape and structure are taken as primary feature used to classify the settlements. Shapes refers to main conformation of the artificial area as it appears at the chosen scale. It can have one readable distribution, or it can be mixed. The data on level of sealing soil is integrated with the study of types of buildings and constructions. So, distinction in shape is done with a macro-distinction on tendency of development of urban areas. The main shapes are assessed as aggregated, linear and spread. The aggregation level is strictly related to the shape and structure, and it refers mainly on the density from a qualitative point of view. Although for urban compact structure there are few differences in the level of aggregation (which is generally medium-high), this feature permits to distinguishing more than one classes of dispersed tissues, because of the diversity in presence of buildings and the variation number and dimensions of interstitial spaces. Aggregation level is seen when comparing diverse types of linear tissues (compact or discontinuous) and diverse types of spread tissues (spread or very spread).
Six main models then are classified from the most compact and aggregated tissue to the absence of buildings and urban shapes. The main classes founded are six. Each class then is identified through the hexagonal window.

1. Aggregated, compact and dense. Portion of the urban area. Comprehensive of historical centre or in proximity of that. This model has readable, structured, and consolidated urban plan. Tissue can be intricate, 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. 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 (DM 1444/68).

3. Linear and discontinuous. 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 (DM 1444/68). 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 (DM 1444/68).

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 (DM 1444/68).

6. Free areas in rural context. The dominant element is a natural area, such as fields, woods, orchards. Buildings are excluded from this pat-

tern. The class about free areas is a category deprived from artificial land. In the present study, the presence of this category is useful in the general picture, but the category is not examined for the urban and peri-urban distinction. According to the urban zoning, these settlements are included in the E zones (DM 1444/68).

As shown in the Figure 2.7, each class generally refers to a specific section of the gradient. Of course, exceptions and significant variations can occur, but the table shows a typical transit from urban to rural. The section comprehends a high quantity of possibilities of configurations, which are summarized in three main possibilities, in which the variation is mainly associated with the shape, the distribution of urban elements and the configuration of the road network. The three typologies then constitute a range which is associated with one main configuration. Precise definition of limits, possible integration and permeation among the configurations showed are not the point of interest of the present work. Such limits are here intended as an instrument usable for the analysis and then they are approached schematically as the result of the classification shows. One selected main example configuration is considered representative of all the typologies included in the class and it will be used as unique reference for the class of belonging.

All the feature investigated are then summarized in supplementary worksheets per each window in Appendix. Each worksheet summarizes the main characteristics of the configuration (Figure 2.8). A worksheet corresponds to one configuration, and it indicates the place name, the general overview in the CLC 2018 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 imageries at various scales, sketches of the main shapes of the settlement, the main road network. The appendix is focused on the first five classes, from Aggregated, compact, and dense tissue to Very spread tissue in rural context. The sixth class with free areas is excluded by the elaboration.

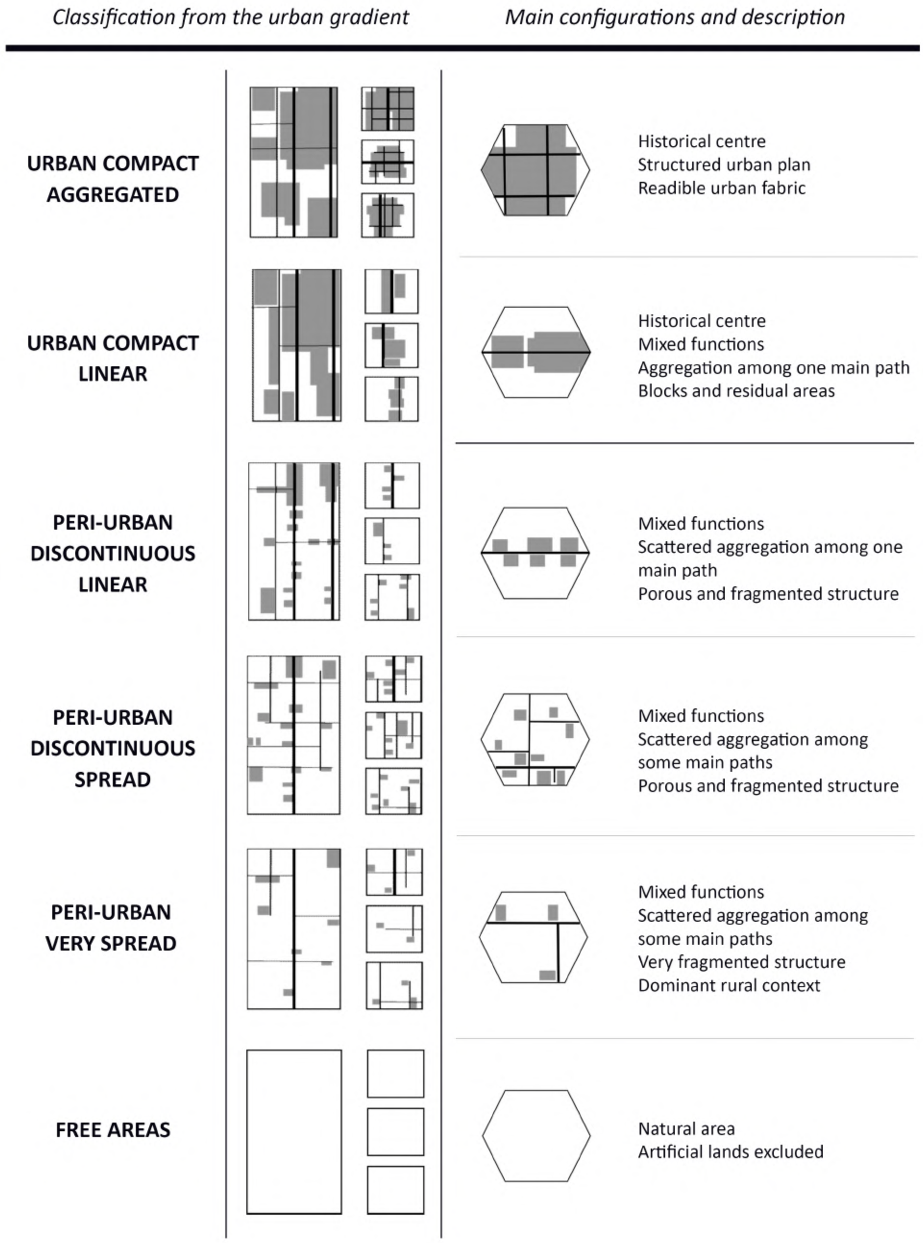


Figure 2.7. The graphs show the main models of reference, the classification in Urban or Peri- Urban.

2.3 Results

The first result are the configurations divided in the 6 classes of the gradient. Each configuration is among the most representative recurrent examples in real configuration of the diverse theoretical classes. As a result, the classification gives 22 windows on the study area. Windows are 9 for FUA of Perugia, 7 for FUA of Terni and 5 for FUA of L'Aquila. The results are

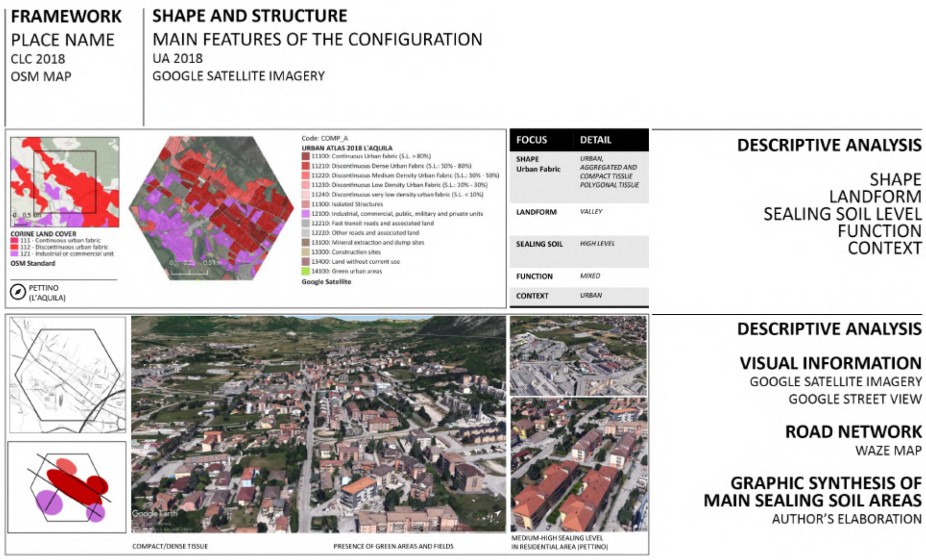


Figure 2.8. Typical scheme of summary worksheets. It comprehends the methodology for the qualitative analysis . The representation of hexagonal window on Urban Atlas 2018 and Google Satellite Imagery is representative of types of artificial surfaces present in the area in the context of satellite imagery which contextualize the UA data.

divided into 6 for aggregated compact and dense; 4 for Linear, compact and dense; 3 for Linear discontinuous; 3 for Spread and discontinuous tissue; 3 for Very spread tissue; 3 for Free areas. The selected configurations are spatialised on the Urban Atlas maps.

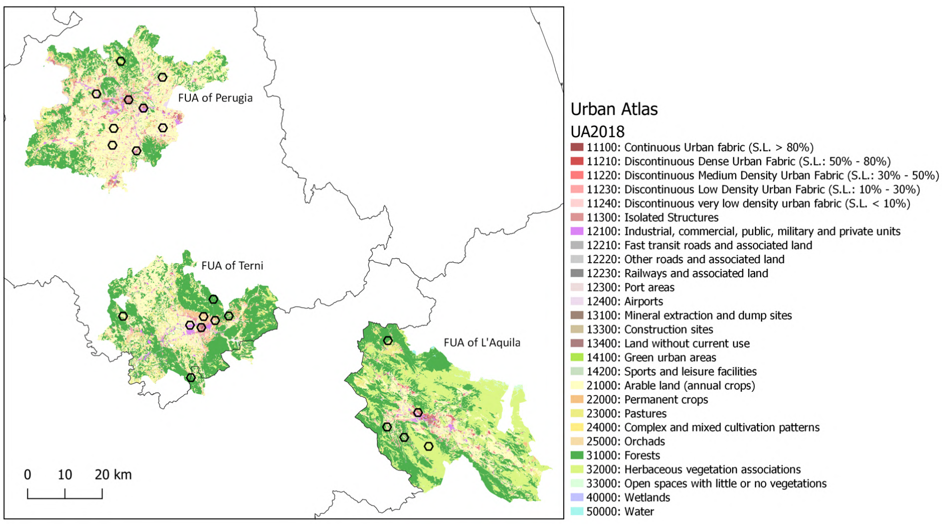


Figure 2.9. Results of window classification.

The highest number of resulting configurations are in the FUA of Perugia, then in the FUA of Terni and lastly FUA of L'Aquila. According to the UA data, urbanised and agricultural areas are more in FUA of Perugia and then they decrease in the other two. At the extreme of the gradient, FUA of L'Aquila is the most characterized by natural and semi-natural areas with a more compact settlement related to the morphological configuration. In this case, the eventual buffer area for the expansion of peri-urban areas then is limited and the representative configurations are less. As the previous macro-criteria study has showed, a north-south gradient related to the morphological configuration is readable also on the structure of the urban and peri-urban configurations. In fact, the development of peri-urban areas generally follows the proximity of the urban centres and rural context ([61]). 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 dispersed). On the contrary, a prevalent mountain context limits expansion possibilities and the soil usable for expansions are more limited (as FUA of L'Aquila). The results highlight that available and advantageous morphology (as agricultural lands) in continuity to the urban core facilitates the presence of heterogeneous peri-urban configurations. This explaines the 9 configurations for FUA of Perugia, 7 for FUA of Terni and 5 for FUA of L'Aquila (Figure 2.9). Some considerations on classes have arisen from the results (Figure 2.10).

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 can be consequential to one central point of interest or aggregation.

2. Urban linear, compact and dense are mostly linear productive plants aligned along a main road. Linearization is a typical way of proceeding in urbanisation 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 (light, water, gas) may be related to economic convenience.

3. Peri-urban Linear discontinuous tissues have variegated characteristics. 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 zones.

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 natural areas involved is variable.

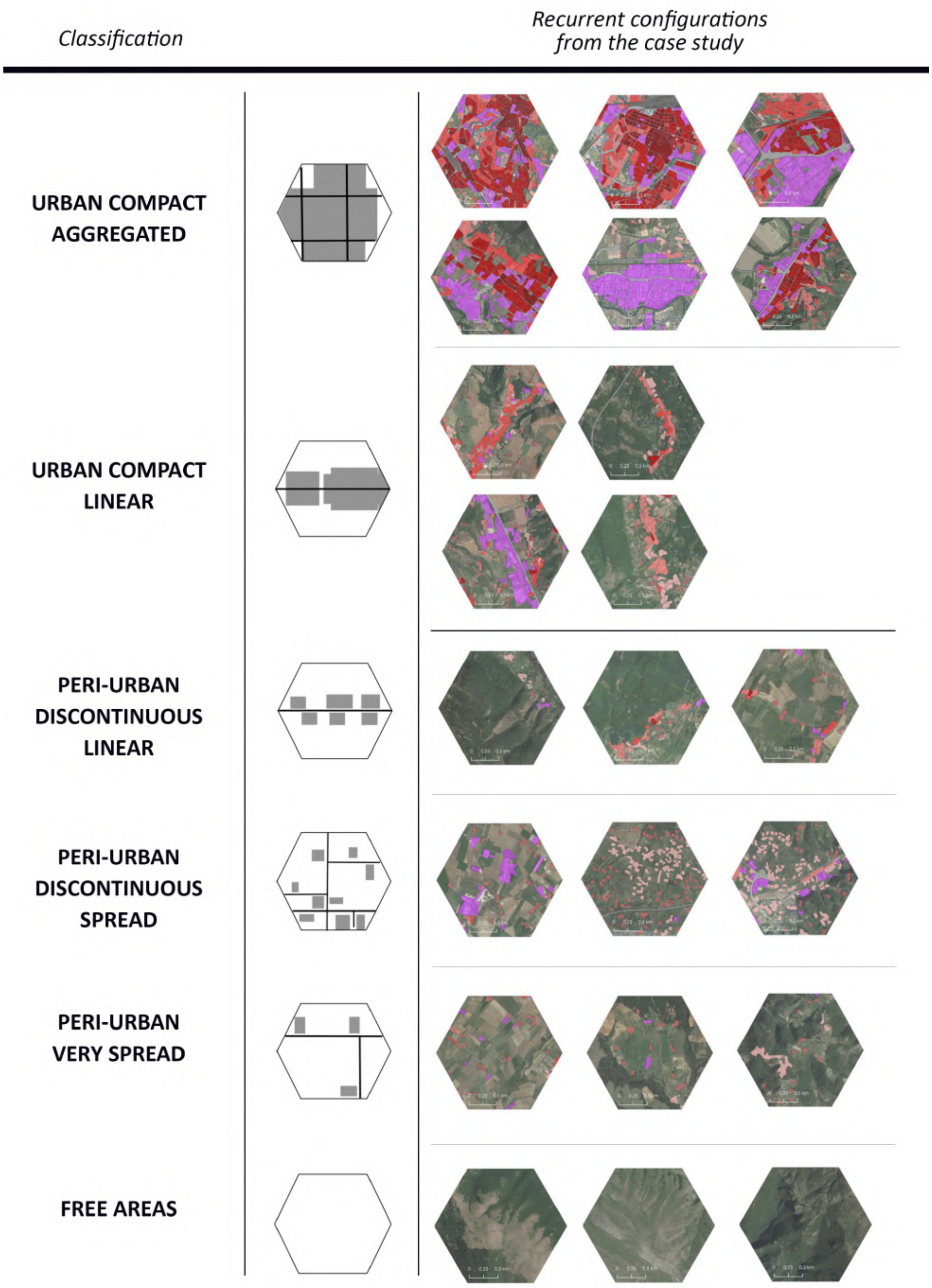


Figure 2.10. Results.

2.4 Discussion

The second chapter introduces a layer related to the structure of settlement in the context of the gradient between urban and rural areas. This work deals with the opportunity to improve sectorial classifications (descriptive or computational) used for distinguishing urban and peri-urban areas (Figure 2.11). In particular, the descriptive and qualitative process represents the base for further applications.

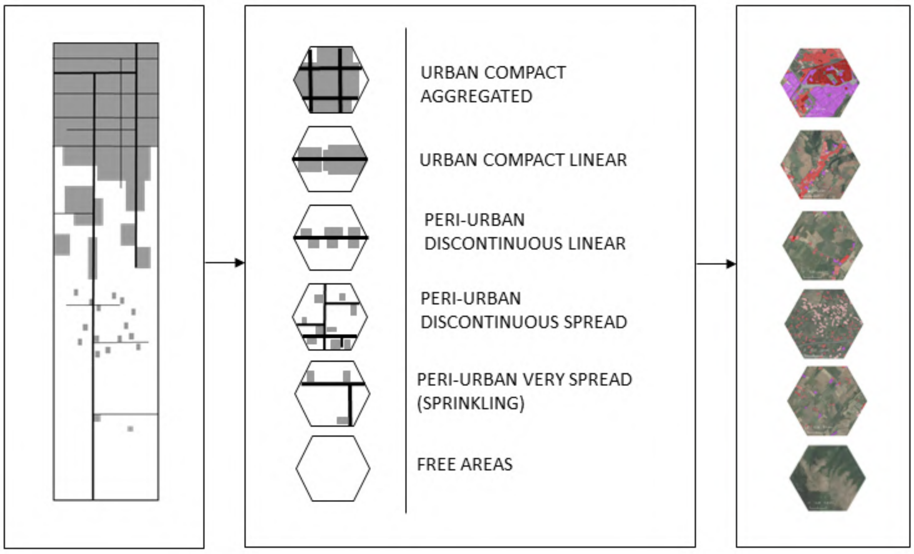


Figure 2.11. Urban gradient, from the model to six classes.

Evindently, the FUA set the perimeter of the analysis, including areas around the 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 periurban configurations which are more dense, whereas uninhabitated and building-free areas are present in less quantity. Considering tissues and configurations outside the perimeters of FUA may be give different results. Other comparison on different levels of peri-urbanization can regard the welfare-related issues like social services and connections, but the focus of the research is related to urban growth and different levels of dispersion. Even though urban elements are related to urban dynamics, the classification has been done considering only the elements readable in the current situation. Of course, these elements can be also involved in prefiguring future trends. As instance, the contemporaneous presence of two similar elements in one configuration may prefigure the possibility of development of similar other elements. This aspect is highly influenced by political and economic choices, and the study of current situation can be indicative only of potential vocation of the configuration. Instead, the analysis deals with the difficulty in delimiting a border between urban and peri-urban configurations.

Calibration among different classes has been one of the main discretional choices. In fact, classes have been defined through qualitative analysis of the case study and the classification, in a mutual process. For the specific case study, three main choices in terms of distinctions have been done during the analysis.

1 Linear, compact, and dense 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, the compact tissues that can only be described for their axial develop have remained in the compact linear class (Figure 2.12).

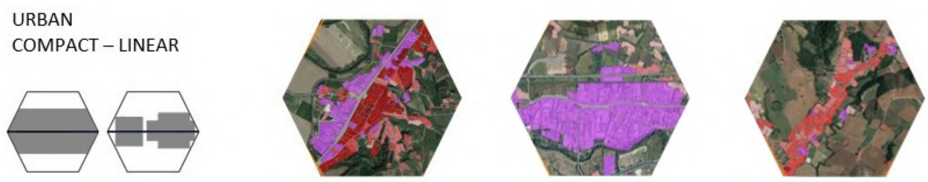


Figure 2.12. First definitions of linear compact and dense configuration.

2 Spread and discontinuous tissue is uneasy to identify, and it presents many specificities and variations in different contexts. At the beginning, a rough classification of spread and discontinuous included the typical sprawl configuration or mixed discontinuous tissues that might be associated with the sprawl model. However, sprawl model has a defined recognisable configuration which should be considered apart from the general discontinuous tissue (Figure 2.13). Since the typology is not common in the case study, the typology has been excluded from the classification.

Figure 2.13. Example of one configuration associate to the sprawl model.

3 Evident variations in discontinuous has led to the necessity of calibrating two different levels of discontinuous classes. Among the classes, the two discontinuous are the most similar ones. Discontinuous tissues can vary consistently but preserving discontinuous characteristics. In fact, calibration of such variations is object of studies on urban growth models. In general, the classification is defined by subjective distinctions: all the differences between the 6 configurations are defined by and comparisons among the cases present in the specific case study, experience, and perception of the author. Moreover, 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 application related to the automation that will be developed in further applications.

Beyond distinctions in classes, general organization and structure of classes vary from one class to another. The classification should be a prime instrument of comparison among the settlements' performances. Configuration is indicative of how resources are distributed on the territory, related costs, and possible loss of biodiversity ([45]).

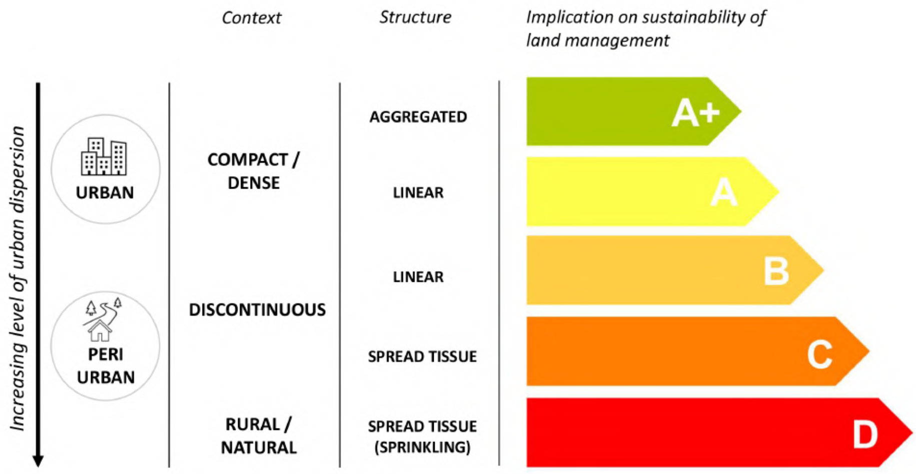


Figure 2.14. The graph shows the main models of reference, the classification in Urban or Peri- Urban and then a general estimation of impact of each type of settlement.

The figure 2.14 refers to the typical scheme about energy class of buildings. It goes from cases of possible higher-performance in efficiency of urban settlement (A+) to the worst case in terms of urban structure which is more energy-demanding (D). Even if compact settlements show issues as worsening of climate condition given by excessive concentrated soil sealing and carbon storage, on the other hand urban dispersion generates other types of impact ([129]; [130]). As instance, the extensive soil consumption is directly related to increasing costs in routine maintenance of roads and in dispersion of services' network ([131]; [132]) and then it relates to social costs ([133]; [134]). Lastly, this model has more impact on environmental fragmentation ([67]).

2.5 Experimental perspectives

An experimental phase with application of supervised machine learning (ML) is proposed with the present chapter. The term derived from the broad field of Artificial Intelligence (AI) and machine learning is a subset of AI. AI refers to train a computer for elaborating data in a way that follows in the footsteps of human brain. It can recognize schemes and associate data, it can also develop new strategies for achieving the same results. More calculating capacity and dataset increase, more AI becomes

faster and accurate in responses ([135]; [136]).
The goal is to automate recognition of recurrent urban and peri-urban configurations, given the classification mentioned and the case study area. The process is composed of different steps: the first concerns the classification and spatial identification already approached. Then, the further steps concern the application of the supervised process through train and test with a proper algorithm and then performance evaluation of the model (Figure 2.15).

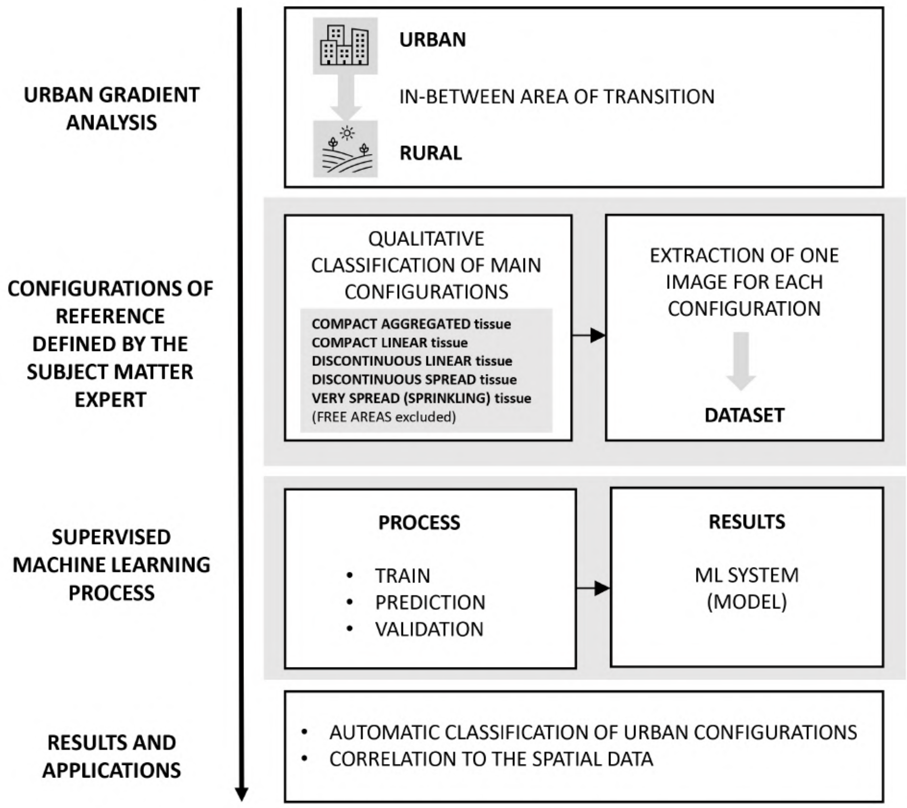


Figure 2.15. Diagram of the approach.

As showed, the classification of urban and peri-urban configurations provides 6 classes which are coherent and homogeneous. Such classes refer to the case study (FUA of Perugia, Terni, L'Aquila) and each of them is associated with some configurations from the case study. The classification then is supposed to be typical of the case study area. Practically, each configuration is recognized through a series of isolated hexagonal windows of the Urban Atlas data. The first part of the process is considered closed with the classification and the spatial identification of the main configura-

tions.
Then, the machine learning application needs a database of images. Generally, in supervised learning the database is labelled by an external supervisor, subject matter expert (SME), or an algorithm. In the present work, the role of subject matter expert is carried out by the author and the process of labelling corresponds to the classification and the spatial identification of the main configurations showed (Chapter 2). The class of free areas is excluded from the present analysis, so the 5 classes from urban compact dense to very spread tissue (sprinkling) are considered.
As result of classification showed, the configurations remain part of the original map (composed of Urban Atlas and Google Satellite imagery) even if they are visually isolated and then selected. In the subsequent step, each configuration is converted into one image. The extraction of each configuration is a GIS operation which include a cut off and a python script to speed up the process. For this process, only the dataset of Urban Atlas is considered. The result is then a dataset composes by the selected hexagonal areas from the study area as represented by the Urban Atlas (Figure 2.16). Images used as dataset are the crucial passage in the elaboration. The ML process extrapolates features from the images. Such features compose the information of the dataset. Then, such dataset will be used inside the training phase.

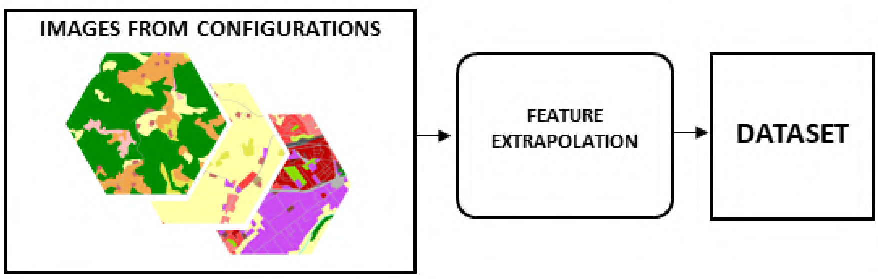


Figure 2.16. Diagram of the passage from images to dataset.

In fact, the group of images is split into two groups: train and validation datasets. The train dataset is composed of labelled dataset, and it serves as training, whereas the validation dataset will be used without labels as comparison for assessing the learnt capacity of the model. The training phase consists in evaluating the performance of the available algorithms. The algorithm that shows the best performance then is chosen for the prediction phase, in which the model is expected to made its attempt of application with the test data. Even if it has been already classified as urban configurations, the test database is not labelled and new for the model. Then, the computer will assign each image to one of the five classes. Then, a process of comparison is done with the same validation dataset which have maintained the labels referred to belonging classes. This is the final test for results given from the process. From this point forward, no changes to the process or data can be acceptable because they could be influenced by operator's bias.

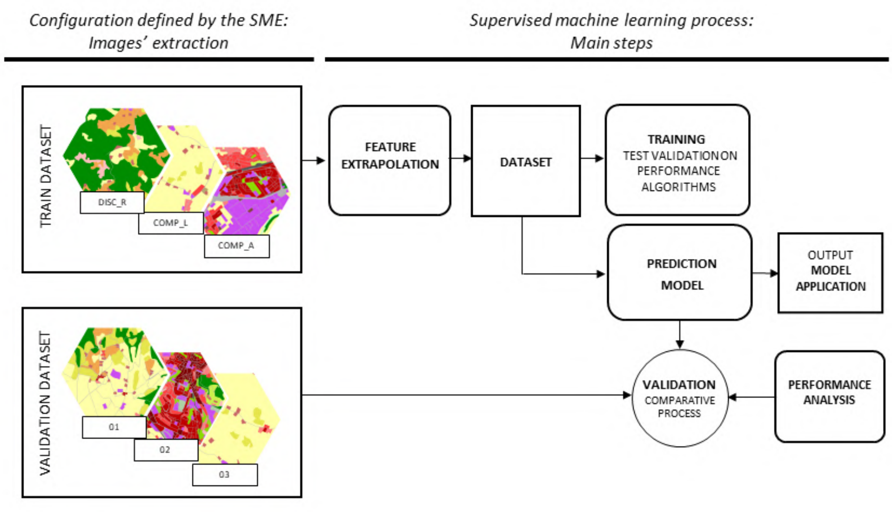


Figure 2.17. Diagram of the passage from images to dataset.

As the final passage, the performance of the model is evaluated for comparing supervised learned model's results and real results. This last step serves for measuring errors and then it permits to evaluate the general performance of the model. A high percentage of images in the right class indicates that the model has worked well. A high percentage of failed assignments for the same class may indicate that images (and then configurations) chosen for that class are difficult to recognise or they are too dissimilar each other. Once tested the reliability of the model, it can be used for applications (Figure 2.17). In this way, the classification based on a mixed approach is a step ahead. The process has produced a trained model on the urban and peri-urban classification that can be tested on other case studies.

One other result of the process is the spatialization. Configurations have been extracted from the Urban Atlas as images, but they are precisely spatialized on the case study area (FUA of Perugia, Terni, L'Aquila). Precise location of the images (and then the configurations) allows to do further considerations about the model's performance and its capacity in recognising configurations.

One application of the supervised learned model provides some interesting results (Figure 2.18). It has considered 55 images from the case study. A training phase on 30 images has produced 21 images classified correctly (70%) and 9 images classified wrongly (30%). Instead, the validation phase has produced 14 images classified correctly (56%) and 11 images classified wrongly (44%) ([137]).

TEST AND SCORE ALGORTHMS

Model	AUC	CA	F1	Precision	Recall
Logistic regression	0.928	0.700	0.710	0.734	0.700
Neural Network	0.898	0.600	0.550	0.523	0.600
Random Forest	0.891	0.667	0.676	0.702	0.667
kNN	0.869	0.667	0.670	0.708	0.667
Tree	0.625	0.400	0.405	0.463	0.400
SVM	0.565	0.500	0.508	0.563	0.500

MATRIX OF CONFUSION - VALIDATION SET

Attuali \ Predette	AGR_1	COMP_1	COMP_2	DISC_1	DISC_2	Σ
AGR_1	4	0	2	2	2	10
COMP_1	0	2	0	0	0	2
COMP_2	1	2	3	0	0	6
DISC_1	0	0	0	2	0	2
DISC_2	0	1	0	1	3	5
Σ	5	5	5	5	5	25

Figure 2.18. Results from the first application. The acronyms refer to 5 classes. COMP_1 refers to *Aggregated, compact, dense*; COMP_2 refers to *Linear, compact, dense*; DISC_1 refers to *Linear discontinuous*; DISC_2 refers to *Spread discontinuous tissue*; AGR_1 refers to *Very spread tissue*.

Further applications can comprehend supervised learned models trained on the same data and validated on different areas or trained and validated with different classification for a completely different area of study.

2.6 Conclusion

The chapter provides a classification of the urban physical structures. The result is a qualitative approach that converges in a practical and usable methodology to investigate the eventual relation to fragility conditions. The framework provides six classes. Each class is defined with a quantification and a description which frames each class inside the urban gradient. The methodology may represent a compromise between the qualitative and the computational approach, but it is not just a middle point between two approaches. Also, the worth stands in the practical application it has in the LIFE UMBRIA Project ([62]). The present methodology is fully part of the research and then the project is the real field of application in place. The project studies the relationship between natural habitats and urban models, investigating the interference with Natura 2000 Network ([138]). Among the goals of the project, modelling the urban growing is fundamental. Models of urban growing (and then the configurations of urban and peri-urban areas) are useful both for analyse the present state and for forecasting future scenarios. Goals of LIFE project include the use of SME's work for detecting relationship between urban and natural configurations. Peri-urban configurations classification is also indicative for approaching possible interferences with the Natura 2000 Network. The methodology then is already supportive of planning strategies.

In an operational process, study of configurations is also functional to provide targeted interventions and projects useful for other levels of planning. The classification explicates and discriminate that urban and peri-urban configurations need different approaches to the urban project. If for a compact dense area, the desealing can be a prevalent need, 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. In this sense the classification of urban and peri-urban configurations is also a tool for studying targeted projects. At the design level, each configuration can fit a series of interventions. Projects then can give specific solutions to configuration-related issues. Urban structure and levels of dispersion deeply impact on land management because they can prefigure and orient scenarios and future developments. In perspective, sustainability and performance of settlements should be evaluated through the classification of configurations. Ultimately, configurations are usable in defining planning strategies as the definition of ecosystem services or implementation of resilience policies.

The effort made for producing the classification of urban and peri-urban configurations is aimed at being the first level of further development. As instrument of knowledge of the reality, the qualitative classification is the inevitable primary step. Then, the semi-automatic model can automatically implement the classification for a given area. The implementation produces a combined methodology between descriptive and computational approaches. The first results of this approach are promising. The implemented procedure aims at stimulating realization of an instrument capable of evaluating configurations from urban gradient due to the use of international LULC standard (UA). It also aims at delimitating the concept of peripheralization and better understanding if there are any correlation between territorial fragility (Chapter 1) and the urban structure.

URBAN REQUALIFICATION PROJECT: THE MOSAIC TILE IN THE CONFIGURATIONS DEFINITION

Chapter abstract
The chapter aims at introducing the theme of design project for deepening the study on structure of urban configurations. The configuration chosen from the classification is a compact aggregated configuration but also a fringe from the urban centre. In fact, the further scale passage is an exercise of in-depth analysis which serves to contextualize the configuration previously modelled within the real urban context. The urban structure reveals lack of green connections and inadequacy of open spaces. Such condition proposes a new level of fragility which corresponds to the fragility seen at the macro-level.

URBAN REQUALIFICATION PROJECT: THE MOSAIC TILE IN THE CONFIGURATIONS DEFINITION

Il capitolo si propone di introdurre il tema del progetto per approfondire lo studio sulla struttura degli assetti urbani. La configurazione scelta dalla classificazione è una configurazione aggregata compatta ma anche una frangia del centro urbano. L'ulteriore passaggio di scala, infatti, è un esercizio di approfondimento che serve a contestualizzare la configurazione precedentemente teorizzata all'interno del contesto urbano reale. La struttura urbana rivela carenze di collegamenti verdi e inadeguatezza degli spazi aperti. Tale condizione propone un diverso livello di fragilità che infatti corrisponde a quello osservato a scala più ampia.

3.1 Introduction

The aim of the Chapter 3 is to develop a specific focus within one selected configuration from the classification of the urban gradient (Chapter 2). The focus is on the planning actions capable of transforming urban tissue's quality in the window of selection. The relevant change of scale highlights urban dynamics complexity inside singular configurations.
The research so far has given a framework on macro-criteria of fragility related to spatial and socio-economic issues. Therefore, the urban environment has been classified in urban and peri urban configurations according to structure and qualities. The understanding of territorial fragilities proceeds in analysing and interpreting the territorial elements which compose the urban physical structure. Therefore, in this chapter the result is an application: a design exercise of urban requalification intervention. It mainly refers to the principles of green infrastructures and Nature Based Solutions (NBS) as tools to implement green areas regeneration and then urban quality and liveability ([67]). Such approach introduces a reflection on the implementation of quality in urban and peri-urban configurations using design projects as part of a superior strategic planning.
The framework is the actual trends of soil lost in the last years ([6]). Quality and liveability of urban areas are involved in worsening of living conditions with the impoverishment of natural resources and increasing of average temperature ([11]). Such framework produces diverse implications in terms of management of cities. On one hand, such grow has excluded nature from cities and on the other hand the same support from nature is requested for re-assessing healthier conditions and urban comfort by implementing strategies for increasing urban greening. In such framework, strategic management and monitoring both natural resources and urban settlements should be resolutive. As regards greening in cities, studies and addressing policies around the green infrastructures are increasing attention in urban discussions ([139]). Among the various declinations from urban scale to landscape scale, green infrastructures are even less studied as simple connections among ecosystems and more as networks. In fact, good management, quality, and strength of their services are the predomi-

nant issues ([140]; [64]). For so doing, implementing actions for sustainable management of resources in terms of benefits for both people and nature then is necessary than ever before. This is the definition for the implementation of Nature Based Solutions ([141]; [142]; [81]). Concerning the urban management, decrease of natural resources and fragmentation of natural habitats often relate to the urban expansion ([61]). Growing urbanization produces soil consumption and growing costs for the settlements, as 'sprawl' and 'sprinkling' phenomena have demonstrated ([44]). The urban gradient which leads from the compact city to peri-urban contexts generates hybrid landscapes in which boundaries between urban and rural are difficult to find and difficult to manage ([4]; [55]). In such condition of uncontrolled or unplanned grow urban areas are losing biodiversity and becoming less liveable. To this extent, some techniques regard the protection of green areas and their network, the requalification of spaces and de-sealing projects. In an urban environment of fringe compact tissue, the first approach should be related to the protection of existent natural areas and creation of new open spaces. Moreover, clear design address should be increasing the presence of green inside the tissue combined with services and public spaces if they are missing.
Within this framework, one window is extrapolated from the various examples of compact urban areas (Chapter 2). The focus of the analysis is one hexagonal configuration selected from the FUA of L'Aquila (Figure 3.1). The analysis develops the results from the classification using an extensive description. The configuration is a hub in the urban system, and it has the combined presence of a dominant urban matrix and the surrounded natural framework. Then, the analysis highlights characteristics and weaknesses of urban settlement and natural elements. The following design application then is considered as outcome of all the reasoning. It is the result of a multi-level approach more than a single project.

Detailed scale is even deepened with a project of de-sealing and urban forestry on one selected area, part of the window U_C_04 which is in the FUA of L'Aquila. The hexagonal window captures an area which comprehends the Centrality of Coppito and the residential area of Pettino. It is mainly an urban fringe, and it is adjacent to the high-quality environmental

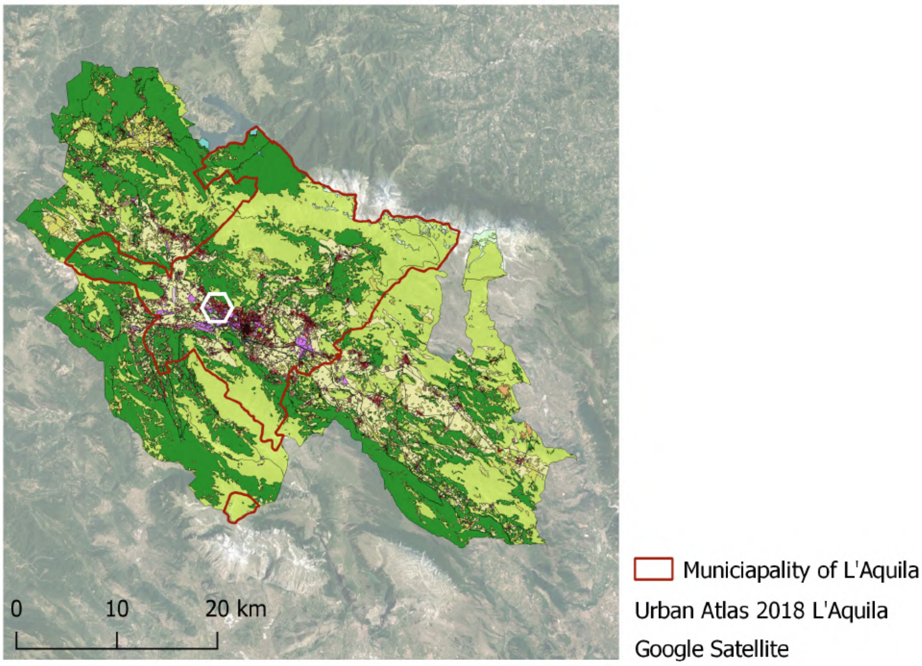


Figure 3.1. One hexagonal configuration selected from the FUA of L'Aquila.

context of Pettino Mountain.

3.2 Materials and methods

The object of analysis id the window U_C_04, which identify one compact dense aggragated urban configurations in FUA of L'Aquila.
The area identifies a fringe of urbanized area which is 3 km distant from the historical centre of L'Aquila and that expands toward north-west.
The city of L'Aquila has about 70 000 inhabitants, and it is the administrative centre of the Abruzzo Region. Its territory is at 714 metres above sea level and mainly composed of a wide valley in-between the Apennines, at the foot of Gran Sasso: the highest mountain chain of central-Italy Apennines (2912 metres above sea level). The earthquake in 2009 deeply damaged some high-urbanized areas, and it has been the prelude of the following re-configuration of the city ([91]). Since the urban plan has not been updated after 1975, the parts of the city damaged from the earthquake have been rebuilt following the conservating renovation or own initiative of citizens. Also, a process of expansion has proceeded towards the creation of more compact peripheries waiting for the rebuilt of damaged areas in the

historical centre. Rapid interventions have started for finding new houses for inhabitants but without developing new territorial strategic configurations ([66]). In such context, sometimes the periphery has been rebuilt as it was before the seismic event without any updated reconfiguration as it happens for the historical centre. In addition, such rebuilt areas came with new settlements that have added soil consumed. Urban dispersion and peri-urban conurbations has been exacerbated. In many cases, such process has impacted on adjunctive fragmentation of surrounding natural areas ([92]).

Moving the focus only on the configuration U_C_04 (Figure 3.2), it represents one of the main urbanized area of the city, and it also occupies a position in-between some relevant natural areas. It is a hub of functions for the city, and it is similar in dimension if compared to the historical centre (extension of about 2,50 kmq compared to about 2 kmq). It can be considered an urban centrality and the 2kmq-wide hexagon captures the central part of the settlement.

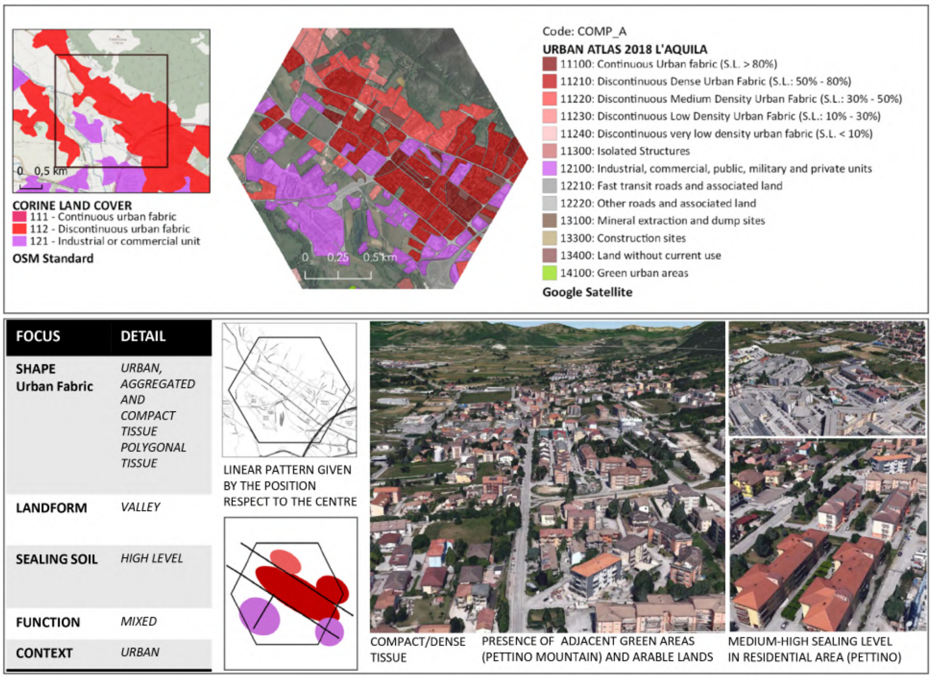


Figure 3.2. The urban configuration U_C_04 selected from the FUA of L'Aquila. Main characteristics of the urban morphology.

The area is composed of urban, aggregated, and compact tissue mainly. A sort of predominant linear pattern is clear if seen from the structure of the main routes. Such structure is consequential from the position of the area in relation to the historical centre. However, in general, it appears a dense and compact tissue if considered the very dense pattern of blocks. As Urban Atlas 2018 shows, the sealing soil is medium-high, around 30% to 80%. The densest area corresponds to the residential district which is located mainly along the principal road axes from north-west to south-east (Figure3.2).

The main settlement is structured as polygonal tissue. Functions are mixed from residential to services. On the average, some of the main characteristics of the area have originated after the seismic event in 2009. This area has been one of the most compromised after the event. In fact, part of the residential area (Pettino) has been rebuilt and today some buildings appear more recent due to the following reconstructions. Although some buildings have been rebuilt, in most cases the plans have remain the same. Reconstruction has not gone in pair with an updated rethinking of the overall settlement and some gaps are still readable. Moreover, due to the prevalent residential function, temporal inaccessibility of existent buildings has created the necessity to allocate people and services in the closest areas.

Then, a process of new constructions and soil occupation have started, and this part of periphery started to expand its boundaries rapidly. Although the identification of the configuration is helpful set the composition of the city, the isolated analysis of a window from the urban tissue might be incomplete.

Considering the configuration relation to the closest elements, some observations highlight critical points in the environmental configuration. The urban area is between two big relevant areas as Pettino Mountain and the Aterno river. Pettino Mountain is 1147 high, and it extends in the northern area of L'Aquila from north-east to north-west. Its surface is covered by wood and its environmental value is mainly recognised from the presence of a compact wood of holm oak. Aterno river is the longest river in the Region and the biggest for river basin (3190 km^2). It passes through all the city crossing the southern area from west to east. It houses fish species that are under protection.

In this context, morphological elements then have influenced the shape of the settlement. In fact, the settlement's expansion has followed the path of the valley area between the mountain and the river. In the south part, the Vetoio lake creates a split in the dense tissue whereas a difference in altitude delimits the settlement expansion in the south-west area, in correspondence with the bed of Aterno River which is located below the main part of the area.

Functional distinctions among the urban settlements identifies one residential neighbourhood and one centre composed of the hospital and the university campus, which are Pettino neighbourhood and the Campus of Coppito. The area is defined at south-west from a highway (A24) which separates it from the historical center. One other fragmented settlement out of the analysis is the historical district of Coppito, which is in the southern area of the Aterno river (Figure 3.3). Pettino neighbourhood is a main residential district with local services, such as gyms and shopping malls. A major part of residential district has been built around 70es. Today, it has 15000 inhabitants, and it is quite populated by workers and students allocated nearby in this area. Among the main issues, open spaces for aggregation and green areas large enough for the settlement are lacking. Then, the main hospital of the city and the university campus compose a strategic centre for workers and students. The University campus is one of the main campuses of University of L'Aquila, which has also other locations in the city. These two services compose a strategic point of interest for the city and the surrounding districts. In addition, the centre comprehends other services and offices. Due to terrain morphology, this area is separated from the rest of the residential settlement. The area has well defined boundaries and recognizable shape (Figure 3.4). It represents itself a case study.

The university campus and hospital hub are characterized by many factors. Architectural incoherence given by reiterated aggregations of new buildings after 2009. Such aggregation should have been temporary, but in most cases the temporary settlements have remained in their place for

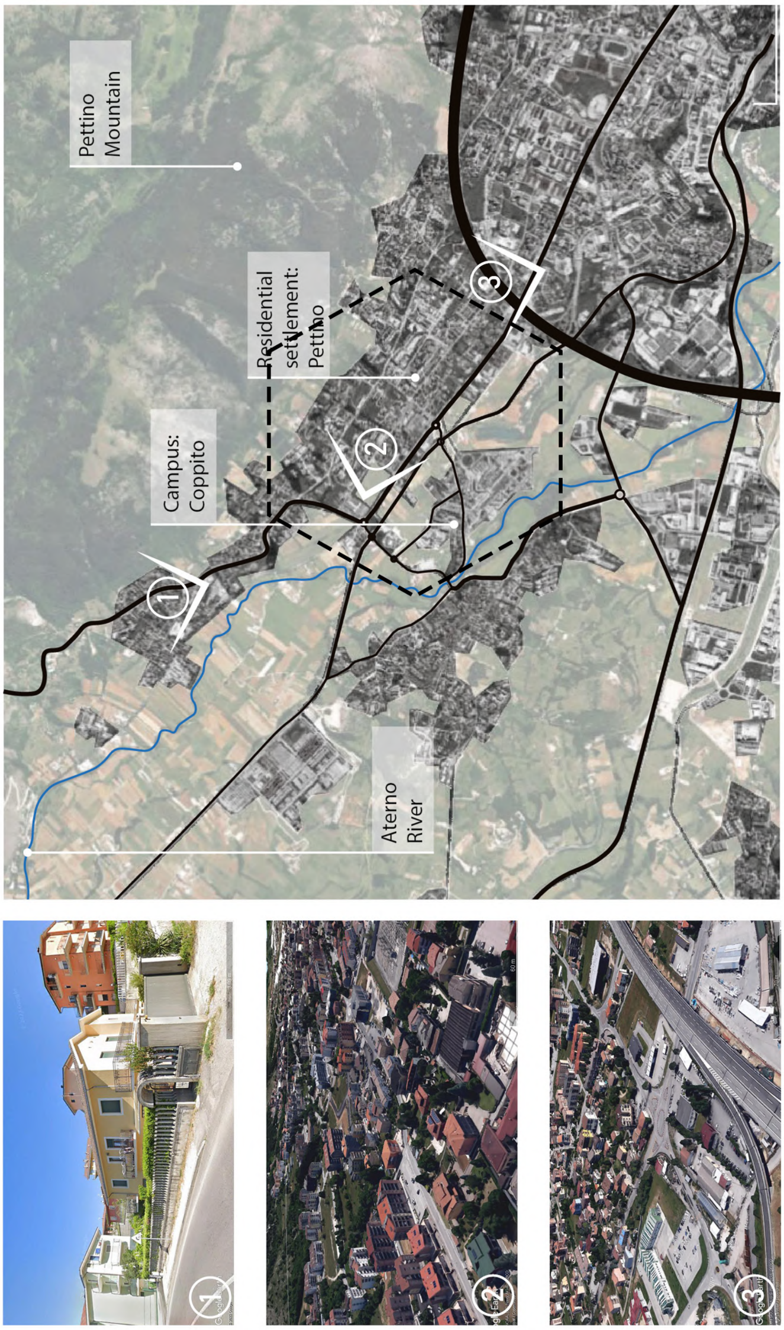


Figure 3.3. The urban settlement dimensions and position related to the context and the main infrastructures. Own elaboration from Google Satellite Imagery and Google Street view.

years. Also, this has generated a broad expansion of sealing soil because the eventual removal of temporary building does not involve the restoration of de-sealed soil. Such condition is evident in the northwest area, where the unbuilt area is inside the property of university. Through the years, such area receives many temporary buildings, and it is used for enlarging

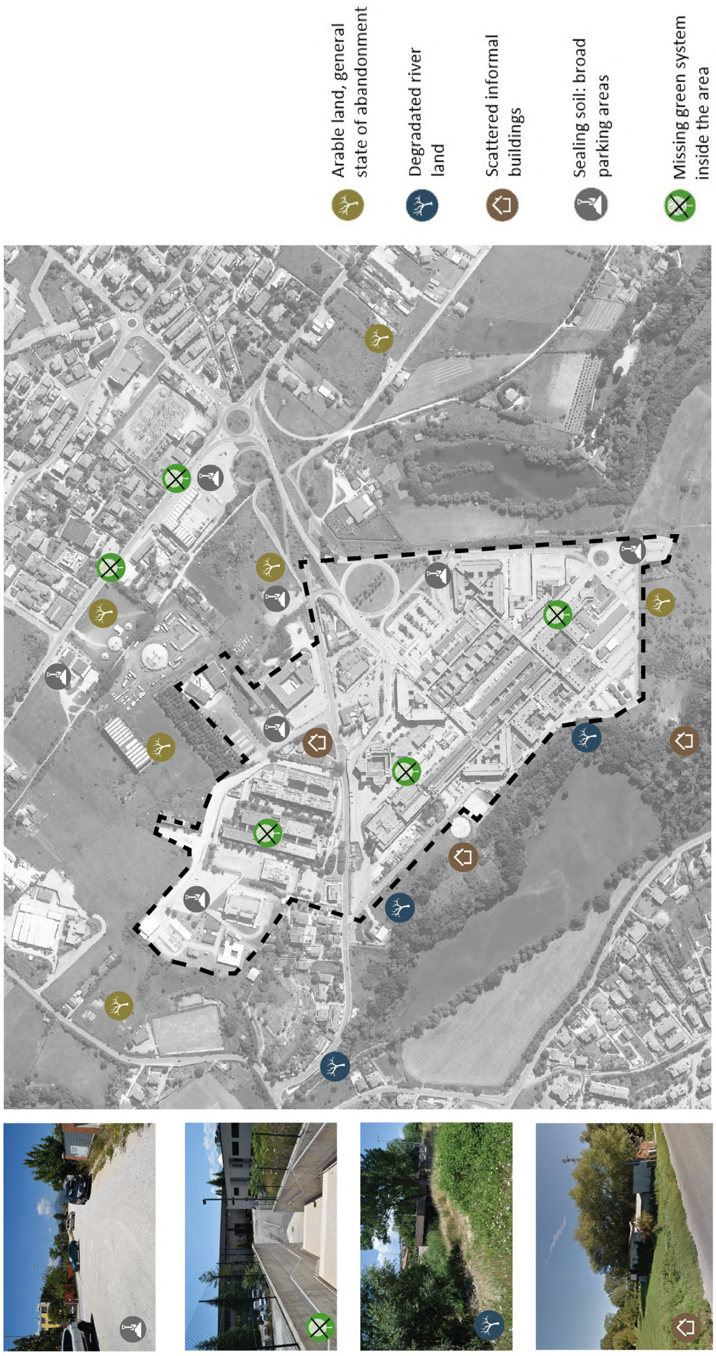


Figure 3.4. Main critical points within the Campus. Own photos and own elaboration from Google Satellite Imagery and Google Street view.

the existent unsupervised parking space. The high level of sealing soil, due to the broad areas of street level parking used by commuters for reaching the area.

Except buildings, the parking spaces and some pedestrian paths, other type of open and aggregative spaces is missing. Generally, inside the settlement the presence of green is lacking. The existent groups of trees are sporadic and too scarce for producing environmental benefits. Such issue is mainly structural, if considering that the area has been built due to modifications to Zoning Plan in 1975. Since the project has never been updated later, it is missing of modern facilities and natural environment integration that are standard for more recent campuses (Figure 3.4). Although the area is surrounded by some broad rural areas, there are no relationship between them. Some fields are cultivated and other are just abandoned or used for grazing. In general, points of contact or interaction between the two configurations are lacking. The hub is prospicient to the river area. However, any relationships are lacking because of the state of abandonment and lack of proper urban furniture that should make the riverside liveable. Moreover, the opposite riverside is characterized by private properties and scattered informal buildings.

As a result, the hub of university campus and hospital is an isolated settlement with poor quality of spaces and lack of green. Considering all the observed issues, any organized green spaces are lacking. The condition is attributable to the lack of strategic lines of expansion of the city after the seismic event of 2009. The reconstruction has involved only buildings without any integrated approach aimed at improving urban quality. In fact, the area has continued to be urbanized from its first developments and over. The process has generated a conurbation in-between the natural areas. Also, the tissue is not all contiguous, but it intersects many residual open spaces. Such areas result from the continuous urban additions made (Figure 3.3). The use of satellite images Copernicus Sentinel Data and Service Information ([143]) and the Normalized Difference Vegetation Index (NDVI) computation support the study of the settlements' features. NDVI is the main index from satellite for studying vegetation information on earth's surface and its variations over time. The NDVI value vary from -1 to 1. The lowest value denotes non-vegetative cover, and the highest value indicates healthy vegetation. Such index gives a framework of both sealed areas and specific presence of forests and tree areas, with values above 0,7-0,8. NDVI studies simplify identification of priority areas in view of implementing NBS. The present analysis indicates that green areas and compact urban areas are both well-defined and separated, above all for the case of hub analysed. Evidently, settlements have interposed among main green areas with evident fragmented tissue (Figure 3.5).

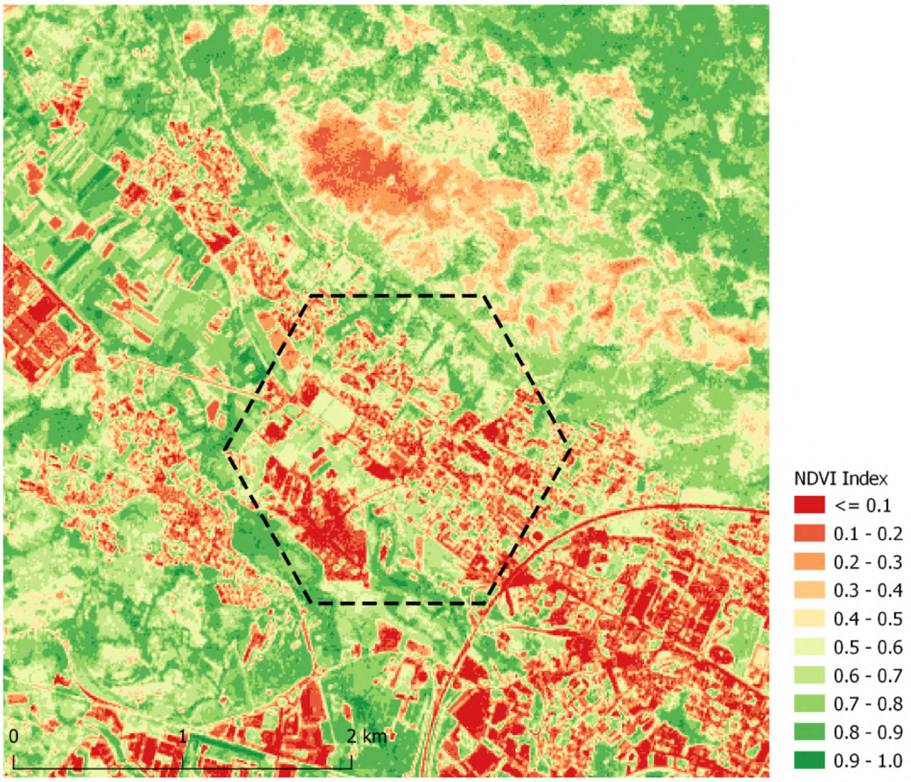


Figure 3.5. NDVI measures for the case study. Images are from June 2020 with the use of Sentinel-2 L2A. The images highlight the presence of a block of urbanised area around the centre of the image: that is the Coppito Campus and the hospital center. NDVI index is elaborated by Dr. Federico Falasca.

3.3 Results

The result illustrates consideration on the analysed configuration and the design exercise of urban requalification. As seen, the main areas of Pettino Mountain and Aterno River are the most relevant for dimension, but also areas as Vetoio Lake and its related park and the tank of expansion of the Aterno River are central. Continuity among the green areas is lacking. This generates lacking ecosystem services' supply and then poor urban quality ([64]).

Lacking green continuity inside the urban configuration occurs in contrast to the presence of natural areas in the surrounding. Green areas' continuity inside the configuration should be advisable for both urban quality and providing ecosystem services. The sum of small interventions of greening inside the settlement tissue then may be a strategy for increasing urban greening and quality of public spaces from north (Monte Pettino) to south (up to the Aterno River) (Figure 3.6). In particular, the area of the river may be redesigned. Proper interventions should be redevelopment of the banks, removing the informal scattered shanties and assessing and implementing trees and shrubs along the riversides. It should become a point of attraction if equipped with street furniture for leisure and sport and then an equipped river park. Moreover, the upgrade of green infrastructures should need more green and de-sealed areas in the interstitial areas of the urban tissue. Many spaces are suitable to be developed in green lungs and host trees and being functional with adequate street furniture.

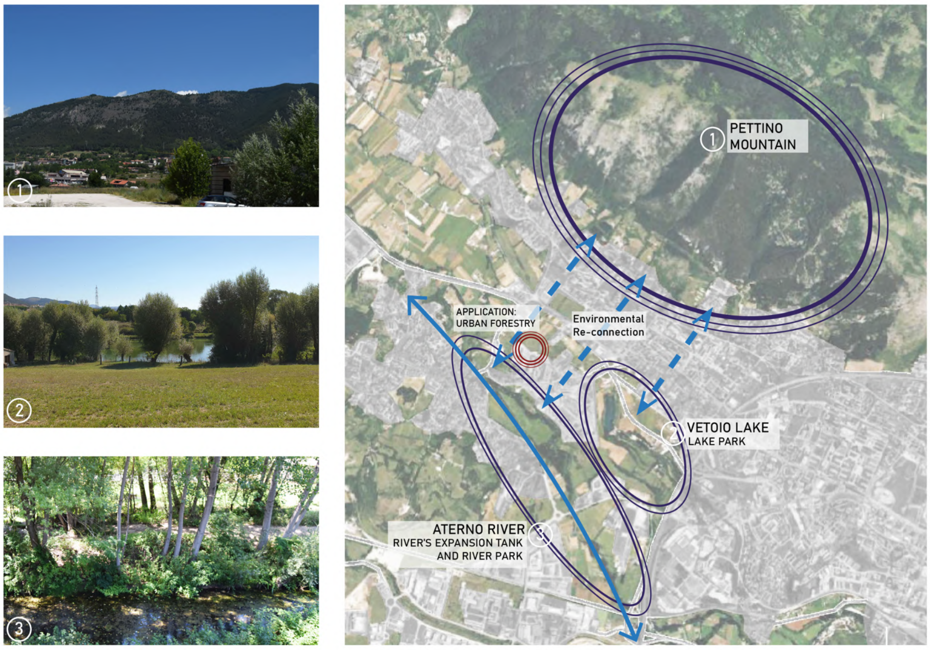


Figure 3.6. Main green configurations to consider for the environmental reconnection with the identification of one first site for de-sealing and urban forestry project. Own photos and own elaboration on Google Maps Imagery.

If at the wider scale the reconnection should be the main strategy, the following step is to individuate proper areas on which the environmental reconnection can be applied. As a significant example for the requalification, one area is chosen as example of greening project. The overall settlement has many examples of interstitial areas on which urban projects should consist in only implementing presence of trees and urban furniture for proving new function. In many cases such areas are already permeable. However, one of the main issues of the settlement is the high sealing soil. Then, one sealed area is chosen as project area.

The work area is a large parking that has been used also for temporary buildings in the northwest part of the University Campus. It is a polygonal-shaped paved area of around 1 hectare (Figure 3.7). Its evolution is directly related to the settlement expansion caused by the seismic event of 2009. In fact, the area was paved as extension of the University area for hosting temporary lecture halls and three donated buildings for research activities. After the emergency, two out three lecture halls have been removed. The three donated building have remained, and they are characterized by architectural incoherence. In general, the area has remained paved, and users have started to use it as parking area. Such area is considered symbolic of the general settlement development. But it should also have a potential for its position at the extreme of the University Campus and then in proximity with the neighbourhood.

Figure 3.7. The area identified for the de-sealing project is at the north-west extreme of the Campus. It presents most of the temporary buildings that have been placed in the area after the earthquake in 2009. Own elaboration on Bing Imagery and own photos.

The first step of the project regards the soil permeability. It includes the removal of the temporary building and other buildings. Then, after the permeable soil is recovered, a grass-covered path can be restored. The main intervention about greening then is the new urban forest, that is the implementation of a mass of tree for enhancing carbon storage and heat mitigation. The selection is done considering local species of trees and shrubs (such as Populus nigra, Acer pseudoplatanus, Prunus avium). Moreover, the analysis of principal winds ([144]) allows to consider the aggregation of trees as the main strategic solution. It permits to create barrier towards cold winds from northwest and southeast. On the contrary, it opens to warm wind from southwest. So, the mass helps in guaranteeing microclimate regulation. About functions, lecture and research activities are assured by two main buildings which aim at compacting the previous diverse blocks in one building that occupies less surface. Buildings' position is not central in the proposal, and it is indicated only as direction for maintaining functions of the Campus. Access to the new buildings is organized in one circular paved area for minimizing sealed surfaces (Figure 3.8). Then, the implemented function regards the leisure activities related to the new urban forest. Such function can regard both the campus and the residential area. Appropriate and various street furniture permit the usage of such space for recreational activities from students, workers, and inhabitants. Moreover, the area can host an equipped area for children as playground for the residential settlement.

3.4 Discussion

The third chapter is an in-depth analysis of the physical elements inside urban and peri-urban configurations. It focuses on one configuration from the classification of urban and peri-urban configurations. The area selected is a compact aggregated configuration in the classification. However, the configuration chosen is comprehensive of more issues which influence quality of the settlement. Compared to the other compact urban areas in the FUA of L'Aquila, the selected one is interesting for the mix of central urban functions, high quality environment and compact but peripheral tissue. Lacking strategies and emergency plans have accentuated the fragmented feature. The scaling process comprehends interpretation of the area inside

Figure 3.8. De-sealing and forestry project. Own elaboration on Google Satellite Imagery. Compass Rose and data elaborated from CETEMPS – Center of Excellence Telesensing of Environment and Model Prediction of Severe events.

and outside the configuration, including a general view for implementing green infrastructures and a proposal for urban project as an example. Critical considerations are focused on qualitative aspects of main elements and then to one final application. It would be more explicative having more than one project on a selected configuration. Moreover, a specific project considers some aspects but omits others. However, the proposed project is considered totally in line with the main issues of the selected configuration, and then explicative and useful for the reasoning. In fact, it is based on few but substantial project strategies that are replicable as the overall process itself.

The main strategy is the urban forestry. Urban forests are recognised as tool for improving better conditions in cities ([145]; [146]) Considering the high value and the efficiency of urban forests, they can be implemented in very diverse urban contexts providing benefits such as contrast heat island effect and moderate the local climate ([147]). Generally, compact urban tissue needs such benefits, because of the high level of soil consumed, the abundance of brown fields ([148]) and the scarce presence of green. Abandoned land that have lose their original function, such as industrial areas, represent an issue because of state of degradation. Potentially, the state of abandonment increases through the years, and it can generate further degradation. Such areas then are destined at increasing risks in cities. Moreover, single necessary interventions for regeneration would need to be combined in strategic configuration. In the case study, the urban forest is combined with de-sealing strategy. Such strategy is preliminary and necessary to restore soil and to implement the forest coverage which is lacking in the area. Moreover, it is a preliminary step for the general necessity of decreasing land consumed in the specific area. Among the proposal of regeneration of the hub there is a less-impact solution which permits to reduce the soil consumed for parking areas. A solution should be one of the existing sealed areas and it might be designed as an underground multilevel car park. All the combined regeneration interventions can contribute to implementing local urban quality.

Even though urban forests are not the only applicable NBS, often they are the more requested for evident positive effects on multiple aspects. In such an urban context, request for more green spaces should also come from the inhabitants. Recently, the neighbourhood committee of Pettino have protested a new shopping center's project, complaining about the soil consumed and the general inadequacy of equipped parks and proper green spaces for leisure activities ([149]). This necessity may come from the high presence of natural areas are rural and arable land which surround the area. Such arable lands do not have roles not in recreational activities neither in ecosystem services' benefits. The position between a mountain chain and a river does not implicate a functioning green infrastructure with all benefits for activities and human health. For example, the University Campus has its boarders adjacent with wide open rural areas. On the contrary, its inner structure is mainly sealed soil without any relevant spaces of aggregation or devolved to outdoor activities.

3.5 Conclusions

The chapter aims at reflecting on the singular urban project as a single tile, which can provide a positive impact on sustainability and liveability of the neighbourhood. Then, if integrated with other projects, a full mosaic of projects can impact in improving the overall urban configuration. Design urban projects are used in urban regeneration for the positive local impact almost all in specific context as urban peripheries ([55]). In the present chapter, a global picture frames the local project. State of emergency and the continuous urbanization through years has created even more interstitial residual areas which do not have any relation with the relevant ecological configurations nearby. In this context, the single project of de-sealing and urban forest is small but ambitious. It is a project for a marginal small area that has hosted temporary uses for years. Instead, the project proposes a change of perspective. The marginality given by position and temporary functions is reversed with the point of interest of a new urban forest and park. Due to its position at the border of the isolated University campus, the project aims at being a first example of reconnection between this hub and the rest of the settlement. As seen, such analysis exceeds the boundaries of window initially given for the recognition of the settlements. The overall study of the context serves as implementing proper comprehension of characteristics and the analysis enriches the study inside the boarders of the configuration. Conversely, the detail level enriches the upper scale of classification with characterization of elements that compose the configuration. Similar analyses are currently considered in the technical documents' first draft of the New PRG of L'Aquila ([150]). One of the strategies is a local ecological network that aims at reconnecting the environmental configurations which are highly compromised by the fragmented expansions of the city (Document B.11. [150]).

In this perspective, the de-sealing and forestry project for the University Campus is an advantageous arrival point for the local strategy. A multi-scale approach has allowed to pass from a wide scale to a scale of project maintaining a shared coherence in the strategic view. So, the passage of scale is functional to the analysis. Moreover, the proposed project has been part of the structured feasibility study for the Campus "Project UNI-CO - Feasibility studies for urban requalification: Campus of Coppito" which has been promoted by the University of L'Aquila. From this study, Municipality of L'Aquila has recently approved a deliberation which provides for intervention on local mobility, organization of parking spaces and equipped green areas ([151]). Such step made by the local administration remarks the potential importance of the area chosen from a strategic point of view. The study is an example of multi-level approach on management of urban compact configuration and implementation of green infrastructures.

Undoubtedly, implementations and strategies in retrospect are fundamental, but planning strategies should aim at integration upstream to produce balanced urban environment that are already combined with green infrastructures ([65]). The idea of an overall green system is the base for local continuous planning actions. Instead of singular interventions, local scales projects then can be evaluated from a broad scale viewpoint. The resulting map should be seen as a framework of addressing policy which considers the green reconnection as a strategic project.

DISCUSSION

The present work places in context some main issues of urban planning in relation to indefiniteness of issues' definitions (1.1 and 2.1) and to the necessity to implement sustainability strategies ([67]). The multiscale approach provides a descending reasoning. The linearity may appear forced because of the high difference in scale from the first to the last object of analysis. However, the approach of keeping scales separated is not aware of urban planning processes. Both natural events and planning choices at macro-scale level have impact at the local scale level. The study of events on a local scale alone does not allow one to comprehend happenings on a broader scale. Understanding the complexity in a multi-scalar approach means approaching the inevitable complexity that characterizes real processes of urban planning, which interacts in both directions, from global to local and from local to global. Each local project needs to consider global scale for setting. Simultaneously, each local scale project in fact needs to consider its consequences at the wide scale in terms of sum with other projects. Because the sum will impact on the global condition. In the present work each step has added a segment, each segment has been approached and deepened with pertinent considerations related to each specific scale.

Firstly, the present work provides an analytical evaluation of territories defined fragile, marginal, inner areas. The area selected (municipalities in S1 and S2) is comprehensive of both inner areas and other fragile areas, and the selection has been based on the criteria of Law158/2017 with data that were partial and revealed later from the administration. However, the selection is feasible, and it gives a suitable framework for analyses and policies devolved to fragile territories ([59]). Then, the same analysis becomes more effective if seen at urban scale in relation to FUA. Criteria that are valid at the national scale here are contextualized and compared each other and with other parameters, such as the seismic risk. Indicators remain central and the relation with urban scale adds instruments of comprehension. Such zooming in has proved that the national and territorial scale of analysis is not even sufficient for the broad picture of fragilities. The analysis should have revealed more specifics if conducted on all the small municipalities analysed or on the three Macro Regions. The classification of urban and peri-urban configurations remarks a passage of scale and the necessity of choosing the specific focus of physical urban structure for proceeding the analysis from the territorial scale. The choice of searching for and classifying recurring configurations in urban morphology can be assessed in the general reasoning aimed at providing replicable frameworks. Moreover, qualitative analysis in functional to schematization which is proper of automatic classifications. Of course, the urban system is complex, and it does not allow a precise and objective classification because various gradients exist. Using a qualitative study discerning the main variables of urban gradient, the SME can find out recurrent configurations. The elaboration may appear forced because of the use of qualitative approach but also the perspective of ML implementation. However, the potentiality of a mixed approach is considered very adaptable, usable, and performative. The output then is a methodology which opens to an innovative system in recognising urban areas. Lastly, the project intends to deal with urban fragilities at the strategical level exploring one possibility of requalification using greening. The proposed project has been one possibility on many others. Also, two or more projects then should be more effective for implementing the concept of green infrastructures and bringing to stronger conclusions. However, the result is even considered remarkable because the project on a very marginal area is the just closure point of a process which would like to highlight the necessity of strategy in planning.

Globally, the analytical effort of the multi-scale approach aims at deepening the possibility of applying replicable methods to various urban planning' s issues. Then, machine learning emerges at the highest level of efficiency and replicability. With such assumption, the research aims at developing automated processes for implementing replicability and then faster processes that can contribute to the sustainability of transformations. Current territorial changes and issues request fast planning actions and efficient monitoring systems. Planners then should be able to use instruments and technologies for reading different scenarios and for addressing actions to reach Sustainability Goals (United Nations, 2015). In the present study, land use and land cover data with ML application are used for identifying recurrent pattern of settlements inside the complex urban and peri-urban scenario. The showed order from the SME analysis to the automated application is fundamental. It could not be reversed. The configurations' recognition passes through qualitative study made by researcher (as the SME) and after to the machine learning process, which would be able to accelerate the process of recognition which is already comprehensive of all the relevant information given by the qualitative study.

CONCLUSIONS

The research has intended the concept of fragility in a possible manifestation at the macro-scale as socio-economic configuration. Then, it has approached the physical context of the urban environment applying a different process expressed as design project. The present work has intercepted a file rouge that crosses more scales and perspectives in the broad concepts of territorial fragility. Of course, it is not exhaustive.

In particular, the analysis on small municipalities considers the broad national context from a general scale. The main issue was to define a comprehensive definition of fragility. The lack of some indicators has not permitted to consider meaningful criteria such as housing distress, welfare services and communication distress. However, the analysis provides a comprehensive picture of two ranges of relevant territorial fragilities, as given by the two simulations. The results do not provide net clusters and most criteria are shared among the municipalities. However, the result is sufficient for the scope because it highlights that gradients of fragility exist and not all the small municipalities are in the same disadvantaged condition. Such differences can be measured, updated and they can be the reference path for future allocations of funds. A so-made dataset is more serviceable than general comprehensive selections that does not permit to evidence differences in territorial peculiarities ([152]).

The focus at FUA scale then shows that nearby areas can be different each other even if part of the same geographical context. It happens because each singular limited context is related to specific different issues. In the case study, local specificities permit to read a gradient of fragility among the three cases, from FUA of Perugia to FUA of L'Aquila. In terms of small municipalities involved and number of criteria met, small municipalities in the FUA of L'Aquila can be considered the most disadvantaged for the same standard area (FUA). Results highlighted that FUA of L'Aquila is composed of the most fragile small municipalities around the central pole, without any transition or buffer zones. The mountainous morphology highly influenced such condition because of all the implications for lower infrastructure and socio-economic development. Comparable fragility indicators are lacking in the opposite case: the FUA of Perugia. Main causes are in the pervasive infrastructural networks given by the favourable morphological condition. The small municipalities around the pole of Perugia are mainly flat valley areas. Such conditions are readable also at structural urban composition of the FUA.

In fact, the urban and peri-urban classification has given an order in physical structure of urban environment which may host territorial fragility. As far as concern peri-urbanization and definition of peri-urban sphere, there is not a univocal definition for the gradient from urban to rural. Find out different classes has been a long process because of such gradient's complexity. The work of analysis, comparison and choice among the gradient's quality has been a preliminary phase for the classification of recurrent configurations. The SME has discerned the main variables of urban gradient which characterise the shift from one class to another. The SME has defined the cornerstones which allow to separate different classes. Distinctions between classes are the result of such decision process. Trying to set reasoned boundaries then is possible and it is preparatory for further analyses. Selected configurations then are the most typical and recurrent for the case study of the three FUA. Resulting configurations match with the highlighted gradient at the FUA level. Morphology influences also urban structure and possibilities of peri-urban expansion. As suggested by location of selected configurations in Figure 2.9 (Chapter 2), Perugia's configurations are more numerous (9 configurations) and expanded, whereas L'Aquila's configurations are lesser (5 configurations), more similar to each other (mainly urban compact aggregated and compact linear configurations) and gathered. The

strict relation with mountainous morphology then gives rise to more fragile conditions and then to less expansion and differentiation among urban physical structures. On the contrary, the flat valley area around the Perugia urban pole gives rise to broad expansion of different configurations (as it has at least one configuration for each class) implementing urban dispersion. Even such considerations are perceivable, here the correlation has been demonstrated both at macro-criteria level and at urban configurations' structure.
If at the upper levels the urban structure can be definable as configurations, some other elements compose it at the detail scale. Which brings to the design project (Chapter 3). This passage gives a material context to the configurations previously modelled within one real urban environment. The case study (Pettino, L'Aquila) is emblematic. A generic approach on peri-urbanization does not exist ([102]) due to the characteristics of the analysed configuration. The compact configuration shows also typical peri-urban features because of its position as urban fringe. Then, local plans can be more effective than general policies because they enhance holistic approach that accounts for multi-functionality as essential in fringe areas. The design project has proposed a relevant change of scale. However, details' addition is central for the upper-level understanding. Such scale permits to make considerations about the opportunity of requalification's projects, above all when configurations include extremes like very dense urban areas and dispersed tissues. Suitability of projects depend in fact on context and the configuration's demand. The presented project responds to specific necessity of protection (as the river basin and tank of expansion) and implementation of green inside the tissue. Even if projects follow economic logics and law of market in transformative processes, questioning about preferable developments of parts of the cities seems to be relevant. The goal of the project should be widening the range of benefits. Increasing quality of the configuration's urban tissue from such level is relevant despite the configuration's dimensions which varies in relation to the chosen parameters. Resuming the process, the U_C_04 configuration has been classified as urban compact aggregated configuration. A detailed study has shown that a series of elements influence the urban quality, from the lack of plan-

ning strategies for the area to the lack of green spaces. Such considerations are put together by the SME and the capacity of discretizing elements from the different scales. Finally, compresence of complex elements at local scale (natural environments disconnection, poor urban quality and fragmented tissues given by repeated emergency solutions instead of long-term strategies) recall the analysed macro-criteria of fragility and the issues given by the lack of any transition areas between the urban pole of L'Aquila and the fragile mountainous small municipalities in the surroundings.

The research thesis has proved that to deal with a typical descending process is appropriate for such theme of research as it is in urban planning processes (from the context analysis to the local application). Some issues need to be studied at global scale, some other need detailed information. Results obtained from each step are relevant to the subsequent passage of scale and the validity of the passages are settled in the previous ones. Fragile areas from the national point of view are defined with an analytical methodology. The derived indicators analysis has been useful for understanding the local conditions of some specific urban contexts. The same area has been investigated with additional instruments such as land cover and land use information and interpretation. The passage of interpretation and the detailed scale then opens to one singular urban project, which is explicative of the contextualization process.

Among the various approaches and methodologies linked to fragility and peri-urbanization, the path developed shows a way of reading territorial and urban issues. The steps of the multi-thematic approach have drawn the definition of a state of the art. From different scale's classifications through indicators to morpho-typological classification, in each case the intent is to link a precise definition to each configuration. Definitions do more than simply describe because they permit to circumscribe some phenomena. This schematic approach may seem to simplify issues, but simplicity gives the opportunity to replicate techniques and procedures in more contexts. Even if qualitive observations are considered, the final goal is an output methodology that draw boundaries among the hundreds of own interpretations. The overall multi-level approach is built to reach possible repetitions of the model because boundaries give rise to replicability of the methodology. In fact, one of the relevant outputs from the present research is an organization of themes and instruments taken from various approaches. The use of very different approaches and subjects is aware because of the potentiality of the overall process in penetrating urban issues. In fact, the turning point is the passage from a qualitative study to the implementation of AI and its computational potential. The subject of AI and automation of processes is now more relevant than ever before. The easy access to advanced AI and the possibility to use it in many activities have never been so direct, explicit, and immediate for so many people ([136]). It is evident that the argument is interesting, and the applications are many. About larger-scale future developments of this type of technology, it is difficult to make previsions. As far as demonstrated, a dual and combined approach can be effective. The conceptual jump has been demanding. However, the dual approach is comprehensive of both, because of the synthesis and accordance done. Such dual approach starts with a qualitative classification as many others in literature. But it is oriented to the implementation of automation techniques towards which it leads.

Ultimately, the effort made for producing the classification of urban and peri-urban configurations serves as creating a framework of reference which is the base for future process of recognition. The SME evaluations and choices are basic layer because the goal is to create premises to expanding possibilities of evaluation and recognition of urban and peri-urban material structures. Such possibilities should not be automatic only as the AI recent development seems to suggest. However, advanced technology instruments should be guided by the expert knowledge of the urban planning. This work gives a reply to the question about the possible replacement of some traditional process with automation and new technologies. Here the attempt is to create a functional balance with both approaches. In urban planning, the computational approach may be meaningful for the potential rapidity in execution for wide analyses. Moreover, increasing development of forms of repetition permit to accelerate the overall process of investigation. Acceleration would mean fast decision processes and then intervention. Also, it would mean rapid production of scenarios and then strategic approaches. Even though the decision-making side from researchers remains necessary, the use of automated advanced instruments appears to be essential in this perspective. Scenarios can be related to forecasted urban transformation of plans, future trends of peri-urbanization to outline sustainable future pathways. For example, scenarios can address the responsible use of energy and help in analysing elements of the urban metabolism in general, including the ones related to land consumption.

Research on scenarios' prediction and use of technology then are useful as technical level. In the same way, SNAI provides recognition of inner areas and urban regeneration projects may lead to the development of a better urban environment. Which are the final uses of all these technical instruments? Utility is readable in terms of monitoring results and expecting performance in relation to Agenda 2030 sustainable development goals ([12]). Predictions are serviceable only if they are oriented, and instruments should be put in relation with strategies and then evaluated in comparison with expected goals (Cavalli et al., 2021). All the discussed approaches should be tested and put in line with sustainable development strategies ([153]; [67]; [154]) for a faster achievement of sustainable development goals ([14]).

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- Marucci A., Di Dato C. (2022) Urban and peri-urban shapes for sustainable governance. In: J. Wolski, E. Regulska, A. Affek (Eds.), IALE 2022 European Landscape Ecology Congress. Book of Abstracts (p. 341), IGiPZ PAN, Warsaw.

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- B. Romano, A. Marucci, F. Zullo, L. Fiorini, L. Saganeiti, C. Cattani, L. Di Berardino, C. Di Dato, G. Di Pietro, R. Donolo, F. Falasca, C. Montaldi, C. Sette, V. Tomei (2022) (a cura di) SOSTENERE - Sostenibilità , resilienza, adattamento per la tutela degli ecosistemi e la ricostruzione fisica in Italia Centrale (2020-2022). Publisher: University of L'Aquila, Editor: University of L'Aquila. ISBN: 978-88-946095-1-6

- Marucci A., Fiorini L., Saganeiti L, Di Dato C., Donolo R.M. (2022). Agenda 2030: ricognizione degli indicatori e analisi di coerenza per la SRSvS della regione Abruzzo. In: (a cura di): Arcidiacono A.; Di Simine D.; Ronchi S.; Salata S., Consumo di suolo, servizi ecosistemici e green infrastructure - Rapporto 2022. p. 43-48, RomaINU Edizioni srl, ISBN: 978-88-7603-233-2

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- A. Marucci, L. Fiorini, F. Zullo, C. Di Dato, V. Tomei, B. Romano (2021), Vision and Project to Retrofit the â€œUrban Dustâ€ Scenario: Simulation in the Region of Umbria, Central Italy, Journal of Urban Planning and Development.

- C. Di Dato, A. Marucci, L. Fiorini, F. Zullo e B. Romano (2021), Regione Abruzzo: Quadro unitario per la legge su ambiente e territorio. Parola d'ordine: politiche verdi vs arcaica visione "grey & brown". Sono maturati i tempi per un testo unico e ricompositivo dell'intera gamma delle materie territoriali. Parte del report organizzato da: Commissione CeNSU - INU - SIU sulla "Riforma della Disciplina Urbanistica" Schedatura dei sistemi di governo del territorio delle regioni italiane. IlSole24Ore.

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- A. Marucci, F. Zullo, L. Fiorini, C. Di Dato, Territorial knowledge management for green infra- structures aimed at conservation of environmental continuity. A study on Italian National Parks, UPLanD - Journal of Urban Planning (2020). DOI:10.6092/2531-9906/7002
- C. Di Dato, F. Falasca, A. Marucci, L’innovazione tecnologica e le performance dei processi di governo del territorio: l’applicazione degli strumenti gis-based per la VAS dalle Regioni alle Città Metropolitane, XXIII Conferenza Nazionale SIU, Società Italiana degli Urbanisti (2020)

Nomenclature

AI Artificial Intelligence

ANCI National Association of Italian Municipalities

ASVIS Italian Alliance for Sustainable Development

CLC Corine Land Cover

CLMS Copernicus Land Monitoring Service

CORINE Coordination of information on the environment

DSS Decision Support System

EEA European Environmental Agency

ESPON European Spatial Planning Observation Network

FUA Functional Urban Areas

GIS Geographic Information System

IndA Indicator for municipalities included in areas affected by hydrogeological instability in S1

IndA2 Indicator for municipalities included in areas affected by hydrogeological instability in S2

IndB Indicator for municipalities affected by strong economic backwardness in S1

IndB2 Indicator for municipalities affected by strong economic backwardness in S2

IndC Indicator for municipalities affected by strong population decrease in S1

IndC2 Indicator for municipalities affected by strong population decrease in S2

IndG Indicator for municipalities characterised by a residential density lower than 80 inhabitants per km2 in S1

IndI Indicator for municipalities that are part of a mountain community in S1

IndL Indicator for municipalities partially or totally included in a national park, a regional park or other protected areas in S1

IndM Indicator for municipalities created by fusion in S1

IndN Indicator for municipalities included in peripheral or ultra-peripheral areas, as defined by SNAI in S1

ISPRA Italian Institute for Environmental Protection and Research

ISTAT Italian Institute of Statistics

LIFE IMAGINE UMBRIA LIFE19 IPE/IT/000015 - Integrated MAnagement and Grant Investments for the N2000 NEtwork in Umbria

LULC Land Use and Land Cover

MEF Ministry of Economy and Finance

ML Machine Learning

MMU minimum mapping unit

MMW Minimum Mapping Width

N2000 Natura 2000 Network

NAP Italian Action Plan for Policy Coherence for Sustainable Development

NBS Nature Based Solutions

NDVI Normalized Difference Vegetation Index

OECD Organization for Economic Cooperation And Development

PCSD Policy Coherence for Sustainable Development

PNRR The National Recovery and Resilience Plan

PRG Municipal General Regulatory Plan

S1 Simulation 1

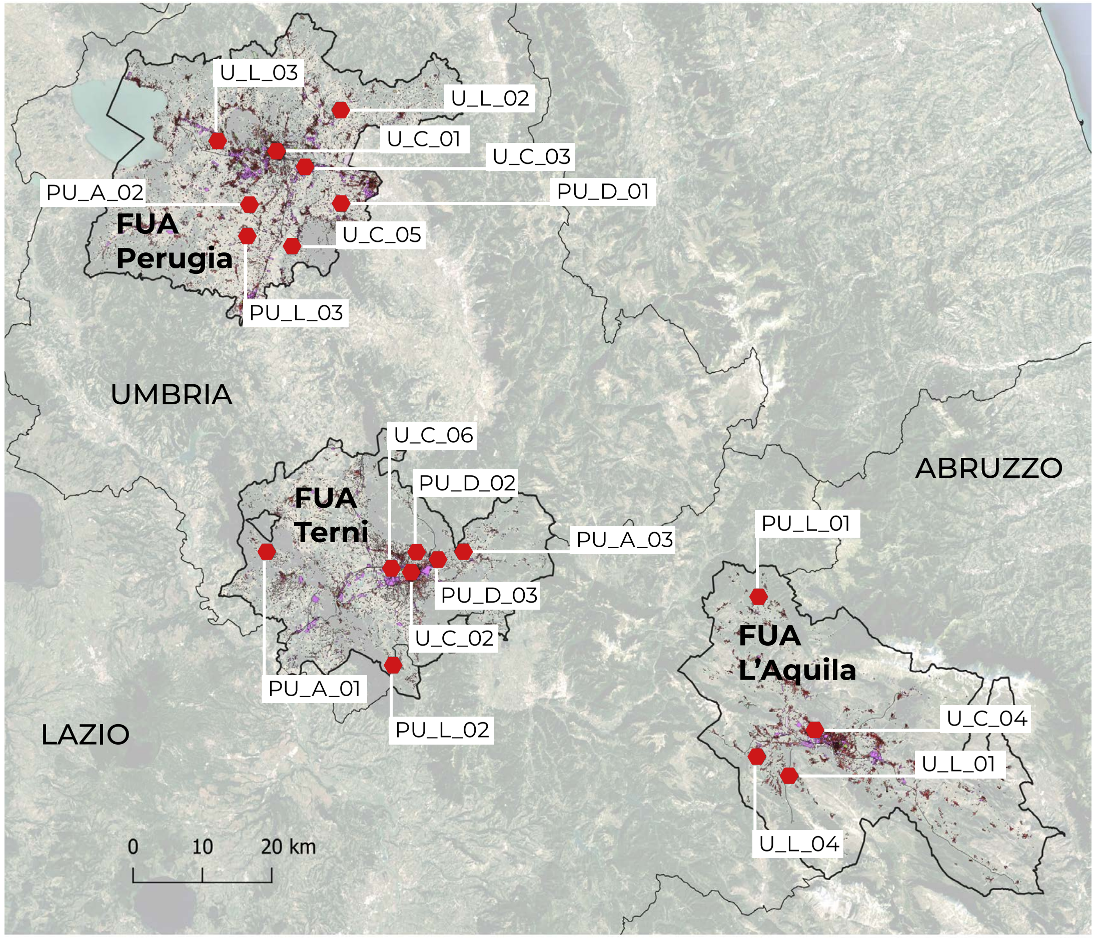
S2 Simulation 2

SME Subject Matter Expert

SNAI National Strategy for Inner Areas

SNPA National System for Environmental Protection

Atlas of urban and peri-urban configurations



URBAN COMPACT AGGREGATED TISSUE

U_C_01 - Perugia (city center)
U_C_02 - Terni (city center)
U_C_03 - San Giovanni (Perugia)
U_C_04 - Pettino (L'Aquila)
U_C_05 - Deruta (Perugia)
U_C_06 - Maratta Alta (Terni)

URBAN LINEAR AGGREGATED TISSUE

U_L_01 - La Menna S.Croce (L'Aquila)
U_L_02 - Colombella (Perugia)
U_L_03 - Taverne di Corciano (Perugia)
U_L_04 - Rocca S. Stefano (L'Aquila)

PERI-URBAN DISCONTINUOUS LINEAR TISSUE

PU_L_01 - Cavagnano (L'Aquila)
PU_L_02 - Fontanelle - Configni (Rieti)
PU_L_03 - Case del Colle (Perugia)

PERI-URBAN DISCONTINUOUS SPREAD TISSUE

PU_D_01 - Bettona (Perugia)
PU_D_02 - San Clemente (Terni)
PU_D_03 - Volge-Prisciano, S. Carlo (Terni)

PERI-URBAN VERY SPREAD TISSUE (SPRINKLING)

PU_A_01 - Località Collepina (Terni)
PU_A_02 - Pila (Perugia)
PU_A_03 - Varcone (Terni)

U_C_01

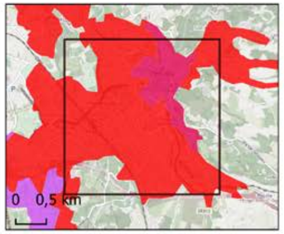
URBAN COMPACT AGGREGATED TISSUE

FUA of Perugia

Window U_C_01

Perugia (city center)

The main characteristic of the area is an Urban, aggregated, and compact tissue, and it presents a complex tissue. The area comprehends the old town centre of Perugia and its following extensions nearby.
The window includes two main tissues: the most part of the historical city and modern sections (ca. 1950). The former represents the typical Medieval tissue with narrow streets, the latter is composed of an ordinary system of apartment blocks and services. It is in direct contact to the main railway station of the city. The window in its entirety it's interesting because it captures some of the main characteristics of the city: old town centre, at least a part of its system of hills, the newest part that included the train station, services of the city, archaeological attractions (i.e., Rocca Paolina), some of the main offices (i.e., municipal hall). Due to its long history, the tissue analysed is stratified from different phases.
The urban area has developed on a system of hills and then has expanded beyond the historical Etruscan walls. The old town tissue of Perugia (about 450 m s.l.m.) is mostly settled on the top of a complex of hills. Then, the subsequent expansions have developed towards south. They follow the train line which goes from south-east to south. The modern part is located on a downer flat level.
Most of the area has a sealing soil from 30% to 80%. It is a medium-high level of sealing level.
Functions are residential areas, productive areas and general services. Functions are settled without a scheme. The main residential area which is clearly recognisable is the old town centre of Perugia. The higher level of urbanization corresponds to this part and to the recognisable Medieval tissue (dark red). One other high-medium dense area is the residential one close to the train station. Even though the sealing level of the two main urbanised areas are similar, the typology of the settlements is evidently different: a medieval tissue and a modern system of blocks. Then, the context is mainly a system of fringe of urban fabrics given from the expansion from the old town centre to the following expansions and there is a minimum permeation with the natural areas surrounding (mainly fields).



CORINE LAND COVER
- 111 - Continuous urban fabric
- 112 - Discontinuous urban fabric
- 121 - Industrial or commercial unit

OSM Standard

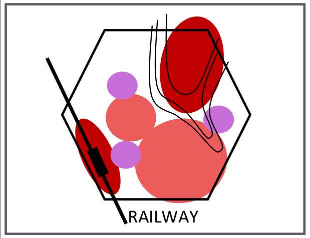
Code: COMP_A

URBAN ATLAS 2018 PERUGIA
- 11100: Continuous Urban fabric (S.L. > 80%)
- 11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
- 11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- 11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12100: Industrial, commercial, public, military and private units
- 12220: Other roads and associated land
- 12230: Railways and associated land
- 13400: Land without current use
- 14100: Green urban areas
- 14200: Sports and leisure facilities

Google Satellite

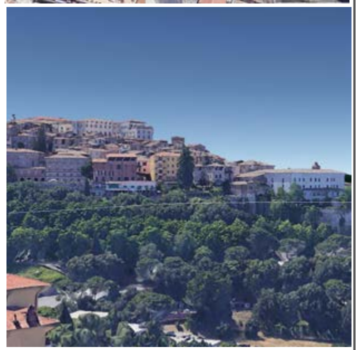
PERUGIA
CITY CENTER

FOCUS	DETAIL
SHAPE **Urban Fabric**	*URBAN, AGGREGATED AND COMPACT TISSUE COMPLEX TISSUE*
LANDFORM	*HILLS*
SEALING SOIL	*HIGH LEVEL*
FUNCTION	*RESIDENTIAL, MIXED*
CONTEXT	*URBAN*



MODERN SETTLEMENT
HIGH-MEDIUM S.L.

HISTORICAL TISSUE
HIGH SEALING LEVEL



DIFFERENCE IN
ALTITUDE

U_C_02

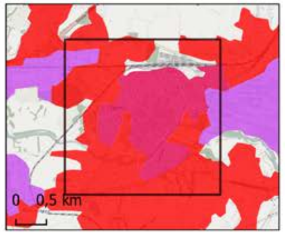
URBAN COMPACT AGGREGATED TISSUE

FUA of Terni

Window U_C_02

Terni (city center)

The main characteristic of the area is an Urban, aggregated, and compact tissue, with reticular, regular tissue. The plan also presents a centric oriented setting starting from the station and developing along three main axes through the town. The city centre of Terni town is captured in this window.
The area is mainly a big valley, enclosed by a mountain chain from north. The Nera River delimits the window and the central part of the town directly connected to the railway station. The river is an important eco-system element, The river represents a green system in one high-level density area, and it has a function in stocking CO2 emissions and in mitigating urban heat islands.
Most of the area is urban pattern, with from 30% to 80% of sealing level (S.L.) as recognised in Urban Atlas. The sealing level is medium-high. The value is higher in the area near the train station. Approximately 10-20% of the area is free from urban fabric and it is composed of green areas used for parks and sport activities (athletics track).
Functions are mixed: residential areas, services and industrial areas. Residential areas are located mainly near the train station and along a path which expands towards south along the river. A consistent area in the north-east part is characterized by less dense residential units. The area is characterised by spots of industrial districts with contained dimensions.
The area is located inside a quite regular pattern, it is called “Conca Ternana”. It comprehends a system of municipalities, and the town of Terni is the biggest. The area is mainly a level ground crossed by a system of one river (Nera) and other streams. The area has a quite-elevate demographic density.



CORINE LAND COVER
- 111 - Continuous urban fabric
- 112 - Discontinuous urban fabric
- 121 - Industrial or commercial unit

OSM Standard

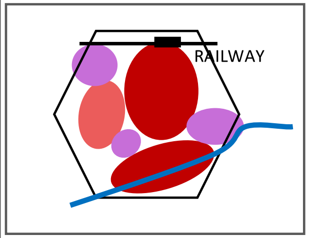
TERNI
CITY CENTER

Code: COMP_A

URBAN ATLAS 2018 TERNI
- 11100: Continuous Urban fabric (S.L. > 80%)
- 11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
- 11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- 11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12100: Industrial, commercial, public, military and private units
- 12210: Fast transit roads and associated land
- 12220: Other roads and associated land
- 12230: Railways and associated land
- 13400: Land without current use
- 14100: Green urban areas
- 14200: Sports and leisure facilities

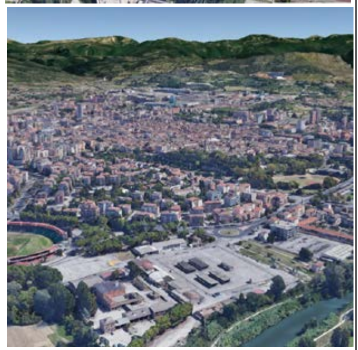
Google Satellite

FOCUS	DETAIL
SHAPE **Urban Fabric**	*URBAN,* *AGGREGATED AND COMPACT TISSUE* *POLYGONAL,* *COMPLEX TISSUE*
LANDFORM	*VALLEY*
SEALING SOIL	*HIGH LEVEL*
FUNCTION	*RESIDENTIAL,* *MIXED*
CONTEXT	*URBAN*



RELATIONSHIP
TOWN-RIVER

HIGH SEALING LEVEL



THE SORROUNDING IS MAINLY A
FLAT AREA HIGLY URBANISED

U_C_03

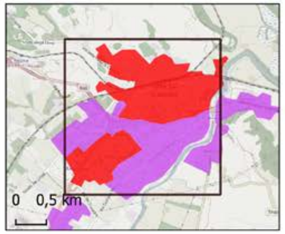
URBAN COMPACT AGGREGATED TISSUE

FUA of Perugia

Window U_C_03

San Giovanni (Perugia)

The main characteristic of the area is an Urban, aggregated, and compact tissue, with reticular, regular tissue. Together with residential settlement, large part of the area inside the window is composed of industrial settlements.
The area is mainly a valley area. The southern part of the window is crossed by the Tevere River. The river delimits the industrial district, which separate it from a field area on the other bank.
The main part of the area is composed of a large industrial district. A consistent part of the residential area has a sealing soil from to 50% to 80%. It is a medium-high level of sealing level. Approximately 15% of the area is composed of a residential area with lower sealing level.
Residential and industrial uses are mixed. Functions are separated by infrastructures: one main road (E45) crosses the area from north-east to south-west and the railway crosses the north part of the area. The resultant areas are 4. There are two industrial areas: the main one takes the most part of the window, whereas the second one takes a little part on the west side. However, the two areas have the same characteristics. Then, a big residential area is located on the north-east zone nearby the railway station and a less-dense residential area is located towards west. The latter is separated by the railway line.
The area represents a fringe from the urbanised area, which has been developed following the main road moving from north-east to south-west. The area stands between the north-east urbanised area of Perugia expansions and a southern area of countryside. The area has recorded significant population increase from 70s. Nowadays, it one of the most densely populated of the city.
The intuitive tendential linear form characteristic of the district is not recognisable. The presence of the railway station creates a polarization around that single point. Moreover, the industrial settlement's tendence is to concentrate and the area expands until the river.



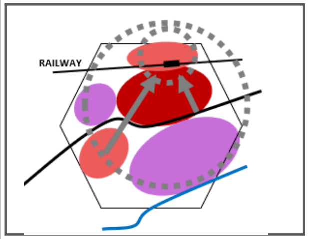
CORINE LAND COVER
112 - Discontinuous urban fabric
121 - Industrial or commercial unit
OSM Standard

PONTE SAN GIOVANNI
(PERUGIA)

Code: COMP_A

URBAN ATLAS 2018 PERUGIA
11100: Continuous Urban fabric (S.L. > 80%)
11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
11240: Discontinuous very low density urban fabric (S.L. < 10%)
11300: Isolated Structures
12100: Industrial, commercial, public, military and private units
12220: Other roads and associated land
12230: Railways and associated land
13400: Land without current use
14100: Green urban areas
14200: Sports and leisure facilities
Google Satellite

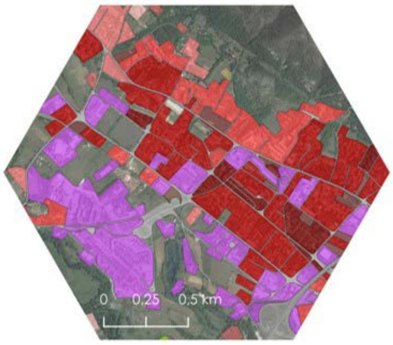
FOCUS	DETAIL
SHAPE Urban Fabric	*URBAN, AGGREGATED AND COMPACT TISSUE POLYONAL TISSUE*
LANDFORM	*VALLEY*
SEALING SOIL	*HIGH LEVEL*
FUNCTION	*MIXED*
CONTEXT	*URBAN*



THE MAIN CHARACTERISTIC IS THE PRESENCE OF A LARGE INDUSTRIAL SITE

MOTORWAY IS A BARRIER BETWEEN THE TWO PARTS

U_C_04



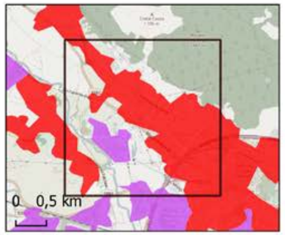
URBAN COMPACT AGGREGATED TISSUE

FUA of L'Aquila

Window U_C_04

Pettino (L'Aquila)

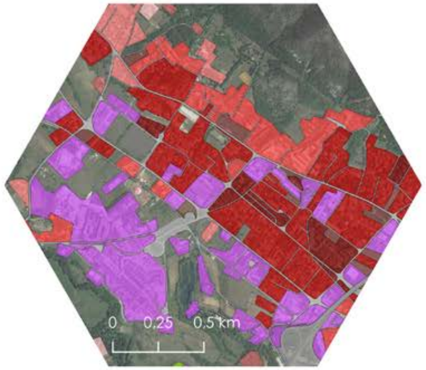
The tissue is classified as urban, aggregated, and linear tissue. The window captures the settlement of Pettino which is part of the urbanised area of L'Aquila. The tissue is both polygonal and mixed. The window can represent a borderline case: it represents more a linear pattern if seen from the structure of the main routes. On the contrary, it is a compact tissue if considered the very dense pattern of blocks.
The expansion follows the path of the valley area. It stands between the Pettino mountain chain (Monte Pettino) and the Aterno River. Some natural elements influence the shape of the settlement, such as the Vetoio lake and the difference in altitude in the southern area.
The sealing soil is medium-high, around 30% to 80%. This area corresponds to the residential district which is located mainly along the principal axes. It is distributed on a polygonal tissue.
Functions are mixed. There is the main residential district (Pettino's neighbourhood) which has also local shops and services. Then, there is the centre composed of the hospital and the University Campus, which comprehends other services and offices. Its shape is isolated and separated from the rest of the settlement.
The area represents a fringe of urbanised area which expands from the old town centre toward north-west. The residential district has been built around 80es. However, the earthquake of 2009 has highly compromised the area. Today, buildings are more recent due to the following reconstructions. Today, the residential district is quite populated, and the district is lively mainly due to the presence of the centre composed of the hospital and the university. The residential area is the nearest to all the services provided in the centre and then it is occupied by a lot of students and workers.



CORINE LAND COVER
- 111 - Continuous urban fabric
- 112 - Discontinuous urban fabric
- 121 - Industrial or commercial unit

OSM Standard

PETTINO
(L'AQUILA)

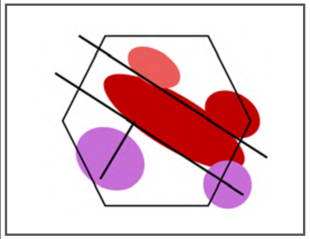


Code: COMP_A

URBAN ATLAS 2018 L'AQUILA
- 11100: Continuous Urban fabric (S.L. > 80%)
- 11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
- 11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- 11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12100: Industrial, commercial, public, military and private units
- 12210: Fast transit roads and associated land
- 12220: Other roads and associated land
- 13100: Mineral extraction and dump sites
- 13300: Construction sites
- 13400: Land without current use
- 14100: Green urban areas

Google Satellite

FOCUS	DETAIL
SHAPE Urban Fabric	*URBAN, AGGREGATED AND COMPACT TISSUE POLYGONAL TISSUE*
LANDFORM	*VALLEY*
SEALING SOIL	*HIGH LEVEL*
FUNCTION	*MIXED*
CONTEXT	*URBAN*



COMPACT/DENSE TISSUE

PRESENCE OF GREEN AREAS AND FIELDS

MEDIUM-HIGH SEALING LEVEL
IN RESIDENTIAL AREA (PETTINO)

U_C_05

URBAN COMPACT AGGREGATED TISSUE

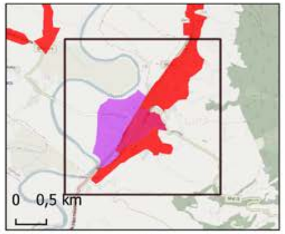
FUA of Perugia

Window U_C_05

Deruta (Perugia)

The main characteristic of the area is an Urban, aggregated, and linear tissue, with both reticular and mixed tissue. The city of Deruta (Perugia) is located along a principal route (E45) of interregional level.

The window catches the valley floor which starts just behind a hilly area. This is where the old town centre is. The Tevere River delimits the valley area in this window, making an inlet which marks out the boundaries of industrial settlements.
About half of the area analysed has a sealing level from 10% to 80%. The densest area is concentrated along the main route.
The route cuts in two the tissue also from a functional point of view. The industrial settlement stands in the north-west side, whereas the various residential areas are in the south-east side. The residential area comprehends also local services and shops.
The settlement stands in the valley of Tevere River and it is delimited by the river itself and the Martani mountain chain. The extension of the settlement is functional to the length of the route. One dense area is the old town centre, which stands on the top of a hill. The rest of the residential area is more recent, and it's made of blocks of 2-3 levels. Even if the buildings are not imposing, the area results highly sealed and it does not reserve space for open and green areas. However, the industrial area is one the major in the field of ceramics. It is imaginable, then, that the residential settlement revolves around the factories themselves.



CORINE LAND COVER
- 111 - Continuous urban fabric
- 112 - Discontinuous urban fabric
- 121 - Industrial or commercial unit

OSM Standard

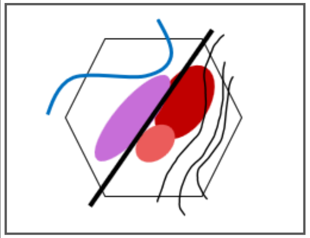
DERUTA
(PERUGIA)

Code: COMP_A

URBAN ATLAS 2018 PERUGIA
- 11100: Continuous Urban fabric (S.L. > 80%)
- 11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
- 11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- 11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12100: Industrial, commercial, public, military and private units
- 12220: Other roads and associated land
- 13400: Land without current use
- 14100: Green urban areas
- 14200: Sports and leisure facilities

Google Satellite

FOCUS	DETAIL
SHAPE **Urban Fabric**	*URBAN,* *AGGREGATED AND* *COMPACT TISSUE* *COMPLEX TISSUE*
LANDFORM	*HILLS*
SEALING SOIL	*HIGH LEVEL*
FUNCTION	*MIXED*
CONTEXT	*PERI-URBAN*



THE PRODUCTION COMPLEX OF CERAMIC AS THE MAIN CENTRE OF THE AREA

TWO-THREE LEVELS BUILDINGS HIGH SEALING LEVEL

VIARIATION OF ALTITUDE: OLD TOWN CENTRE AND THE MODERN DISTRICT

U_C_06

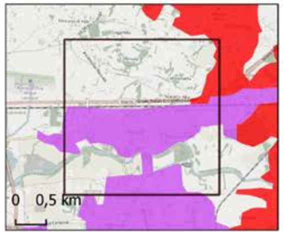
URBAN COMPACT AGGREGATED TISSUE

FUA of Terni

Window U_C_06

Maratta Alta (Terni)

The tissue is classified as urban, aggregated, and linear tissue. The window captures a mono-functional settlement which is located among the western suburbs of Terni. Even if the district is only 3km distant from the city centre, it can be considered a separate part and not a fringe. In fact, the tissue is irregular and interrupted by a quite consistent rural area (and the city's cemetery) between the city and this area.
The district is located along a valley area (Conca Ternana) crossed by some routes. It is delimited from south by the Nera River.
The sealing level is mainly given from the class 121 (Industrial, commercial, public, military, and private units). It means that in this category buildings, other built-up structures and artificial surfaces occupy most of the area. In this window, about half of the area is in class 121 and then it has a high sealing level. The other half is composed of fields and natural areas. There is a little neighbourhood which has a sealing level between 10% and 30%. It is classified as Discontinuous low density urban fabric. There are also some detached houses scattered in the northern area of the window. The sealing level of these parts is less than 10%.
The relevant functions of the area are industrial and commercial activities. However, there is also a minimum residential function. There are the little neighbourhood Maratta Alta and other small residential buildings. There are also some farm activities even in the northern part.
The district is characterised from the presence of some main routes: the SS675, the railway line and Bruno Capponi Street. These three linear paths, together with the Nera River in southern part, follow the same trajectory from east to west. They direct the extension of the district, which is narrow and long.



CORINE LAND COVER
112 - Discontinuous urban fabric
121 - Industrial or commercial unit
OSM Standard

MARATTA ALTA
(TERNI)

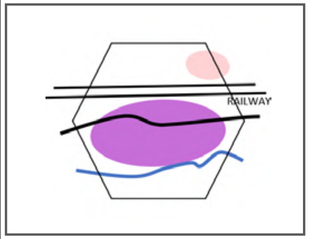
Code: COMP_A

URBAN ATLAS 2018 TERNI

- 11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
- 11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- 11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12100: Industrial, commercial, public, military and private units
- 12210: Fast transit roads and associated land
- 12220: Other roads and associated land
- 12230: Railways and associated land
- 13100: Mineral extraction and dump sites
- 13300: Construction sites
- 13400: Land without current use
- 14100: Green urban areas
- 14200: Sports and leisure facilities

Google Satellite

FOCUS	DETAIL
SHAPE Urban Fabric	*URBAN, AGGREGATED AND COMPACT TISSUE COMPLEX TISSUE*
LANDFORM	*VALLEY*
SEALING SOIL	*HIGH LEVEL*
FUNCTION	*INDUSTRIAL*
CONTEXT	*PERI-URBAN*

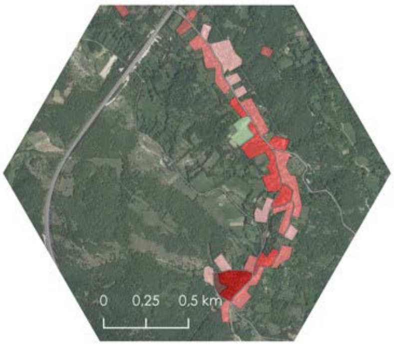


ALL THE ELEMENTS (ROUTES, RAILWAY AND THE RIVER) GIVE THE DIRECTION TO THE SETTLEMENT SHAPE

HIGH SEALING LEVEL IN THE INDUSTRIAL SETTLEMENT AND POOR QUALITY OF SPACES

THE RIVER DELIMITS THE AREA FROM THE SOUTH

U_L_01



URBAN LINEAR AGGREGATED TISSUE

FUA of L'Aquila

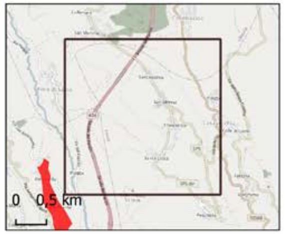
Window U_L_01

La Menna S.Croce (L'Aquila)

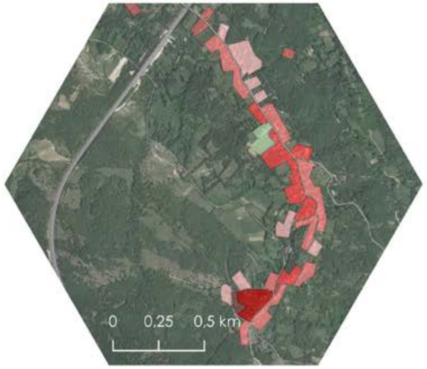
The main characteristic of the area is an urban, aggregated, and linear tissue.

The window captures the aggregated and linear tissue of La Menna and S. Croce (Lucoli) in L'Aquila. The neighbourhood is part of the satellite settlements of L'Aquila.
Settlement follows the crest of the hill, inside a system of hills. In fact, the landform guides the one main linear axis, and then it has also generated the linear concentration and shape of the settlement. Such axis is a narrow street.
Sealing level is various, generally from medium to high. Densest areas correspond to the most ancient tissue of the settlement.

The main function of the settlement is residential. The typical building is directly related to the street. Also, it is a detached house or a series of terraced houses with two or three floors and sloping roofs. There are also some farms and local activities, such as the Post Office, a church, and restaurants. Due to the closeness to the city of L'Aquila, the area depends on it for main services.
The context is rural and natural. There are fields and a major part of the surrounding is composed of woods. A compact wood is in the north-east area and in general there are many relevant compact woods.



CORINE LAND COVER
112 - Discontinuous urban fabric
OSM Standard



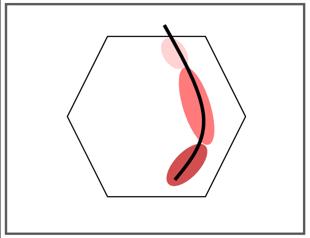
Code: COMP_L

URBAN ATLAS 2018 L'AQUILA
- 11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
- 11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- 11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12210: Fast transit roads and associated land
- 12220: Other roads and associated land
- 13300: Construction sites
- 13400: Land without current use
- 14200: Sports and leisure facilities

Google Satellite

SAN MENNA/S.CROCE – LUCOLI (L'AQUILA)

FOCUS	DETAIL
SHAPE Urban Fabric	*URBAN, AGGREGATED AND LINEAR TISSUE*
LANDFORM	*HILL*
SEALING SOIL	*MEDIUM LEVEL*
FUNCTION	*RESIDENTIAL*
CONTEXT	*RURAL*



MEDIUM-LOW DENSITY: DETACHED HOUSES

LINEAR CONCENTRATION AND SHAPE IS GIVEN BY LANDFORM

ANCIENT AND DENSELY AGGREGATED TISSUE

U_L_02

URBAN LINEAR AGGREGATED TISSUE

FUA of Perugia

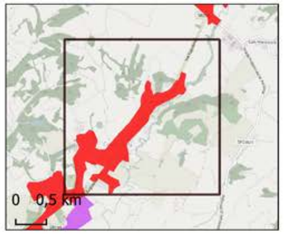
Window U_L_02

Colombella (Perugia)

The main characteristic of the area is an urban, aggregated, and linear tissue. The window captures a part of Colombella, a district of Perugia's municipality. The area is easily recognisable and isolated from the rest of urban areas because it develops along one main central road (SR 298, also called Eugubina Street).
The area is flat with minor hilly spots. Districts are concentrated on the wide valley floor (257m s.l.m.), following the trace of main routes. The minor hilly spots are mainly at the edge of this flat area (north-east corner), where the linear district is concentrated. One minimum area of the district loses the linear path and splits in two around the hill on which there is the local church.

The area presents a sealing soil level from less than 10% to 50%. It is a low-medium sealing level. The path is a bit scattered, but there is a main direction which is recognisable. The sealing level inside the window is quite low and very concentrated because all the area around is free, mainly countryside and fields.

The main function is residential. These are valuable types of residential units: they are mainly 2-3 floors blocks and there are some detached houses with private courtyards. There are some local shops and few scattered industrial activities.
The neighbourhood is 12 km far away from the centre of Perugia. It depends on the main centre expected for primary services (schools, church, and local shops) that are present inside the urban area. However, the district is nearest to the border of Perugia's functional urban area (FUA) than to the town itself. This condition makes the area being outside the urban pattern and its nearest expansions. In fact, it is developed along a regional road because the context around is composed only by fields and other natural areas like woods.

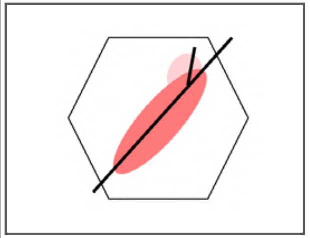


CORINE LAND COVER
112 - Discontinuous urban fabric
121 - Industrial or commercial unit
OSM Standard

Code: COMP_L
URBAN ATLAS 2018 PERUGIA
11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
11240: Discontinuous very low density urban fabric (S.L. < 10%)
11300: Isolated Structures
12100: Industrial, commercial, public, military and private units
12220: Other roads and associated land
14100: Green urban areas
14200: Sports and leisure facilities
Google Satellite

COLOMBELLA
(PERUGIA)

FOCUS	DETAIL
SHAPE Urban Fabric	*URBAN, AGGREGATED AND LINEAR TISSUE*
LANDFORM	*VALLEY*
SEALING SOIL	*MEDIUM LEVEL*
FUNCTION	*MIXED*
CONTEXT	*RURAL*

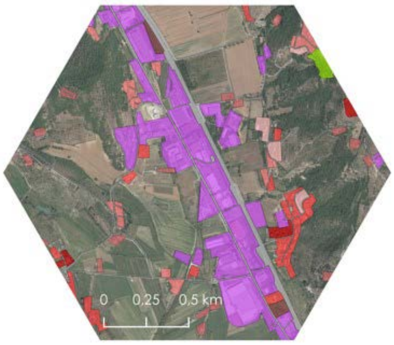


MEDIUM-LOW DENSITY:
DETACHED HOUSES

LINEAR
CONCENTRATION

THE AREA IS MAINLY
A FLAT AREA

U_L_03



URBAN LINEAR AGGREGATED TISSUE

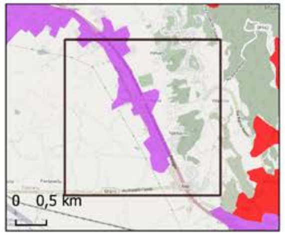
FUA of Perugia

Window U_L_03

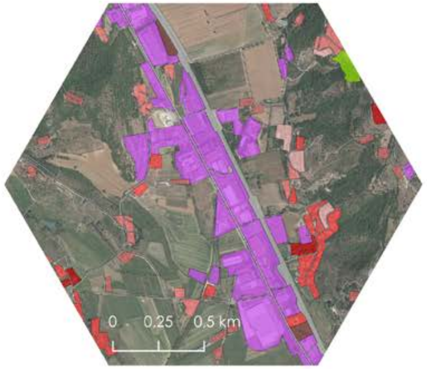
Taverne di Corciano (Perugia)

The main characteristic of the area is an urban, aggregated, and linear tissue. The window captures Taverne di Corciano in the north-west municipality of Perugia.
The area is mainly a valley in the middle of a system of hills. The valley is crossed by a main path that is basically a main route that expands from the centre of the city to north-east of the boundary of the FUA. The configuration analysed is distributed along such main path, which cut the window in half. On the east side, the area is mainly natural valley with some woods. On the west side the valley presents cultivated fields.

Sealing level is medium-high with the almost all entirety of the settlement composed of class 12100 which indicates areas mainly occupied by industrial activities of manufacturing, trade, financial activities, and services. In this window the configuration is mainly composed of an industrial district. The settlement is located mainly on the west side of the main road. Inside the main area of sealed soil, the permeable land is almost missing.
The function is industrial. On the east side of the main road there is a small dimension residential settlement. The shape of the configuration retrace the linear path of the main road, in the view of maximize the proximity to the main connection and also to main services related to resources.
The context is mainly rural with farmland in the proximity of the main settlement. This is a case in which the two conditions of soil availability and the accommodation given by the valley area permit to develop a configuration which follows the profit logic and then the advantage of being in direct connection with the main road as much as possible.



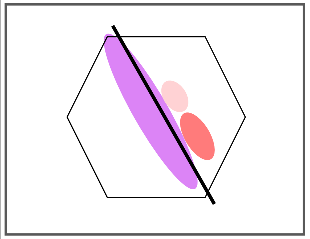
CORINE LAND COVER
112 - Discontinuous urban fabric
121 - Industrial or commercial unit
OSM Standard



Code: COMP_L
URBAN ATLAS 2018 PERUGIA
11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
11240: Discontinuous very low density urban fabric (S.L. < 10%)
11300: Isolated Structures
12100: Industrial, commercial, public, military and private units
12220: Other roads and associated land
13400: Land without current use
14100: Green urban areas
14200: Sports and leisure facilities
Google Satellite

TAVERNE DI CORCIANO
(PERUGIA)

FOCUS	**DETAIL**
SHAPE **Urban Fabric**	*URBAN, AGGREGATED AND LINEAR TISSUE*
LANDFORM	*VALLEY*
SEALING SOIL	*HIGH-MEDIUM LEVEL*
FUNCTION	*INDUSTRIAL*
CONTEXT	*RURAL*

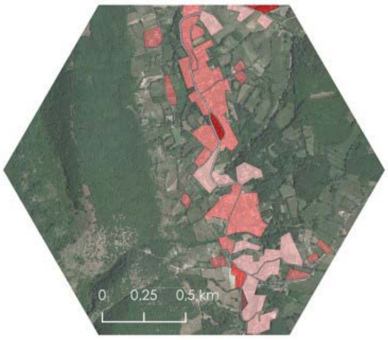


HIGH DENSITY:
INDUSTRIAL DISTRICT

LINEAR
CONCENTRATION

THE AREA IS MAINLY
A FLAT AREA

U_L_04



URBAN LINEAR AGGREGATED TISSUE

FUA of L'Aquila

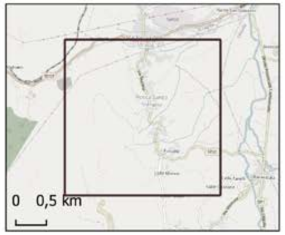
Window U_L_04

Rocca S. Stefano (L'Aquila)

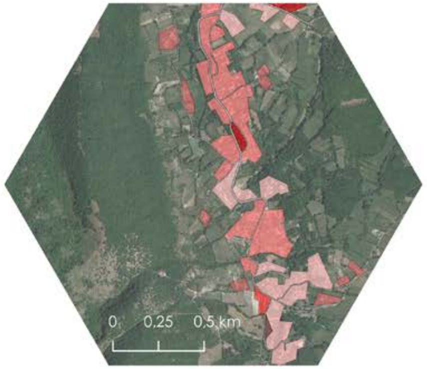
The main characteristic of the area is an urban, aggregated, and linear tissue. The window captures the district of Rocca S. Stefano – Forcelle in the south-west area of L'Aquila municipality.

Settlement follows the crest of the hill, inside a system of hills. The landform of the crest guides the one main linear axis, which is very fragmentary and wavy. The surrounding is mainly composed of field and some woods that innervate the borders of fields. Some parts of the settlement are detached in relation to the main path, and it indicates availability of valley areas also around the main path on the crest. The linear dense shape is also interrupted by the morphological variations.

Sealing level is mainly medium. The dense main path is wavy, and buildings seems associated in sub-groups. A small densest area corresponds to the most ancient tissue of the settlement.
The main function of the settlement is residential. The typical building is directly related to the street. Also, it is a detached house or a series of terraced houses with two or three floors and sloping roofs. There are also some farms and local activities, such as the Post Office, a church, and restaurants. Due to the closeness to the city of L'Aquila, the area depends on it for main services.
The context is mostly rural. The window seems cut in two main sub-sections. There is a compact wood in the west area, which is a free area without any settlements. Then, the central-east part of the window is occupied by field in valley area. The main linear settlement is in-between such part. Then, the extreme eastern area of the window is mainly composed by field without any settlements. As a typical mountain configuration, the urban structure is concentrated and mainly linear.



OSM Standard



Code: COMP_L

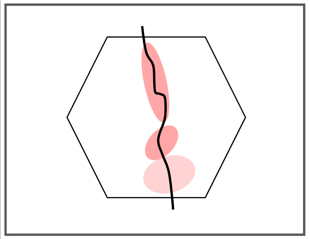
URBAN ATLAS 2018 L'AQUILA

- 11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
- 11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- 11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12100: Industrial, commercial, public, military and private units
- 12220: Other roads and associated land
- 12230: Railways and associated land
- 13100: Mineral extraction and dump sites
- 13400: Land without current use

Google Satellite

ROCCA S.STEFANO – FORCELLE (L'AQUILA)

FOCUS	DETAIL
SHAPE Urban Fabric	*URBAN, AGGREGATED AND LINEAR TISSUE*
LANDFORM	*VALLEY*
SEALING SOIL	*MEDIUM LEVEL*
FUNCTION	*RESIDENTIAL*
CONTEXT	*RURAL*

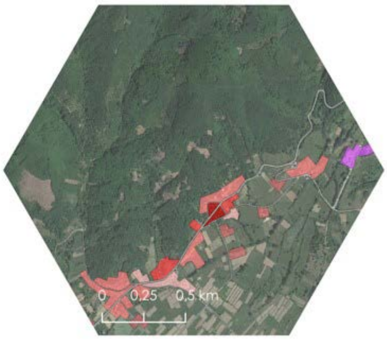


MEDIUM DENSITY:
HISTORICAL-RESIDENTIAL DISTRICT

EXAMPLE OF COMPACT LINEAR WITH MEDIUM LEVEL OF SELING SOIL.
LINEAR SPOTS ALONG THE MAIN ROUTE: URBAN AGGREGATES

THE AREA IS MAINLY
A FLAT AREA

PU_L_01



PERI-URBAN DISCONTINUOUS LINEAR TISSUE

FUA of L'Aquila

Window PU_L_01

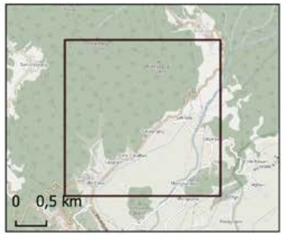
Cavagnano (L'Aquila)

The main characteristic of the area is a peri-urban, discontinuous and linear tissue. The window captures a non-typical example of linear tissue. In fact, little urban aggregates stand along the main direction (SS 260). Similarly, various near districts are aggregated along the same highway. The window comprehends district of Cavagnano, part of Montereale municipality (L'Aquila).

The analysed area extends along the end of a slope and it is mainly in a valley. A mountain chain occupies major part of the window. The mountain chain is mainly covered by wood.
The area presents low sealing level, the medium is around 30%. Sealing soil occupies only a low of the window. The path is scattered along one main route. Buildings are aggregated in various small or medium aggregates.

The main function is residential. There are some isolated units, and lots used for agricultural activities. The area is not central for services that are missing (bank, schools, pharmacy) and the district depends on the municipality's services.

The context is rural. The route considered stands in the half-way between mountain chain and the valley.



OSM Standard

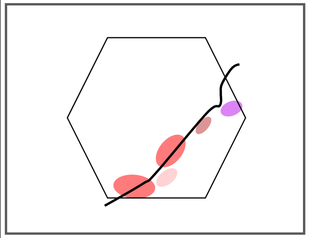
CAVAGNANO
(L'AQUILA)

Code: DISC_L

URBAN ATLAS 2018 L'AQUILA
- 11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
- 11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- 11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12100: Industrial, commercial, public, military and private units
- 12220: Other roads and associated land
- 13400: Land without current use
- 14100: Green urban areas
- 14200: Sports and leisure facilities

Google Satellite

FOCUS	DETAIL
SHAPE Urban Fabric	*PERI-URBAN, DISCONTINOUS AND LINEAR TISSUE*
LANDFORM	*VALLEY*
SEALING SOIL	*LOW-MEDIUM LEVEL*
FUNCTION	*RESIDENTIAL*
CONTEXT	*RURAL*



LOW DENSITY:
ISOLATED STRUCTURES AND URBAN AGGREGATES

NON-TYPICAL EXAMPLE OF LINEAR. LINEAR SPOTS ALONG THE MAIN ROUTE: URBAN AGGREGATES

THE URBANISED AREA CONCENTRATES AT THE SLOPE AND MAINLY ALONG THE VALLEY

PU_L_02

PERI-URBAN DISCONTINUOUS LINEAR TISSUE

FUA of Terni

Window PU_L_02

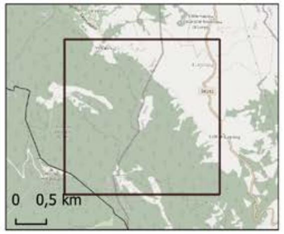
Fontanelle - Configni (Rieti)

The main characteristic of the area is a peri-urban, discontinuous and linear tissue.

The window captures the settlement Località Fontanelle (Rieti, Lazio). The area is part of the commuting zone of Terni even if it is part of another region (Lazio Region).
The area is mainly hilly. Almost all the window is occupied by mountain chain, which extends from the road considered towards southwest. The mountain chain is mainly covered by wood.

The area presents a very low sealing soil level, which is less than 10%. The path is scattered along one main route/direction. Moreover, the tissue is scattered also because it follows the terrain morphology. The sealed area occupies very little part of the window.

The main function is residential. There are some isolated units, and lots used for agricultural activities. The context is rural. The route considered stands in the half-way between mountain chain and the valley.



OSM Standard

Code: DISC_L

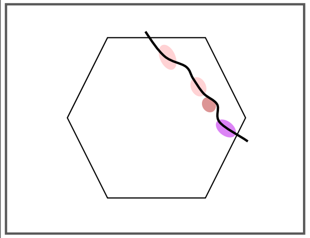
URBAN ATLAS 2018 TERNI

- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12100: Industrial, commercial, public, military and private units
- 12220: Other roads and associated land
- 13400: Land without current use

Google Satellite

LOCALITA' FONTANELLE – CONFIGNI (RIETI)

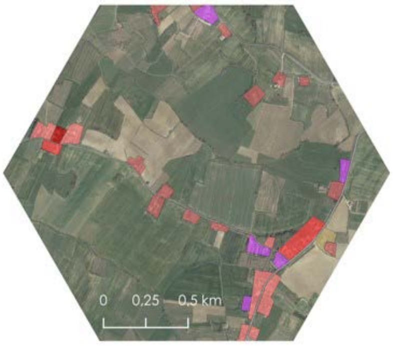
FOCUS	DETAIL
SHAPE Urban Fabric	*PERI-URBAN, DISCONTINOUS AND LINEAR TISSUE*
LANDFORM	*HILLS*
SEALING SOIL	*LOW LEVEL*
FUNCTION	*RESIDENTIAL*
CONTEXT	*RURAL*



VERY LOW DENSITY: ISOLATED STRUCTURES AND LINEAR SPOTS: LOTS OF LANDS

THE AREA IS MAINLY HILLY

PU_L_03



PERI-URBAN DISCONTINUOUS LINEAR TISSUE

FUA of Perugia

Window PU_L_03

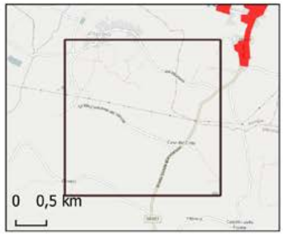
Case del Colle (Perugia)

The main characteristic of the area is a peri-urban, discontinuous, and linear tissue. The window captures the settlement Case del Colle, a district in the south area of the FUA of Perugia.

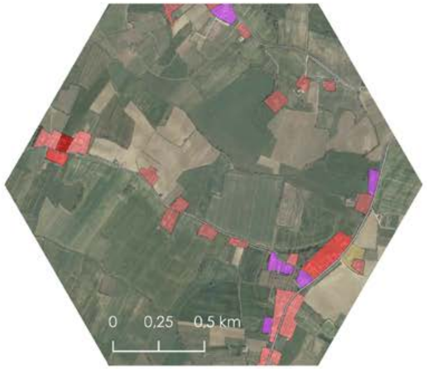
The area is a valley mainly used for agriculture. Some occasional lines of tree folloe the main paths.

The sealing level is very low. The path is scattered along two main directions. Moreover, the tissue is scattered also because it follows the terrain morphology and the shapes of fields which seems to guide the shapes inside the window. The sealed area occupies very little part of the window.
The sealed areas are mainly industrial, private, and residential and they are few spots in the dominant rural context.

Functions are mainly little and medium warehouses for the adjacent fields and residential units composed of detached houses. The route considered is one of the local roads which innervate the local network. However, the linear path is guided by the presence of boundaries of the field, more than the selection of a specific optimal direction.



CORINE LAND COVER
112 - Discontinuous urban fabric
OSM Standard

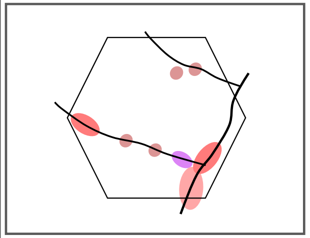


Code: DISC_L
URBAN ATLAS 2018 PERUGIA
- 11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
- 11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- 11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12100: Industrial, commercial, public, military and private units
- 12220: Other roads and associated land
- 13300: Construction sites

Google Satellite

CASE DEL COLLE
(PERUGIA)

FOCUS	DETAIL
SHAPE **Urban Fabric**	*PERI-URBAN, DISCONTINOUS AND LINEAR TISSUE*
LANDFORM	*VALLEY*
SEALING SOIL	*LOW-MEDIUM LEVEL*
FUNCTION	*RESIDENTIAL, FARMING*
CONTEXT	*RURAL*

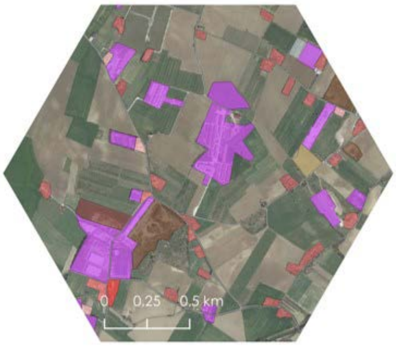


LOW DENSITY: ISOLATED STRUCTURES, DETACHED HOUSES AND FARMS

VARIOUS TYPES OF AGGREGATES ALONG THE LINEAR PATH.

THE AREA CONCENTRATES MAINLY THROUGH THE VALLEY

PU_D_01



PERI-URBAN DISCONTINUOUS SPREAD TISSUE

FUA of Perugia

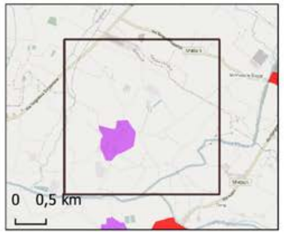
Window PU_D_01

Bettona (Perugia)

The tissue is peri-urban in a rural context, with spread and discontinuous tissue. The area is part of the municipality of Bettona in the FUA of Perugia.

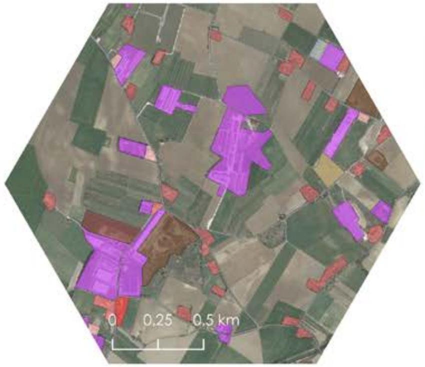
The area is a valley mainly used for agriculture and it is crossed by the Chiascio River in a small area in the southern part of the window, from south-east to south.
The sealing level is low. The sealed areas are mainly industrial, private, and residential and they are spots in the dominant rural context. Two settlements are the biggest ones, whereas the others are smaller.

Functions are mainly warehouses, residential units (detached houses) and a little church. The warehouses belong to companies of building materials, cars and to a farm.
The window is part of a larger valley area with the same urban pattern. The pattern is made of scattered built areas. A sense of emptiness in this area is given by the presence of the large warehouses and few houses. As monofunctional activities they attract people only during the working hours. As a brief conclusion, the area seems to have typical problems of mono-functional districts.



CORINE LAND COVER
112 - Discontinuous urban fabric
121 - Industrial or commercial unit
OSM Standard

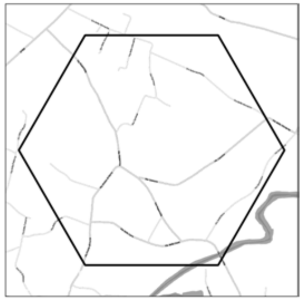
BETTONA
(PERUGIA)

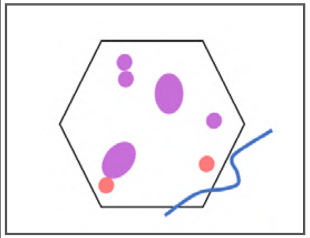


Code: DISC_R

URBAN ATLAS 2018 PERUGIA
11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
11240: Discontinuous very low density urban fabric (S.L. < 10%)
11300: Isolated Structures
12100: Industrial, commercial, public, military and private units
12220: Other roads and associated land
13100: Mineral extraction and dump sites
13300: Construction sites
13400: Land without current use
Google Satellite

FOCUS	DETAIL
SHAPE **Urban Fabric**	*PERI-URBAN, RURAL SPREAD TISSUE*
LANDFORM	*VALLEY*
SEALING SOIL	*LOW LEVEL*
FUNCTION	*INDUSTRIAL, FARMING*
CONTEXT	*RURAL*

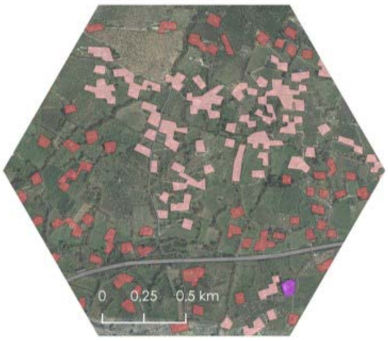




LARGE WAREHOUSES
AS A TYPICAL MONO-FUNCTIONAL DISTRICT

THE AREA PRESENTS ALSO FEW ISOLATED
DETACHED HOUSES

PU_D_02



PERI-URBAN DISCONTINUOUS SPREAD TISSUE

FUA of Terni

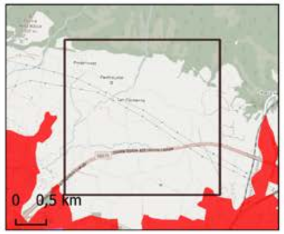
Window PU_D_02

San Clemente (Terni)

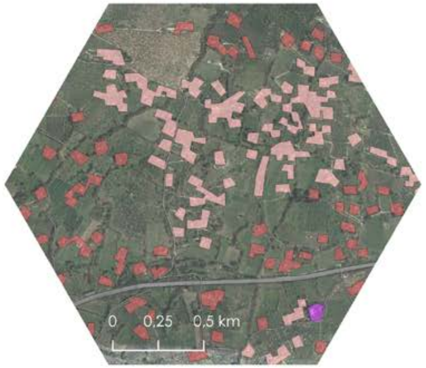
The tissue is peri-urban in a rural context, with spread and discontinuous tissue. The area is in the northern expansion of the FUA of Terni.

The area is a valley, mainly used for orchards. The window catches the first part of the valley close to the mountain chain (Monti Martani) which closes the area from north. The valley continues through south.
The sealing level is low. The sealed areas are mainly private and residential units, and they represent a series of spots in the dominant rural context.

Functions are mainly residential units (detached houses) and there are some little and medium warehouses for the adjacent orchards.
The area represents the northern expansion of the city. The district has a non-defined shape, and it is very scattered. It is delimited to south from the route SS675.The density which characterises this area is evidently different from the more central areas.
The shape of the configuration recalls the typical sprawl urban model.



CORINE LAND COVER
112 - Discontinuous urban fabric
121 - Industrial or commercial unit
OSM Standard

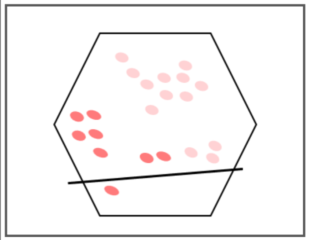


Code: DISC_R

URBAN ATLAS 2018 TERNI
11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
11240: Discontinuous very low density urban fabric (S.L. < 10%)
11300: Isolated Structures
12100: Industrial, commercial, public, military and private units
12210: Fast transit roads and associated land
12220: Other roads and associated land
13400: Land without current use
Google Satellite

SAN CLEMENTE
(TERNI)

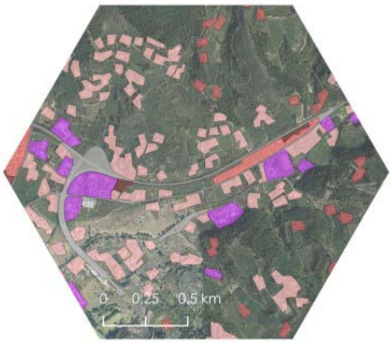
FOCUS	DETAIL
SHAPE Urban Fabric	*PERI-URBAN, RURAL SPREAD TISSUE*
LANDFORM	*VALLEY*
SEALING SOIL	*LOW LEVEL*
FUNCTION	*RESIDENTIAL*
CONTEXT	*RURAL*



LOW DENSITY:
DETACHED HOUSES PART OF A PATTERN OF ORCHARDS

THE RELATIONSHIP BETWEEN THE
VALLEY AND THE MOUNTAIN CHAIN

PU_D_03



PERI-URBAN DISCONTINUOUS SPREAD TISSUE

FUA of Terni

Window PU_D_03

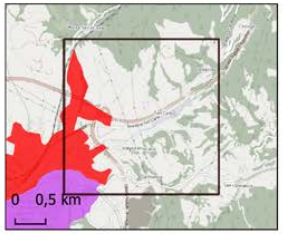
Volge-Prisciano, S. Carlo (Terni)

The tissue is peri-urban in a rural context, with spread and discontinuous tissue. The window captures the district of Volge-Prisciano San Carlo, a part of the northeast expansion in the FUA of Terni.

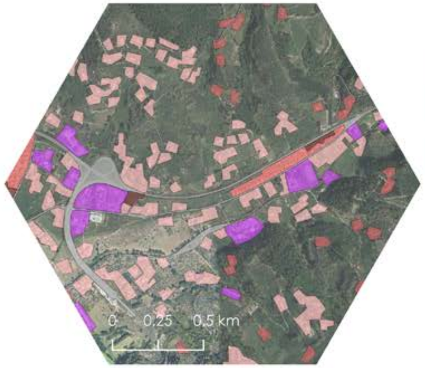
The area is a valley, it comprehends field, orchards, and some woods. The southeast and the northern areas are most natural and free from settlement also because the morphology which becomes hilly.

The sealing level is mainly low-medium. It is composed of both residential small, scattered areas and some bigger service districts. The sealed areas are mainly private and residential units, and they represent a series of spots in the dominant rural context.
A main road is impacting with a road junction in the western area of the window. Residential and industrial uses are mixed. Functions are all connected by one main infrastructures which cut in half the configuration and it is supposes to isolate each part of the settlement. Residential units are mainly detached houses and there are some little and medium warehouses for the adjacent orchards.

The area represents one of the northeast expansions of the city. The district has a non-defined shape, and it is very scattered. The shape of the configuration recalls the typical sprawl urban model.



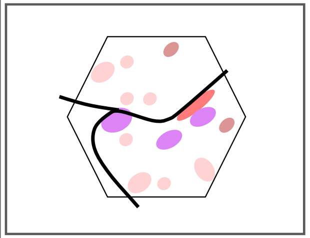
CORINE LAND COVER
111 - Continuous urban fabric
112 - Discontinuous urban fabric
121 - Industrial or commercial unit
OSM Standard



Code: DISC_R
URBAN ATLAS 2018 TERNI
11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
11240: Discontinuous very low density urban fabric (S.L. < 10%)
11300: Isolated Structures
12100: Industrial, commercial, public, military and private units
12210: Fast transit roads and associated land
12220: Other roads and associated land
12230: Railways and associated land
13100: Mineral extraction and dump sites
13400: Land without current use
14200: Sports and leisure facilities
Google Satellite

VOLGE - PRISCIANO,
SAN CARLO (TERNI)

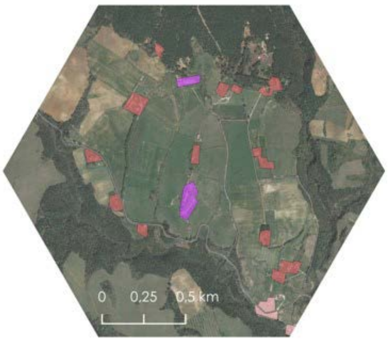
FOCUS	DETAIL
SHAPE Urban Fabric	*PERI-URBAN, RURAL SPREAD TISSUE*
LANDFORM	*VALLEY, HILLS*
SEALING SOIL	*LOW-MEDIUM LEVEL*
FUNCTION	*INDUSTRIAL, FARMING, RESIDENTIAL*
CONTEXT	*RURAL*



DETACHED HOUSES, WAREHOUSES AND INDUSTRIAL SITES SCATTERED IN A LOW DENSITY AREA

DIVERSE PATTERNS: ISOLATED DETACHED HOUSES AND VALUABLE PROPERTIES
LINEAR PATTERN ON THE MAIN ROUTE

PU_A_01



PERI-URBAN VERY SPREAD TISSUE (SPRINKLING)

FUA of Terni

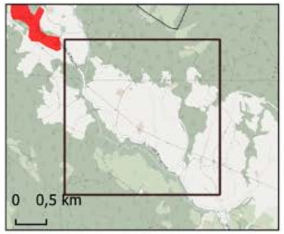
Window PU_A_01

Località Collepina (Terni)

The main characteristic of the area is a peri-urban spread and discontinuous tissue, in a rural area. The area is part of Amelia municipality.

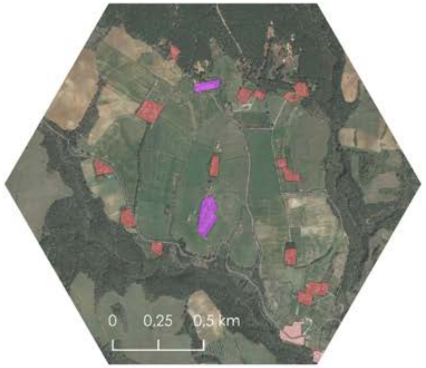
The area is a hilly and rural context which is part of the southern area of Ametini mountain chain. It is a part of the sub-Apennines ridge, and it is parallel to the Central Apennines chain. Some woods are distributed along two directors both from north and northwest to south. The area between the two directors of wood contrasts for presence of various types of fields.

The sealing level is very low. The sealed areas are few spots in the dominant rural context. Spots of sealing soil are concentrated in the centre of the window, along some main distribution streets that branches off one main road which crosses the window from southeast to northwest. In general, the road neatwork is composed of narrow streets that follow the shape of fields.
Functions are mainly holyday farms, isolated residential units, and warehouses. Agriculture is the main activity of the geographic area. The shape of the configuration recalls the typical sprinkling urban model.



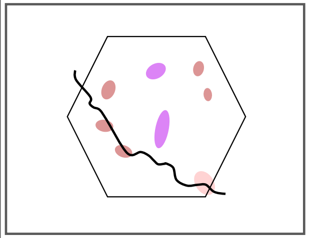
CORINE LAND COVER
112 - Discontinuous urban fabric
OSM Standard

LOCALITA' COLLEPINA,
AMELIA (TERNI)



Code: AGR_D
URBAN ATLAS 2018 TERNI
11240: Discontinuous very low density urban fabric (S.L. < 10%)
11300: Isolated Structures
12100: Industrial, commercial, public, military and private units
12220: Other roads and associated land
14200: Sports and leisure facilities
Google Satellite

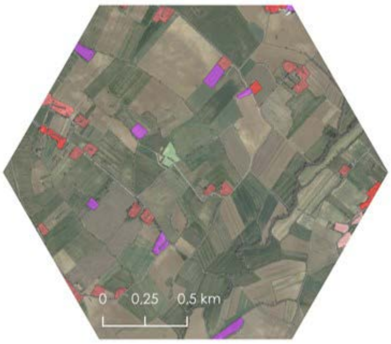
FOCUS	DETAIL
SHAPE Urban Fabric	*PERI-URBAN, RURAL SPREAD TISSUE*
LANDFORM	*VALLEY, HILLS*
SEALING SOIL	*LOW LEVEL*
FUNCTION	*RESIDENTIAL, MIXED*
CONTEXT	*RURAL*



LOW DENSITY:
DETACHED HOUSES PART OF A PATTERN OF ORCHARDS

ISOLATED STRUCTURES ARE IMMERSED IN THE RURAL CONTEXT. IT COMPREHENDS ALSO SOME WOODS

PU_A_02



PERI-URBAN VERY SPREAD TISSUE (SPRINKLING)

FUA of Perugia

Window PU_A_02

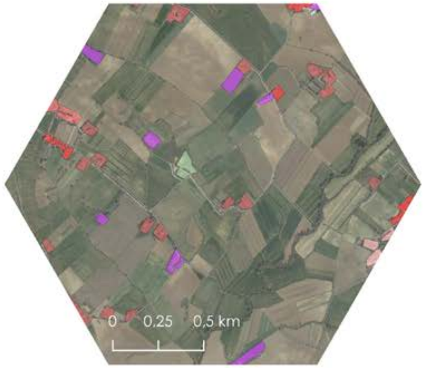
Pila (Perugia)

The main characteristic of the area is a peri-urban spread and discontinuous tissue, in a rural area. The area is part of Pila district in Perugia municipality.

The area is a valley mainly used for agriculture. There is no relevant variation in altitude. Various and diverse fields create a mosaic of polygonal block which occupy almost all the window. The area is crossed by the Genna stream in the east part of the window, from north-east to south. Few trees and shrubs are scattered along the streets, whereas two compact lines of trees and shrubs compose banks of the stream.

The sealing level is very low. The sealed areas are few spots in the dominant rural context. Buildings are both isolated and aggregated in groups of two or three. Shapes of artificial lands are arranged in different ways because they follow the shape of fields.
Functions are mainly holyday farms, isolated residential units, and warehouses. The area is not central for services that are missing (bank, schools, pharmacy) and the district depends on the municipality's services. Use is mainly related to farm activities, included one field is occupied by solar panels. The road neatwork is composed of narrow streets that follow the shape of fields. All the streets have the same degree. The shape of the configuration recalls the typical sprinkling urban model.

CORINE LAND COVER
112 - Discontinuous urban fabric
OSM Standard



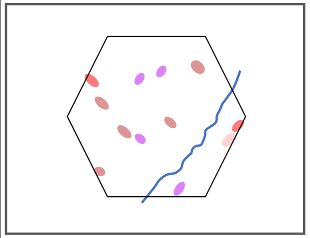
Code: AGR_D

URBAN ATLAS 2018 PERUGIA
- 11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
- 11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- 11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12100: Industrial, commercial, public, military and private units
- 12220: Other roads and associated land
- 14100: Green urban areas
- 14200: Sports and leisure facilities

Google Satellite

PILA
(PERUGIA)

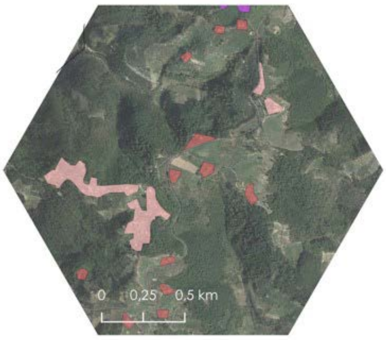
FOCUS	DETAIL
SHAPE Urban Fabric	*PERI-URBAN, RURAL SPREAD TISSUE*
LANDFORM	*VALLEY*
SEALING SOIL	*LOW LEVEL*
FUNCTION	*RESIDENTIAL, FARMING, TOURISM*
CONTEXT	*RURAL*



LOW DENSITY:
DETACHED HOUSES PART OF A PATTERN OF ORCHARDS

ISOLATED STRUCTURES ARE SURROUNDED BY THE RURAL CONTEXT. IT COMPREHENDS A SMALL RIVER

PU_A_03



PERI-URBAN VERY SPREAD TISSUE (SPRINKLING)

FUA of Terni

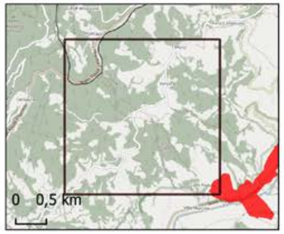
Window PU_A_03

Varcone (Terni)

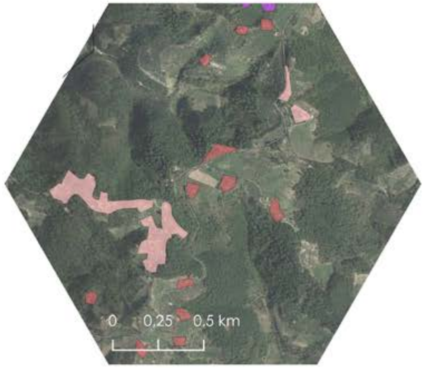
The main characteristic of the area is a peri-urban spread and discontinuous tissue, in a rural natural area. The area is in the north-east branch of Terni territory, it is part of Varcone small district in Montefranco municipality.

The area is part of the north-eastern branch of the city that is located outside the so-called “Conca Ternana”. The area is a hilly and rural natural context. The average altitude is around 400 m, and it has variations inside the window.

The sealing level is very low. The sealed areas are few spots in the dominant rural context. Aggregations of buildings is very scattered in the window.
Functions are mainly holyday farms, isolated residential units, and warehouses. The area is not central for services that are missing (bank, schools, pharmacy) and the district depends on the municipality’s services. Use is mainly related to farm activities.
Generally, the settlements’ arrangement is not strictly related to road network. In fact, the main road (SP68) crosses the window from south to north and it is shifted compared to the settlement. Some other streets follow the crest of hills. Because of morphology, all the road network is tortuous.



CORINE LAND COVER
112 - Discontinuous urban fabric
OSM Standard



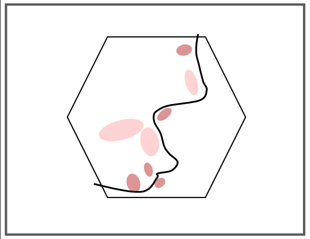
Code: AGR_D

URBAN ATLAS 2018 TERNI
- 11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- 11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12100: Industrial, commercial, public, military and private units
- 12220: Other roads and associated land
- 13400: Land without current use

Google Satellite

VARCONE (MONTEFRANCO) (TERNI)

FOCUS	DETAIL
SHAPE Urban Fabric	*PERI-URBAN, RURAL SPREAD TISSUE*
LANDFORM	*HILLY*
SEALING SOIL	*LOW LEVEL*
FUNCTION	*RESIDENTIAL, FARMING, TOURISM*
CONTEXT	*RURAL*



LOW DENSITY: DETACHED HOUSES AND BUILDINGS PART OF A PATTERN OF FIELDS AND WOODS

ISOLATED STRUCTURES ARE SURROUNDED BY A SYSTEM OF HILLS