Drosscape as raw material for the implementation of Green-Blue Infrastructure

The study-case of Napoli Orientale

Daniele Cannatella

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Tutors

Carlo Gasparrini

Taneha Kuzniecow Bacchin

For Salvatore and Carla.
For Alice.
For Mimmo.

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Acronyms and abbreviations

3PA	Three Points Approach
4DA	Four Domains Approach
ARPAC	Agenzia Regionale per la Protezione Ambientale in Campania
CAS	Complex Adaptive System
DTM	Digital Terrain Model
EPA	Environmental Protection Agency (United States)
GBI	Green-Blue Infrastructure
GI	Green Infrastructure
GIS	Geographic Information System
LECZ	Low Elevation Coastal Zone
LU	Land Use
NBS	Nature Based Solutions
OMI	Osservatorio del Mercato Immobiliare
PSAI	Piano Stralcio di Bacino per l’Assetto Idrogeologico
PTCP	Piano Territoriale di Coordinamento Provinciale
RIR	Rischio di Incidente Rilevante
SED	Socio-Economic Development
SES	Social-Ecological Systems
SIN	Sito di Interesse Nazionale
SIR	Sito di Interesse Regionale
UA	Urban Atlas
WSUD	Water Sensitive Urban Design

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Abstract

La maggior parte delle grandi città del nostro pianeta si trova in aree connotate da un alto livello di vulnerabilità alle alluvioni, come le pianure costiere e fluviali (IPCC, 2014). Ciononostante, i trend di urbanizzazione di queste aree sono in rapida crescita, così come il conseguente incremento dell'esposizione di beni e di persone al rischio di inondazione.

Nei paesi sviluppati – e specialmente nel contesto europeo – l'adattamento e la mitigazione del rischio legato alle inondazioni sono strettamente connessi con azioni di riqualificazione e riciclo delle aree abbandonate (de Graaf, 2012). Ciò avviene per due motivi: da una parte, la mancanza di risorse finanziarie adeguate rappresenta un ostacolo faticosamente sormontabile all'attivazione di misure per l'adattamento a livello locale; dall'altra parte, l'ingente processo di urbanizzazione basato su un eccessivo consumo di suolo ha generato come effetto una inevitabile scarsità cronica di spazi aperti disponibili nel tessuto più denso delle città. Queste condizioni, unitamente agli impatti generati dai cambiamenti climatici, rendono sempre più indispensabile e urgente l'implementazione di strategie adattive che siano in grado di rispondere alle diverse necessità e specificità dei territori, e che al contempo possano essere incorporate nei più canonici progetti di manutenzione, modificazione o riqualificazione delle infrastrutture, degli edifici e dello spazio pubblico (Gersonius, 2012).

In questo senso, allora, coltivare una capacità di comprensione e di interpretazione dei sistemi urbani e della loro dimensione dinamica e

non-lineare diventa obiettivo prioritario, al fine di riuscire a sviluppare strategie adattive virtuose a partire da quei materiali che la città stessa ha a disposizione, e che contestualmente siano in grado di conciliare gli aspetti relativi alle necessità di mitigazione del rischio con le esigenze e le limitazioni derivanti dalla scarsa disponibilità economica. Le aree abbandonate, e più in generale il *drosscape*, rappresentano dunque una preziosissima risorsa. Il *drosscape* (Berger, 2006) è una vera e propria tipologia di paesaggio, composta da aree interstiziali generate da due meccanismi principali: il primo è il processo di rapida urbanizzazione orizzontale; il secondo è la crisi dei precedenti regimi economici e di produzione. Questi frammenti, caratterizzati dall'assenza totale o parziale di usi, diventano lo strumento ideale per l'implementazione di strategie multiscalari in grado di tenere assieme e valorizzare le relazioni urbane e territoriali che essi riescono ad innescare (Gasparrini, 2014), e possono quindi contribuire alla costruzione di infrastrutture verdi e blu per diversi motivi.

La gestione del rischio legato al *flooding*, alla luce dei cambiamenti climatici, necessita infatti di una forte sinergia tra diverse discipline: affrontare il problema con un approccio esclusivista e settoriale si è rivelato nel recente passato un fallimento, ed in particolar modo nella gestione delle acque. Questo perché i valori e gli aspetti relativi all'acqua non sono solamente legati a questioni tecniche, né esclusivamente a quelle ambientali, ma anche alla sfera sociale e a quella economica. Ciò si riflette dunque nella necessità di affiancare ad una virtuosa gestione delle acque la modellazione di un ambiente urbano che sia in grado di fornire servizi ai cittadini, di garantire loro un adeguato livello di sicurezza e di migliorare il grado di qualità della vita. Per queste ragioni, la transizione da una infrastruttura 'grigia' e monofunzionale ad una infrastruttura 'verde e blu' rappresenta di fatto un'opportunità per incrementare i benefici che la natura fornisce, traendo il massimo dalla loro sinergica messa a sistema (Hansen & Pauleit, 2014).

Il paesaggio, e nello specifico il paesaggio dello scarto, gioca dunque un ruolo fondamentale, soprattutto nel momento in cui viene concepito esso stesso come infrastruttura (Bélanger, 2009), poiché rappresenta un'opportunità per catalizzare progetti che siano in grado di tenere assieme le diverse scale spaziali – da quella regionale a quella del singolo lotto o edificio – e temporali – nel breve e nel lungo periodo. D'altra parte, i diversi bisogni e le criticità che possono palesarsi in una città sono latori di potenziali conflitti a livello spaziale e, al contempo, una inadeguata pianificazione degli interventi a livello temporale può rendere inefficace se non addirittura controproducente qualsiasi strategia adattiva.

Lo scopo di questa tesi di dottorato, dunque, è investigare quali siano i fattori, spaziali e non spaziali che favoriscono o impediscono l'utilizzo delle aree di scarto per l'implementazione di infrastrutture verdi e blu nel tempo. I presupposti da cui questa ricerca parte sono basati sull'idea che la sola concezione economica non sia sufficiente a definire il valore dei drosscape e la loro potenzialità, che si rivela invece soprattutto nell'aspetto relazionale, in quanto spazi eterotopici (Foucault, 1998). Ciononostante, essi sono spesso caratterizzati da un degrado ambientale per l'eccessivo consumo di risorse e per l'inquinamento dovuti ai precedenti utilizzi del suolo, legati sovente ad attività industriali. Il lavoro di tesi, quindi, va a definire quali siano i valori, le potenzialità e le criticità del *drosscape*, fornendo una chiave di lettura strutturata a partire dai princìpi definiti dalle teorie relative ai Sistemi Adattivi Complessi e da un framework elaborato a partire dal *Dutch layer approach*. Successivamente, all'interno di questo lavoro, vengono individuati i fattori morfologici e relazionali attraverso cui re-interpretare il *drosscape* per utilizzarlo attivamente ai fini della costruzione di infrastrutture verdi e blu in territori densamente urbanizzati.

La metodologia elaborata è stata testata sul caso studio di Napoli Orientale, area caratterizzata dalla preponderante presenza di insediamenti industriali abbandonati, dichiarata Sito di Interesse Nazionale a causa degli alti livelli di inquinamento di aria, suoli e acque, e soggetta ad allagamento per l'aumento del livello delle acque di falda dovuto alla progressiva dismissione delle aree industriali.

01 Introduction

1.1 | Problem statement

Most of the largest cities on our planet is located in areas characterized by a high level of vulnerability to flooding, such as coastal and river plains (IPCC, 2014). Despite this critical aspect, hundreds of millions people live in these vulnerable areas, and more and more people are moving toward them as cities continue to grow. This constant increasing trend of urbanisation process has led to a large increment of the exposure of both goods and population in vulnerable areas, resulting in an unavoidable and dramatic rise of flood risk.

More in general, these areas are particularly prone to the impacts related to both slow and fast variables. Slow variables are the ones that can push a system (see chapter 3) toward thresholds beyond which fast variables can trigger disasters (Ernston, et al., 2010). Consequently, a combination of stresses provided by slow variables – i.e., sea level rise, periodic flooding, etc. – and of sudden shocks – i.e., tsunamis, hurricanes, etc. – can bring a system to collapse.

Beside the fragility derived by natural and morphologic conditions that a peculiar portion of territory can show, human-related impacts represent a proper pressure on a system. For instance, it has been calculated that the *Low Elevation Coastal Zone*[1] (LECZ), which represents merely the 2 percent of the emerged lands of the planet, contains the 10 percent of the world population – approximately 600 million people – and the 13 percent of world urban population – around 360 million (McGranahan, Balk, &

Anderson, 2007; IPCC, 2014). People exposed to 1-to-100 extreme sea level in the LECZ have increased by 95% from 1970 to 2010; furthermore, 13 trillion US$ worth of assets are exposed as well. Human pressure has been showing as well in urbanisation processes in flood prone areas, leading as a consequence to an increase of flood risk. This is mainly due to the exposure of population and capital, which have incremented in time for the socio-economic development (SED). Hence, socio-economic development is perhaps the most impacting driver related to man, as it influences the number of people and assets exposed, directly impacting the ecological footprint caused by cities, both in terms of resources consumption and systems alteration.

In developed countries, and especially in the European context, dealing with flood risk in order to reduce vulnerability is tightly tied with redevelopment processes (de Graaf, 2012), for disparate reasons. Undeniably, the lack of financial resources represents one of the main obstacles for the implementation of adaptive strategies at a local level. Moreover, a massive process of urbanization in time has produced a chronic shortage of available space within cities. Due to these conditions, enhancing urban resilience to flood risk in western countries – taking account of the exacerbation of this phenomenon as a result of climate changes – inevitably involves redevelopment, regeneration and recycling of existing areas which are abandoned, discarded or simply underused.

All these specific areas can be defined as *drosscape*. Drosscape consists of the set of those interstitial spaces that 'emerge[s] out of two primary processes: first, as a consequence of current rapid horizontal urbanization […] and second, as the leftovers of previous economic and production regimes, which are both catalysed by the drastic decrease in transportation costs (for goods and people) over the past century' (Berger, 2006). These fragments and portions within the dense and less dense tissues of the city call for the implementation of multi-scalar strategies in order to link them and to take advantage from the urban and territorial relations that these peculiar urban landscape materials can trigger (Gasparrini, 2014).

Thus, although the implementation of adaptive strategies ‘should as much as possible be based on the incorporation of adaptation responses with *normal* investment projects, such as for the maintenance/modification/ renewal of infrastructures, buildings and public spaces’ (Gersonius, 2012), it is not sufficient if broader strategies that consider space and time are not developed. One of the reasons of this issue is related to time: arguably, often short-term needs and long-term strategies can generate conflicts and, in some extreme cases, achieving short-term goals can be harmful for long-period objectives.

Time, then, is one of the main keys through which this research work could be interpreted and understood. Wasted lands are defined by the waiting time before being actively reintroduced into the dynamics of an urban system: they exist in those periods of shift in uses, becoming subjected to a progressive and relentless loss of meaning and alteration of their values. In addition, time defines the steps of possible incremental strategies for adaptation and potentially instructs the degree of flexibility of each element that flows into and plays a role in the latter. Lastly, time makes explicit the urgencies and the objectives of a territory, giving the possibility to take advantage of them, transforming them in opportunities starting from drosscape’s hidden potential to enhance urban resilience.

A second key is provided by the morphological aspect of drosscape. Understanding drosscape as a proper landscape allows to make explicit its potential for the construction of Green-Blue Infrastructure, supporting the design of the network and exploit the adaptive capacity of the available spaces within the tissues of the city.

1.2 | Research objectives

The aim of this Ph.D. research project is to investigate the spatial and non-spatial factors that play a role in employing wasted lands for the implementation of green-blue infrastructures, using the study area of Napoli Orientale as a test case. The study area is located in the eastern part of the city of Napoli, Italy (fig. 1.1), and it is a post-industrial site in which refineries, deposits and industrial plants – mostly related to the oil sector – are currently under closing and abandonment process. This case has been chosen as study subject because of its critical issues: one is related to environmental degradation and the severe contamination of air, soil and water systems; the other concerns the vulnerability to flood events due to an increase of ground-water level as a result of a disposal of productive uses. In addition, the study area is hallmarked by a massive presence of neglected spaces of various origins. These voids are mainly the result of the previous industrial use but, at the same time, they originate from a various set of land uses, which have arisen in a proper *geography of the void*. Moreover, the density of uses and interactions that take place in this area represents a clear occasion to investigate and identify methods that are based on flexibility and on adaptive strategies.

In order to better understand the potential of drosscape, this research goes beyond the economic conception of 'wasted land', according to which voids no longer have a value since they have no recognised and formalised use or purpose at all. In fact, the environmental value of these spaces represents a clear opportunity for the construction of ecological continuity and connectivity within the dense built environment of cities, making them an indispensable resource for urban systems. From this perspective, their morphology and their spatial configuration can be seen as a main features through which re-interpret their role in the design process. Furthermore, drosscape discloses a substantial social value that is often hidden. In these spaces, indeed, not seldom self-organisation and

fig. 1.1 | The study area: Napoli Orientale

novelty take place, as they turn to be spaces of freedom of thinking and acting, creativity and experimentation. This variety of values, together with their constant and unavoidable presence within the urban tissue, constitutes a distinctive trait that makes them fundamental for adaptation strategies. Undeniably, drosscape is an endless resource available for the city to enhance its resilience and to develop flexible plans to cope with flood risk.

Moreover, the study of the processes that contribute to the formation of drosscape can provide an extremely useful tool for the understanding of cities as complex adaptive systems (see chapter 3). These spaces, indeed, supply the opportunity to comprehend complexity, acting as a lens through which the recognition of the subsystems that form an urban system and interdependencies that they establish is possible.

1.3 | Research hypotheses

The main hypotheses from which this research origins are the following:

1. Drosscape is an unavoidable component of the growth of a city, as the city itself acts in the same way of a living organism. In their evolutionary path, cities tend to expand but also to retreat, according to changing needs coming from social and economic issues over time.

2. Drosscape is an indicator of a healthy urban growth. This statement, formulated by Berger (see Chapter 2), puts more emphasis again on the analogy between urban systems and living organisms. This implies that, in their lifetime, living organisms produce waste as they grow. More generally, such analogy can be extended to the ecosystems' level.

3. At the same time, drosscape is an indicator of resilience loss, since its formation is closely related to crisis of economic regimes. For this reason, it is a tangible effect of fragmentation condition in Complex Adaptive Systems and it represents a clear signal that a system is slowly moving towards dangerous thresholds beyond which an external shock can result into its collapse.

4. Drosscape is the set of abandoned and residual spaces, which are characterized by a high level of diversity, which in turn is difficult to find within the dense patterns of an urban system. Such diversity is a common trait that is easy to find in all the different domains that hallmark cities, such the environment – i.e., the number of species that these areas host – and the socio-economic sphere – i.e., the amount of unformal activities, and regulated and not regulated uses.

5. A landscape is generally perceived as waste when man is not able to assign it a proper use. Nonetheless, it can provide services that are not directly recognizable, but still vital for man. In the compact tissue of the city, open spaces are sporadic and, for this reason, priceless elements for enhancing resilience. However, drosscape is often tied to the consumption and pollution of primary resources such as soil, air and water.

6. Cities can be conceived as Complex Adaptive Systems, as they are defined by a wide number of agents and subsystems that interact among them and influence each other, generating non-linear and unpredictable evolutionary processes. Drosscape is a tangible result of such processes, and it helps to explicit some of those dynamics that contribute to unpredictability.

7. Green-Blue Infrastructure provides a wide range of benefits, which are more widespread than its primary function, as it can contribute to protect and/or restore the hydrological value, as well as the ecological one, and at the same time, it contribute to the health and quality of life of people.

1.4 | Research question and sub-questions

In the light of the above proposed set of hypotheses, the main question from which this research work takes place is: *how drosscape can be used for the implementation of green-blue infrastructure in western countries*?

The main research question directly implies the formulation of a series of sub-questions that investigate different but significant aspects related to it. The subsequent research questions include:

- What is the definition of drosscape? What values characterise it?
- Is it possible, and if so, how to define a drosscape's life-cycle?
- How can drosscape be interpreted in the light of Complex Adaptive Systems Theories?
- How does drosscape interact with the main subsystems of a city understood as a Complex Adaptive System?
- Can drosscape describe the condition of fragmentation of a CAS?
- What is a Green-Blue Infrastructure, and what benefits – both direct and indirect – does it provide?
- How can drosscape's morphological features be exploited in the construction of Green-Blu Infrastructure?
- Beside this, what it the set of tangible and intangible features that foster and/or impede the reintroduction of a drosscape in a Green-Blue Infrastructure?

1.5 | Methodology

The methodology developed within this research work is based on a spatio-temporal approach, and supported by Geographical Information Systems (GIS) design tools. It is composed by three phases, In this paragraph, a brief overview of each phase is proposed, and it will be examined in depth in Chapter 5.

The first step is the organisation of a data model that consists of spatial and non-spatial data related to drosscape. This phase is very important, since it provides the opportunity to describe drosscape according to its main features and supports the elaboration of a classification for wasted areas. Within this research project, the spatial scale of reference is the urban scale. However, spatial data are collected, organised and represented with the aim to create an 'open' and transcalar methodology. Spatial and non-spatial data were collected within the P.R.I.N. Re-Cycle Italy and successively integrated and re-elaborated for the purpose of this research work. A classification of drosscape is proposed in this phase.

The second step foresees the morphological analysis of drosscape. In this phase, the study area is sub-divided in two areas according to the process described in paragraph 5.1. Successively, the land use of the areas are analysed and compared, as well as the category of drosscape, to identify the spatial conditions that wasted lands present.

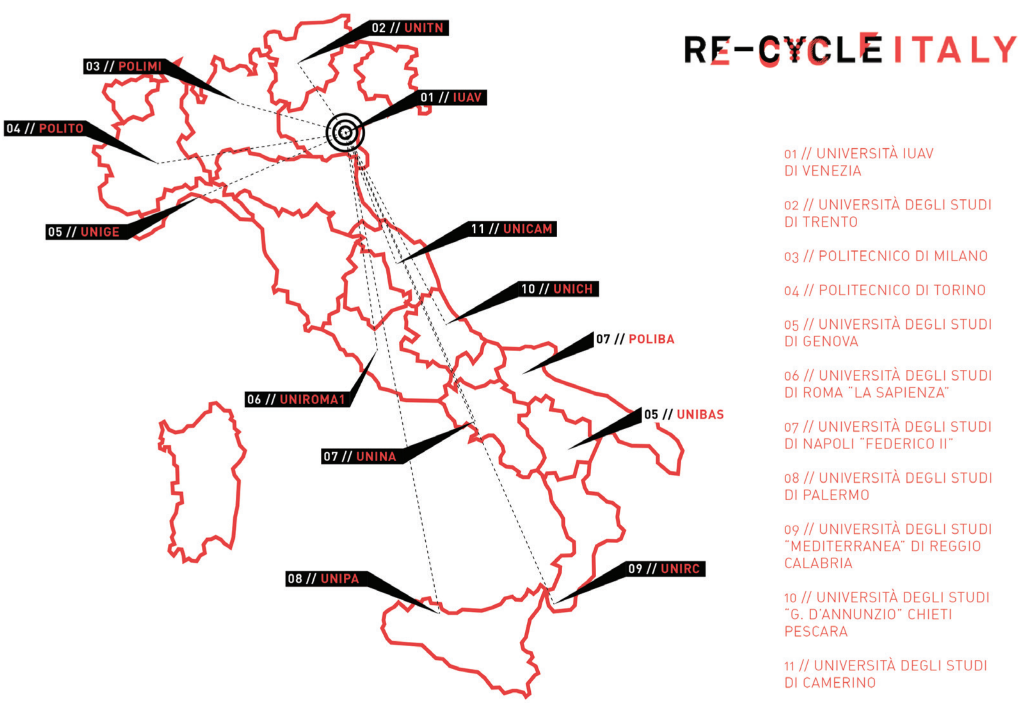
The third step focuses on the identification of the values of wasted lands emerging from the body of literature presented in chapter 2. Such values are organised according to a framework derived by the Dutch layer approach. This approach, developed in the late nineties of the past century, presents a stratified model able to describe different time scales of spatial dynamics. Within the methodology implemented in this research work, such approach is used to classify the selected indicators according to the different interactions that drosscape establishes with the other parts of the city understood as a Complex Adaptive System. Values are then spatialized according to the previously collected data and represented through the employment of maps.

The proposed methodology is tested here on the study case of Napoli Orientale, Italy, in Chapter 6.

1.6 | Scientific and social relevancy

This research has been developed under the *P.R.I.N. Re-Cycle – New life cycles for architecture and infrastructure of the city and the landscape*. The P.R.I.N. is a three-year Research Program of National Interest, funded by Italian Ministry of Education, University and Research, for the scientific-disciplinary area 08: Engineering and Architecture. It started in 2013 and ended in 2016. The aim of the research – in which eleven Italian universities have been involved (fig.1.2) – was to explore the operative implications of the recycle process on the urban system and on the trails of urbanisation that involve the territory, in order to make those 'materials' part again of a unique metabolism, together with the environmental system[2]. In this framework, two are the principal issues that contribute to define the research: the first is the progressive abandonment of the

fig. 1.2 | the PRIN network of Italian Universities



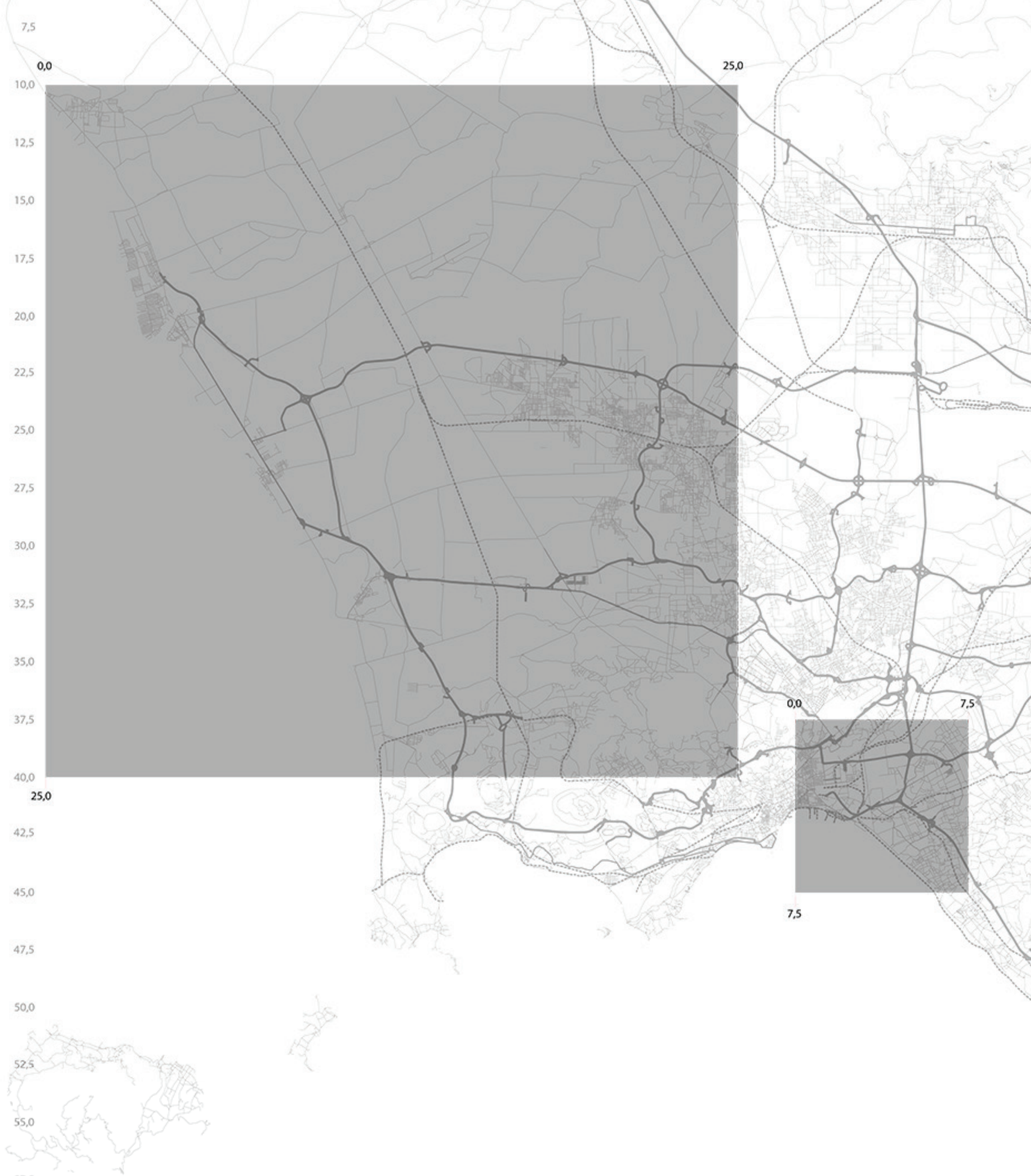
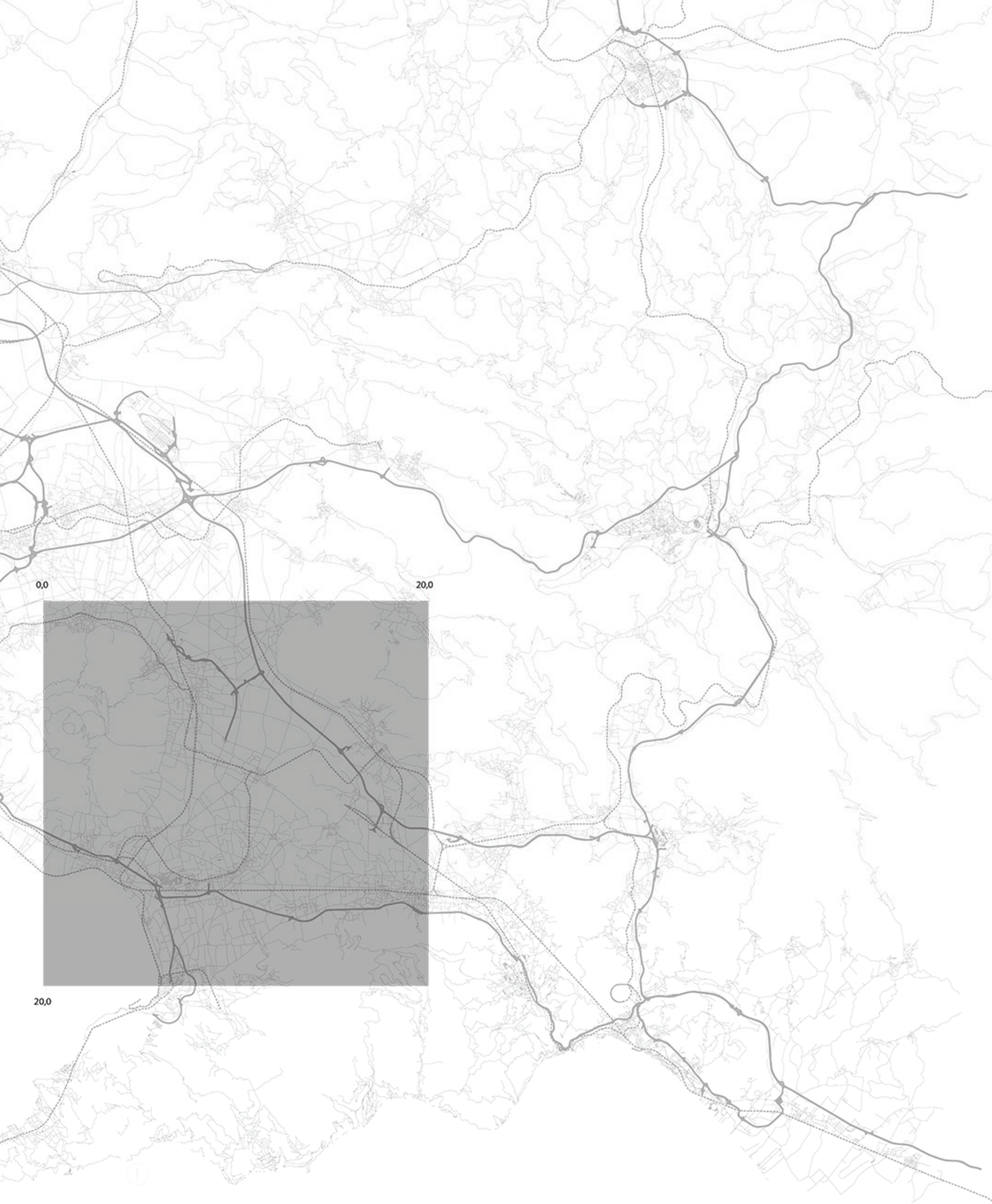


fig. 1.3 | the PRIN study areas. From left to right: the Domitio-Flegreo Coast, the plain of the Sebeto River, the Plain of the Sarno river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built environment in the post-production city; the second is the new urban ecological dimension.

Specifically, the research unit of Naples[3] focused on 'Re-cycling and Re[land]scaping the Drosscape'. Within its research work, amongst other aspects, a methodology has been implemented in order to map drosscape and assess it according to a multidimensional, qualitative-quantitative approach. The methodology was tested on three study cases, all of them referring to three river basins in Campania Region and classified as SIN or SIR[4]. These are (fig. 1.3):

- *Domitio-Flegreo coast*, situated in the north side of Naples and affected by the spread of legal and illegal landfills which contribute to the degradation of ecosystems. This area comprehends the Regi Lagni water basin;

- *Plain of the Sebeto River*, in the oriental side of the city of Naples, mostly characterised by the presence of abandoned industrial areas;

- *Plain of the Sarno River*, in which urban sprawl, pollution and contamination have contributed to the weakening of the territory.

This Ph.D. research starts from these premises, to understand the role of drosscape in Complex Adaptive Systems employing the Plain of the Sebeto River as study case. The research benefits from the latest social-economic data collected in the official documents, as well as the data coming from the *Autorità di Bacino Regionale della Campania Centrale*, specifically those elaborated within the PSAI[5].

1.7 | Outline of the dissertation

This research work is articulated in seven chapters.

Chapter 1 introduces the main subject, together with the aim and its relevance. In order to highlight such relevance, in this part evidences and solutions to the following research question will be provided: how can drosscape be used as raw material within the urban tissue in order to implement Green-Blue Infrastructure.

Chapter 2 provides a focus on drosscape, through a literature and theory review. It consists of two parts. The first part investigates the different definitions that have been used to better explain the concept of void within the urban context. This consequently concerns the identification of different aspects in relation to the typology of void that is taken into account time after time. The second part of the chapter identifies the values and the factors that come into play in relation with drosscape. Specifically, it is argued the ecological value of drosscape, together with the social and economic values and the critical issues. Furthermore, the morphological aspects are taken into account and described trough the lens of landscape ecology. The aim of this section is to highlight both the criticalities and the potentialities of drosscape, going beyond its conception of 'wasted land'. This interpretation, indeed, is a heritage of the same economic regime that mainly gave rise to drosscape, and which tends to underestimate the potentialities that come from the social and the environmental aspects.

Chapter 3 introduces the concept of resilience, its evolution in time and the reason why it is important for the definition of Complex Adaptive Systems. Moreover, this chapter describes the meanings and the implications in conceiving cities as complex adaptive systems. Here, the role of drosscape is analysed as indicator of resilience loss within urban systems. Furthermore, through the lens of the Dutch Layers Approach,

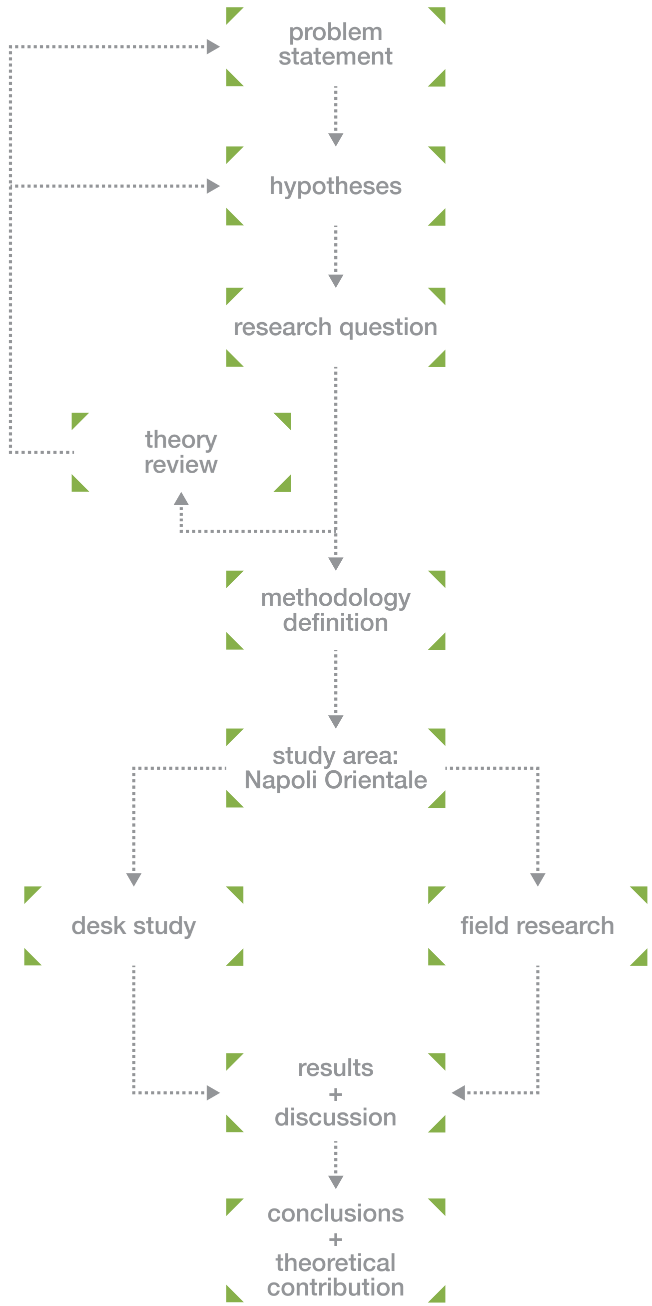

fig. 1.4 | Outline of the dissertation

drosscape is observed and described, to identify the variety of typologies of relationships that it establishes with the city and its parts.

Chapter 4 is composed by two separated sections. The first one provides an overview on the emerging role of the landscape for adaptation strategies, taking into account the theories that come from Urban Ecology and Landscape Urbanism disciplines. The second one focuses on Green-Blue Infrastructures, analysing the diverse proposed definitions for this concept, and describing their role in water management. In the latter section, the benefits of Green-Blue Infrastructure will be stressed out, and the four domains approach will be presented as a tool to address the role of drosscape as a peculiar urban landscape in water management.

Chapter 5 represents the core of this research work. It describes the developed methodology and its implications for the reintegration of drosscape in urban systems. It underpins the role of drosscape as a descriptor of fragmentation conditions within complex adaptive systems, and provides a set of parameters that are useful for the assessment of wasted lands according to the different typologies of vulnerability and their degree of susceptibility to transformation. Two sets of metrics will be proposed within this chapter. The first set aims to describe drosscape mainly from a morphological perspective, the second one identifies those multi-dimensional parameters that can be used to guide the implementation of GBI.

Chapter 6 describes the case study researches of Napoli Orientale. The chapter is divided into two sections. The first one introduces the study area, outlining its history and the socio-economic drivers that have been determined land use and morphological transformations over time. This section concludes with a description of the current state of the area, and the critical issues related both to the environmental risk and the flooding risk. The second section focuses on drosscape in Napoli Orientale. Here each identified category of drosscape is illustrated and studied in terms of spatial and relational features, returning a set of information that describes the geography of voids that characterises the study area

Chapter 7, the last one, re-articulates the scope of this research and its usefulness. The centrality of drosscape for redevelopment processes is highlighted here. In addition, it is explicated what are the dynamic relationships that drosscape establishes with the urban system, underpinning the critical aspects that can impede the implementation of adaptive recycle of wasted lands and the opportunities that they offer. The relationship between these key points and the hypotheses in the light of the main theoretical frameworks considered in this thesis is clarified. The role of drosscape as a descriptor of cities' resilience is emphasised. Suggestions to the case study are proposed as reflections of the conclusions on current approaches to adaptive strategies linked to redevelopment processes.

Endnotes

1 The *Low Elevation Coastal Zone* refers to the specific area and population up to 10 m elevation (Vafeidis, Neumann, Zimmermann, & Nicholls, 2011)

2 http://recycleitaly.net/il-progetto/

3 The 'Re-cycle Italy' Unit of Naples is composed by: Carlo Gasparrini (scientific coordinator), Vito Cappiello, Antonio Cavaliere, Massimo Fagnano, Lodovico Maria Fusco, Fabrizia Ippolito, Rocco Lafratta, Antonio Passato, Marina Rigillo, Michelangelo Russo, Roberto Serino. The Laboratory of Naples is composed by: Fabrizia Ippolito (site responsible), Anna Terracciano (operations coordinator), Libera Amenta, Daniele Cannatella, Danilo Capasso, Susanna Castiello, Gennaro Cozzolino, Emanuela De Marco, Cecilia Di Marco, Davide Di Martino, Nunzio Fiorentino, Enrico Formato, Paola Galante, Adriana Impagliazzo, Massimo Lanzi, Francesco Stefano Sammarco, Antonella Senatore, Ciro Sepe, Giancarlo Sorrentino, Sabrina Sposito, Danilo Vinaccia.

4 SIN areas are those in which the amount and/or type of pollutants pose a risk to the environment and to human health, and at the same time, they can also prevent the development of areas of strategic importance for their historical and scenic prerogatives, namely for the opportunities of land development which would achieve their rehabilitation (ARPACAMPANIA, 2009)

5 The PSAI is the Hydrogeological Structure Plan (Piano Stralcio di Bacino per l'Assetto Idrogeologico), adopted by the Institutional Committee with resolution n.1 on 23 February 2015.

02 The values of drosscape

2.1 | Introduction

Land is shaped according to human needs, driven by economic models that grow, experience an exploit, and then plunge into crisis. When a macroeconomic transformation happens, several leftovers remain within urban systems, almost as symbols of human failure. Alan Berger (2006) named these areas *drosscape*. According to Berger's definition, drosscape is made by all those areas at end of their life cycle, sharing conditions of abandonment, rejection and disposal. These voids are the direct consequence of the rapid horizontal urbanisation, as this peculiar phenomenon triggers hybridization dynamics within the urban environment.

As cities changed their shape, they have been undergoing through a progressive juxtaposition between nature and built environment, which involved a wide range of uses such as agriculture, dwelling and production, together with all the related spaces. Consequently, human activities and the connected urban, economic and social trends were been subjected to an acceleration that progressively made territories no more able to absorb and deposit the effects of this change. Furthermore, these dynamics contributed in time to the hybridisation of the urban environment. These hybrid conditions of contemporary cities undermined the conception of city as a continuous and regular space able to unify individuals, society and environment (Secchi, 2000). On the contrary, this trend has resulted in an explosion of a myriad of lives, landscapes, waste, contributing thus to the creation of the basis for conflicts and inequity. This profound crisis of values reverberates as well within an environmental emergency, recognisable in all those sites used in the recent industrial past, as well as in other sites related to production and resources extraction.

Indeed, the market-driven economy that characterised the past century based itself on *input-output* processes. Cities established a 'linear' relationship (Fusco Girard, 2012) with their surrounding environment, built on logics of resources exploitation and consumption – input – and waste dumping – output. Undoubtedly, human waste is not completely absorbed by the environment anymore, resulting in an increasing environmental degradation and economic loss. Nonetheless, the role of waste is predominant in humankind history: it has always been a priceless resource for the city, as its reuse and recycle played an important role within the history of cities (Pavia, 2014).

Furthermore, the gradual drift between the physical frame – provided by the territory – and the activities – which determine the metabolism of the cities – more and more resulted in a lack of synchrony that nowadays causes a large amount of wasting lands, 'frozen fragments of built and natural environment, expelled from the metabolism of the city' (Lanzi, Cannatella, De Marco, & Sposito, 2014). In this framework, a new geography made up of dross arises, through which the vacuum acquires a new and fundamental meaning. Therefore, voids gain a completely new meaning, making clear their substantial ecological, economic and social potential. As Gasparrini pointed out (2014), within the void, 'the density of landscape becomes the main key factor, in its most dynamic definition'. The reason is identifiable in the abundance and multiplicity of demands and actions that converge towards these spaces, and in the way they can trigger connections between flows and places.

The intrinsic potentiality that characterises void, thus, brings to a substantial shift of attention towards a redefinition of the values within cities and the role of landscape. Certaintly, brownfields, landfills, unfinished buildings and all those elements that city tends to refuse for the most disparate reasons are not just *waste*: they become a set of devices, strongly connected and intertwined to the city and its system of networks.

However, dealing with wasted lands could not be simple at all. Demolition of industrial buildings is often extremely expensive and, arguably, it is not often the preferable option. In addition, not rarely these areas present contaminated soils and water – both the superficial hydrographic system and the groundwater system – claiming for remediation processes. Furthermore, as they become marginal parts of the city, the consequent lack of control generates several dangerous social issues. The condition of marginality, then, is not only related to the physical position and to the degree of connection of wasted areas: it shows itself through the vast amount of unformal activities – often even illegal – that proliferate, due to the absence of any kind of regulation.

The landscape of waste can have different meanings. As Berger (2006) stated, voids that emerge out from the urbanised environment can be actual *waste* – for instance, municipal solid waste, sewage, etc. – *wasted* places – such as abandoned and/or contaminated sites – or *wasteful* places – such as huge parking lots, retail malls, etc. All of these spaces and buildings are tangible products on the planet's surface of the contemporary modes of industrial production, conceived in a consumerist logic. From this perspective, the processes of the city are similar to those of a living organism: within an urban system, waste is expelled and then reintegrated, becoming relevant part of the landscape and acquiring new meanings. According to Berger, this is a natural process, since cities are not static structures, but open systems, crossed by flows of energy that continuously trigger transformations over time. Hence, time itself becomes an important key in the understanding of how landscape, buildings and, more generally, all anthropic transformations are not permanent but transitional structures. Additionally, time becomes the proper device through which interpret and understand this phenomenon. The state of dereliction that defines wasted lands is the by-product of the absence of change in time, and consequently suspension appears. Thus, it is a suspension that generates voids. The latter, in turn, become spaces waiting for an act of destruction (Doron, 2000) that can trigger a change. At the same time, transformation is led by growth. In this perspective, it becomes clear that there is no growth without waste. Within cities, in the processes of transformation and evolution, urban landscape is a natural thing to waste, and for this reason drosscape can be interpreted as a proper indicator of a healthy urban growth (Sagan & Schneider, 2005).

Nonetheless, on the contrary, drosscape is a clear signal of resilience loss of an urban system. A massive presence of drosscape within the urban tissue often discloses the effects of an economic contraction, perhaps exacerbated by a narrowly specialized economy. Consequently, the city becomes less able to cope with natural and anthropic shocks and stresses, as the whole system is pushed toward the threshold beyond which recovering is not possible anymore and, actually, increasing the probability of a system to collapse. The vicissitudes of the city of New Orleans (fig.2.1) are a clear example. Before Hurricane Katrina, the American city was experiencing a period of decline, which started in the early 1960s and continued for forty years. Economic decline and depopulation contributed to the scarce maintenance of the water regulation systems (Campanella, Etheridge, & Meffert, 2004; Ernston, et al., 2010), setting the conditions for one of the five deadliest hurricanes in the history of the United States[1].

Drosscape is a broad concept that considers different spaces united by a state of suspension and/or abandonment. Such lands are not easily definable. In time, several definition were proposed to describe them. In the next paragraph, some of the most relevant concepts describing this peculiar urban landscape are analysed to take into account the different aspects that characterise them.

2.2 | A multitude of labels for one issue

Waste is a broad concept that includes the most disparate aspects of life. It is closely connected with the path of growth of any living organism and, at the same time, it has to deal with the different values that it can acquire. In nature, waste is a fundamental component for the activation of

fig. 2.1 | New Orleans, one day after Hurricane Katrina made landfall. Photograph: Smiley N Pool/AP. Source: www.theguardian.com

cycles: the waste of some organisms is, in all respects, a resource for some others. Within societies, this principle remains intact. In history, buildings have been dismantled in order to reuse their materials for other purposes, as needs or beliefs of societies changed over time; entire portions of cities have been abandoned, and successively rebuilt. Abandonment and redevelopment processes can take place for disparate reasons. Not infrequently, the main reason of the decline of a city can be found in the hyperspecialisation of its economy, which brings to a decrease in flexibility and a consequent difficulty to shift toward new activities (Lynch, 1990).

The causes that drive toward the abandonment and waste of land are various. For instance, some activities generate irreversible resources consumption – as it happens with mining activities – while some manufacturing processes contribute to the massive contamination of soils and waters. These activities, thus, bring the land through a state of dereliction, making it ‘simply unpleasant or dangerous’ (Lynch, 1990). At the same time, waste ground can be determined by uses that are not desirable, although they are essential in order to guarantee the efficiency of a city or a region. Beside this aspect, their relative geographical position unavoidably deals with the development of urban systems. Airports, distribution centers, industries, as well as dumps and incinerators: although these places have been initially located in the fringes of the cities, urbanisation processes had resulted rapidly in their reappearance at the centre of the city.

Despite this, abandoned lands are not only described by their state in present time: their values find more deep roots in their past, as well as in their future and in the vast range of possibilities they can have. The condition of dereliction should be contextualised as a narrow phase in a broader timeframe, during which a portion of land has been hosting a set of different activities, and in all likelihood, it will keep on hosting others in the future. Once again, time can help describing these places, as they are the result of dynamics of suspension and crises, and, at the same time, they offer the opportunity to produce development processes; they can recall themes related to the ever-accumulating past and cycles.

However, giving a precise definition of dereliction is not simple at all, and numerous terms have been used in time to name these places.

The concept of wasteland has been associated with the notion of *heterotopia* (Foucault, 1998; Hall, 2013), places in which is not possible to find either good or evil, as they are simply characterized by their state of ‘being different’. Michel Foucault was particularly interested in those that he defined as counter-sites, in which ‘the real sites are simultaneously represented, contested, and inverted’ (Foucault, 1984), coining the term heterotopia, in contrast with those utopian spaces, characterised by ‘a general relation of direct or inverted analogy with the real space of Society’ (*ibid.*). For this reason, they can intrinsically offer a vast number of interpretations, as they can assume different meanings and establish a multitude of relationships with other places, contributing to their

fig. 2.2 | Highway#1 Intersection. Los Angeles, California, Photograph Edward Burtynsky. Source: http://www.americanphotomag.com

definition and understanding. However, they are places of duality and contradictions: as the mirror does, they provide an image that does not exist in reality and, at the same time, they are real and tangible objects located in space.

Foucault identified six principles able to describe heterotopias:

- The first principle states that every single culture is able to constitute its own heterotopias. Nonetheless, the latter can show themselves in various forms and shapes. This implies that a universal form of heterotopia does not exist, thus it is impossible to be found.

- The second principle argues that a society can make an existing heterotopia function in a different fashion. In other words, every heterotopia can change in its functions according to the evolution of society and its needs.

- The third principle highlights how a heterotopia is capable of juxtaposing several spaces, even the incompatible ones, in a single real place.

- The fourth principle claims that heterotopias are often linked to time – in particular, to short timeframes.

- The fifth principle states that heterotopias are not freely accessible, like a public place.

- The sixth and last principle asserts that heterotopias have a function in relation to all the space that remains. This function can have two opposite meanings: the first one is that they are able to create a space of illusion that clarifies and exposes how more illusory the other sites are; the second one defines their role in the creation of a perfect space, in opposition to the messy and ill constructed one in which we live.

Wasted lands are, thus, the result of all those hybridization dynamics and processes within the urban tissues, which emerge both in the spatial and in the temporal dimensions, carrying out conditions of vacancy, dereliction, contamination, obsolescence. Although they can show themselves in several ways – either in morphological and spatial terms – they are present in every society as heterotopias, regardless of any meaning they can have. Nevertheless, with the concept of *Terrain Vague* (Solà-Morales, 1995), the potentials of these places have been progressively rediscovered.

The *terrains vague* of Solà-Morales are indefinite spaces without any use nor function; they are the palpable form of absence in the contemporary metropolis. Starting from the etymological choice of the terms 'terrain' and 'vague', Solà-Morales clarifies the multiplicity of meanings that these residual spaces express. The etymology of the word is not casual: the word *terrain*, a French term, is able to connote a qualitative aspect that goes beyond the mere meaning of piece of land; in addition, it refers to less precisely defined territories that are already characterised by a definition. The word *vague* derives from the French too, but it finds its roots both in Latin and Germanic languages. The Latin word *vacuus* can be translated as 'unoccupied', but also as 'free, unengaged'; the German term *Woge* alludes to movement, instability, fluctuation.

These places are physical voids, but not mental vacuums. They provide opportunities and hope; in such spaces a sense of freedom exists, as they are free from all the regulations and the constraints of the city. It may seem a paradox, but their state of obsolescence makes some residual values survive. Once the mere economic aspect collapses and they end at the fringe of the city, these spaces become 'foreign to the urban system, mentally exterior in the physical interior of the city, appearing as its negative image as much in the sense of criticism as in that of possible alternative' (*ibid.*). However, this dualism represents the key for understanding these spaces, as they present both a spatial connection and a social value, and at the same time, they are defined by their marginalization condition and a sense of alienation: 'spaces as internal to the city yet external to its everyday use. In apparently forgotten places, the memory of the past seems to predominate over the present.' (*ibid.*). As ruins within the more comforting order of the urban tissue, they make us aware of our history, since they are the present form of a past life, according to their past as such (Simmel, 1958; Hansen, 2010).

Another interesting and useful way to describe these voids is by putting them in relation with the other parts of the city. Hormigo and Morita (2004), for instance, coined the term *gapscape* in order to define empty spaces that tend to be considered vacant. In this case, the use of the word ‘gap’ is functional to highlight their condition of being intervals, both in a spatial and in a temporal dimension. Here, the meaning of these areas is reversed: an interval cannot exist itself, but it is defined by a set of limits and the context. It is something that breaks the continuity between homogenous elements: an interruption. These gaps contribute to create spatial fragmentation within the continuous urban context, for their conditions of exclusivity and restricted access, offering an interpretation of emptiness based on the idea that they are a product of density and pressure.

Despite their conditions of gaps, wasted areas can offer a wide range of opportunities related to uses. Doron (2000) points out that not rarely, these areas labelled as ‘dead zones’ are actually vibrant and experienced by different people. Furthermore, within these spaces nature slowly appears and starts to reconstruct the built environment, establishing a ‘cyborgian landscape, not an Arcadian one’ (*ibid.*). He defines these places as ‘landscape of Transgression’, as they are simultaneously in any place and in a non-place. In addition, the term ‘dead zones’ is closely related to the conception of time, because of the temporariness and impermanence that characterise such spaces, consequently setting conditions of suspension. That is precisely the spark from which wasted lands generate.

Another frequently used term is *brownfield*. According to the US Environmental Protection Agency (2016), a brownfield is ‘a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of hazardous substance, pollutant or contaminant’. The term refers mainly to the abandoned or under-used industrial facilities that are in a state of suspension due to high costs of remediation processes. Thus, it becomes evident that within brownfields there is often a clear correlation between industrial processes and environmental resources (Bélanger, 2009). The redevelopment of these sites is fundamental for several reasons: their strategic position, since they are located close to transportation and local workforce, as well as the opportunity they provide to create jobs and revitalize the economy. Nonetheless, brownfields call for recolonization strategies based on the restoration or the reintroduction of natural processes and features of landscapes (Shannon, 2006). This represents a useful opportunity for experimentations and studying urban ecology in a more free and secure way (Berger, 2006), therefore stimulating creativity of designers, planners and citizens. This is particularly true in the light of the recent growing awareness with regard to the need of crossing sectorial boundaries and approaches for remediation interventions.

2.3 | Drosscape and life-cycles

The lack of control of life-cycles related to industrial, agricultural, commercial uses and other kinds of activities, together with their unavoidable depletion, has produced massive repercussions on the environment, accelerating the exhaustion of primary resources, such as soil and water. Thus, arguably, cities have altered the natural metabolism, exacerbating the dichotomy between society and environment. This happens in the same historical period in which any spatial separation between city and country is no more easily recognisable, and the boundaries are dramatically blurred. In the light of metabolism concept, this dichotomy finds an interpretation, provided by the environmentalist Girardet (1996). He argued that the natural world is characterised by a ‘circular’ metabolism, in which one organism’s waste is another’s sustenance while a ‘linear’ metabolism characterises the city, in which resources enter, and waste goes out.

However, introducing the concept of life-cycle for urban systems means that the latter should be considered as an actual ecosystem. Thus, city can be intended as an open system, through which energy, material and information flow, and resources are imported and processed, and subsequently exported as goods or wastes (Wolman, 1965; Brunner, 2007; Pickett, Cadenasso, & McGrath, 2013). Understanding cities as urban ecosystems highlights the relation between efficiency and waste: the less efficient the use of resources is, the more wastes are produced and contamination increased.

Working with waste landscapes puts more emphasis on the need of a shift of paradigm, from the linearity to a circularity of the city's metabolism, which pays more attention to the environmental dynamics and works together with nature. Thus, wastelands cannot be considered only from an economic perspective. On the contrary, they can play a crucial role in activating new life-cycles for the city. As Paola Viganò (2012) observed: 'What remains on the ground, the leftover, the materials, artefacts and infrastructures that have supported the formation of an economic and social capital are not a minor or marginal constituent of the possibility to open new cycles.' According to this sentence, drosscape is not just a mere void within the urban tissue. Instead, it is a primary feature of the landscape conceived as infrastructure, consequently becoming a resource itself, especially in the highly urbanised context of European cities.

Carlo Gasparrini (2013) pointed out that drosscape's regional and landscape dimension can trigger recycling strategies that are multi-scalar, involving the single fragment of wasted land, and the set of urban relations that the fragment itself can activate. In this regard, recycling drosscape is closely connected and intertwined with the system of rural-urban spaces, as well as the network of superficial hydrology and the transport infrastructure. The potential of drosscape, then, reveals itself in the opportunity to constitute a new 'backbone' from which to start for the design of Green-Blue Infrastructure (see paragraph 4.3), linking together all the systems that make up a city.

Nonetheless, reactivating new life cycles implies the development of strategies in time. This because not rarely wastelands are subjected to remediation processes, due to condition of soil pollution for the former activities they used to host. The urgency of a reintroduction of these areas claims for an integrated approach which is able to mix a broad long-term vision with a set of temporary activities.

2.4 | Mapping drosscape

In order to represent the real world, men have always been using maps. Maps as a tool for understanding and explaining phenomena are a mix of conventional signs and symbols that are only the last output of a process of selection and reduction that can afford to avoid perfection (Rossi, 2014). Reduction, thus, is a simplification of reality that must deal with limitations in order to make maps able to communicate information. Klaasen (2004) summarises some of the aspects that are often excluded or represent a limitation in drawing maps. These are:

- Non-visible components. These components are often left out of maps, even if a city can be experienced not only by sight, but also with other senses;

- Societal processes. They are extremely hard to catch, since they are not visually apparent;

- Spatial scale. Maps, as models, are scaled down representations. This implies that the visual or non-visual perception point in reality is inevitably different from the one from which we view the model;

- Temporal dimension. The inability to illustrate the temporal dimension implies that 'time' and 'process' can only be indicated indirectly (for instance, using arrows, isochrones, etc.).

All these aspects are even more pronounced and noticeable when approaching the *reverse city* (Secchi & Viganò, 1998), which worms itself in marginal areas related to transportation infrastructures, hydrographic systems, the horizontal city, the abandoned areas and buildings, etc. According to Piero Ostilio Rossi (2014), two-dimensional maps are no longer sufficient to identify and represent drosscape, and none of the tools that technology provides nowadays is able to return a convincing portrayal of these phenomena.

fig. 2.3 | Land use maps of Naples (a) and Rotterdam (b). Source: EEA, Urban Atlas. Year: 2009

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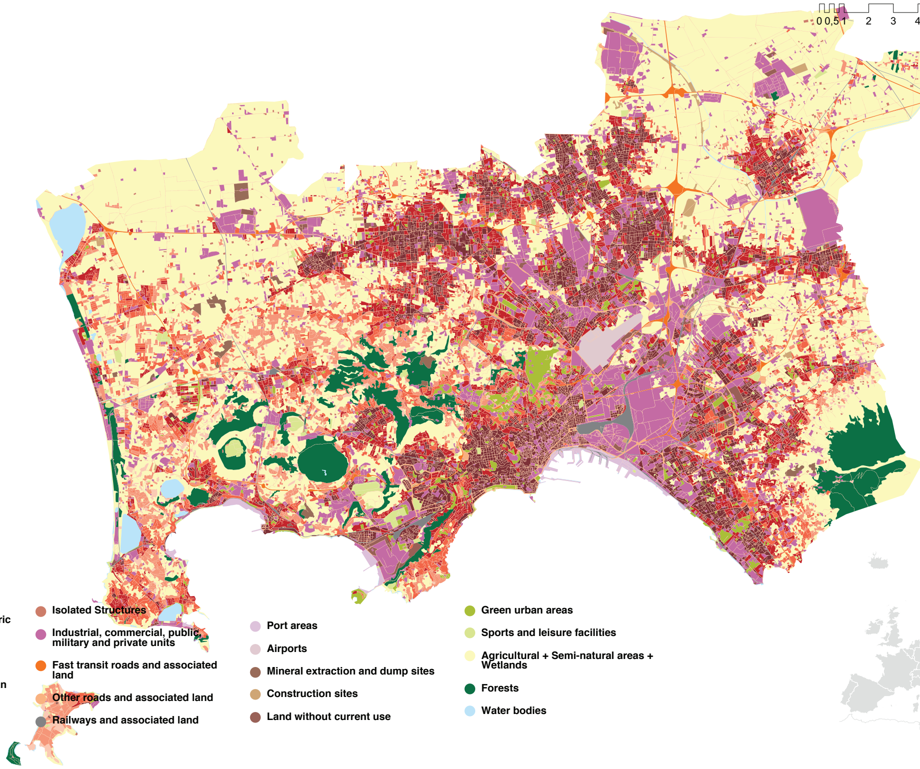
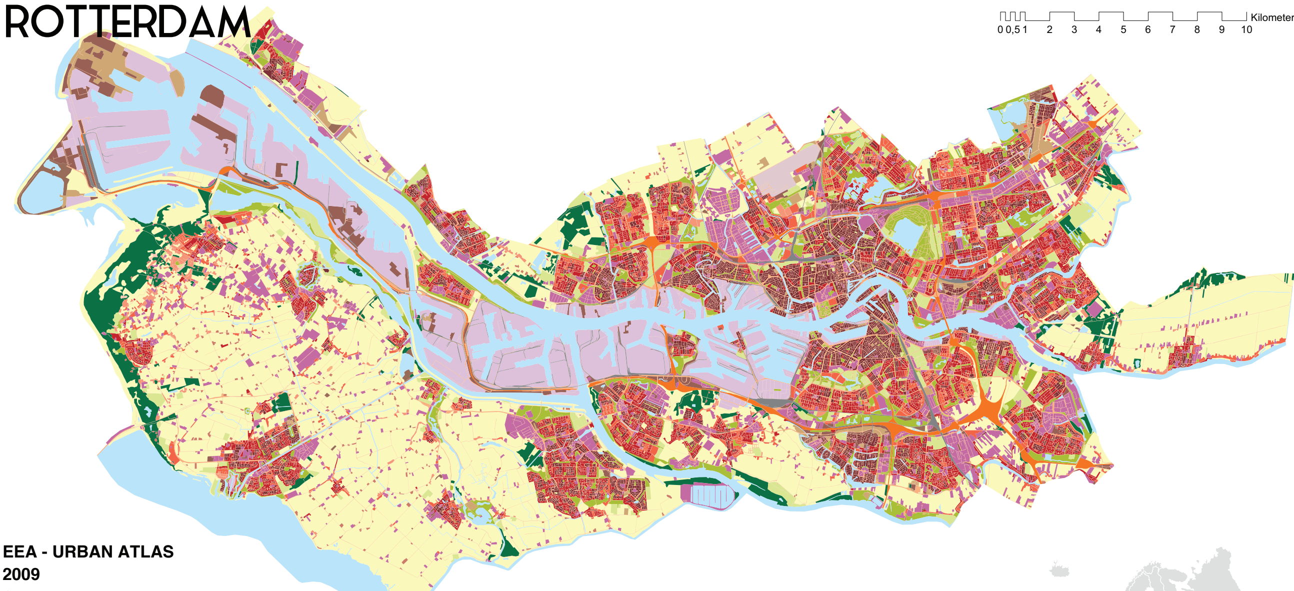


EEA - URBAN ATLAS
2009

- Continuous Urban Fabric (S.L. > 80%)
- Discontinuous Dense Urban Fabric (S.L. : 50% - 80%)
- Discontinuous Medium Density Urban Fabric (S.L. : 30% - 50%)
- Discontinuous Low Density Urban Fabric (S.L. : 10% - 30%)
- Discontinuous Very Low Density Urban Fabric (S.L. < 10%)
- Isolated Structures
- Industrial, commercial, public, military and private units
- Fast transit roads and associated land
- Other roads and associated land
- Railways and associated land
- Port areas
- Airports
- Mineral extraction and dump sites
- Construction sites
- Land without current use
- Green urban areas
- Sports and leisure facilities
- Agricultural + Semi-natural areas + Wetlands
- Forests
- Water bodies

ROTTERDAM



EEA - URBAN ATLAS
2009

- Continuous Urban Fabric (S.L. > 80%)
- Discontinuous Dense Urban Fabric (S.L. : 50% - 80%)
- Discontinuous Medium Density Urban Fabric (S.L. : 30% - 50%)
- Discontinuous Low Density Urban Fabric (S.L. : 10% - 30%)
- Discontinuous Very Low Density Urban Fabric (S.L. < 10%)
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- Railways and associated land
- Port areas
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- Mineral extraction and dump sites
- Construction sites
- Land without current use
- Green urban areas
- Sports and leisure facilities
- Agricultural + Semi-natural areas + Wetlands
- Forests
- Water bodies

Drosscape claims for a further effort, in order to grasp the dynamics and the flows that it involves and triggers, and to describe them in a deeper and more satisfying way, through processes of information synthetisation, which does not necessarily mean simplification. For this reason, the act of mapping drosscape is the field in which topology should be preferred to topography (Gasparrini, 2014), leaving room for interpretation rather than slavish and uninspired description. The identification and mapping of drosscape, thus, cannot avoid those parts of the city that are directly or indirectly involved in the dynamics that contribute to the production of waste lands (Lanzi, Cannatella, De Marco, & Sposito, 2014).

In addition, in mapping drosscape, the spatial and the temporal dimensions constitute a thorny issue. Since they are a multi-scalar phenomenon, residual areas can be found within the more compact urban tissue as well as the horizontal and dispersed city, and they can have considerably different size and shape. This means that cartographies produced by administrations or institutions are not able to return an extensive overview of all this fragments. Maps have another limit as well: they are fixed representation of certain phenomena, and in a certain moment. Consequently, they hardly can return phenomena that reveal themselves in the transitions from a land use to another, in time windows that can be very short or can take decades (fig.2.3).

In this sense, the spatial and morphological features of these areas become fundamental, together with the production of new forms of representation and new ways of localization and mapping. Indeed, connecting drosscape with recycling necessarily involves dealing not only with the physical parts of the city, but also with social and political dimensions. This implies an additional effort for designers: they need to work ‘in a bottom-up manner, conducting fieldwork while collecting large-scale trends, data and phenomena in search of waste’ (Berger, 2006). These conditions call for a solution. It is not clear until what point it is acceptable to conceive drosscaping as ‘a sort of scavenging of the city surface for interstitial landscape remains’ (Berger, 2006). In order to make this practice clear, scalable and transferable, it needs to find some rules that can be applied

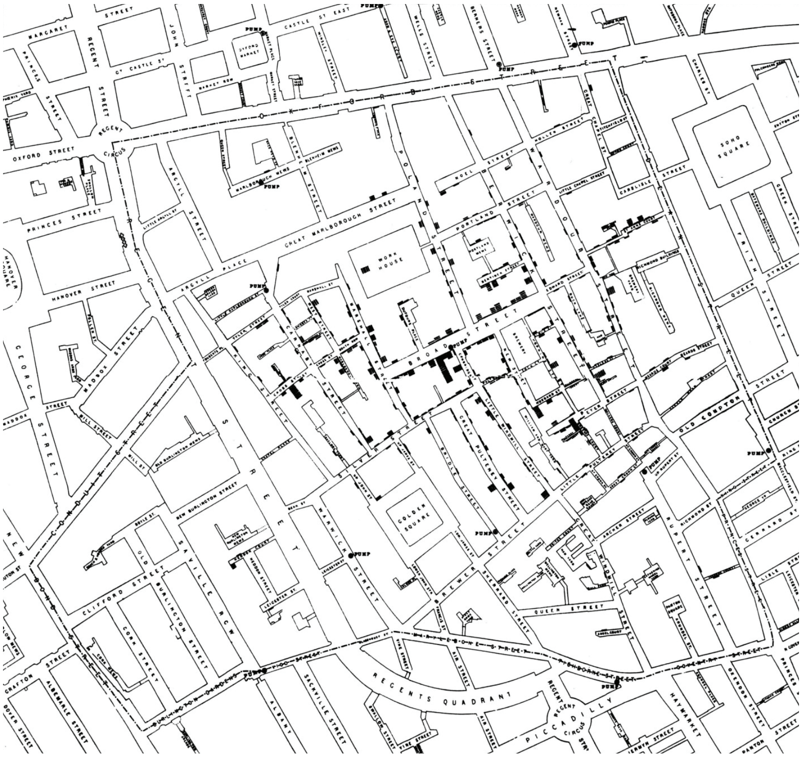

fig. 2.4 | The "Ghost Map", made by doctor John Snow

in the process. This happens because of the difficulty to grab processes that are faster than cartographic productions; furthermore, because of the multi-scalar nature of this phenomenon, both cartographic and thematic maps cannot provide a wide and satisfactory description.

From this perspective, mapping drosscape seems to be a practice similar to the one made by John Snow[2], an English doctor that, during the second half of the nineteenth century, used a map to illustrate the outbreak of cholera in the Victorian London. Following his intuition, Snow started to map the addresses of people who died for the disease in the neighbourhood of Soho, correlating this information with the position of water pumps and a proto-version of isochrones to highlight the area within which reaching the pumps was more comfortable. Finally, he found that the cause of the spreading of the cholera was a water pump located in Broad Street (fig.2.4). The intuition of doctor Snow, together with the use of a map to correlate phenomena that apparently did not have any relation gave an enormous contribute to science. That moment was one of the first times in which a map was used for medical purposes and, above all, it represents a brilliant example of how to mix human behaviour and social habits in relation with the morphology of the city.

2.5 | The values of wasted land

As already stated in the previous paragraphs, although drosscape is often described as a void that puts itself on contrast with the 'fullness' of the city, it does not correspond to a total absence of meanings. Arguably, such a viewpoint is closely related to the same economical and consumerist influence which contributed to the formation of waste landscapes (Berger, 2006). Such hidden meanings find their roots into a wide range of diverse aspects. They encompass the perception sphere as well as the presence of uses; the cultural domain, thanks to drosscape's capacity to tell a piece of history of a city, as well as the imagination that such places can trigger; both the environmental criticalities and the potentialities that wasted lands present. Such range of values emerges only when one goes beyond that kind of investigation involving methodologies which view these places from a distance, in order to understand that much more often that it might appear, wastelands are not waste at all.

In order to elucidate more clearly what are the potentialities and the criticalities related to drosscape, the values of wasted lands will be summarised in this paragraph according to four different categories: social values, economic values, ecological values, spatial values.

The social value

> 'Wastelands are the havens of rebellious, marginal, illegal people, [...] they are places of despair, but they also shield relicts, and the first weak forms of some new thing [...] They are places for dreams, for antisocial acts, for exploration and growth' (Lynch, 1990).

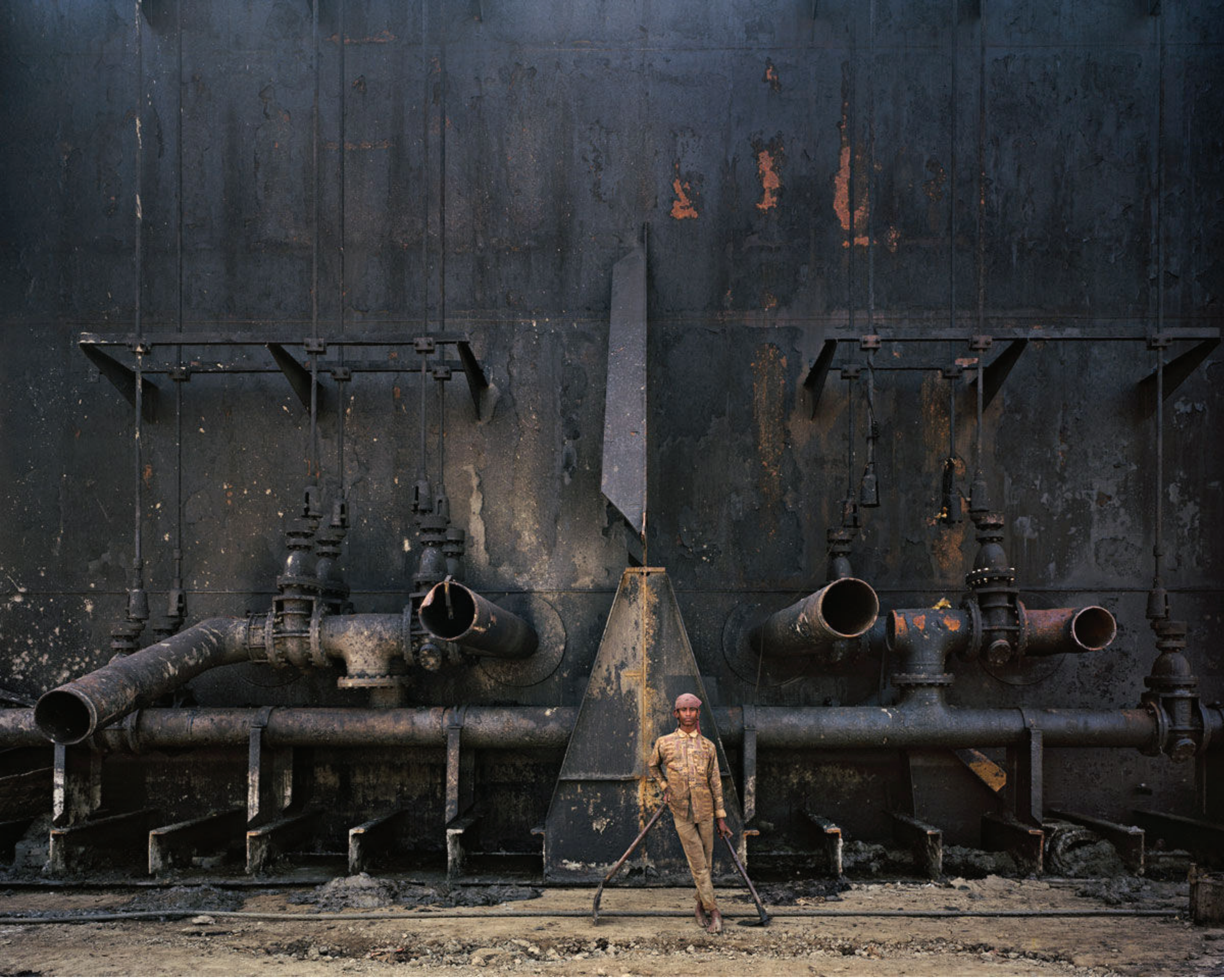

fig. 2.5 | Shipbreaking #23, Chittagong, Bangladesh, 2000. Photograph Edward Burtynsky. Source: http://www.americanphotomag.com

In his paper 'The Dead Zone and the Architecture of Transgression' (2000), Doron tells about the work done by the Civic Trust[3] for the publication *Urban Wasteland Now*. The Civic Trust conducted a survey involving people who lived near abandoned areas. The results were, in some way, surprising: almost the 60% of the interviewed people stated that those areas were an asset. Moreover, the survey revealed that those sites hosted informal uses. On the other hand, drosscape was perceived as 'ugly' and 'dirty', making people claim for intervention. In his comment to these findings, Doron observed that the nature that had taken hold of these places and the informal activities that were there, were not disordered, but they were simply characterised by an order of a different kind. Such disorder, in some way, is the main feature that makes drosscape appealing. In fact, even though wastelands are undoubtedly physical voids, one of their main intrinsic values is related to the sense of freedom that they provide, together with the creativity they can boost.

Furthermore, abandoned areas can have benefits. The price level of houses, for instance, is lower than the one in other parts of the city. However, the other side of the coin is the low aesthetic quality of the environment. Wasted areas, as they are conceived as proper waste, are perceived as the tangible and appreciable epitome of loss and abandonment, the incarnation of the decline. Nonetheless, this set of conditions can nurture activities and uses that, although far and marginal from the more consolidated uses of the other parts of the urban system, can represent a resource for the enhancement of urban resilience. Arguably, it is possible to find some resemblances with colonization and ecological succession processes. For instance, after a wildfire, pioneering species begin to appear in the damaged area, triggering a chain of ecological successions that lead to an increase of the complexity of the ecosystem, towards a steady-state ecosystem itself. In the same way, drosscape can experience processes that are characterized by similar steps: the social pioneers can be some peculiar groups of people that take advantage from the lowering of the control level due to a lack of interest in those areas, preparing the field to a subsequent 'social chain' of successions.

This emphasises an interesting correlation: drosscape, as *liminal space* (Turner, 1995), cannot be separated by the community and its formation process. It is in the etymology of the word *limen* – a Latin word meaning threshold, margin – that it is possible to find a particular insight. In his book, Turner identifies three phases that mark all rites of transition in communities. The first phase – the separation phase – foresees the detachment of the individual from an earlier fixed point in the social structure. During the second phase – the liminal period – the characteristics of the subject are not definable anymore, as he loses the attributes of the past state. The third phase – reaggregation or reincorporation – sees the reintroduction of the individual within the community, as he is expected to behave according shared norms and ethical standards superimposed by the community itself. Such condition of liminality is related to ambiguity, avoiding any classification: 'liminal entities are neither here nor there' (*ibid.*). Liminality that characterises drosscape makes it a heterotopic space, as it can offer a vast number of interpretations, in terms of meaning and relationships that it can establish with other places. However, they are places of duality and contradictions. They provide an image that does not exist in reality; at the same time, they are real objects located in space. These spaces, in which humans retreated in time, are no longer used; here it is possible to find some legacy of anthropization processes, together with the advancement of the nature, which is not enough to give back a perception of wild. These conditions make drosscape hybridised heterotopias, in which the constant interaction between man and nature becomes clear, as well as its results.

Of course, dealing with drosscape cannot be easy. As Kennet Frampton (1995) argued, filling the void represented by drosscape could be risky, since it might bring to a flattening of cultures and places. It is arguable that these fragments of landscape within the densely urbanised city constitute the proper environment in which novelty can take place. Indeed, drosscape is often subjected to a series of bottom-up processes (Berger, 2006), from which it is possible to learn useful lessons and take advantage from them to enhance urban resilience. Hence, drosscape becomes the ideal place through which it is possible to steer a shift toward a new adaptive cycle

(see Paragraph 3.5). The cultural values and the meanings that still resists in such places, which are in their reorganisation phase, are the basilar collection of information and assets from which the entire urban system can take advantage to adapt and cope with both environmental issues and socio-economic needs.

The ecological value

Exploring the potential of drosscape cannot avoid the ecological aspect. The main reason can be easily found within the former uses of wasted lands: permanently destroyed sites such as landfills and manufacturing sites need to deal with pollution conditions before being reintroduced in the urban metabolism. More in general, reusing drosscape can often be complicated for the presence of hazardous substance or contaminants. According to the European Environmental Agency (EEA, 2017), in the EU member countries, approximately 250000 contaminated sites are present, and potentially polluting activities are estimated to have occurred at nearly 3 million sites. On the other hand, remediation processes are progressing relatively slowly, as only 80000 sites have been cleaned up (fig.2.7). Unfortunately, the rate of cleaned up drosscape is still low.

However, the environmental potential of drosscape is very high even when it endures in its state of abandonment. Haid (2011) pointed out that urban wasteland is a form of interstitial wilderness, characterised by the spontaneous growth of vegetation. According to this vision, wastelands as wilderness acquire more importance, since they go beyond the cultural values and find additional value into the environmental sphere. This because, from an ecological point of view, urban wastelands can offer high degrees of biodiversity, thus becoming proper habitats for wild animals. Indeed, drosscape represents the place in which wilderness and the city, usually intended as opposites (Lerup, 2006), meet up with each other.

The spontaneous growth of vegetation in these spaces marks man's retreatment and wildlife's re-conquest, shaping a hybridised landscape, mixing nature itself with culture, adding a new meaning layer and

fig. 2.6 | photo: Valentina Procopio, Roccelletta di Borgia (Catanzaro), February 2017 amplifying the shades of interaction between man and nature in urban systems. However, the ecological importance of these areas is overshadowed by the common idea that they are waste or worthless land, without any productive use or any value. In addition, the role of perception is predominant: most of the time, wild nature is considered unattractive, in opposition to the homogeneous spaces shaped by capitalism.

Nonetheless, although wastelands' contribution to urban biodiversity is recognized to be ecologically significant, it is hard to assess, and the knowledge on this topic is still little (Hall, 2013). However, such ecological importance for the urban system widens the possibilities for a time-based design, since drosscape can be taken into account for the implementation of a green-blue network (see paragraph 4.5) even though initially it cannot be directly used for human purposes. This perspective opens to a set of temporary uses that foster a gradual reintroduction of drosscape in the city, and claim for a more awareness on the potential benefits and co-benefits that they can potentially deliver, in particular when they are designed according to a multi-scalar approach.

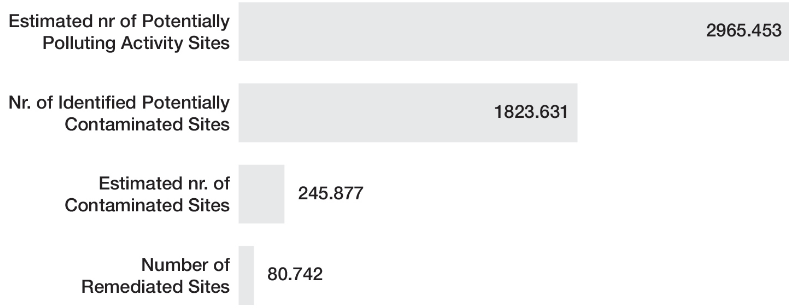

fig. 2.7 | number of contaminated and potentially contaminated sites in EU countries. Source: EEA. Year: 2006

The economic value

In the past, the majority of North Americans saw the land as something to be conquered and made productive (Hall, 2013). For this reason, it is not surprising that the choice of areas to protect was historically linked to an idea of uselessness, in which there was no profitable activity. Wilderness is still conceived as waste or worthless land, land without any value.

The heritage of capitalism forged the idea that in order to have assigned some kind of value, land needs to be made productive. Consequently, people usually do not assign some value to wastelands. Thus, the aesthetic aspect of these spaces plays a crucial role in defining their dereliction condition (Barr, 1969), contributing to the fact that the urban areas often contain more plant species than rural ones (Pysek, 1989). The presence of a high diversity of species within urban areas is the result of several processes (Hall, 2013). For instance, flows related to trade, transport and tourism ease the introduction of new species; in the same time, they provide conditions of isolation and hybridization, which facilitate the evolution of the species.

This is the case of brownfields. In 1995 the US Environmental Protection Agency (EPA) established the *Brownfields Program* (www.epa.gov, 2017), a proven, results-oriented program that influenced over time the way drosscape was perceived and managed. One of the main goal of EPA's Brownfields Program was to empower governments, communities and stakeholders in the reintroduction of brownfields in the urban system. EPA's program highlighted the opportunities that drosscape's redevelopment could bring in terms of job growth, local taxes increase and, obviously, environment protection and improvement. According to EPA, brownfields' redevelopment has had multiple economic benefits: a study found that the values of residential property increased by 5-5.12 percent once a nearby brownfield was cleaned up. Other indirect benefits are related to traffic – a massive reduction in vehicle miles travelled happened when development occurred for a brownfield – and a reduction between 47 to 62 percent of stormwater runoff for brownfields site development was recorded.

The spatial value

As drosscape is an *in-between* space, it intrinsically lives in transition. For this reason, it often eludes any attempt of classification, as it reveals itself between ‘occupancies and uses, successional phases, and (dis) investment cycles’ (Berger, 2006). Nonetheless, drosscape is often in advantageous locations, accessible to infrastructure and close to people. This is due to the explosion of the city, which in time has expanded and incorporated all those functions that were considered necessary for the urban system but that, at the same time, they were unpleasant and/or unhealthy. Consequently, industrial areas, as well as landfills, or the so-called greyfields, represent real ‘holes’ within the tissue of the city, an archipelago of contaminated open spaces (Gasparrini, 2013) which hosts the scrap of the city itself, outlining a certain degree of porosity. Such archipelago finds its strength in the myriad of possibilities to reconnect each fragment according to its importance within a spatial strategy.

Such possibilities become more evident when approaching to drosscape as a proper category of urban landscape. Observing drosscape through the lens of landscape ecology, then, can provide an interesting insight, highlighting wasted lands’ morphological aspects, such as, for instance, their grain and distribution within the urban system, as well as the structure and the shape of each fragment and the entire network of voids that emerges from the city.

Focusing on these aspects can support the design process for the network of green and blue spaces, identifying a possible window of opportunity that this landscape offers. This perspective, then, furnishes a key for a systematisation which is a proper morphologic design of the networks that constitute the city, facilitating the setting up of the possible strategies that focus on the reintroduction of nature in the city paying attention on the hydrological cycles, as well as the ecological functioning.

2.6 | The need of a multi-scalar approach

In order to adapt to internal and external pressures and stresses, cities need to be restructured through environmental infrastructure systems that interact among them through different scales (Pavia, 2014). Obviously, this implies a considerable effort in order to shift toward a new paradigm: it needs a deep cultural change at different levels: the local dimension, as well as the regional and the global dimension. Drosscape provides an occasion to virtuously steer the transition of the whole urban system according to the different dimensions that compose the latter. Landscape dimension allows going beyond the redevelopment of the single fragment, paying more and more attention to urban and territorial relations and providing the opportunity to reconstruct ecological cycles (e.g. the water cycle), rethink to energy cycles, and promote new and more sustainable economic cycles.

In order to maximise the understanding of drosscape, as well as opportunities that it provides, a multi-scalar approach becomes essential, both in space and time. From a spatial perspective, it helps recognising the processes that lead to the formation of voids in the city. Such processes can be internal and external to the city intended as an open system (see Paragraph 3.5), and determine the way in which land is used and its shape. On the other side, from a design perspective, space reveals to be crucial: the possible morphology of drosscape as flexible backbone of a green-blue network deals with the morphological features of every single fragment of void and the entire set as a whole.

Time adds another layer to complexity, and this is particularly true for drosscape. As stated above, wasted lands are in a liminal condition, related to an absence of uses. The time frames in which they reveal their selves is highly variable, and depends on external factors – such us macro-economic crises – as well as internal aspects – i.e., the governance, economic interests. In addition, the redevelopment of drosscape has to deal necessarily with its environmental condition, which can heavily influence their reuse and the range of uses that they can host.

2.7 | Conclusions

Drosscape are a priceless resource for the city, for their characteristics and the values that they deploy. Nonetheless, involving them in more broad strategies implies dealing with extreme complexity, especially if recycling and remediation take place at the urban scale. According to Bélanger (2007), this complexity can be decoded through mapping procedures. Mapping is of primary importance for a better and deeper understanding of drosscape, and the identification of the flow of industrial processes, together with the mapping of urban processes can be extremely useful.

Mapping drosscape is a process that includes as well all those parts of the cities that interact with wasted lands and influence or are influenced by them. Such a variety of elements that are involved fosters the understanding of linkages and interaction with the landscape networks that characterise an urban system.

Beside the physical features of abandoned land, the recognition of the 'hidden' values of drosscape is fundamental to fully exploit their potential and reactivate them, reconnecting them to the city. This because, although they can be defined as portions of city at the end of their life-cycle, such interpretation is related only to the intensity of their – formal – land use. Indeed, they reveal all their potential through three different characteristics:

- The *morphological complexity*, which can be read as the result of the complex interaction of internal and external dynamics. Drosscape morphology is crucial for the design of the network of green spaces within the dense tissues of the city, as well as for the reconstruction of the hydrological cycle.

- The *intrinsic complexity*, made by the social, economic, ecological aspects that come into play within drosscape. Drosscape is often subject of bottom-up initiatives and hosts informal uses that can affect both positively and negatively communities. Drosscape often claims for long-term remediation processes, which in turn present high costs that are often not sustainable. In addition, such places provide high levels of biodiversity, if compared to other parts of urban systems.

- The *relational complexity*, that takes place in the dynamics that drosscape triggers. Again, such dynamics can be both positive and negative, depending on the characteristic of the single abandoned area. For instance, their surrounding residential areas often present lower prices.

The next chapter will provide a framework to re-structure and re-interpret the above-proposed levels of complexity, in order to identify the potential socio-economic and ecological barriers that can impede the reintroduction of drosscape within the urban system, as well as the potential that can boost such process of re-cycling abandoned areas.

Endnotes

1 Knabb, Richard D; Rhome, Jamie R; Brown, Daniel P; National Hurricane Center (December 20, 2005).Hurricane Katrina: August 23 – 30, 2005 (PDF) (Tropical Cyclone Report). United States National Oceanic and Atmospheric Administration's National Weather Service. Retrieved January 8, 2016

2 The story of John Snow is present in the book 'On the Map', written by Simon Garfield in 2012.

3 The Civic Trust was a charitable organisation founded in 1957 by Duncan Sandys, a British politician, and the former son-in-law of Sir Winston Churchill. It campaigned to make better places for people to live. It ran until 2009 before going into administration due to a shortage of funding. http://www.civictrust.org.uk, visited 08/02/2017

03 Complex Adaptive Systems

3.1 | Introduction

In his Utopia[1], Thomas More, during a conversation with the Lord Cancelor and Cardinal John Morton, talks about the political issues in England, tracing an interesting and sharp concatenation of events and relationships:

> The increase of pasture […] by which your sheep, which are naturally mild, and easily kept in order, may be said now to devour men, and unpeople, not only villages, but towns; for wherever it is found that the sheep of any soil yield a softer and richer wool than ordinary, there the nobility and gentry, and even those holy men the abbots, not contented with the old rents which their farms yielded, nor thinking it enough that they, living at their ease, do no good to the public, resolve to do it hurt instead of good.
>
> They stop the course of agriculture, destroying houses and towns, reserving only the churches, and enclose grounds that they may lodge their sheep in them. As if forests and parks had swallowed up too little of the land, those worthy countrymen turn the best inhabited places in solitudes, for when an insatiable wretch, who is a plague to his country, resolves to enclose many thousand acres of ground, the owners as well as tenants are turned out of their possessions, by tricks, or by main force, or being wearied out with illusage, they are forced to sell them.
>
> By which means those miserable people, both men and women, married and unmarried, old and young, with their poor but numerous families (since country business requires many hands), are all forced to change their seats, not knowing whither to go; and they must sell almost for nothing their household stuff, which could not bring them much money, even though they might stay for a buyer. When that little money is at an end, for it will be soon spent, what is left for them to do, but either to steal and so to be hanged (God knows how justly), or to go about and beg? And if they do this, they are put in prison as idle vagabonds; while they would willingly work, but can find none that will hire them; for there is no more occasion for country labor, to which they have been bred, when there is no arable ground left.

One shepherd can look after a flock which will stock an extent of ground that would require many hands if it were to be ploughed and reaped. This likewise in many places raises the price of corn. The price of wool is also so risen that the poor people who were wont to make cloth are no more able to buy it; and this likewise makes many of them idle. For since the increase of pasture, God has punished the avarice of the owners by a rot among the sheep, which has destroyed vast numbers of them; to us it might have seemed more just had it fell on the owners themselves. But suppose the sheep should increase ever so much, their price is not like to fall; since though they cannot be called a monopoly, because they are not engrossed by one person, yet they are in so few hands, and these are so rich, that as they are not pressed to sell them sooner than they have a mind to it, so they never do it till they have raised the price as high as possible.

And on the same account it is, that the other inds of cattle are so dear, because many villages being pulled down, and all country labor being much neglected, there are none who make it their business to breed them. The rich do not breed cattle as they do sheep, but buy them lean, and at low prices; and after they have fattened them on their grounds sell them again at high rates. And I do not think that all the inconveniences this will produce are yet observed, for as they sell the cattle dear, so if they are consumed faster than the breeding countries from which they are brought can afford them, then the stock must decrease, and this must needs end in great scarcity; and by these means this your island, which seemed as to this particular the happiest in the world, will suffer much by the cursed avarice of a few persons; besides this, the rising of corn makes all people lessen their families as much as they can; and what can those who are dismissed by them do, but either beg or rob? [...]

For if you suffer your people to be illeducated, and their manners to be corrupted from their infancy, and then punish them for those crimes to which their first education disposed them, what else is to be concluded from this, but that you first make thieves and then punish them?


12 VTOPIAE INSVLAE TABVLA.
Amaurotū vrbs.
Fons Anydri.
Ostium anydri
Hythlodaeus.

Here, More starts with the description of the dynamics that involved the land use out of the borders of the city, in the open countryside, and pointing out way the shift in land use – from farming to grazing – has shaped the landscape, directly provoking repercussions on the city and the society, on occupation and criminality, and the consequent policies. In few pages, More has been able to provide a clear example of a complex system and its dynamics, emphasising cause and effect relationships that generate from a single – apparently – innocuous choice. That is a decision taken in response to market and its demand, that has an immediate and visible effect on the countryside which progressively generates unemployment and poverty, rise in food and raw materials prices. Within the city, criminality level increments, and calls for some responses by the king – the governance – to avoid a collapse.

This piece, then, is extraordinarily exemplifying of how a city can be interpreted as a complex system, since it is shaped by the co-evolution in time of knowledge, desires and technology. Defining complexity means taking into account two main aspects: evolution and change. Both of them contribute to determine the dynamicity of a system, since the stability of any existing structure is influenced by behaviours and possibilities. A dynamical system, thus, can be defined as a system which 'may have several different possible configurations and structures concerning the same set of variables' (Allen, 2012). Moreover, in the longer term, complexity is determined by the possibility that new variables can emerge over time.

This understanding necessarily implies accepting that there is no stable and univocal state in nature nor in human-made systems, and places the attention on unpredictability and uncertainty as main features of systems, claiming for a deeper insight of the concept of resilience and adaptive capacity, together with the role of time.

Complexity goes beyond the dichotomy between man and nature, as both the bio-physical part of the system – made by hydrology, soils, vegetation, ecology, etc. – and the anthropic part of the system are dynamically linked.

fig. 3.1 | On the The isle of Utopia

Such understanding of complexity has more and more influenced the concept of resilience, shifting the focus on dynamic, non-linear patterns due to the vast amount of systems and agents interacting between them.

3.2 | The evolution of the resilience concept

In the last decades, the concept of resilience has gained more and more attention within a wide range of different disciplines – from psychology to ecology, to urban planning. Over time a vast number of definitions has been formulated, fostering consequently the production of diverse methodologies (Martin-Breen & Anderies, 2011) and, furthermore, generating a concrete risk of value loss of the concept itself, as it can become unable to effectively support planning, also because of the difficulties of its practical application (IPCC, 2014). Nevertheless, resilience is a key concept for operationalising of sustainability (Pickett, McGrath, Cadenasso, & Felson, 2014), as it is a conceptual framework that can help to identify phenomena, and consequently to ease or impede reaching the goals established by sustainability itself.

Before starting with an analysis of the resilience concept, in order to better understand the possible shades that the concept itself can acquire, asking two extremely simple questions is of primary importance. The first question is ‘resilience *of* what?’; the second one is: ‘resilience *to* what?’. These questions can help defining resilience, through the identification of the objects to consider, as resilience itself can describe the properties of a single object as well as those of a complex system (Martin-Breen & Anderies, 2011).

As previously stated, the evolution of resilience’s concept has accompanied a progressive relation of humankind with the ecosystems’ dynamics and processes and, at the same time, it has encouraged a radical shift of paradigm of the urban project. Indeed, the latter cannot be sustained by a *fail-safe* oriented design anymore, which is a design concentrated on safety and systems' control, according to a more engineering perspective. On the contrary, it should be more focused on a *safe-to-fail* approach, thus capable of metabolizing possible errors (Shannon, 2014), and reducing systems' vulnerability, or at least avoiding undesired situations.

Retracing some of the main stages of the evolution of this concept becomes thus useful for two reasons: on the one hand it allows to highlight some of the components and further concepts tied to resilience, and which can be applied to cities; on the other hand, to draw attention to the progressive shift of paradigm in the conception of the relationship between man and nature.

Specifically, three diverse definitions of resilience are notably useful to this purpose. The first, known as 'engineering resilience', was proposed by Crawford Stanley Holling (1973). It describes resilience as the capacity to get back to an equilibrium state after a stress and, more generally, to tolerate major strains. Few years later, Holling enunciated a diverse definition, naming it 'ecologic resilience' (Holling, 1996). According to this interpretation, the degree of resilience is given by the amount of disturbance that a system can absorb before it changes its structure through the switch of those variables and processes that control it and define its behaviour.

An initial comparison between these two definitions emphasises a shift of the focus, from maintaining the efficiency to maintaining the existence of a system. This is closely correlated to the growing awareness of the non-existence of an equilibrium state that remains unchanged over the course of time in nature, rather than the presence of different possible balance states toward which systems tend, through non-linear and non-gradual changes (Franklin & MacMahon, 2000).

A third definition is called 'evolutionary resilience' (Davoudi, 2012). Such definition takes into account and highlights the whole concept of balance, being grounded in the idea that systems can transform over time, regardless of the action of external disturbance (Scheffer, 2009). Such hypothesis promotes the existence of complex systems, characterised by both social and spatial connections, and by unpredictable processes that act at different spatial and temporal scales.

The three definitions of resilience are explained in detail in the following subparagraphs.

Engineering resilience

The first definition from which to start can be ideally positioned on a more basic level of an ideal scale that represents complexity. According to Holling, a Canadian ecologist who contributed to the foundation of ecological economics, engineering resilience implies 'bouncing back faster after stress, enduring greater stresses, and being disturbed less by a given amount of stress' (Holling, 1973)

In this perspective, the word *stress* refers to crisis that can happen in the short term, as well as those chronic difficulties that are typical of more extended timeframes. Conversely, the acceptation *engineering* finds its own roots in materials science, which focuses on the behaviour and the specific properties of materials. Within this disciplines, some of these properties – namely resistance and elasticity – are described by the concept of stability rather than resilience. In fact, the word engineering recalls that domain of design that is more tied to bridges, buildings and infrastructure construction. These elements require the capacity of managing massive stresses, and quickly getting back to a 'normal' state once the stress ends.

According to this definition, then, being resilient means being robust, resisting to disturbance without mutating the own condition, without permanently being damaged or even being subjected to destruction. In addition, this implies the capacity to come back to the original state as quick as possible, warping the less possible under the pressure of external forces. Thus, the concept of engineering resilience underlines three fundamental aspects. The first one highlights that in nature a unique balance state that is possible to define as 'normal' exists; the second aspect puts the emphasis on the possibility that an object can come back to its normal state after a stress; the third one marks that forecasting both internal and external uncertainties is possible.

Taking for granted that a unique state exists, and consequently being a stationary state, means paying attention on the stability of a system that is structured on a well-defined equilibrium. Then, time – intended as the velocity with which a system gets back to its initial state after a disturbance – becomes a measure of this property. Therefore, engineering resilience focuses on the maintenance of the efficiency of a function, rather than on the maintenance of its existence.

Ecological resilience

The second definition analysed here takes place from the premise that the dynamics that govern our planet are not constant, and for this reason, the world is in a continuous flow in which conditions – the ecological, social, economic, technologic conditions – constantly change. This implies that conditions that can be defined as 'normal' do not exist, especially if long-term timeframes are taken into consideration.

Thus, the ecological resilience stresses the impossibility of the existence of a constant balance state, and therefore this condition, together with internal and external instabilities, can influence a system, until carrying it toward a completely different behavioural regime (Holling, 1973; 1996).

Ecological resilience, then, can be intended as 'the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behaviour' (Walker, Ludwig, Holling, & Peterman, 1969). In other words, it is the capacity of maintaining the systemic functioning after a specific event of disturbance.

Albeit constant conditions do not exist, it is true that human beings need certain specific functions, which are stable and perpetual, in order to survive (Martin-Breen & Anderies, 2011): food, water, resources, even entire cities are some of these functions.

The shift of attention from *efficiency* to *existence* of a function, and therefore to the management for the maintenance of the latter, means accepting the possibility that change can happen, both in the short term and in the long term. Moreover, in order to better understand the 'internal' changes, it is necessary to consider the systems' resilience (*ibid.*). Therefore, according to this definition, when systems are taken into account, we have to accept that they are dynamic, exposed to a constant change, and that their resilience depends on the maintenance of their functioning during a disturbance event.

Evolutionary resilience

The third and last definition that is the evolutionary resilience, proposed by Simin Davoudi (2012). Such interpretation implies moving from an idea of balance and shifting from a stable state to another, consequently acknowledging socio-ecological systems – a peculiar typology of system – the ability to change, adapt and transform in response to stresses and tensions (Carpenter, Westley, & Turner, 2005). This idea of resilience, characterised by an 'evolutionary' vision, seems to be, according to Galderisi (2009), the one that better fits the nature of urban systems understood as complex systems. This is true because of the dynamic nature of cities and because of their constant state of modification under the pressure of both endogenous and exogenous processes.

Evolutionary resilience underlines mainly two different aspects: shifts of regime are not necessarily the product of external disturbance and of cause and effect relations; on the contrary, they can happen for internal stresses, with non-proportional and non-linear cause-effect relations. In addition, changes at the small scale can have significant impacts on major scales, while, on the other hand, massive interventions can have minimum impacts, or even none at all (Davoudi, 2012).

Furthermore, such a vision stresses the possibility that the past behaviour of a system cannot be useful to predict its future behaviour, even when circumstances are similar (Duit, Galaza, Eckerberga, & Ebbessona, 2010). This implies the reconsideration of the conventional tools that planners have, like the extrapolation of valid scenarios starting from past trends in order to elaborate a credible forecasting and reduce uncertainty (Davoudi, 2012), and signifies the realisation that likely 'planning is condemned to solve yesterday's problems' (Taylor, 2005). For this reason, it is of primary importance to recognise and define the properties that a system has to have, and understand their significance and their role in all the diverse temporal phases that characterise the response of an urban system to a perturbation (Galderisi, 2009).

Resilience	Main features	Main implication
Engineering resilience	Robustness, stability, persistence	Balance state
	bouncing back faster after stress, enduring greater stresses, and being disturbed less by a given amount of stress	
Ecological resilience	Adaptability	Non-linearity
	the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behaviour	
Evolutionary resilience	Dynamic interaction, transformability	Multiplicity of spatial scales and temporal scales
	the ability of complex socio-ecological systems to change, adapt, and, crucially, transform in response to stresses and strains	

table 3.1 | Three definitions of resilience

3.3 | Systems approach

In the previous paragraphs, the word 'systems' appeared several times. Within this work, a system is intended as a group of agents that interact among them. This implies that, when approaching a system, the minimum set of agents taken into account depends on the system itself and on the limits that define it. Consequently, the definition of a given system, together with its boundaries, is an arbitrary valuation: the system indeed can represent a family, a village, a region, a nation, or the entire planet.

As previously observed, the concept of resilience is applied for the construction and modelling of systems that are dynamic and non-linear. Consequently, using systems in modelling implies the acceptance that the initial conditions of the system itself define its behaviour in time. This happens because models related to dynamic non-linear systems are deterministic, with fixed input variables and thus without any uncertainty.

In this view, a peculiar typology of system can be an illustrative example, as it puts together the ecological domain with the social sphere. Precisely, it is called *socio-ecological system* (SES). The term social-ecological system has been coined by Berkes in the first years of this century (Berkes, Colding, & Folke, 2003). Somehow, this term represents a milestone of a gradual shift in conceiving the relation between man and nature.

This shift of paradigm took place in ecology, in the last thirty years, during which the concept of 'balance of nature' has been gradually substituted with the 'paradigm of non-equilibrium'. The first was established during the second half of the Nineteen century, when George Perkins Marsh, in his book *Man and Nature*, published in 1864, stated that nature can maintain its own balance unless the intervention of man causing disturbance. Such vision reverberated as well in the modern western industrialised civilisation – which traditionally did not consider mankind as being part of an ecosystem – and in the approach of some researchers in biology, that viewed cities as 'the opposite of life', that is to say without nature. The introduction of the 'non-equilibrium paradigm', according to which ecological systems are driven by processes, brings to the inclusion of human beings as components of the ecosystems. A peculiar event that convinced researchers to reconsider the role of humankind in influencing nature was the publishing of data related to the presence of CO_2 in the atmosphere, in the first years of 1960's. This event contributed to make the awareness grow on the global effects of climate change, and that no ecosystem was completely free from the anthropic influence.

In this perspective, *urban ecology* discipline started to spread. Alberti defines urban ecology as the study of the possible ways in which anthropic systems and ecological systems evolve together in the urbanised areas. Such interpretation fostered the simultaneous diffusion of the term *social-ecological systems*. This term strengthened the idea that there is a growing need to reconsider the objective of ecosystems' management, since the main goal should not be to restore them and their initial state as much as possible, because of the massive number of modifications that man's actions cause. Such interaction between man and nature, then, makes this peculiar type of systems 'complex, non-linear, able of self-organisation, characterised by uncertainty and discontinuity' (Berkes & Folke, 1998). As stated in the previous paragraph, according to the vision proposed by evolutionary resilience, the regime of uncertainty and chaos that connotes social-ecological systems is not due uniquely to external drivers and shocks, but also to some sets of internal stresses which do not necessarily present a linear cause-effect relation.

Social-ecological systems are, then, a peculiar typology of Complex Adaptive Systems (CAS), the study of 'is a study of how complicated structures and patterns of interaction can arise from disorder through simple but powerful rules that guide change' (Levin, 1998). This definition is particularly true when dynamics of interaction between man and nature happens in the city, contributing to shaping its parts.

3.4 | City as Complex Adaptive System

Cities are the places in which the interaction between man and nature finds its greatest expression. Urbanisation process lead by man is described by Harvey (1996) as a multidimensional process that shows itself through fast changes of density of urban population and land uses. Such view provides a key insight of the city as agglomeration of spaces that generates a wide range of urban services – such as transportation, dwelling, medical care, work, financial markets, etc. – closely tied to ecological processes, which are in turn modified and canalised within social processes. This bi-univocal and circular relation is identifiable at each possible scale, even the global one. In this perspective, cities can be interpreted as Complex Adaptive Systems.

A Complex Adaptive System is defined by an extensive set of subsystems, each of them characterised by its own features and dynamics, and able to influence each other and subjected to the influence of external conditions (Mitchell, 2009). Such conditions create the basis for a non-linear, non-predictable evolutionary process, that can adapt and evolve in response of the changes of the context (Meyer, 2014). In this view, within the cities, the landscape becomes a medium between nature and society, and the existing relations can be explored through the deconstruction of landscape itself in different layers.

Levin (1998) identifies three main properties that determine and characterise CAS:

- Sustained diversity and individuality of components;
- Localized interactions among these components;
- An autonomous process of selection from among these components, based on the results of local interactions, a subset for replication or enhancement.

These are the properties that better describe the functioning and the characteristics of Complex Adaptive Systems: here, adaptation is guaranteed over time by the dispersed and local nature of an autonomous selection process and by the emergence of *hierarchical organisation*.

Furthermore, the maintenance of diversity of each component creates the necessary conditions for a perpetual novelty. Thus, it becomes clear that the state in which they are is distinguished by far-from-equilibrium dynamics.

The study of ecosystems can provide an interesting insight of the properties that define CAS. Ecosystems are indeed complex adaptive systems, compounded by parts that have evolved over longer time scales and broader spatial scales (*ibid.)*. Holland (1995) identifies four basic properties of CAS:

- Aggregation: as a natural consequence of the self-organisation of any complex system, together with hierarchical organisation. These two aspects emerge from local interactions through the formation of patterns within the system, and as they arise, they determine the rules for the interaction of the individuals, influencing the whole system's development.

- Nonlinearity: complex adaptive systems change in reaction of events, such as environmental variation. However, their change is bounded to path dependency. Path dependency is a consequence of non-linearity, which describes the change in the rules of interaction as the system evolves and develops.

- Diversity: in ecosystems, diversity within a species provides resiliency and helps to avoid extinction. Diversity is fundamental to adaptive evolution.

- Flows: they are the means through which interconnections between parts are established. Flows turn the community from a random collection of individuals into an integrated whole.

The application of Complex Systems Theories on territories opens to a wide range of opportunities for the reinterpretation of all those existing dynamics between man and nature, offering a systemic frame able to put into relation the different subsystems that form a territory.

A Complex Adaptive System is, then, a complex network of agents that constantly adapt themselves to their environment (Mitchell, 2009), bounded to a set of rules that determine the way they react and behave. Although the rules are simple and basic, the complexity and the unpredictability that characterise the system are given by the range of interactions among them (Giacomoni, 2012).

Understanding a territory as a Complex Adaptive System, then, means identifying the totality of subsystems that compose it. In addition, each subsystem that characterises a complex system is marked out by its own dynamics and paces, and at the same time, by the way in which it influences and is influenced by others. Consequently, no subsystem is completely isolated; on the contrary, the amount of relations that occur among diverse subsystems determines the degree of connectivity of a Complex Adaptive System, giving rise to a state of uncertainty and inability of being sure of the definition of the system's evolution path.

3.5 | Characteristics of Complex Adaptive Systems

Complex Adaptive Systems are characterised by a diverse properties. Firstly, CAS are open systems that interact not only with the surrounding environment, but also with external factors that influence them (Grus, Crompvoest, & Bregt, 2008). Interactions take place through flows of matter, goods, people and information, between the system and the environment. Furthermore, the former defines the latter. This implies that there are no well-defined and strict boundaries circumscribing the set of spatial functions that exist on a territory. Consequently, such boundaries are not clearly identifiable. Indeed, each subsystem can have its own boundaries, though they vary in time and depend on the agents involved.

Secondly, within Complex Adaptive Systems the distinction between the system and the environment repeats itself through the different scales: thus, a system represents the environment in which a subsystem lies, and in turn, it is surrounded by an environment which is composed by different systems (Pols, Edelenbos, & Dammers, 2015). According to this perspective, the entire biosphere itself can be intended as a complex adaptive system 'whose composition changes evolutionarily in response to the dynamics of its component complex adaptive systems, ecosystems, and feeds back to affect their further dynamics by changing the attributes of the players' (Levin, 1998).

Another important feature of CAS is that they are dynamic. This because of the influence that some factors – like population, economy, climate – have on a system. Such factors are subjected to variations that are more or less easily predictable, as well as to 'transitions' that trigger more substantial changes (Rotmans, 2006).

In the long term, different paces of development of the subsystems of a CAS, together with diverse processes and relations, can bring to an uncertain future and the adaptation of a system to a given environment – and to its modification in time – cannot happen automatically. Change, indeed, cannot arise, either cannot be sufficient or, moreover, can take place in different timeframes.

Lastly, systems are continuously evolving, and their development is characterised by the path undertaken in time. This peculiar attitude is called path-dependence, as a result of a constant process of adaptation. Transformations in time keep playing a primary role in the determination of a system's state and its possible evolution. This means that it is not possible to consider a state fixed in time of a CAS as a starting point from which to move to define possible paths of evolution in the future. Rather, it is necessary to understand how a system has evolved in the past and what kind of factors have participated in the determination of the current state in the most critical phases of the system's evolutionary path.

The existence of multiple subsystems that contribute to compose a CAS can bring to a *fragmentation condition*. Fragmentation can represent an obstacle for adaptation processes to conditions' change. Fragmentation can take place for different reasons: one is the extreme specialisation of social, economic, technical activities; another one is the variety of values and ideas put in place by different stakeholders, as a result of the wide range of different backgrounds. Variety of relations, diversity of subsystems, transformations and interactions that exist among them, together with fragmentation, are some of the aspects that contribute to the complexity of systems, and to the state of uncertainty in which they are. This condition of uncertainty, thus, makes the identification and the achievement of preconditioned objectives extremely complicated, consequently revealing all the limits that systems' management presents.

For this reason, planning and managing systems according to a deterministic approach is not the main target anymore. Rather, it is the understanding of how they can self-sustain, and the identification of those factors that potentially represent an obstacle or push systems to the loss of their balance condition, making a consequent change of the whole system necessary (Scheffer, 2009). Thereupon, the attention of scientific research and the planning and design disciplines has been gradually focusing on the reduction of systems' vulnerability and in what way it is possible to make them more robust, resilient and adaptive (Pols, Edelenbos, & Dammers, 2015), with the aim to safeguard a continuous evolution over time.

Within the built environment, drosscape is a tangible manifestation of the fragmentation conditions of a CAS. The openness of the urban systems makes them subjected to changes of states which are quick and sudden, and that have physical repercussions on the way parts of the city are used and, consequently, on the intensity of such use.

3.6 | Spatial scales, temporal scales

As already stated before, scales play a key role in understanding dynamics of Complex Adaptive Systems. It is no coincidence that the different shades of interpretation of resilience's concept arise from the different spatial scale that time after time are considered. Such diversity of approaches not rarely generates confusion, resulting from an unclear definition of the system to which the concept itself is applied (Martin-Breen & Anderies, 2011).

A key point in understanding Complex Adaptive Systems is provided by Allen (2012), as he states: 'on an even longer time-scale, complexity thinking and evolution tell us that although the spatial structures of the present variables matter in the short term, the actual variables relevant to the system will evolve over time and the model will not only be *wrong* in the long term, but will be written in terms that are not relevant to the later situation'. The dichotomy between short and long terms highlights the issue related to what is possible to define 'normal' and 'prefixed'. Indeed, given that our planet is constantly changing, it is easy to recognise that transformations to which it is subjected have different paces compared to the ones proper to humankind. In this sense, man's perception of the world can be interpreted as something fixed and static. Although associating an idea of stability to the 'Earth system' is wrong or even damaging, two distinct conditions can be considered as true:

- Some prefixed functions do exist, and man can not overlook them in order to survive;

- Thinking in terms of stability can have some positive aspects, especially the ones linked to the opportunity of understanding some dynamics in a more efficient way. This becomes possible only subdividing everything through a process of 'compartmentalisation', assuming then that nothing, in other context, is subjected to variation. For instance, it is the case of the water cycle.

In the long term, slow changes have a significant impact on a system's resilience. Slow changes refer to the way the parts of a system interact, in times of – relative – stability. In opposition, fast changes take place in response of crisis.

In this perspective, then, the amount of time that it takes to return to a pre-existent condition cannot be used as a measure of how a system can fail in maintaining its essential functions (Walker, Holling, Carpenter, & Kinzig, 2004). Furthermore, systems are composed of nested dynamics that work at different scales. This peculiar typology of system, thus, can be connected through both temporal and spatial scales and levels of organisation, consequently composing a *panarchy* (fig.3.2; fig.3.3). A panarchy is a conceptual model that describes the ways in which complex systems – both human-related or natural – are dynamically organised and structured trough spatial and temporal scales (Gunderson & Holling, 2002). Panarchy theory puts emphasis on trans-scalar connection, for which processes that take place in one defined scale affect other processes on different scales, influencing consequently the entire global dynamics of the system. In ecology, such interaction between living and abiotic organisms that belong to a specific domain, within the same scale, is defined *adaptive cycle*.

Panarchy provides a useful insight through which observe the formation of voids within the tissues of the city. Such voids can be intended as

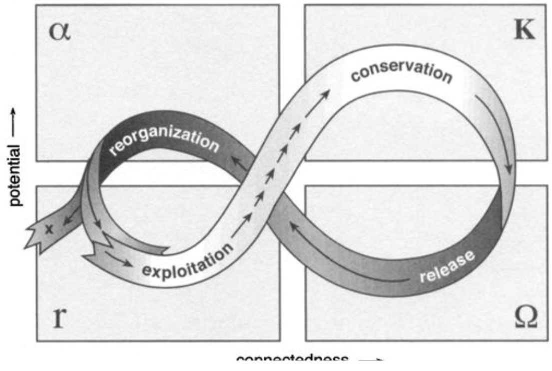

fig. 3.2 | a schematic representation of an adaptive cycle, composed by the four ecosystemic functions

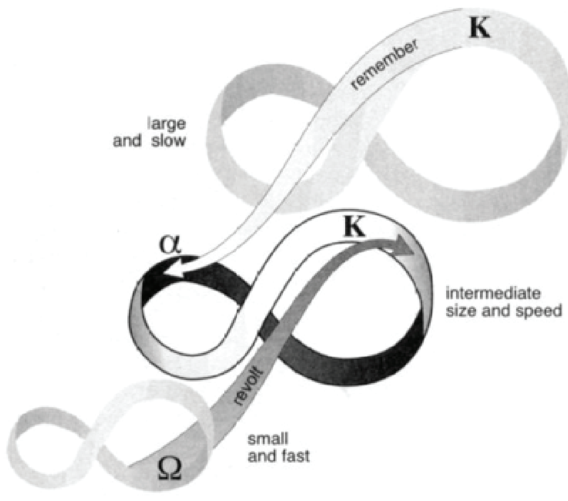

fig. 3.3 | The connections of a Panarchy

elements belonging to the different subsystems of a city that, for several reasons, come to the end of their life-cycle. A change in the scale of analysis of a system can hide their existence or highlight the dynamics of interaction that they establish with the elements of the other subsystems. Furthermore, since each subsystem is characterised by its own pace, consequently, when a part of it falls in a state of abandonment, the time that defines this condition can be directly dependent on the pace of the subsystem of which it belongs.

3.7 | The systemic approach and the territory: the Dutch Layers Approach

Complexity theories focus on interactions among the parts of the city and non-linear paths of evolution. Taking into account all the dynamics that come into play in the definition of a state of an urban system is not easy. Nonetheless, the employment of a model in order to provide a hierarchical set of rules is still important. From this perspective, then, landscape can act as a medium between nature and society, therefore becoming a useful

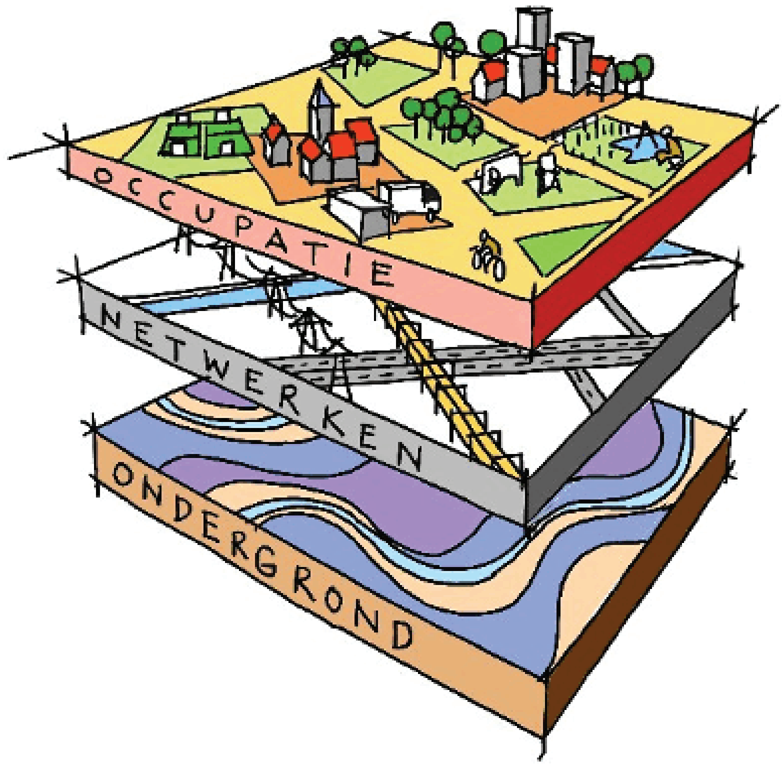

fig. 3.4 | A schematic representation of the Dutch Layers Approach

tool for the description of the interactions between man and ecosystems. These relations can be explored through the deconstruction of landscape in different levels and through the consequent stratification according to the degree of influence that they present, and the dynamics and the paces that characterise them (Nijhuis & Pouderoijen, 2014).

Through such a deconstruction process, it becomes possible to obtain a first level of comprehension of those modifications that anthropisation processes have triggered in time on the territory through land reclamation and the intensification of resources consumption. This approach finds its roots in the *layer-cake representation* proposed by Ian McHarg (1969). Through the layer-cake representation, the understanding of the territory takes place from the structuring of a bio-physical model of the latter, which is able to describe not only the subsystems – or even the single elements – that form it, but also the relations that happen among them, at different spatial and temporal scales.

The *Dutch Layers approach* is a stratified model developed in order to distinguish and organise different planning tasks starting from the diverse spatial dynamics of the components – or subsystems – of a territory understood as a Complex Adaptive System. Although employing layered models was not a novelty, this approach – born in 1998 – had a huge impact on the spatial planning practice in the Netherland and, obviously, it underwent a lot of interpretations and transformations.

As introduced before, the practice of mapping layers in urban design and planning is not new. McHarg proposed a layered thematic mapping in his work as landscape architect during the 1960s, before the arrival of computational science and Geographic Information Systems (GIS).

Initially, the subdivision in layers was made to highlight the different aspects of concern in the domain of urban and regional design and planning (van Schaick & Klaasen, 2011). The main peculiarity of the Dutch Layers Approach, developed by De Hoog, Sijmons and Verschurren, is the central role that it gives to time aspect. The creators of this approach proposed a stratified model, in a regional scale, in order to connect planning tasks to different time scales of spatial dynamics (*ibid.*).

The Dutch Layers Approach defines three main levels that differ in terms of change dynamicity (fig.3.4). The deeper layers are the ones of the *substratum* and the climate. The first consists of the topography of the territory, the typology of soils, the hydrographic system, and the bathymetry. The second, on the other hand, is made up by temperature and precipitations, together with the winds. These systems represent the conditions that mostly influence land use. Moreover, they are characterised by longer life cycles and wider spatial domains. The second layer is composed by the networks and the physical infrastructures. As the substratum and the climate, these two features influence land use as well, but they are characterised by a faster develop than the environmental conditions. The third and last one is the occupational layer. It is made by spatial patterns inherited by the anthropic use of substratum and network. Such patterns are, for instance, urbanisation and agriculture among others. The occupational layer's evolution is characterised by much faster dynamics and change, and consequently by life cycles that are shorter, and it is more subjected to external dynamics that belong both to the environmental and the social-economic domain.

Furthermore, for each layer a set of design and planning tasks was identified. For the substratum layer, the main tasks were dealing with the physical effects of climate change and the modernisation of the water management system; regarding the second layer, the identified tasks were the strengthening of the position of the Netherlands in the international networks and the control of the growth of the mobility. Lastly, accommodating the spatial claims and the shrinkage in relation to values and attractiveness was the main tasks for the occupational layer. According to van Schaick (2005), this model finds its strength in its capacity to link and integrate societal questions with physical and spatial issues through the time concept.

Nevertheless, it was often argued that such model presents some limits. Priemus (2004; 2007) points out that the hierarchic structure of the layers approach is not supported by real life spatial dynamics, highlighting the existence of reciprocal relationships between layered networks that take place on multiple scales. Furthermore, The *Netherlands Institute for Spatial Research* found several difficulties to develop policy recommendations from an analysis based of such approach, as it offered little room to think about future spatial questions in the long term. Despite such critics, the Dutch Layer Approach can provide an interesting framework in order to analyse and describe cities. Firstly, it is a model, and consequently a reduction of physical reality. Secondly, the approach is descriptive, as it describes the elements that constitute a city or a region.

These characteristics make the Dutch Layer Approach a useful tool to describe the process of formation of drosscape. Indeed, drosscape can be intended as the set of elements that are part of those subsystems on the occupational layer. Hence, the velocity with which different land uses succeed in time and, above all, the lack of new uses in given time frames, define waste lands. Besides, the Dutch Layer Approach can be used as a model to make explicit the relations that drosscape establishes with the other networks of the system, helping identifying in which way they affect each other.

3.8 | Conclusions

Observing cities with the lens of Complex Adaptive Systems theories implies the recognition of a different and wide range of subsystems. As already stated in paragraph 3.7, such subsystems can be organized according to their dynamicity and pace of change.

Subsystems having a faster pace in development are closely related to anthropic use – as it happens for urbanisation and agriculture. Consequently, their life-cycles are shorter and the formation of drosscape can take place more frequently. Thus, from the perspective of adaptive cycles (see paragraph 3.5), wasted lands can be understood as element that are in the reorganization phase. Reorganization phase may be rapid or slow, depending on different factors and on the presence/lack of a set of assets (i.e.: governance, financial availability, physical conditions). Nonetheless, it is the phase in which innovation and new opportunities take place, allowing the steering of the whole urban system toward new adaptive cycles. Indeed, innovation and novelty are fundamental features in order to maintain functions and dynamics in CAS and keep high levels of resilience. In this context, they define the degree of adaptability on an urban system, and its level of self-organisation. More generally, they provide the ‘core memory’ of a system (Allen & Holling, 2010): in a socio-ecologic system, such memory is made by physical and immaterial elements. Physical elements are buildings, facilities, infrastructures, open spaces; immaterial elements are the cultural values that drosscape provides, as well as aesthetic ones.

In addition, novelty can be exploited starting from a new interpretation of those relationships that drosscape, as set of elements of different subsystems, can establish among them and with the other parts of the city. The Dutch Layer Approach can provide a useful framework to structure both the intrinsic and the relational complexity (see Paragraph 2.8) of drosscape, according to the elements that come into play at each diverse level. These elements have different paces and cycles, and drosscape can heavily influence them. Such elements could need years to recover. Pollution of soils related to industrial uses is a clear example: while the life-cycle of abandoned areas can be 'easily' and relatively quickly re-activated, the one of the affected resources needs massive physical and economic interventions. In Chapter 5, the proposed approach starts from these premises, reinterpreting the values of drosscape and restructuring them in order to better identify the opportunities that it offers for the implementation of Green-Blue Infrastructures.

Endnotes

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04 The role of landscape in water management

4.1 | Introduction

During the last twenty years, landscape is sharply emerging as model and medium for the contemporary city. Even the term itself over the centuries has undergone a massive evolution in its conception. From its origins, in the sixteenth century, as a genre of painting, it became, a century later, a means through which to express a peculiar and personal way of experiencing the world. Progressively, it transformed into a tool to describe of the land and lastly to a more broad concept concerning all those practices related to land modification.

The evolution of the notion has accompanied the evolution of the city and its relationship with its surrounding environment, in terms both of spatial configuration, and uses and flows of energy.

Nowadays the meaning of this term is not univocal. As Charles Waldheim (2016) observed, the emergence of landscape as a medium of urbanism can have different reasons, depending on the specificities of the sites. Sites associated with rethinking the urban environment through landscape can be found at the limits of a more strictly architectonic order of the city's shape, as well as sites in which such order of the city has been rendered obsolete because of transformations of social, technological or environmental aspects. Furthermore, landscape revealed itself as a useful lens through which observing and understanding phenomena in the wake of macroeconomic transformations; more recently, it is becoming more and more relevant within the domain of risk and resilience, adaptation and change.

This development, together with all these diverse realms in which landscape finds its pragmatic applications, calls for an intertwining of ecological performance and design culture. These are the premises from which the discipline of landscape urbanism takes place, as landscape itself has been reconceived again in the face of the contemporary post-fordist industrial economy. In this light, landscape becomes a performative medium associated with remediation processes that involve former industrial sites; additionally, it is called on as well to conceive new forms of urban living. The Duisburg Nord Steelworks Park in Germany (fig. 4.1), designed by Peter Latz, is a clear example of how landscape can be a remediating practice for brownfields. This project is part of the IBA Emscher Park project, a programme based on the ecological regeneration of the entire Ruhr industrial district. The Duisburg Nord Steelworks was one of the areas in the Ruhr District, which experienced a massive process of industrialization starting from the 20th century and which decayed in the mid-80s because of the overcapacity in the European steel market. In this area, a cultural, natural and leisure park has been created starting from the industrial buildings of the previous economic activities.

More generally, a vast number of projects involving brownfields has

Fig. 4.1 | The Duisburg Nord Steelworks Park in Germany. Source; http://amb-architect-blog.tumblr.com/post/52214125207/landschaftspark-duisburg-von-oben

increasingly stressed the importance of reintroducing the processes and the features of landscapes and the role of open space. The reason lies, among others, in landscape's capacity to 'theorize sites, territories, ecosystems, network, and infrastructures, and to organize large urban fields' (Corner, 2006). Indeed, the explosion of the city, together with the development of the transportation system and the blurring of the boundaries between city itself and the 'natural' land, is contributing to make the landscape the most capable medium of ordering contemporary urbanism.

From this perspective, landscape planning can play a key role in anticipating and adapting to changes, and, at the same time, providing multiple functions (Kato & Ahern, 2009). In other words, a landscape can host a wide range of uses and serve multiple goals or values, because of natural systems capacity to provide a broad spectrum of ecological services and compensate for scarce space, a condition that characterises highly dense built environments. According to the definition given by the Millennium Ecosystem Assessment (MA), ecosystem services are 'the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious, and other nonmaterial benefits'(Millennium Ecosystem Assesment, 2005). Designing through landscape, thus, means supplying several benefits which are direct and indirect, and contribute to enhance the citizens' quality of life. In this work, benefits and co-benefits will be described more deeply in paragraph 4.5.

4.2 | From blueprints to scenarios

Landscape finds further relevance in describing transformations in **time**, thus highlighting the 'fourth dimension' and its implications within the contemporary city. According to Waldheim (2016), 'landscape is a medium uniquely capable of responding to temporal change, transformation, and adaption'. This is perhaps one of the most important features of landscape,

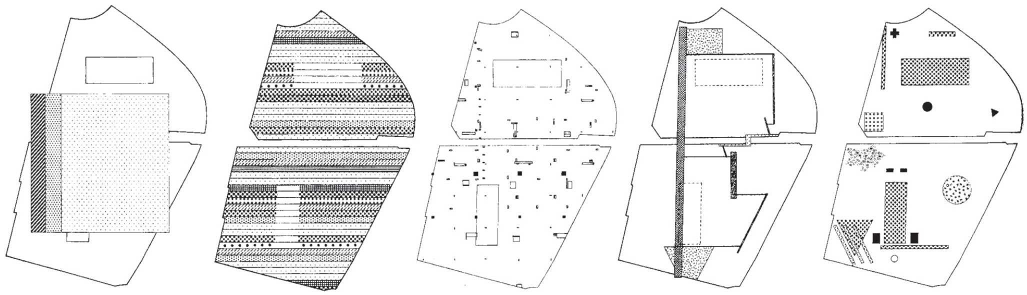
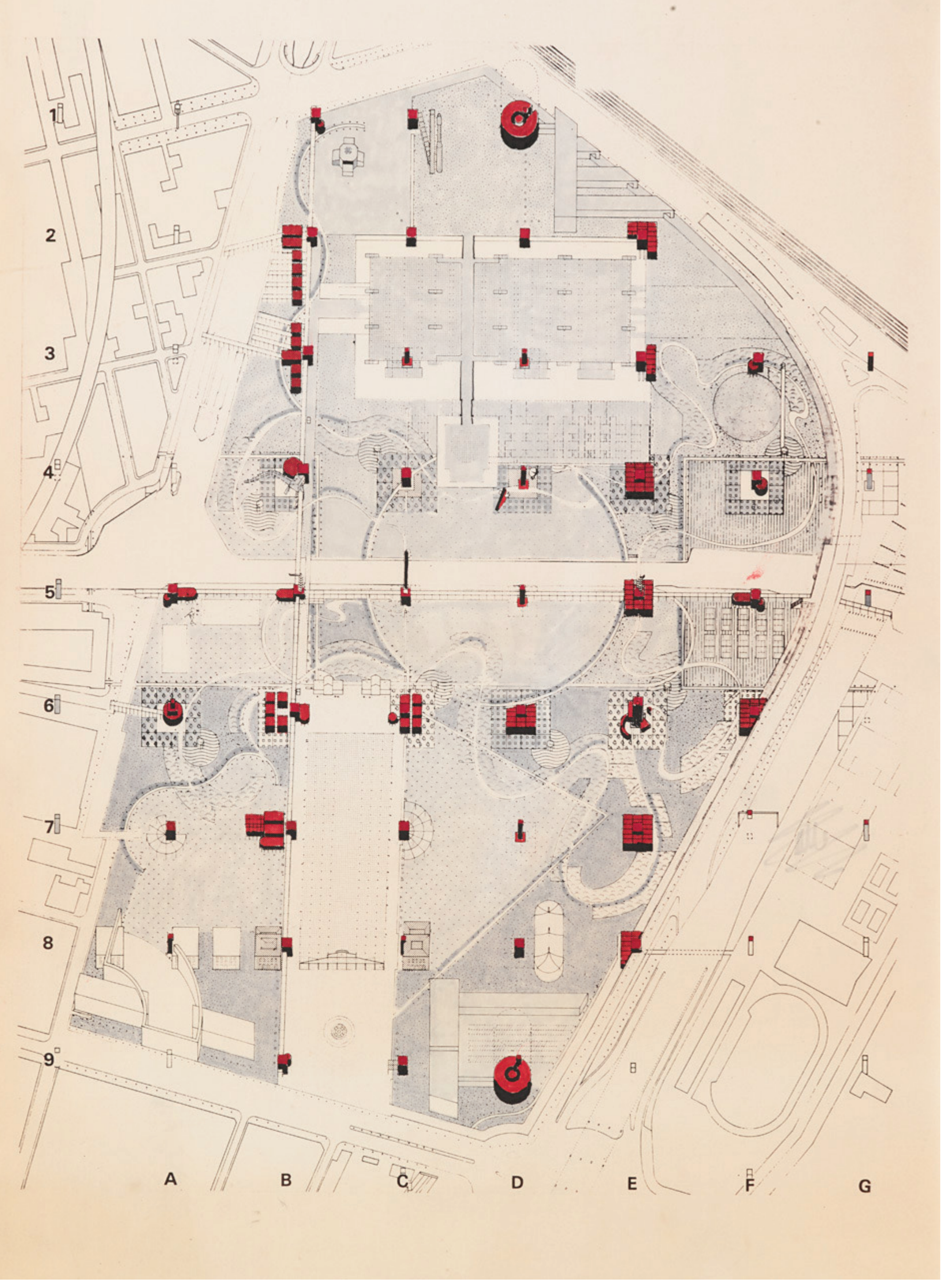


Fig. 4.2 | The project submitted by Koohlas and OMA for Parc de la Villette

as it becomes an effective model for process (Allen, 2012), and at the same time, it is a means for understanding the dynamics and the interaction of a set of elements in space and time (Corner, 2006).

As already introduced in the previous chapter, including time in design practices is a direct consequence of the growing acknowledgment that planners, designers and more generally practitioners must deal with uncertainty. Embracing uncertainty in design means recognising that the realization of a prefixed and static blueprint is something almost utopic. The indeterminacy, even during the construction phase, can move the result very far from the initial hypothesis. Once accepted this, the importance to develop flexible measures and actions to face the need of a territory comes up in a stronger way. From this perspective, a clear example has been represented by the projects for Parc de la Villette designed during the early 1980s by Bernard Tschumi and Rem Koolhas (fig.4.2, fig.4.3). The project proposed by Tschumi put landscape as a medium through which to order and structure programmatic and social change over time and was one of the first cases that gave a contribution to the development of landscape urbanism. The second-prize entry, submitted by Koohlas and OMA, proposed the juxtaposition of planned and unplanned elements and relationships among various park programmes to support an indeterminate and unknowable range of uses over time. Both schemes focused on the role of time and the uncertainty related to the impossibility to predict future uses, basing themselves on the employment of a horizontal field of infrastructure able to accommodate a various set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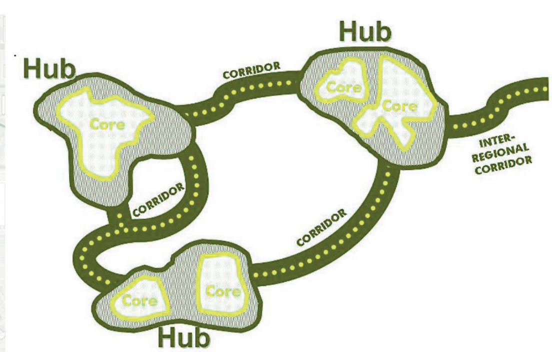
of urban activities.

Fig. 4.3 | Bernard Tschumi's project for Parc de la Villette

In the following years, landscape has gained more and more centrality as a medium through which conceiving an open-ended and responsive urbanism (Waldheim, 2016). Progressively, projects have been incorporating functioning and regulations belonging to natural systems in the attempt to transfer these qualities to urban communities.

The growing attention in projects and designs of a larger scale, rather than single buildings or little spaces, has determined in time the role of landscape as infrastructural device. This shift of perspective puts the landscape in a leading position, as landscape urbanism practices recognize its potential as ordering mechanism of the urban field (*ibid.*). In addition, the need for more flexibility and the recognition of the values related to nature's dynamics have leaded the paradigm shift from blueprint to process, from *fail-safe* model to *safe-to-fail* model. Whilst the *fail-safe* model assumptions are based on the idea of predictability and focus on efficiency and constancy, the second one supplies a more flexible structure that integrates aspects related to science with professional practice and stakeholders through the use of experimental design guidelines, monitoring and assessment protocols (Ahern, Cilliers, & Niemelä, 2014), in order to embrace the multiplicity of possibilities.

Fig. 4.4 | Design of a Green Infrastructure and diagram of the network components. Source; http://2014-2015.nclurbandesign.org/tag/green-infrastructure/



4.3 | Green Infrastructure

As already stated in the introduction of this chapter, multifunctional landscapes can provide multiple services, such recreation, transportation, nature conservation, and aesthetics. From this perspective, such landscape feature makes it a 'sophisticated, instrumental system of essential resources, services, and agents that generate and support urban economies' (Bélanger, 2009). According to Bélanger, then, redefining the conventional meaning of infrastructure is possible, and this should be done embracing the biophysical landscape. Infrastructure is commonly defined as the facilities and services necessary for a society to function in the best possible way. These facilities and services can be 'hard' – e.g. transportation and utilities – or 'soft' – e.g. institutional systems such as education, health care and governance.

Green Infrastructure (GI) is considered a 'soft' infrastructure. GI includes natural, semi-natural and artificial networks of multifunctional ecological systems within, around and between urban areas (Sandstrom, 2002). This includes waterways, wetlands, woodlands, wildlife habitats, greenways, parks, and other natural areas that support native species, maintain natural ecological processes, sustain air and water resources, and contribute to the health and quality of life for communities and people (Commission of the European Communities, 2009). Several definitions underline the importance of GI, and its capacity to establish connections. According to Benedict and McMahon (2001), GI is an 'interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human population'. Furthermore, Benedict et al. (2006) put some emphasis on the strategic aspects that GI involves, defining it as 'a strategically planned and managed network of wilderness, parks, greenways, conservation easements, and working lands with conservation values'.

Ahern (2007) defines GI as 'a means of spatially organising urban environments to support a suite of ecological and cultural functions', where the ecological functions are related to 'services' that ecosystems

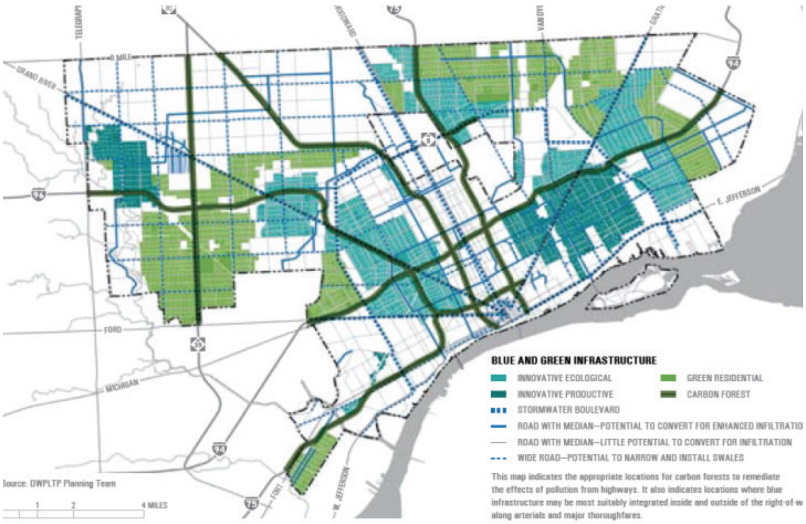


Fig. 4.5 | Design of a Green Infrastructure and diagram of the network components. Source; http://2014-2015.nclurbandesign.org/tag/green-infrastructure/

can provide in moderating climatic extremes, cycling nutrients, detoxifying wastes, maintaining biodiversity and purifying air and water. By contrast, the cultural services are related, among others, to the experience of natural ecosystems, the physical recreation, and the interpretation of cultural history.

Of course, definitions can vary, depending on scale. At a larger scale, such as the regional and the city ones, GI can be intended as a multifunctional network of open spaces; at the local scale, as a stormwater management approach, able to mimic natural hydrological processes , such as rain gardens, swales, constructed wetlands and permeable pavements (EPA, 2011). At the city scale, GI is important to improve environmental conditions, providing as well a valid framework for economic growth and nature conservation. In any case, GI stresses the primary role that open spaces and green spaces can play, especially in the denser parts of the city.

4.4 | Scales in Green Infrastructure

Spatial scales

In the landscape ecology discipline, landscapes are considered as broad heterogeneous areas of land. At the same time, they are nested in larger areas and regulate ecological processes. This peculiarity has encouraged the implementation of a multi-scaled approach in order to address spatial patterns and ecological processes, and the way they interact among scales (Ahern, 2007).

Within urban systems, it is possible to identify three different scales: the metropolitan region or city, the districts or neighbourhoods, the individual sites (*ibid.*). Nonetheless, such scales are not isolated. On the opposite, they interact and influence each other.

One of the properties of landscape is connectivity. Connectivity refers to the 'degree to which a landscape facilitates or impedes the flow of energy, materials, nutrients, species, and people across a landscape' (*ibid.*). Within cities, landscapes present a highly reduced degree of connectivity, which generates a wide set of impacts on some ecological processes. This is particularly true for water flow, perhaps the most important flow for man.

Ahern proposes a set of guidelines for planning and designing a green urban infrastructure, based on landscape ecology principles, in order to include a multi-scaled perspective and respect the importance of connectivity.

The first point highlights the importance of the spatial concept. Spatial concepts are the meeting point between the empirical knowledge and rational knowledge, and they can help to structure planning processes. Moreover, they play an important role in communicating in a quick and simple way, as they act as proper metaphors.

The second point refers to the strategic thinking. Strategies can vary according to the condition of landscapes. For instance, when a landscape supports sustainable processes and patterns, it could be useful to adopt a protective strategy in order to avoid substantial changes that could compromise its condition and prevent fragmentation, especially in urbanised landscapes. On the other hand, when a landscape is characterised by conditions of fragmentation, as it presents isolated and limited core areas, a defensive strategy is often applied. The main aim of this strategy is to arrest or at least control the negative processes of fragmentation or urbanization. An offensive strategy involves restoration or reconstruction of a given landscape and its elements, and it requires the displacement or replacement of intensive land uses with extensive land uses, green corridors or new open spaces in urban areas.

Connectivity is one of the main features of GI, together with multiscalarity and multifunctionality. Multiscalarity is defined by the interconnection of different spatial levels in GI planning. Davies et al. (2006) define three different spatial levels that should be considered. The first and the lowest level is the 'individual elements' level, which is compounded by parks or rivers. The second level is the 'linked elements' level, in which different elements, and linkages and relationships between them are represented. Such conditions form a network through which movement of species and flows of matter are nurtured (Hansen & Pauleit, 2014). The highest level is represented by GI, which is made of interlinked networks of elements on the regional level.

On the other hand, the idea of multifunctionality is a core element of GI planning (Kambites & Owen, 2006). In GI planning, ecological, social and economic function should be considered, intertwined and combined through a more efficient use of limited space. Hence, multifunctional land use is achieved if at least one of the following four conditions is met (Rodenburg & Nijkamp, 2004; Priemus, Rodenburg, & Nijkamp, 2004; Kato & Ahern, 2009):

1. increase in the efficiency of land use (intensification of land

use)

2. interweaving of land use (which is defined as the use of the same area for several functions)

3. use of the third dimension of the land (i.e., vertical space such as the below and/or above ground level along with the surface area);

4. use of the fourth dimension of the land (i.e., over a certain time frame).

An interesting perspective emerges from this set of conditions: the importance of the third dimension – space – as well as the fourth dimension – time. This because the selection of an infrastructure that can provide essential services while maintaining or implementing the quality of life needs to deal with its effectiveness in the short, medium and long term (Leonhardt, et al., 2015).

Temporal scales

The use of GI can bring different benefits. For instance, it is true for society, because of the mutual support that ecosystem services and human living can provide each other. This capacity to combine together social and ecological perspectives, thanks to its holistic approach, makes GI planning perfectly suited for urban areas, on the one hand. On the other, it makes GI able to manage complexity in a more efficient way than the traditional planning for nature conservation or open space (Kambites & Owen, 2006).

This reinforces the idea of landscape as infrastructure, and as tool for renaturing cities via hybrid measures, making public administrations and citizens the main actors of transformation processes, since the development and the deployment of hybrid measures require a programmatic openness. This implies a harmonic, virtuous and flexible synchronisation between the long-term goals and the short-term necessities. Indeed, landscape as a process-based method that triggers multi-disciplinary experimentation requires the acceptance of time passage (Williams, 2017). Consequently services must be programmed to adapt to changing demands and societal expectations.

4.5 | Green-Blue Infrastructure

Multifunctional landscape can provide multiple benefits, functions and values simultaneously. These include also strategies related to water management. Linking together the aspects related to water management and green infrastructure and its benefits, then, is the main purpose of a Blue-Green city. In other words, the main scope of a Blue-Green city is the recreation of a naturally-oriented water cycle within the urban tissue while contributing to the amenity of the city (Hoyer, Dickhaut, Kronawitter, & Weber, 2011; Lawson, Thorne, Ahilan, & al., 2014). GBI can supply a vast set of benefits, which are more widespread than their primary functions. However, quantifing the externality values that GBI provides is not so easy. The estimates mainly derive from ecosystem services categories, together with green infrastructure (Bacchin, Ashley, Blecken, Viklander, & Gersonius, 2016).

The urban landscape is the field in which GBI combine and protect the hydrological and ecological values, enhancing the resilience of urban systems and providing adaptive measures that can contribute to deal with flood events. While green infrastructure is oriented to natural land, thus operating through the systematisation of open spaces – mainly characterised by pervious soils – blue infrastructure is a mixed system that involves both the minor and the major drainage systems. In order to better explain what is meant for minor and major drainage systems, here the definition from the CIRIA Research Project '*Managing urban flooding from heavy rainfall - encouraging the uptake of designing for exceedance*' (Digman, Ashley, Hargreaves, & Gill, 2014) is used:

> Traditionally surface water systems have been designed wholly as minor drainage systems in which the flow is contained within the pipes. When the flow in the drainage system exceeds the capacity of the minor system then the major drainage system will come into use. The major drainage system is the system of formal and informal above ground flood pathways, including open and culverted watercourses and dry rivers. The interaction between the minor and major drainage systems is complex and can be difficult to assess accurately.

Therefore, blue infrastructure comprises ponds, waterways, wet retention basins, wetlands and all those devices that are part of the drainage network.

The interplay between green and blue assets, structured by means of a networked system, contributes to supply direct and indirect benefits to communities. These benefits are related to a set of services that include: water supply, climate regulation, pollution control, hazard regulation, crops, food and, more generally, resources, biodiversity, cultural services – such as health, aesthetics, spirituality – plus abilities to adapt to and mitigate the impacts of climate change (Maksimović, Xi Liu, & Lalić, 2013; Lawson, Thorne, Ahilan, & al., 2014). This set of services produces different repercussions, according to the different states of the system, in relation with flood events. During a flood state, GBI contributes – among the other things – to the reduction of water pollution and helps controlling the water supply. When a system is in a non-flood state, GBI provides numerous benefits related to the environment – as the reduction in the urban heat island effect, the groundwater recharge – as well as social and cultural benefits – as traffic calming, road safety, etc.

Benefits of Green-Blue Infrastructure

GBI belong to the domain of those 'solutions to societal challenges that are inspired and supported by nature' (Raymond, et al., 2017). From this perspective, the EKLIPSE project[1] supplies a useful framework that identifies the domains in which GBI – and more generally, Nature Based Solutions (NBS) - deliver benefits and co-benefits, simultaneously identifying geographic and temporal scales.

GBI can contribute to transform urban areas, and particularly the denser built-up areas, having an effect on impervious surfaces and restoring water flows and functions related to water. GBI, also in combination with grey infrastructures, can provide additional co-benefits, concerning ecological and biophysical aspects (e.g.: urban biodiversity, air quality, climate mitigation) and social and economic ones (e.g.: quality of life, indirect economic benefits, such as increasing real estate values).

The framework proposed by the EKLIPSE project consists of ten challenge areas:

1. *Climate mitigation and adaptation*: GBI can be aimed at macro-scale mitigation (e.g.: by enhancing carbon storage and sequestration in vegetation or soil), or at meso and microscale adaptation (e.g.: through planting vegetation to improve the local or regional micro-climate);

2. *Water management*: GBI and NBS can contribute to sustainable urban water management by increasing infiltration, enhancing evapotranspiration, providing storage areas for rainwater and removing pollutants; furthermore, they can prevent precipitation water from directly flowing into the sewerage system and create natural spaces for temporary water storage;

3. *Coastal resilience:* Natural Based Solutions are more and more employed in maintaining or restoring key ecosystem services provided by coastal areas;

4. *Green space management*: green and blue spaces can help urban planners to achieve sustainability, since they provide, among others, aesthetic and heritage-related values (Niemelä, 2014), recreation, social interaction

(Kaźmierczak, 2013); as well as improve the functional and structural connectivity at the urban level (Iojă, 2014);

5. *Air/ambient quality*: in urban areas, air quality directly generates consequences on human health. Hence, the creation, enhancement or restoration of urban ecosystems through the implementation of GBI can help to mitigate issues related to air pollution, capturing air pollutants and reducing energy needs;

6. *Urban regeneration*: urban regeneration calls for improvements in the economic and social conditions, as well as in the physical and environmental aspects of interested areas. This represents a great opportunity to focus on ecological restoration across scales (Andersson, et al., 2014) and social justice;

7. *Participatory planning and governance*: governance has to support and foster accessibility to green areas and maintaining their quality for the provision of ecosystem services. Thus, a more integrated approach is needed to link ecosystem thinking and urban planning, starting from the comprehension of citizens' needs and perceptions (Buchel & Frantzeskaki, 2015). Thus, GBI represent the field in which the experimentation of new types of participatory processes becomes possible;

8. *Social justice and social cohesion*: planning GBI involves environmental justice, in terms of distribution (e.g.: social and spatial distribution of environmental qualities) and recognition (e.g.: involving typically excluded social groups), thus enhancing social cohesion.

9. *Public health and well-being*: NBS are able to improve the health and well-being of citizens, as they assist the provision of ecosystem services from different perspectives.

For instance, they help to mitigate the urban heat islands in highly dense areas and to reduce exposure to environmental pollution and noise. In addition, they can contribute to a range of positive psychological outcomes, such as stress reduction;

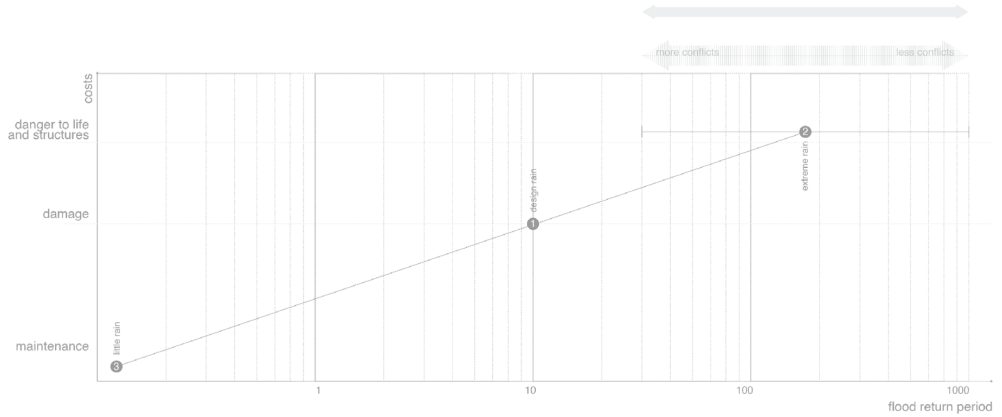
10. *Potential for new economic opportunities and green jobs*: lastly, GBI have positive effects on real estate values, improving water management and recreational services (BOP Consulting, 2013). This helps to validate the cost-effectiveness of GBI, as they can help saving money for privates and public spheres and, at the same time, contributing in the creation of opportunities for green jobs.

The challenge areas cover both the ecological and the socio-economic domains according to an intertwined approach. Each challenge area is connected to the others, and not rarely the set of actions and criteria interweaves and overlaps, because of GBI's multi-functionality, understood as its capacity to perform different functions and present a range of benefits simultaneously and over time.

4.6 | Water-Sensitive Urban Design

In normal conditions, water operates in a circular way that foresees different and subsequent phases: precipitation, infiltration and surface runoff, and evaporation. Built-up areas disturb water cycle, altering not only the process – for instance, impeding water to infiltrate, because of the imperviousness of artificial soils – but also the quality of water itself. This reverberates in negative impacts on groundwater recharge, water supplies, the state of rivers and, more broadly, urban climate.

Urban areas present increased surface runoff and a lower evaporation rate compared to other land uses characterised by a less impervious



3 I little rain

Domain of day-to-day values

particular attention is given to **the way urban space is perceived and used on a daily base** by its inhabitants.

This domain suggests that projects hold strong day-to-day values when they are able to **improve the quality of life** within the area in focus. Such considerations are expected to create a solid base for political and public support and thus ask for a higher participation in the decision making process.

1 I design rain

Domain of technical optimisation

application of **design standards for sewers and other drainage infrastructures.**

Here professionals discuss **technical solutions** to deal with defined design storms in order to prevent damage and meet the service level established politically.

3 I extreme rain

Domain of urban resilience and spatial planning

urban water managers, in order to deal with extreme events, have to **interact with urban planners and architects.**

Here the aim is to mitigate the effect of possible future extreme rains, but also to **create the technical basis for adaptation to future changing scenarios.** The idea is to make the urban area more resilient to future changes by finding new spaces for water conveyance and storage within the urban area.

Fig. 4.6 | The "Three Points Approach" and the relationships with landscape

coverage – in rural areas, soils' imperviousness is averagely 2 percent, while in dense metropolises it can be over 90 percent (Schueler, 2000) – which can result in the flooding of infrastructures and buildings. In order to avoid this problem, sewerage systems are implemented to drain water. It is possible to identify two types of sewerage systems (Hoyer, Dickhaut, Kronawitter, & Weber, 2011):

- *Combined sewerage systems,* in which wastewater and stormwater are collected in one pipe network and, after being cleaned, discharged into rivers or seas;
- *Separate sewerage systems*, in which wastewater and stormwater are collected in separate networks, and the latter is directly discharged to the receiving water.

Nonetheless, such conventional systems can have negative effects for different reasons: on local climate, due to the low amount of infiltration and evaporation, which results in the Heat Island Effect; on drinking water availability, since they reduce infiltration, affecting groundwater recharge rates. In addition, conventional systems are unadaptable and thus cannot be employed to face changing conditions deriving from socio-economic development and climate change. Consequently, such systems increase the risk of flooding.

Water-sensitive Urban Design (WSUD) is the interdisciplinary cooperation of water management, urban design and landscape planning which aims to bring water cycles in urban environments close to natural ones (fig. 4.6). As Lawson et al. stated (2014), WSUD is 'a multidisciplined approach to urban water management that aims to holistically consider the environmental, social, and economic consequences of water management strategies'. The core of this approach is based on the idea that the water cycle management must be able to integrate the engineering and the ecological aspects that converge toward the protection of urban water resources, linking them with the built environment, treating stormwater as close to the source as possible.

The outcome of the process of WSUD is the water sensitive city. This is of course a sustainability ideal, a kind of state to aspire and work toward, as there are no cities anywhere in the world so far classifiable as 'water sensitive'. This ideal encompasses four different dimensions: resilience, liveability, productivity and sustainability. A water sensitive city must reach these different goals through the virtuous interaction between the urban hydrological cycles, in order to provide a proper level of water security to ensure economic prosperity through the different efficient uses of water resources. At the same time, it should enhance and protect the health of watercourses and wetlands, mitigate flood risk and damage and create public spaces.

A vision for WSUD including a more wide idea of flood resilience must encompass:

- Managing different water regimes (water scarcity and water excess), both in terms of quantity and quality, and in an integrated way;

- Emphasising the local opportunities in the use of the water cycle;

- Promoting synergy within urban environments, among ecosystems, urban services, design and planning processes.

Despite these premises, in the practical application of the concept, WSUD still tends to focus on stormwater management. In addition, applying and developing WSUD in European countries can be challenging for various reasons. One of these concerns the economical aspects, since local governments in Europe are experiencing a period of strict austerity. Another issue is related to the slow return of the investments and the high upfront costs. Furthermore, other constraints to investment include lack of familiarity, limited information and knowledge, and limited expertise in WSUD (OECD, 2012).

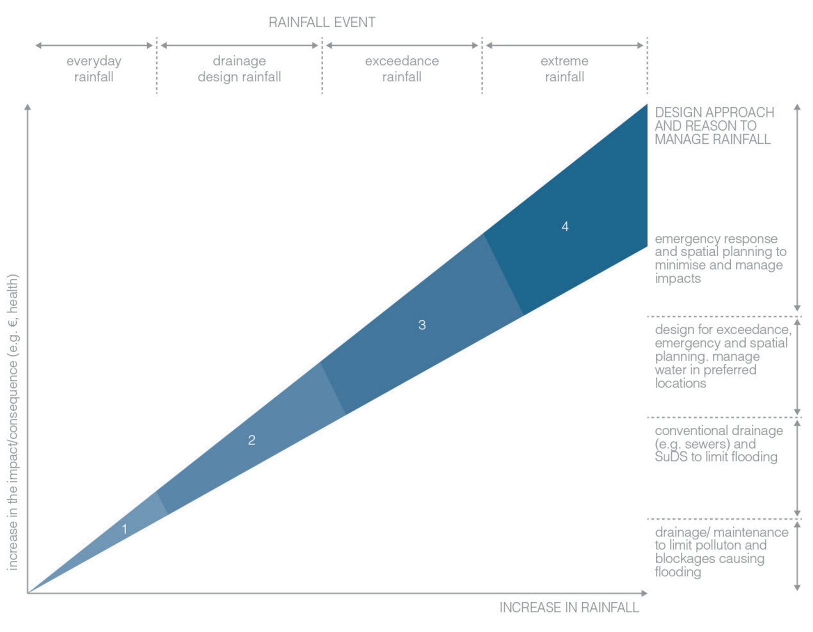


Fig. 4.7 | The Four Domains Approach to demonstrate how to manage different types of rainfall events

Nonetheless, a Blue-Green-oriented approach should be able to reach a wider extent of benefits, ranging from the improvement of water quality and the mitigation of flood risk, to the provision of important ecosystem services and social benefits, when the urban system is in a non-flood condition.

4.7 | The Four Domains Approach

> We can create safe and resilient flood routes, temporary storage areas and make use of other measures to reduce the impacts, even though occasionally it may cause disruption. We call this designing for exceedance. (Digman, Ashley, Hargreaves, & Gill, 2014)

Taking into account the range of different conditions among which a system can shift is important. In flood risk management, the different types of rainfall are the key through which different urban system's states can be defined.

Concerning this, the 'four domains approach' (4DA) (Digman, Ashley, Hargreaves, & Gill, 2014) is a useful tool through which it becomes possible to delineate a set of scenarios in relation with the quantity of rainfall, and the best way to benefit urban areas in each condition. The 4DA adapts and implements the three points approach, proposed by Fratini et al. (2012), which main aim is to provide managers and operators that deal with flood prevention with a tool that helps formulating future scenarios and the effects of different possible solutions. The three points approach identifies three different system states. The first one is the non-flood state, in which a 'green condition' is present, the second one is a design standard state, and finally, the third one is characterised by an extreme event state, which corresponds to a 'blue condition'.

The approach provided by the 4DA highlights four different spheres that represent the relationship between rainfall and its impact on a catchment.

The identified four domains are (fig.4.7):

- *The Everyday rainfall (1).* This domain considers the small rainfall events, during which the drainage systems perform as designed, unless they become blocked. Here, the low intensity and volume of rainfall are taken into account, and hazards are rare. In this condition, the benefits of using rainfall as a resource predominate;

- *The Drainage design rainfall (2).* Here, as the rain gets heavier, the drainage helps to protect homes and open spaces from flooding. Thus, an adequate maintenance of the systems helps to prevent from hazards;

- *The Exceedance rainfall (3)*, in which the drainage system can no longer cope with flooding and, thus, managing the exceedance that consequently happens becomes necessary. Here it is possible to manage exceedance events through interventions and multi-functional land use. Furthermore, in this domain, both structural and non-structural responses can be employed. This domain bridges the gap of interventions required to manage the exceedance and greater extreme events;

- *The Extreme rainfall (4).* This domain takes into account the situations in which rainfall is extreme and emergency planning and services are the tools to help managing and controlling flooding and its impact on people.

These scenarios are all important in spatial planning and urban design for ensuring resilience and spatial quality together (Salinas Rodriguez, et al., 2014). Whilst the first two domains are characterised by minor and/or acceptable hazards – and consequently by the adequacy of grey infrastructure to manage water – the third and the fourth domains are the ones in which land use and urban form become fundamental.

Consequently, the exceedance rainfall is the domain in which landscape architects and urban designers can intervene, designing open spaces to enhance the existing urban environment in dealing with water. Reaching this goal means as well providing spaces that can be used as amenity, wildlife and recreation areas.

From this perspective, urban environment can represent an extremely useful resource in dealing with flooding. Through regeneration processes, according to recycling principles, changing and reshaping the topography of the landscape become possible. Indeed, flooding 'occurs when a drainage system does not have the capacity to carry more surface water' (Digman, Ashley, Hargreaves, & Gill, 2014), and free space within the city, together with the infrastructure systems can play a fundamental role in managing the water temporarily present on the surface. This is called *designing for exceedance*. Exceedance flow in urban drainage is defined as 'flow that is conveyed or stored on the surface because the capacity of a drainage system carrying surface water (including as a result of a blockage to an inlet) has been exceeded' (*ibid.*).

Designing for exceedance provides a great opportunity: indeed, it can help to shape and create public space and, at the same time, to implement a more flexible infrastructure, characterised by multi-functionality.

Undoubtedly, exceedance follows surface pathways and ponds in low spots. The opportunity in creating space in order to manage exceedance flows lies in the possibility to assign to space a wide range of different functions. These functions can include, for instance, recreation, transport, biodiversity, well-being improvement, together with flood and water management. Concerning storing and managing water, open green spaces and, more generally, public spaces provide an opportunity to regulate flood risk while reducing costs.

This approach to design, of course, needs a strong interplay between different disciplines: spatial planners, urban designers, landscape architects, together with engineers need to work together according to the different issues and conditions of a territory, recognizing the values that such a cross-sectorial and cross-scale approach can provide. Furthermore, designing for exceedance cannot avoid the involvment of community, as the latter can potentially become a substantial part of the solution in managing exceedance, and at the same time, involving communities means make people more aware about the importance of even a small change. From this perspective, wasted lands represent the ideal field in which experiment new forms of participation in which technicians, stakeholders and citizens converge, and can be involved in co-creation, co-design and co-implementation processes.

4.8 | Conclusions

Major infrastructure projects unfold over time and space employing of an interconnected, circular set of design, consultation and implementation phases, which are not fixed but, on the contrary, constantly undergo significant changes. These changes directly depend on changes in physical context, as well as on the response to practical challenges deriving from social needs and governance skills and issues.

This results in a more and more emergent awareness of the central role of process design as a tool to engage citizens and, more in general, different types of stakeholders in participation (e.g.: co-design, co-development, co-implementation). Process design can foster flexibility in the implementation of GBI, sustaining the addressing of the unforeseen changes in climate and the urbanization patterns and their expected impacts on supporting, provisioning, regulating and cultural services.

From this perspective, landscape can act as a performative medium, fostering adaptation measures and providing opportunities to increment multi-functionality both in the third – space – and fourth – time – dimensions. Furthermore, landscape is becoming increasingly relevant within the domain of risk and resilience, adaptation and change, as there is a growing consensus on its ability to deliver multiple benefits.

Integrating landscape whit WSUD, then, means providing a fundamental tool to develop non-traditional measures for flood risk management, incorporating natural solutions and cooperating with and sustaining grey infrastructure, thus contributing to increment flexibility in water management.

From this perspective, the implementation of WSUD in highly dense cities – as the ones in the European context - often comes about through the redevelopment of derelict areas. Then, a higher focusi on improving resilience of vulnerable areas, systems and functions in redevelopment and regeneration processes (Veerbeek, Ashley, Zevenbergen, Rijke, & Gersonius, 2010; Gersonius, 2012) is needed, as well as the development of incremental strategies that can foster the implementation of GBI. Such strategies should be process-oriented, in order to link long-term goals (e.g.: flood risk mitigation, enhancement of citizens' quality of life) and actions (e.g.: remediation chains related to polluted areas, retrofitting), with short-term tactics, to reactivate natural and social processes and minimize the waiting time for technical remediation works. Defining temporary uses can be effective to make spaces and capital available for transformation.

The 4DA helps in defining a set of timeframes according to four rainfall return periods, thus structuring a framework for the definition of spatial strategies tied to redevelopment of drosscape for each rainfall type.

Endnotes

1 The European Commission requested the EKLIPSE project to help building up an evidence and knowledge based on the benefits and challenges of applying Nature Based Solutions, in 2017.

05 Planning with drosscape for Green-Blue Infrastructures

5.1 | Introduction

> Without an 'interpretive framework' or 'model' there is nothing with which to compare an on-going evolution to its on-going 'expected evolution'. We will not know that the real world is evolving qualitatively and deviating from our representation of it, unless we can compare the on-going situation with that 'predicted' by the model. Indeed, it may well turn out that the most useful information that comes out of a model is that it is failing to fit reality and its predictions need to be reassessed. (Allen, 2012)

According to what emerged from the previous chapters, within urban systems, drosscape represents the two sides of the same medal. On the one hand, its presence reveals the fragmentation conditions of a city intended as a complex adaptive system, and consequently, a lack of resilience; on the other hand, it constitutes the element that supplies flexibility and opportunities for adaptation.

For these reasons, the recognition of these areas is of primary importance, as they are able to provide an efficient description of the state of a system and give suggestions about toward which state it could shift. Nevertheless, the identification of these remnants and slivers through the continuous and discontinuous urban tissue is not simple at all.

Along these lines, the methodology here proposed intends to give value and take advantage of landscape, and more specifically the discarded urban landscape for the achieving of multi-functionality water sensitivity (Ferguson, Frantzeskaki, & Brown, 2013; Leonhardt, et al., 2015) through the implementation of Green-Blue Infrastructure. In order to gain this goal, the methodology developed within this research considers different aspects related to distinct issues that emerged in the previous chapters.

The methodology is supported by a spatial approach and is based on GIS design tool, and takes advantage of the features made available by the software Fragstats for the morphological analysis of the case study.

The aim of such methodology is dual. The first scope is the understanding of the spatial dynamics that contribute to the formation of wasted lands. As already stated in chapter 2 and chapter 3, drosscape can be intended as the result of both internal and external processes that bring some parts of the city toward the end of their life-cycle. Such dynamics unavoidably generate a set of different land uses and an associated shape of the elements that compound an urban system. A morphological analysis of these shapes can highlight the cause-effect relationships that have brought to the ‘final’ spatial condition of a city.

The second intent moves from the premises that the potential of drosscape is stronger when it is put in relation with all the sub-systems belonging to the same layer (see paragraph 3.7), and it affects and is affected by the sub-systems which belong to the other layers that compound a city. For this reason, the here proposed methodology moves from a landscape-oriented perspective and from the idea that drosscape, as a proper landscape, presents peculiar morphological features which, when linked and organised through a multi-scalar approach, can offer a myriad of possibilities for the design of a green-blue network, providing at the same time flexibility for adaptation strategies.

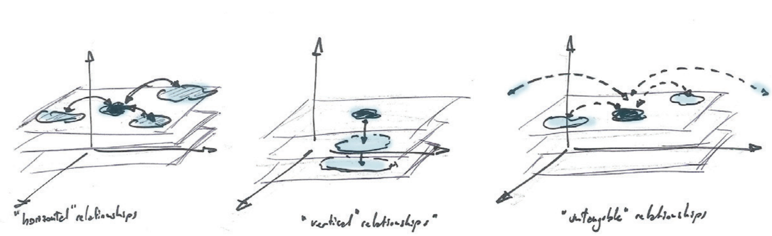


fig.5.1 | Diagrams of relationship typologies of drosscape.

In the following paragraphs, a deeper and more exhaustive description of the above mentioned scopes will be proposed, and a set of metrics and indicators will be developed.

The approach proposed within this research work starts from the definition of *drosscape* (see chapter 2), and the recognition of the intrinsic values that mark it. These above mentioned values present different levels of acknowledgement. Some of them are related to the morphological and topological aspects. Others emerge out from an ecological perspective; some others better describe the opportunities and the criticalities concerning the social and the economic spheres.

In general, we can distinguish them according to two main characteristics that delineate a first classification. These characteristics describe the meaning of the values according to the degree of connection of wasted lands. Some aspects are relevant when we consider wasted areas themselves – like the level of biodiversity, or the presence of human activities within their boundaries – and for this reason, they are considered here as intrinsic values.

Other aspects acquire significance only when we consider them in relation with the context. From this perspective, the *Dutch layers approach* (described in paragraph 3.7) helps to provide a useful framework to categorise and interpret the relations that drosscape establishes with the other parts of the city. Hence, starting from these premises, here a three-branch system of classification is proposed, according to three different typologies of relation that drosscape can stimulate. The *horizontal relationships*; the *vertical relationships*; the *intangible relationships*. The horizontal relationships are those relationships that materialise themselves among subsystems belonging to the same layer. Since drosscape is generated by the absence of uses, and, according to the Dutch layers approach, uses are part of the layer of the occupation pattern, we can assume that, for the transitive property, drosscape exists in the latter layer, which is the most 'superficial' one. Nonetheless, it interacts with subsystems belonging to different layers, such as the layer of substratum and the layer of the networks. Both the horizontal and the vertical relationships are intended here as interactions that spawn physical effects on the subsystems that form the urban system. Hence, some additional categories need to be added to this group, in order to achieve a satisfactory description of all the drosscape's values. These categories are the one of the intangible relationships, as already introduced above, and the territorial set, which will be more deeply described in paragraph 5.4.

Furthermore, the framework provided by the Dutch layers approach finds its relevance in the role that gives to time scales. The issues related to time are central to this work. The structure of the methodology takes place starting from the definition of different timeframes, according to the domains identified by the Four-Domains Approach (see chapter 4), which defines when and according to what issues landscape can play a fundamental role for adaptation and implementation of Green-Blue Infrastructure. Such a definition of different timeframes can help delineating a flexible strategy, based on the availability of wasted land in different lapses of time and on the individuation of possible conflicts among time. Even though the Four-Domains Approach identifies a set of multi-scalar tasks and goals for GBI, due to the nature of this work and the availability of data, the third domain – the exceedance rainfall one – is mainly taken into account here.

Figure 5.1 summarises the structure of the methodology, conceived as a flow chart articulated in four steps. These are the following:

- The first step concerns the data collecting and the consecutive classification of drosscape. In this phase, then, a data model is structured according to a set of categories that allocates homogeneously drosscape according to its former use and its degree of abandonment.

- The second step forecasts the morphological analysis of drosscape using the metrics deriving from landscape ecology discipline, putting in relation drosscape with the urban landscape within which it lies. Such metrics are then employed as descriptive parameters of waste lands' morphological condition.

- The third step proposes a set of performance indicators that can support the performance assessment in the design of exceedance process, in order to identify what are the features of wasted lands that can boost or impede the redevelopment of drosscape and its use for the implementation of GBI.

5.2 | Data collecting and drosscape classification

Data collecting

The first step contemplates the organisation of a data model, in order to hold together all the collected data and their subsequent cataloguing. This phase is indispensable and, at the same time, extremely thorny, for several reasons. First, because of the non-homogeneity of the data that can be used to describe drosscape, both in terms of intrinsic and relational features. The intrinsic features are all those characteristics that define areas in terms of morphological aspects and land uses. It is not always clear and immediate, indeed, how to define the exact boundary of a wasted land (see Paragraph 2.4). The extent of these peculiar areas can vary, depending mainly on their former land use and location. For instance, there is a correlation between their size and their location, as the first augments as the position becomes far from the centre of a city. At the same time, their borders are easily recognisable when they are close to core of the urban system, becoming more and more blurred in the dispersed city.

In addition, it is hard to collect and combine spatial information, alphanumerical information, and information that come from non-institutional sources. Spatial information deal with scale for representation issues, and for this reason, they cannot be meaningful according to the scale used to analyse this phenomenon. In particular, drosscape is a multi-scalar phenomenon, which shows itself through different scales. This often implies that data from European, national and local agencies and institutions cannot always be exploited at their best for the mapping process. A further issues is represented by time. Drosscape comes up at different paces and shows itself at different timeframes, as wasted lands are phenomena that are closely related to time, due to their suspension conditions (see Paragraph 2.2). Dynamics of abandonment and under-utilisation are not easily mappable and they happen with a pace that is absolutely faster than cartographic production. This implies that the utilisation of maps coming from institutions can solely be the first step of the identification process concerning drosscape. An additional and extremely powerful tool is provided by desktop web mapping services. In the last decade, technology companies have been offering more and more accurate satellite imagery, which covers almost the entire globe and displays a higher and higher resolution. This, of course, enhances the possibility to recognize this phenomenon through different scales and adds a qualitative information based on interpretation, which is hard to catch within the institutional maps.

The second main issue is related to alphanumerical data or, more generally, to historical data. Dealing with wasted land implies the understanding of how processes developed in time. In this sense, the lack of data reduces the accuracy in description of these processes, thus limiting the comprehension of the present conditions. Moreover, drosscape's formation is determined by both local factors and global dynamics, which are easy to describe mainly through qualitative graphs and diagrams, but they may not be significant if added on a map (see Paragraph 2.4). However, the identification of the most appropriate time intervals has to be functional to the spatial scale through which the phenomenon is observed, which in turn can vary according to the typology of wasted land taken into account time after time.

Thirdly, the definition of all the relationships and the interactions that drosscape establishes with the context implies a sharp selection. In the construction of a reliable and valid model that is able to communicate and represent the real word, simplification operations are unavoidable. Reliability is given by a certain structural kinship of the model with reality (Klaasen, 2004), but sometimes model building is obliged by data availability and weak consistencies among data.

Drosscape mapping, thus, is a process composed by two main and complementary steps. The first is data collection, as described before. The second is a mix between desk work and field work, based on an empirical approach that needs systematisation before the classification of the elements. Concerning drosscape classification, the main principle according to which wasted areas are categorized in this research is their former land use.

Data collecting and drosscape classification represent the basis for the construction of a model in order to describe reality. Data selection is essentially a phase of reality reduction determined by the omission of elements and attributes that are considered not relevant; classification is the act of categorizing attributes of elements (*ibid.*).

Drosscape Classification

As previously stated, the voids that emerge out from the urbanised areas can have different meanings, as they generate from different land uses and have a wide range of impacts on resources consumption. Berger (2006) identifies three macro-categories of drosscape: voids as actual waste, voids as wasted places, and voids as wasteful places. In the first category the municipal solid waste, the sewage system, scrap metal, are included. The second category refers mostly to abandoned and/or contaminated sites. The latter comprehends places that are not exploited at their maximum potential, such as oversized parking lots or big-box retail venues. From this classification, the extreme heterogeneity of drosscape emerges, and it reverberates in a wide range of different features that characterise each category. Some of them are morphological, such as the size and the extension; some others are related to the way they affect resources or the urban system. Berger, then, identifies seven categories of drosscape that are:

1. Waste landscape of dwelling: this category comprehends the monofunctional residential areas;
2. Waste landscape of transition: the areas of land speculation;
3. Waste landscape of infrastructure: areas related to infrastructure and interstitial spaces;
4. Waste landscape of obsolescence: areas related to landfills and waste management;
5. Waste landscape of exchange: areas of logistic and large retail sectors;
6. Waste landscape of contamination: polluted areas with high degrees of environmental degradation.

Within the PRIN Re-Cycle (see Chapter 1), seven categories of drosscape were identified in order to describe the voids of the Piana Campana. These categories are[1]:

1. Derelict soils
2. Waterways network and abandoned hydraulic devices
3. Compromised ecosystems
4. Critical urban fabrics
5. Abandoned special and industrial buildings

6. Quarries and landfills

7. Abandoned infrastructures and related interstitial areas

Such classification highlights the multiscalarity of the phenomenon, together with the uttermost diversity of the elements. Undeniably, this categorisation takes into consideration elements that are strictly related to natural processes, as well as extremely urbanised portions of the city and even single isolated buildings. Within this research work, a slightly different classification is proposed. This because of the need of consistency related to the analytic phase, as this focuses mainly on the morphological characters of drosscape. Consequently, the abandoned industrial buildings have been associated to their corresponding areas, and classified as abandoned industrial areas; furthermore, the other buildings have been redistributed according to their previous use.

This, together with the choice to not include resources – such as soils and water system – led to a reformulation of the typologies according to a more traditional categorisation based on land use. The categories, then, are:

1. *Abandoned industrial areas*: this category includes those areas associated to a former industrial use, together with the related buildings and facilities, which are currently disposed. These portions of city are often connected with high degrees of contamination of primary resources such as water, soils and air;

2. *Hydraulic devices:* this category mainly refers to wastewater treatment plants and their related areas. The elements that compound this category are not characterised by a state of dereliction, however, they are specialised areas which, even though necessary for the city's metabolism, represent a fenced void within the urban landscape.

3. *Compromised ecosystems*: this category encompasses those areas characterised by an altered ecosystem. They are semi-natural spaces

in which the presence of waste treatment facilities or the use of pollutants contributed to the level of contamination. Within this work, compromised ecosystems are mainly compounded by the agricultural fragment, heritage of the past production system.

4. *Critical urban fabrics*: this category refers to those urban areas that are at the end of their original life cycle – both from an architectural and a functional perspective. These areas call for a compelling physical and social regeneration for different issues. The age of buildings, on the other hand, can represent a window of opportunity for the regeneration of such areas, while the lower price of houses and commercial spaces offers the possibility to less advantaged social classes to have a shelter.

5. *Quarries and landfills*: this category combines areas allocated for the excavation of resources and waste storage areas; these elements are not rarely characterized by a mismanagement that influenced in a negative way natural resources and adjacent urban tissues;

6. *Interstitial areas of infrastructures*: this category includes all the empty areas left along and under the railway and highway infrastructures, often characterised by oversizing and a gap in the interaction with the urban tissue. From a design-oriented perspective, such areas represent the ideal elements from which develop ecological corridors.

7. *Abandoned or underused areas of logistics*: the last category refers to those areas designated for logistics and, for this reason, they can be considered as wasteful places. Logistics need wide spaces that, on the other hand, are not completely exploited during their life time.

5.3 | Drosscape analysis: descriptive parameters

The second step focuses on the analysis of landscape.

Within this work, the map of land use provided by the Urban Atlas has been preferred to the Corine Land Cover (CLC) maps, for two reasons. The first one is the scale of representation of such maps, and consequently the grain, which is 1:5000. CLC's scale of representation is, on the other hand, 1:25000, and then it has been deemed not adequate for the landscape analysis at the urban scale. The second reason is represented by the possibility to replicate the here proposed approach to the metropolitan areas of the European Community. In fact, EEA makes available such land cover data for large urban zones with more than 100000 inhabitants. On the other hand, this limits the application of such approach to the European metropolitan areas.

The identification and the setting up of the sub-basins for the landscape analysis and the comparison of the case study forecasted the elaboration of spatial analysis based on GIS software, which is described in paragraph 6.5.

The selected landscape metrics have been chosen in order to describe two phenomena from a morphological perspective. The first is represented by the landscape as a whole. Thus, the metrics aimed to describe the main features of the identified sub-basins within Napoli Orientale. At a later stage, a selection of such metrics has been applied for the analysis of the previously described categories of drosscape, and subsequently put in relation with the results emerging from the landscape analysis. The here proposed metrics are derived from landscape ecology discipline, and are presented below.

Landscape composition (see Annex 1)
Composition refers to features and to the variety and abundance of patch types, focusing on quantitative aspects.

Abundance

The proportional abundance of each patch type in the landscape is quantified by the percentage of landscape metric. Abundance, then, is a descriptor of the landscape’s composition.

Diversity

Diversity can describe a degree of flexibility of a landscape. It is a result of composition and configuration of the patches of landscape. Patches are ‘relatively homogeneous area[s] that differ from its surroundings’ (Ahern, 2007), and, from the ecosystem’s perspective, are able to provide essential functions for man and nature. Diversity expresses the spatial heterogeneity of a landscape and in ecology it is function of the number of different patch categories and their relative abundance (McGarigal, 2002; Bacchin, 2015). Within this work, it is measured through the use of Shannon’s Diversity Index (SHDI).

Richness

Richness, refers to the number of patch types present in a landscape. Thus, it is a further measure of diversity. In this work, richness is expressed by Patch Richness (PR) metric.

Evenness

Evenness expresses the relative abundance of the patch classes. It is a function of the maximum diversity possible for a given richness.

Subdivision

Subdivision is an aspect related to the degree of aggregation of a landscape. In this work, Number of Patches (NP) and patch density (PD) are employed to calculate subdivision. These metrics are simple measures of subdivision or fragmentation at the class and landscape level. They uniquely refer to the number of patches that compound a class or a landscape, thus not conveying any further information about area, distribution, or density of patches. While NP provides the amount of patches, PD expresses a similar information on a per unit area basis.

Dominance

This indicator equals the area of the largest patch of the corresponding patch type, divided by total landscape area. In particular, for drosscape, largest patch index is calculated at the class level, thus it is a simple measure of dominance. Here, LPI is used to quantify dominance.

Landscape configuration (see Annex 1)
Configuration refers to the spatial character of patches within the class or landscape. It can be quantified at patch, class or landscape level.

Size

Patch size is the simplest measure of configuration. Within this work, it is calculated at the patch level, as well as at the class one. In the latter case, patch size has been summarised using the mean. Patch size is computed as the total area of each patch.

Extent

Extent, together with size, are measures of how much a landscape is heterogeneous and fragmented (Bacchin, 2015). It expresses how far-reaching a patch is. Here, the associate metric is GYRATE, which computes how far across the landscape a patch extends its reach on average (McGarigal, 2002)

Complexity

It refers to the geometry of patches – whether they tend to be simple and compact, or irregular and convoluted (McGarigal, 2002). The most common ways to measure complexity are based on the perimeter-to-area ratio. Consequently, the greater the index is, the more complex the patch. Due to the wide variety of drosscape's size, within this work PAFRAC is used to measure complexity.

Aggregation

Aggregation comprehends a set of various information referring to the spatial distribution of the patches within a landscape. Such aspect is particularly relevant for drosscape analysis, as it shows the potential of fragments according to the spatial relations that they establish among the patches of the same class and the ones of other classes.

Subdivision

This feature refers to the degree to which a landscape is broken up into separate patches. Subdivision and aggregation are highly correlated. Here, subdivision is computed through the employment of PD.

Isolation

Isolation refers to the tendency for patches to be relatively isolated in space (McGarigal, 2002). It is correlated to subdivision, but it deals with the distance between patches.

Contagion

This indicator considers the size and the proximity of the patches of landscape, quantifying them according to the degree of influence between the elements that compound a landscape. Such aspect is complementary to Isolation. Thus it expresses a certain degree of landscape homogeneity (Bacchin, 2015). It is calculated through the use of the Proximity Index (PROX).

5.4 | Performance parameters

The reintroduction of drosscape in the urban systems depends on a set of different factors. Some of them are easily identifiable – i.e., the degree of resources' pollution – some other can represent a potential when put in relation among them. Furthermore, such features can impede the recycling process of wasted lands in time, limiting the range of uses they can host. Nonetheless, from a GBI point of view, drosscape can serve different scopes and guarantee certain flexibility in the incremental process of design and, consequently, multifunctionality of the elements that form a green-blue network and of the network itself as a whole.

The design of Green-Blue Infrastructure in urban contexts employing abandoned areas means dealing with two distinct main issues: on the one hand, the water management; on the other hand, the level of environmental degradation that not so rarely connotes drosscape. According to the framework provided by the Four-domains approach (see Paragraph 4.8), wasted lands can play an important role for the implementation of adaptive strategies. This is particularly true for the third domain, the exceedance rainfall one. Within this domain, the drainage system can no longer cope with flooding and, thus, managing the exceedance that consequently happens becomes necessary. Here it is possible to manage exceedance events through interventions and multi-functional land use and employing both structural and non-structural responses.

The multi-dimensional features that explicit the potential of drosscape for the implementation of GBI are here organised into four different sets.

Each indicator is a descriptor of the constraints and opportunities for the implementation of Green-Blue Infrastructure, related to the physical – ecological – aspects, as well as the socio-economic and political aspects. Such framework is elaborated starting from the classification proposed by the Dutch layer approach, and represents a model able to isolate and highlight those variables that come into play in the design of a green-blue network, in the light of CAS theories. Below, the proposed sets of performance parameters are described.

Set 1: intrinsic

The first set collects all those parameters that are able to portray the intrinsic values of abandoned lands, from different aspects. Spatially speaking, they are descriptors of those phenomena that connote drosscape and take place within the boundaries of the latter. Some of these indicators refer to the drosscape's morphology (such as size, extent, complexity) and they have been already described in the previous paragraph. Others refer to their former or current land use and the pressure, and some others describe the topological aspects.

Morphological parameters

Size

Size can influence richness and abundance of biodiversity. Thus, it is an important parameter to consider in the design of GBI. The identification of different size of patches within the urban system can support the design of nested networks according to a hierarchy based on the most significant patches based on size.

Extent

Extent refers to how far across the landscape a patch extends its reach. Such feature is essential for some organisms and ecological processes. It can play an important role in the identification of corridor in a highly dense urban system.

Land Use parameters

Land Use

Land use and cover are descriptor of changing conditions. They can be intended as direct drivers of change (Bacchin, 2015). Land use is perhaps the simplest parameter to consider in the implementation of GBI. Land use determines the flexibility of a green-blue network, and thus the range of benefits that its element can provide. Within this work, for the analytical phase, land use is derived from Urban Atlas maps of the metropolitan area of Naples (year 2009).

Intensity of use

This parameter is a descriptor of how much a wasted land is used. It refers to the main activity that characterizes the areas, and connotes it according to the intensity of use. Areas which are at the end of their life cycle can potentially host a wider set of uses than areas that are wasteful places. Areas allocated for logistics, for instance, can have a low rate of direct benefits for human purposes. Nonetheless, they can be designed in order to maximize their environmental values.

Density

Considered as an intrinsic aspect, density express the degree of spatial consumption (Bacchin, 2015). Here, as intrinsic aspect, density refers to the land cover intensity.

Topological parameters

Landform

Landform, elevation and steepness can be used to derive surface hydrology and catchment areas. Here, landform is derived by the digital terrain/elevation model (DTM/DEM).At the urban scale, landform determines how the hydrological system works, the direction of water flows and the areas of accumulation. Thus, landform can influence the degree of multi-functionality of areas.

Set 2: relational-spatial

The second set of parameters gathers together the features that drosscape presents in its relationships with the context. Specifically, it takes into consideration the spatial relationships, according to the framework provided by the Dutch Layers Approach (fig. 5.3).

Thus, two criteria have been chosen to organise the indicators: the ones that describe the 'horizontal' parameters compose the first group. Horizontal relationships happen when an interaction between elements of those subsystems belonging to the same layer occurs. Such indicators highlight the relations between abandoned lands, as well as the relations that drosscape sets up with the elements of the subsystems that form the occupation pattern layer. On the other hand, the 'vertical' parameters are those that take place between drosscape and the elements belonging to the subsystems that form the layer of substratum and the layer of networks.

Horizontal parameters

Aggregation

Aggregation is a fundamental aspect when considering drosscape in the implementation of GBI. Indeed, it reveals the potential that it offers for the design of the network, deriving from the spatial configuration of the voids. Not often, wasted lands are small fragments in-between the city. Consequently, their degree of aggregation can be even more relevant than their size.

Isolation

Isolation of habitat patches is a critical factor in the dynamics of spatially structured populations (McGarigal, 2002). Hence, it is an important parameter to assess the habitat loss and the degree of fragmentation. A GBI should be designed in order to reduce isolation.

Heterogeneity

From an ecological perspective, heterogeneity directly influences the amount of information contained within a landscape, and thus, its richness. From a socio-economic perspective, heterogeneity can enhance the degree of an urban system's resilience to economic crises and foster social cohesion.

Vertical parameters

Pollution

Drosscape are not rarely related to resources pollution and consumption, due to their former use. This can limit the range of possible uses, and slow down redevelopment processes in polluted wasted areas. Polluted areas need remediation processes which have to be conceived as flexible as possible, comprising natural technologies that can foster the ecological succession, together with temporary uses that can encourage social re-appropriation. Hence, pollution directly acts in the temporal sphere.

Hydrogeological risk

Vulnerability and Exposure to flooding claim for a design oriented to water management. In areas subjected to flooding, technical interventions and infrastructures should be planned paying attention to the opportunities provided by landscape, according to a multi-dimensional and a multi-disciplinary approach. Thus, multipurpose spaces should be considered, as green areas or floodable public spaces, in order to provide benefits affecting both man and nature.

Infrastructure network

The infrastructure system returns the degree of accessibility of a certain areas. From an analytical perspective, the infrastructure network provides two types of information. The first is the level of provision of and accessibility to green spaces in an area. The second is the potential hydraulic connectivity between streets carrying runoff and the green patches in the near areas.

Services

The presence or the absence of public buildings (e.g. schools, universities, hospitals, courts, etc.) can boost or slow down the redevelopment of drosscape, and/or steer the allocation of the elements that form GBI. This information is particularly useful in order to reach higher levels of social cohesion, and to maximise benefits related to physical and psychological ealth.

Set 3: relational-intangible

The relational-intangible set includes all those indicators that are useful to depict the relationships that drosscape settles and which are not directly related to space.

Hence, the indicators refer here to the economic aspects (such as the residential values, the commercial values, the productive values, etc.), as well as those values that come from the possible presence of masterplans that directly or indirectly involve drosscape.

Economic values

Drosscape generates repercussion on the surrounding environment, affecting not only the primary resources, but also the economic value of the adjacent land use. When observed according to a temporal perspective, economic values of the land are a useful parameter to identify a correlation between the formation of drosscape and its sourrounding areas. Within this work, economic value is represented by the residential, commercial, productive values of the study area derived from the Italian Osservatorio del Mercato Immobiliare .

Population

Population is a measure of anthropic pressure on the land. Demographic trends can return the variation in intensity and pace of this phenomenon. An uncontrolled and fast growth in population proportionally influence the degree of exposure and, consequently, vulnerability to flood events. On the other hand, population is a basic indicator to quantify the demand of services and infrastructures in the urban systems. Here, population is considered ad intangible parameter. Here, the population is calculated at the neighbourhood using cadastral sections and data provided by ISTAT, using as indicator both the effective population and the density, expressed in inhabitants per hectare. The indicator is calculated trough using proximity analysis. Specifically, for each point identifying a service, Euclidean buffers are calculated, in a two-dimensional Cartesian plan.

Presence of informal activities

As drosscape are places in which a formal use is no longer present, wasted lands are subjected to a social recolonization, which is often hardly recognisable. Nonetheless, such process represents an opportunity to learn from the 'soft' dynamics that bring drosscape to new possible balance states. In addition, considering such aspect, can help avoiding the flattening of meanings that wasted lands present, contributing to social cohesion.

5.5 | Conclusions

The approach proposed within this chapter has a dual aim. The first is the identification of morphological features related to drosscape that describe its composition and configuration. In order to define such characteristics, wasted lands are analysed as proper categories of landscape. The main purpose of this analysis is the identification of any possible existing correlation between land use and related wasted area. Hence, the here proposed metrics solely refers to the morphology of landscape.

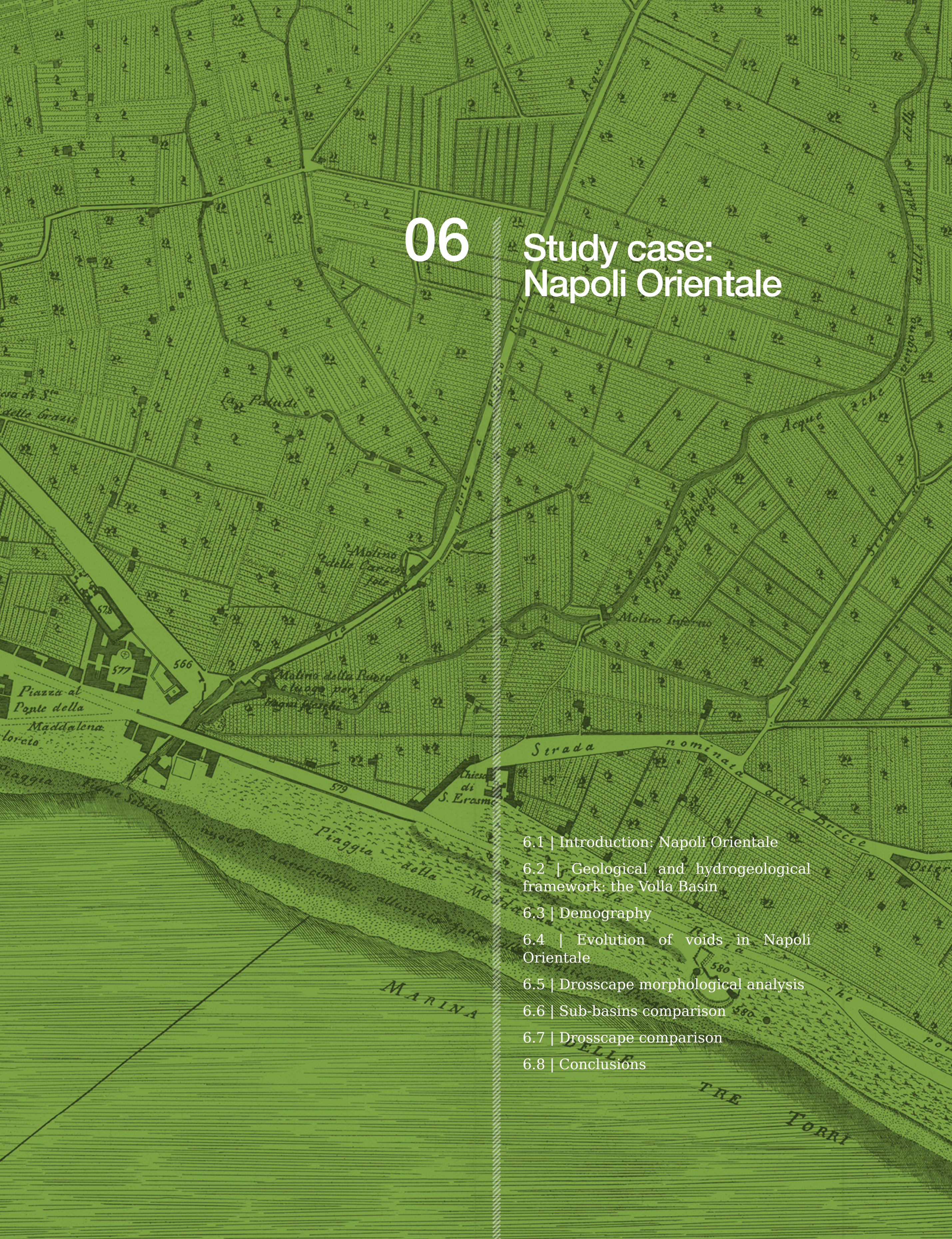
In a second phase, the metrics used for the analysis have been integrated in a multi-dimensional set of parameters, organised according a structure derived by the Dutch layer approach, in order to identify what characteristics of wasted land represent an opportunity for the design of a flexible GBI in densely urbanised contexts. Performance parameters selected to best match with the issues highlighted by the exceedance domain, proposed by the four domains approach. Such parameters represent a first step for the setting of performance objectives in the design for exceedance, and a tool for the evaluation of the flexibility degree of GBI.

In the next chapter, the here described approach is applied to the study case of Napoli Orientale.

Endnotes

1 In the original version, the categories identified within the PRIN Re-Cycle are:

1. Suoli relitto
2. Reti delle acque e dispositivi idraulici dismessi
3. Ecosistemi compromessi
4. Tessuti insediativi critici
5. Edifici speciali e industriali dismessi
6. Cave e discariche
7. Infrastrutture dismesse e aree interstiziali

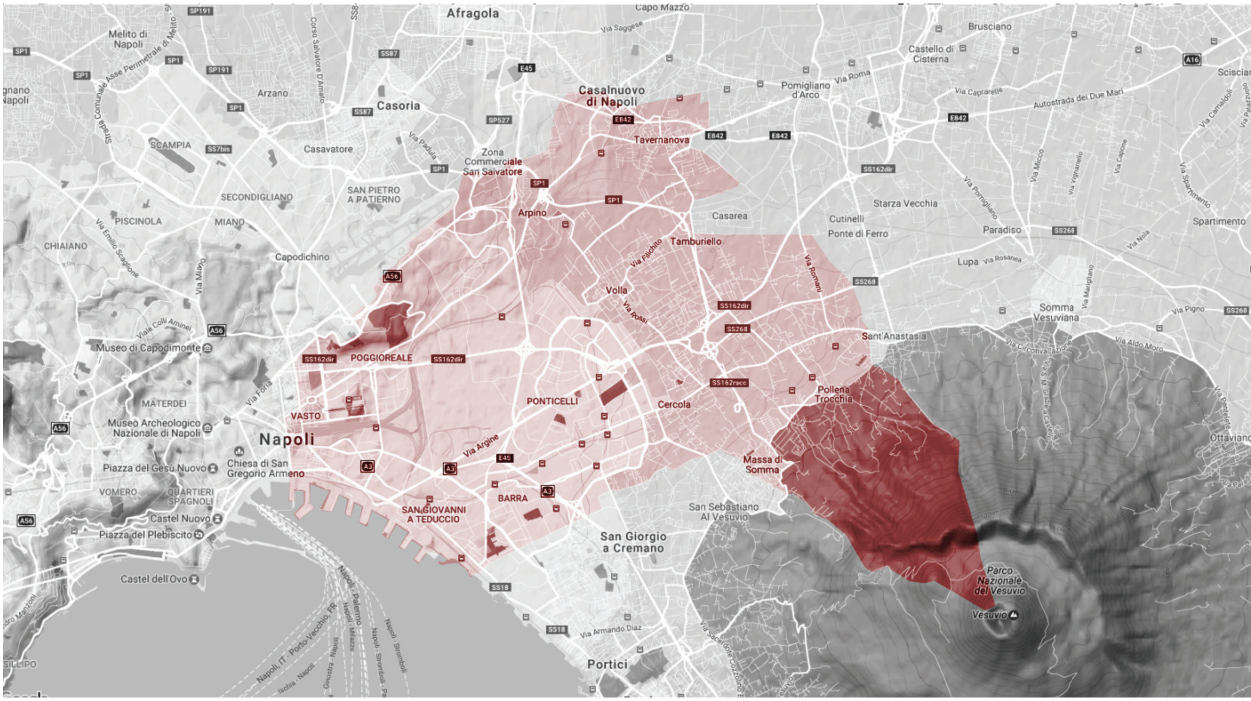


06 Study case: Napoli Orientale

6.1 | Introduction: Napoli Orientale

The study case of this research work coincides with the Valley of Sebeto, a portion of territory that lies in the south-eastern side of the *Piana Campana*, the plain known as *Campania Felix*, which extends from the Garigliano River to the slopes of Vesuvius volcano. The Valley of Sebeto is located close to the consolidated city of Naples and the Tyrrhenian coast, and it is bordered to the east by the Somma-Vesuvio complex, and to the west from the eastern hills of the city of Naples (fig. 6.2). This orographic depression, which wedges toward the Gulf of Naples, has represented over time a real barrier to the expansion of the city, because of the nature of its places. In fact, this area conveys the water coming from the hills of Santa Maria del Pianto and Capodichino – located in the north-east side

fig. 6.1 | The City of Naples



of Naples – and the western slope of mount Somma. This topographical condition made it a flat, marshy plain. For this reason, in ancient times, the spring waters of the Volla and the rainwaters coming from the neighbouring reliefs stagnated, because they had not effectively disposed, because of the low permeability of the subsoil and the inadequacy and irregularity of surface water, such as that of the Sebeto River.

A large number of modifications over time has marked the evolution of this portion of territory. Starting from the period of Aragonese domination (by the middle of 1400), in fact, the Valley of Sebeto has been subjected to constant reclamations in which the system of surface water had a leading role. The access and transit roads unfolded around the waterways system, thus determining the principal planes of arrangement; during the reign of Alfonso I, channels became the main elements along which the access roads to farms and the gardens outside the walls assigned to crops were traced, parallel and transverse to the waterways. The result was a uniform flat agricultural landscape, in which the punctual systems of farms – the so-called *masserie* – and mills for grinding grain clearly emerged (Fig. 6.3).

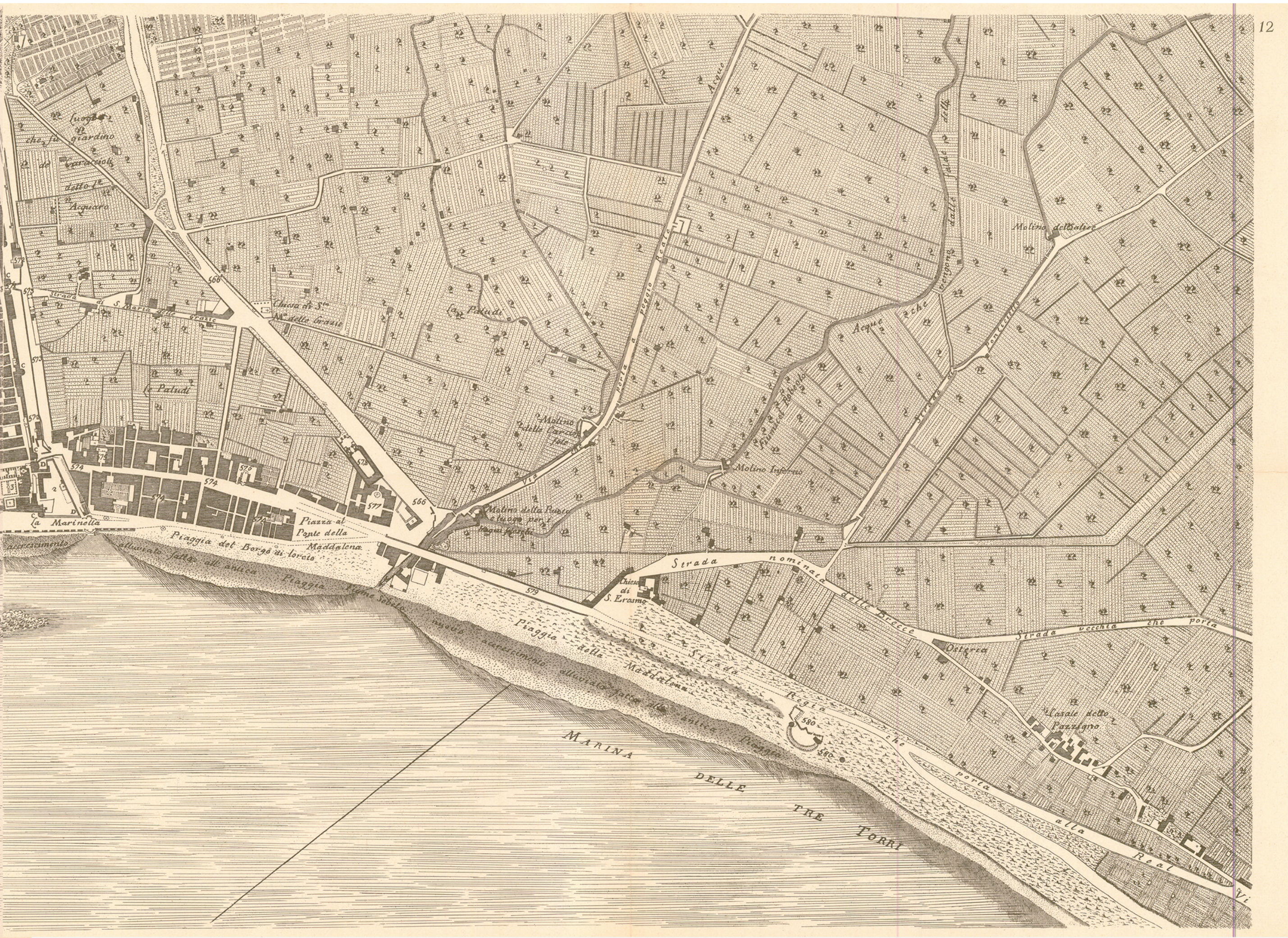
The boundary between town and country was marked by the Aragonese city walls, from which two main roads departed. The first, from west to east, headed towards Puglia, starting from Porta Capuana; the second unfolded in parallel with the Vesuvian coast and proceeded to south, towards Calabria.

Over time, according to these principal axes' direction, and thanks to the flat nature of the area, the first rail connections were developed. Between the sixteenth and seventeenth centuries, during one of these reclamations – aimed for controlling the Clanio within the Regi Lagni system – the Sebeto River was reshaped as a channel (Campania Bonifiche S.r.l. 2012). Consequently, the new conditions of the waterways system inherent to

fig. 6.3 | Duke of Noja's map of Naples (1775). Detail of the eastern side of Naples.

the Sebeto River basin triggered the development of a vast number of proto-industrial activities and the first factories dedicated to ceramics, the tanning of leather, the silk manufacture, hemp and linen, in addition to the widespread presence of grain milling sites. This represented the beginning of the area's further industrial vocation.

At the turn of 1700 and 1800, in fact, the first industrial factory was founded, the large factory of *Granili*, between the mouth of the Sebeto River and the Pollena Channel. The *Granili*, mega structure made by Bourbons, occupied an area of over 10000 square meters. It was about 300 meters long and wide from 15 to 20 meters. This building was used to store grains, and at the same time, it was a factory of ropes and a storage of artillery. From then on, the slow but inexorable transformation of the eastern area of Naples, from farming land to industrial area, began. In this phase, agriculture and industry continued to coexist. In 1820, in fact,



within this portion of territory, numerous farms and country houses – the so-called *casali* – are still recognizable on the cartographic production; during the second half of the nineteenth century, however, the process of removal of the mills and water energy began, fostering the energy transition through the employment of coal as principal resource.

In the same period, new public facilities were located, such as the slaughterhouse, the cemetery, the prison, and the customs house. In 1861 the Royal Decree that authorized the construction of the new railway station was enacted, characterising then this part of town as the main accessibility one – condition that persists even today – making it the new gate to Naples.

Simultaneously, the Bourbon Administration's activities of Reclamation[1] started with the delimitation of the area of the marshes – le *Paludi* – having an extent of about 2500 hectares. This marked the total disappearance of malaria from the territory, although at the same time it opened to the progressive consumption of agricultural land recovered by reclamation, with the proliferation of the building fabric in the north eastern part up to the Somma-Vesuvius Mountain. Within the perimeter of the area, the first settlements of mechanical, steel and shipbuilding industry – Guppy, Pattison, Zino & Henry, Pietrarsa – and the gasometer were localized. During the last decade of the nineteenth century, when the campaign was finally completely drained, the construction of the first social housing districts began, in conjunction with the hygienic restoration of the historic centre.

In the early 1900s, the site of Napoli Orientale experienced a rapid development, boosted by the special law designed to uplift the economic conditions of the city, which designated the eastern part of Naples as the prime area for manufacturing activity, recording a number of employees around to 60000 units. Later, in the decade between 1920 and 1930, the vocation to the petrochemical sector was clearly affirmed, with the settlement of Agip, Socony and other industries related to this sector; at the end of the 30's the first refinery was built, directly connected to petroleum dock of the port through a pipeline.

At this juncture, the area completely lost its relationship with the surface water system. The drainage canals were transformed into sewage drains, and nowadays it is not possible anymore to recognise the ancient paths of the water. The radical transformation of the area, in fact, takes place in the typical way of the modern urban expansion. The location of industries, mainly based on the accessibility and not on the characteristics of the territory, is carried out according to autonomous plots and dispositions, through a process in which the large industrial blocks – totally out of scale – are overlapped to the existing territory, heedless of the relationship with the morphology of the latter. At the same time, the road infrastructure system appeared, marked by the autonomy of its tracks, completely avulsed from the territory and not coordinated among its parts.

The gradual decline of the industrial sector, started during the ‘70s of the last century and continued in the next two decades, initially created a process of transformation of many factories in deposits, and then the closing of the same. At the same time, the expansion dynamics of the residential areas, started in the 50s in the north and east side of the industrial area, with INA CASA neighbourhoods of Barra, Ponticelli and via Stadera, generated as a result an almost total sealing of the residential suburbs with the industrial area.

This bundling, characterized by the absence of any logic and by a blind overlapping of infrastructure systems and land uses, resulted in a morphological structure in which some elements remained, and others were abandoned or gradually subjected to decline. This process necessarily created an ‘assembled landscape’ (Lucci e Russo 2013) connoted by the continuous accumulation of different logical and fortuitous relationships, in which, however, episodes of regeneration characterized by a marked shift towards the service and culture sector began to emerge. This is the case of the new headquarters of the Faculty of Engineering, in San Giovanni a Teduccio neighbourhood, inaugurated on September 2016. The same area was chosen to host the iOS Developer Academy, the Center for app developers that Apple and the University of Naples Federico II launched. Furthermore, in 2014, the *Brin 69* was inaugurated in via Brin. The Brin 69 is a reconversion intervention that involved the depot of the former Mecfond, and that was a successful example of urban recycling of the outskirts of Naples. Conceived for the service sector, nowadays it hosts the ‘Eccellenze Campane’, a gastronomic center that covers an area of 2000 square meters.

6.2 | Geological and hydrogeological framework: the Volla Basin

As already stated above, the eastern area of the city of Naples falls in the south-eastern part of the Piana Campana. From a geological perspective, the Piana Campana is a massive structural depression, filled during the Quaternary by pyroclastic, alluvial, sandy-clay deposits of marine origin. The area forms the southern part of the Volla plain, limited to the east by Vesuvius and west by the eastern hills of the city, with SW-NE orientation.

In this area, the subsoil is mainly composed by pyroclastic deposits characterised by a succession of a set of layers with different degrees of permeability, which disposition has a sub-horizontal pace[2]. In the study area, then, two main superimposed water levels are identifiable and they are in hydraulic communication through direct vertical flows of “drainage”, under normal hydrogeological conditions of equilibrium, from the bottom upwards through the tufaceous formation (ARPACAMPANIA 2009).

The plain of Volla – which corresponds to the Sebeto River Valley – makes up the water catchment of the eastern area along with the basin of *Regi Lagni* and the Vesuvius streams. This water catchment is characterized by the highest urbanization rate (defined as the population density, together with the presence of productive activities on the territory) of the Campania Region. The transformations that occurred in this area over time, marked by an unmistakable and variable consumption of water resources, have led to the gradual loss of its original connotation, with consequent unavoidable implications on the environmental balance and on the general structure of the basin. The Volla Basin covers an area of about 20 square kilometres. It is constituted by an articulated system of artificial channels that collect the high waters of a part of Monte Somma and the ones coming from the plain between Volla and Poggioreale.

The Volla water catchment is a highly industrialised area, in which the presence of man is massive, but at the same time, brownfields and disused sites form a constellation of voids that contribute to the high level of environmental degradation which represents the general condition of the study area. Two are the main hydraulic systems: the first one is composed by the Sbauzone canal, of about 5 kilometer, that intercepts the basins of *lagni*[3] Pollena, Trocchia e Zazzera, and flows into the sea in the area of S. Giovanni a Teduccio. The second one collects the waters through the Couzzo canal and the Reale canal, flowing into the sea near the port of Naples.

Furthermore, nowadays, the plain of Volla is currently devoid of an efficient superficial hydrographic network for the disposal of rainwater, thus being subjected to phenomena of flooding. The superficial water network is completely canalised artificially, and mostly put underground.

Nonetheless, the area is a strategic asset, since it is designated as part of secondary ecological Corridor – the Sebeto/Agro Nolano Corridor – which is to connected to the Provincial Ecological Network design proposed by the PTCP of Naples[4].

fig. 6.4 | In the next page, on the left: pervious soils within the study area

fig. 6.5 | In the next page, on the right: the system of green areas

6.3 | Demography

The demographic development of the area is closely tied to the interventions that have been transformed it in time, incrementally adapting it for residential uses through land reclamation processes. During the 15th century, the main use of the area was related to agricultural purposes.

It is only during the second half of the 20th century that population started to grow. In 1953, 4000 inhabitants were counted, mostly living in small rural dwellings connected with a garden designated for cultivation (Franciosa 1955). Thirty years later, after the Irpinia earthquake[5], the entire area underwent a deep transformation that saw a progressive degradation of the built environment, together with a substantial increase of the population, which nowadays is around 275000 units[6]. Furthermore, population density in this area is 4079.31 inhabitants per hectare, which is approximately 1.5 times higher than the population density of the entire province of Naples (see fig.6.6).

6.4 | Evolution of voids in Napoli Orientale

The changes that took place over time have marked the evolution of the part of territory to in the east of the historic city of Naples, characterizing the different vocations time after time, and keeping intact its nature of land linked to production. The gradual alternation of uses that has connoted different certain parts of the territory through slow and nonlinear transitions has resulted in a territory made by more or less extensive fragments, in which different uses are now close to each other, as evidenced by the presence of residential quarters, now almost completely welded to the industrial areas. That moment was ratified by the appearance of the first Bourbon factories along the coastline and their coexistence with the system of the 'casali' at the beginning. At a later time, the change towards the final consecration of the area as a major

fig. 6.6 | Population distribution according to census areas. Source: Istat, 2011

industrial manufacturing centre, occurred with the construction of the first refinery in 1937.

Nowadays, the predominant nature of the area is given by the vacuum determined by the long waiting time of transformations. This vacuum is made by waiting areas, residuals and interstices, and by the disproportion of bypass roads and the relationships that they establish with the entire territory. This is the case of the S.S.162. This viaduct connects the city and the Business District Centre with all the great eastern conurbations, and it is linked with the external highway and with the urban ring road. Below its path, in fact, it is possible to find barely legal micro-activities, a number of illegal dumps, open-air street markets: marginal activities that find their place in the spaces that have lost their meaning and that, probably, they have never had.

The vacuum present in the Napoli Orientale may have diametrically opposed interpretations: it can be read as a real lack; or it can become a significant presence, leveraging on its value as heterotopic space. Undeniably, within these spaces, some different meanings can settle, and thanks to them, some of the surroundings elements can emerge clearly (Lucci e Russo 2013). This peculiar condition ennobles wasted lands here, as the abandoned spaces become landscape themselves, thus constituting the basis for urban construction and the definition of the future nature of this area. As written above, indeed, it is in these areas that the possibility to identify existing structures and permanencies, the recognisable signs of a system, and the water catchment, which for centuries have been the basis for human activities, becomes concrete.

The anthropic process over the centuries, however, has been characterized here by a slow shift ofhe bond between land and water, which historically connoted and contributed to the existence of a single and united production system (Barca 2005), and it has resulted in the almost complete disappearance of the surface water system.

The little virtuous water management – as much of the superficial waters of the deep waters – is the result of an arbitrary juxtaposition of the infrastructuresin the reticular system of existing roads and water networks, on one hand, and the excessive groundwater withdrawal during the industrial period.

Nowadays, this territory is characterized by a high level of hydrogeological risk, closely connected to water contamination and to phenomena of ground waters emergence. The pumping of water, in fact, led to the pollution of the ground water; the subsequent cessation of pumping activities facilitated the recharge of the water table, which depth, today, is on average 2-3 meters below ground level. These factors have contributed to exacerbate flooding phenomena due to the number of critical points of the surface drainage network. This situation entails a context characterized by a high level of environmental degradation.

The eastern area of Naples is also Site of National Interest (fig. 6.7), identified with the Law 426 of 1998. The Sites of National Interest (SIN) are areas in which the amount and/or type of pollutants pose a risk to the environment and to human health. At the same time, SIN can also prevent the development of areas of strategic importance for their historical and scenic prerogatives, namely for the opportunities of land development which would achieve their rehabilitation (ARPACAMPANIA).

The SIN of Napoli Orientale extends over about 830 hectares, and includes four major sub-areas:

- The oil refining core, where the main companies in the petrochemical sector are located, together with large mechanical and vehicles industries. This sub-area covers approximately 345 hectares;

- The Gianturco area, in which many manufacturing and wholesale trade are located. Its extension is of about 175 hectares;

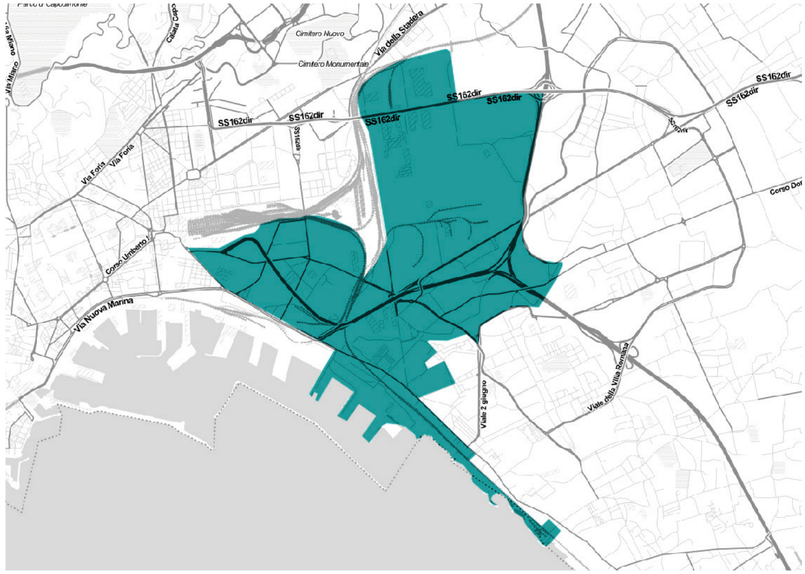


fig. 6.7 | The perimeter of the SIN area “Napoli Orientale”

- The Pazzigno area, in which small companies are located, and that extends for about 200 hectares;

- The coastal strip of San Giovanni a Teduccio neighbourhood, of about 100 ha. This sub-area includes the marine area in front of 3,000 meter limit from the coastline, and in any case within the bathymetry of 50 meters, in which large abandoned settlements are located, like the thermoelectric power central plant of Vigliena and the water treatment plant of San Giovanni.

The Regional Agency for Environmental Protection of Region Campania, ARPAC[7] classified the areas inside the perimeter of the SIN of “Napoli Orientale” in three different categories:

- **Private areas**: mainly including industrial and commercial areas, active or abandoned, which may be potential sources of direct or indirect pollution; the functions included in this category are related to industrial and/or commercial ones and account for about the 63% of the entire surface of the

SIN (515.9 hectares):

- Discontinued operations;
- Productive activities in effect;
- Industries in Major Accident Risk (RIR[8]);
- Deposits (for goods, vehicles, containers);
- Points of sale for fuel distribution;
- Railway facilities (stations or areas of relevance).

- **Public areas**: this category primarily includes the areas that may be subjected to caused pollution or that may have changed the intended use without having undergone any reclamation; in this typology, all those areas of public property and/or public competence and/or brownfield sites acquired over time by public entities, generally used for different activities are included. These areas represent about the 10% of the entire surface of the SIN, for a total of 85.4 hectares.

- **Residential areas**, for social and agricultural uses: they are areas that may be subjected to caused pollution or may have changed intended use without having undergone any reclamation. These areas do not have any industrial heritage and, thus, they have never hosted potentially polluting activities. Within this category all those areas on which buildings for housing and related appurtenances (garages, car parks, gardens, etc.), schools, churches, hospitals, public areas and green areas – for farming or uncultivated but with a previous agricultural use – are included. These areas represent the 13% of the entire surface of the SIN, for a total of 104.3 hectares.

6.5 | Drosscape morphological analysis

The study case of Napoli Orientale has been employed to test the methodology proposed in chapter 5. In order to set the basis for the morphological analysis of drosscape, a set of vectorial and raster data has been selected and successively elaborated with GIS software.

The study area has been determined according to the boundaries proposed by the *Consorzio di Bonifica delle Paludi di Napoli e Volla*[9], and corresponds to the valley that extends from the east side of the city to the slope of the Somma-Vesuvio complex. Such area, then, matches effectively the basin of the Volla river.

The second step foresaw the building of a Digital Terrain Model (DTM). The DTM was elaborated starting from the merging of more than 350 quadrants of LIDAR data, provided by the Metropolitan City of Naples's geographic information system[10]. The acronym LIDAR stands for Light Detection and Ranging, and it is a method that uses pulsed laser to measure ranges to the Earth. Concerning the Metropolitan Area of Naples, the information is composed by a cloud of points which density is 4 p/mq, with a pace of 1mx1m. The year of survey was 2009.

In the third phase, the two sub-basins were calculated through the employment of the hydrology toolset made available by ESRI ArcGis software. Such toolset is employed to model the flow of water across the surface, starting from a DTM. In order to derive the final areas of the two basins, the following procedure has been applied:

- The Flow Direction raster has been determined, starting from the DTM of the area;

- A point shapefile was created to represent the pour points of the water system. Pour points are the outlets of each watershed. The set of information was elaborated taking into account the Flow Accumulation raster, derived from the Flow Direction raster, and the hydrological system, including the grey network. Such data are provided by the Regional Water Authority of Campania Nord-Occidentale[11];

- Finally, the sub-basins were calculated using the previous set of information, and resulted in the division of the area in two parts.

Beside the calculation of the sub-basins, a map of Land Use (LU) was implemented in order to proceed with the morphological analysis. As already introduced in paragraph 5.3, the map of the Metropolitan Area of Naples displaying the land cover data provided by EEA was used[12]. Data were elaborated in 2012, and refer to year 2009. The Urban Atlas is a digital thematic map based on Corine Land Cover nomenclature, characterised by a positional accuracy of 5 m circa. Fig.6.8a, 6.8b and 6.8c show the LU maps of the study area.

The nomenclature proposed by the Urban Atlas includes the following categories (EEA 2012):

table 6.1 | Urban Atlas - Nomenclature

Urban Atlas No.	Vector Data Code	Nomenclature
1		Artificial surfaces
1.1		Urban Fabric
1.1.1	11100	Continuous Urban Fabric (S.L. > 80%)
1.1.2	11200	Discontinuous Urban Fabric (S.L. 10% - 80%)
1.1.2.1	11210	Discontinuous Dense Urban Fabric (S.L. 50% - 80%)
1.1.2.2	11220	Discontinuous Medium Density Urban Fabric (S.L. 30% - 50%)
1.1.2.3	11230	Discontinuous Low Density Urban Fabric (S.L. 10% - 30%)
1.1.2.4	11240	Discontinuous Very Low Density Urban Fabric (S.L. < 10%)
1.1.3	11300	Isolated structures
1.2		Industrial, commercial, public, military, private and transport units
1.2.1	12100	Industrial, commercial, public, military and private units
1.2.2	12200	Road and rail network and associated land
Urban Atlas No.	**Vector Data Code**	**Nomenclature**
1.2.2.1	12210	Fast transit roads and associated land
1.2.2.2	12220	Other roads and associated land
1.2.2.3	12230	Railways and associated land
1.2.3	12300	Port areas
1.2.4	12400	Airports
1.3		Mine, dump and construction sites
1.3.1	13100	Mineral extraction and dump sites
1.3.3	13300	Construction sites
1.3.4	13400	Land without current use
1.4		Artificial non-agricultural vegetated areas
1.4.1	14100	Green urban areas
1.4.2	14200	Sports and leisure facilities
2	20000	Agricultural areas, semi-natural areas and wetlands
3	30000	Forests
5	50000	Water

For a deeper description of each category proposed by EEA, see Annex 2 – Description of Mapping Units for the Urban Atlas.

Within this work, such categories have been aggregated into seven categories. Table 6.3 shows the categorisation used here and the aggregation for each category.

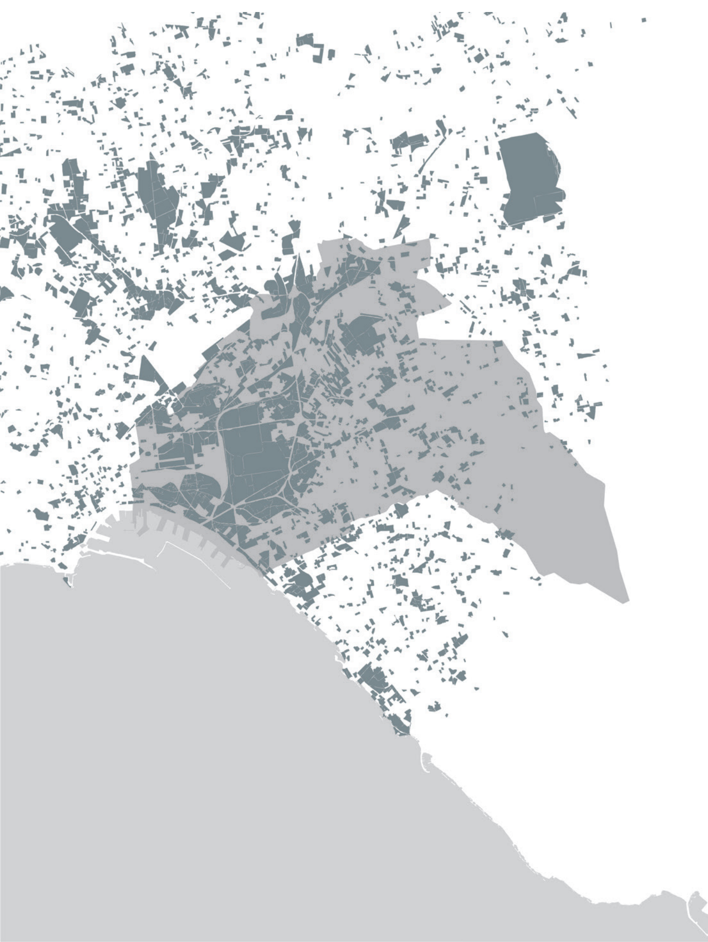
table 6.2 | Urban Atlas categories reclassification

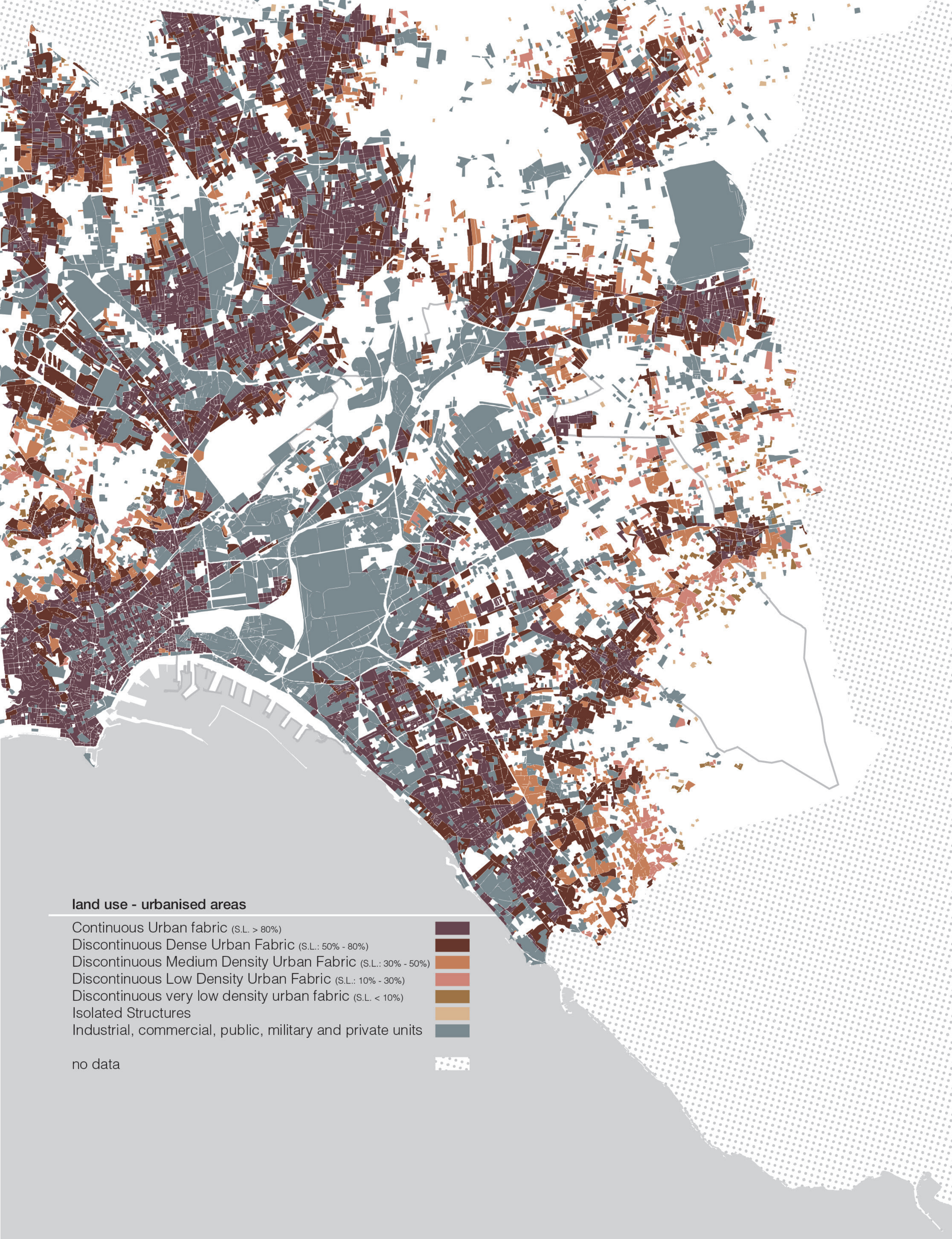
01_ Dense Urban Fabric	Continuous Urban Fabric (S.L. > 80%) Discontinuous Dense Urban Fabric (S.L. 50% - 80%) Discontinuous Medium Density Urban Fabric (S.L. 30% - 50%)
02_ Low Density Urban Fabric	Discontinuous Low Density Urban Fabric (S.L. 10% - 30%) Discontinuous Very Low Density Urban Fabric (S.L. < 10%) Isolated structures
03_ Industrial, commercial, public, military, private and transport unites	Industrial, commercial, public, military and private units
04_ Road and rail network and associated land	Fast transit roads and associated land Railways and associated land
05_ Logistic areas	Port areas Airports
06_Agricultural areas, semi-natural areas and wetlands	Agricultural areas, semi-natural areas and wetlands
07_ Forests	Forests

For the purposes of the analysis, the classes that do not appear in the table have been split and/or associated to the most preponderant adjacent land use.

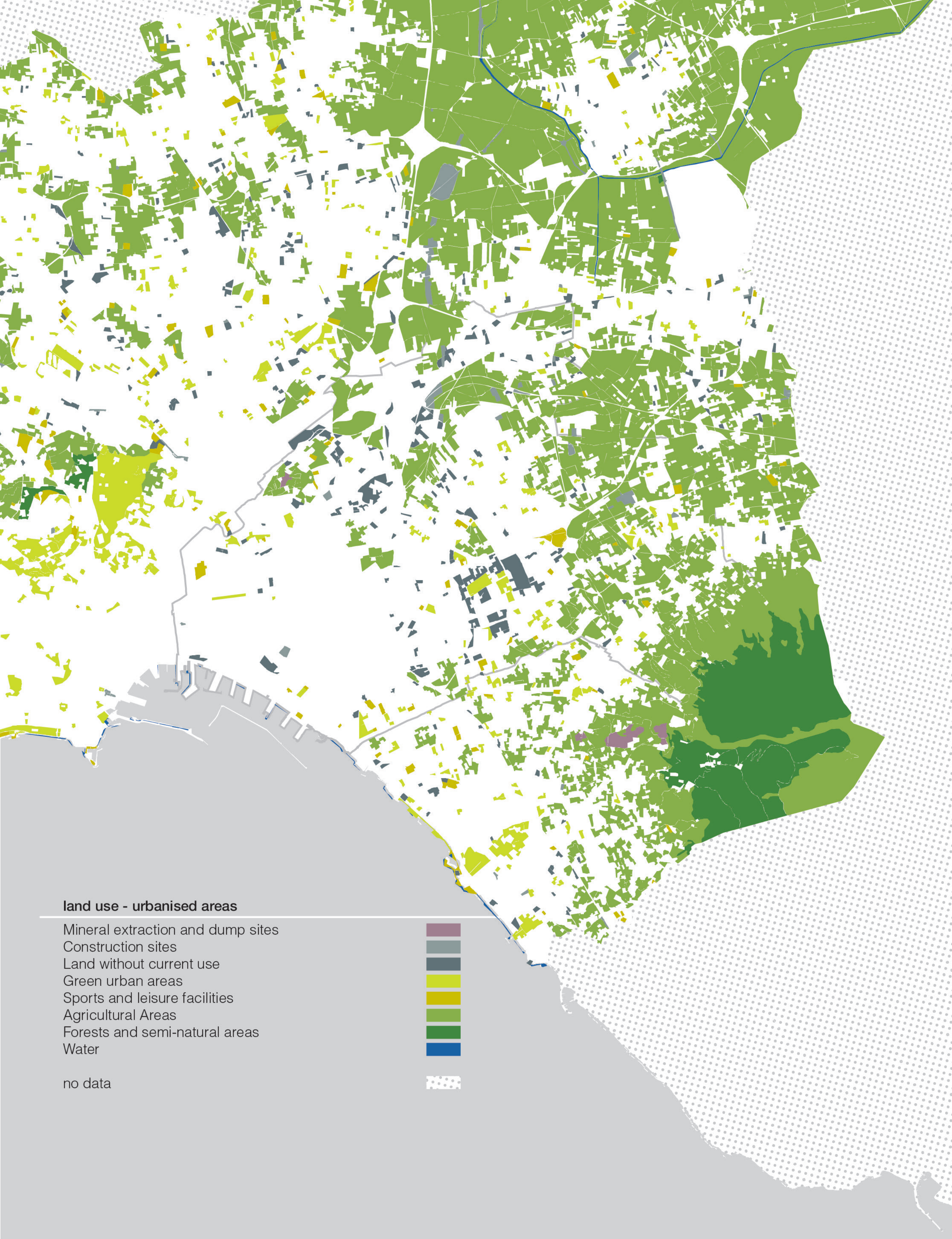
For the morphological analysis of the sub-basins, Fragstats software has been employed. Such software is designed to compute a set of landscape metrics for categorical map patterns[13]. The landscape analysis was conducted at the patch, the class and the landscape levels for both the sub-basins, in order to compare them. Class level is the patch type categorisation. The derived indices describe the spatial distribution and the pattern within a landscape of a single patch type, and consequently, they describe the configuration of a landscape (McGarigal 2015). On the other hand, landscape indices represent the spatial pattern of the landscape analysed as a whole, thus acting as descriptor of its composition. Composition represents the dimensionless aspect of landscape, without considering its spatial configuration (*ibid.*).

fig. 6.8 a, b, c | In the following pages: Land Use Maps. Source: Urban Atlas, 2009




land use - urbanised areas
Continuous Urban fabric (S.L. > 80%)
Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
Discontinuous very low density urban fabric (S.L. < 10%)
Isolated Structures
Industrial, commercial, public, military and private units
no data


land use - urbanised areas
12210: Fast transit roads and associated land
12220: Other roads and associated land
12230: Railways and associated land
Port areas
Airports
no data


land use - urbanised areas
Mineral extraction and dump sites
Construction sites
Land without current use
Green urban areas
Sports and leisure facilities
Agricultural Areas
Forests and semi-natural areas
Water
no data

6.6 | Sub-basins comparison

Landscape metrics

At the landscape level, the employed metrics are descriptors of the two sub-basins as a whole.

The Total Area (TA) metric shows the extent of the two sub-basins. The extent of the sub-basin 1 is slightly bigger than the sub-basin 2 one, representing the 53.85% of the entire basin of Volla river.

Number of Patches (NP) and Patch Density (PD) are descriptors of the degree of subdivision of the sub-basins. NP gives back a basic information, regardless of the area, the distribution or the density of patches. On the other hand, Patch Density provides a similar information than NP, weighted according to the total area of landscape. Since sub-basins 1 and 2 are similar, the redundancy of this set of information confirms the high level of landscape fragmentation of the two areas.

Beside this first set of basilar landscape metrics, Largest Patch Index (LPI) has been calculated to identify the dominance.

The Landscape Shape Index (LSI) describes the overall geometric complexity of the whole landscape, and it can be interpreted as a measure of landscape disaggregation. Thus, the analysis conducted on the two sub-basins shows that the sub-basin 1 is more disaggregated than the sub-basin 2.

At the landscape level, richness is computed by the Patch Richness Density (PRD). Richness is partially a function of scale (McGarigal 2015). According to this index, the sub-basin 2 results to be characterised by more richness than the sub-basin 1.

Shannon's Diversity Index (SDI) gives back the degree of diversity of landscape. Such index is directly proportional to the number of different patch types and to their degree of equal distribution. SDI is lower in the sub-basin 1, showing that higher levels of urbanisation lead to a low diversity.

Class metrics

The Total Class Area (CA) shows how much of the landscape is comprised by a particular patch type. For the sub-basin 1, the Industrial, commercial, public, military, private and transport units have a total area of 1694.24 ha. According to the Percentage of Landscape index (PLAND), it represents the 46.63 percent of the entire area. More generally, the sub-basin 1 is characterised by a prevalent presence of three categories. The Dense Urban Fabric (01), the Industrial, commercial, public, military, private and transport units (03), and the Agricultural areas, semi-natural areas and wetlands (06) constitute the 90.08 percent of the entire sub-basin 1. On the other hand, the composition of the sub-basin 2 is more variegated, and it is characterised by the predominance of class 01 and class 06, respectively constituting the 33.05 and the 28.62 percent.

At the class level, Number of Patches (NP) describes how each analysed class comprised within a given landscape is fragmented. For the sub-basin 2, the high number of patches for Low Density Urban Fabric (02), which is 90, indicates the strong presence of a horizontal urbanisation. On the contrary, within the sub-basin 2, Forests (07) class is constituted by 2 patches, highlighting its low level of fragmentation. Concerning the Agricultural areas, semi-natural areas and wetlands (06) class, the higher number of patches in the sub-basin 1 (40), together with lower LPI and AREA_MN indices, reveals that, even though they represent the 19.46 percent of the entire sub-basin, the patches of such class are smaller and thus more fragmented than the ones of the sub-basin 2.

Another interesting information is provided by LPI, as it expresses the dominance of a class within the entire landscape. In the sub-basin 1, the class 03 has the highest LPI, and the class 01 is the second. In the sub-basin 2, the largest patch belongs to the Forests (07) class. An interesting information emerges out from the comparison of the LPI for the class 03. In the sub-basin 1, as stated above, it represents the largest patch of the landscape, with 8.28 hectares, while in the sub-basin 2 the class 03 LPI is solely 2.04, which is to say 4 times lesser than the one in the sub-basin 1.

Lastly, proximity (PROX_MN) shows the degree of distribution of patches of the same class, thus quantifying the spatial context of a patch. The lower is the index, the more isolated is the patch. At the class level, the mean proximity index is calculated. PROX was calculated assigning a 200 m radius of search. While class 02 is the most isolated for both the sub-basins, the Dense Urban Fabric results more isolated in the sub-basin 1 than in the sub-basin 2. This depends on the boundaries of the study area. In fact, the patches of class 1 are part of the historical centre of Naples, which is not comprised within the study area.

Patch metrics

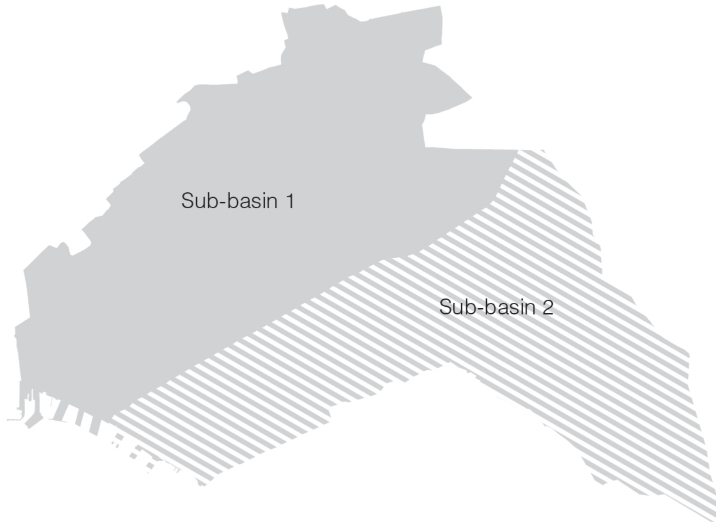
At the patches level, the graphs elaborated for the Patch Area (PA) show the distribution of the sizes for each patch, thus in a disaggregated way. At this level of analysis, it is clearer how the patches belonging to class 03 are bigger in the sub-basin 1, and how they are preponderant in such basin. Furthermore, the amount of infrastructures and associated lands acquires in the sub-basin 1 a greater importance, for the presence of industrial areas and the port area. In the sub-basin 2, agricultural areas are more present, whilst the biggest patches belong to class 06 and 07.

Radius of Gyration (GYRATE) is a measure of how much a patch extends across the landscape. In the sub-basins 1, patches showing a higher GYRATE are the ones belonging to the Road and rail network and associated land (class 05), while in the sub-basin 2, class 01 patches present higher levels of extent. This is partly due to the typology of the settlements in the sub-basin 2, characterised by a linear development in time.

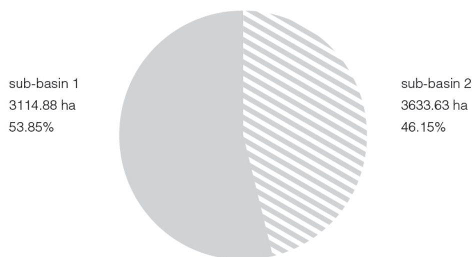
Fractal Dimension Index (FRAC) is used to describe complexity of the patches. Lower values express a less degree of complexity, which grows proportionally to the growing of the values themselves. The comparison between the two sub-basins' patches reveals that the ones of class 01 in the sub-basin 2 are more complex than the ones in the sub-basin 1. Class 02 patches present a low complexity in both the two sub-basins. On the other hand, class 04 presents a higher index in both the two cases.

At the patch level, Euclidean Nearest Neighbour Distance Index (ENN) shows the isolation of each single patch. The graphs show the distribution of the index for every element, organised by class. The sub-basin 1 presents a higher variation of ENN for classes 01, 02 and 06, while class 03 patches are the less isolated. In the sub-basin 2, ENN is low for each class, showing then a higher connection among patches.

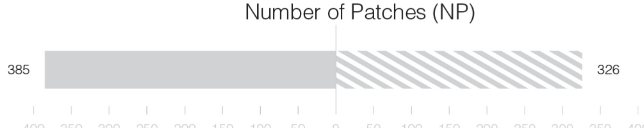
fig. 6.9 a-m | In the following pages: morphological analysis of landscape



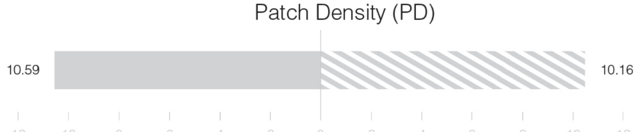
Total Area (TA)



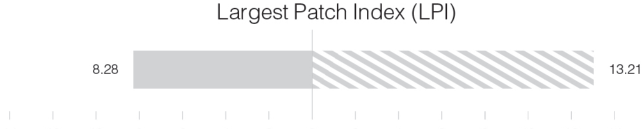
Number of Patches (NP)

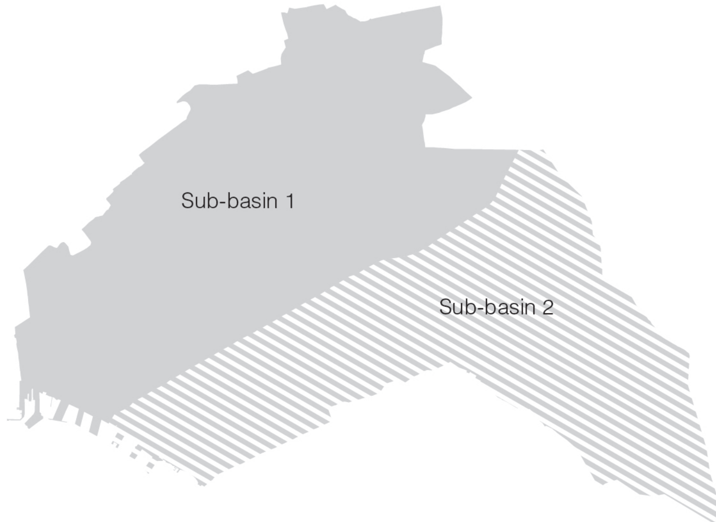


Patch Density (PD)

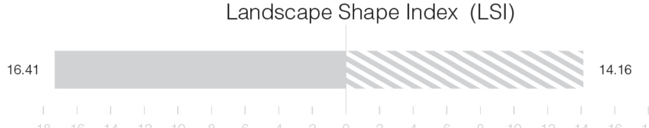


Largest Patch Index (LPI)

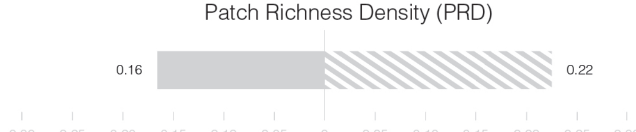




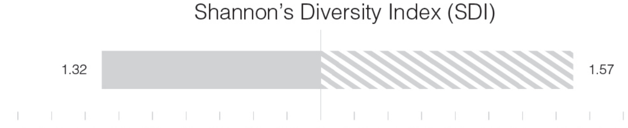
Landscape Shape Index (LSI)



Patch Richness Density (PRD)



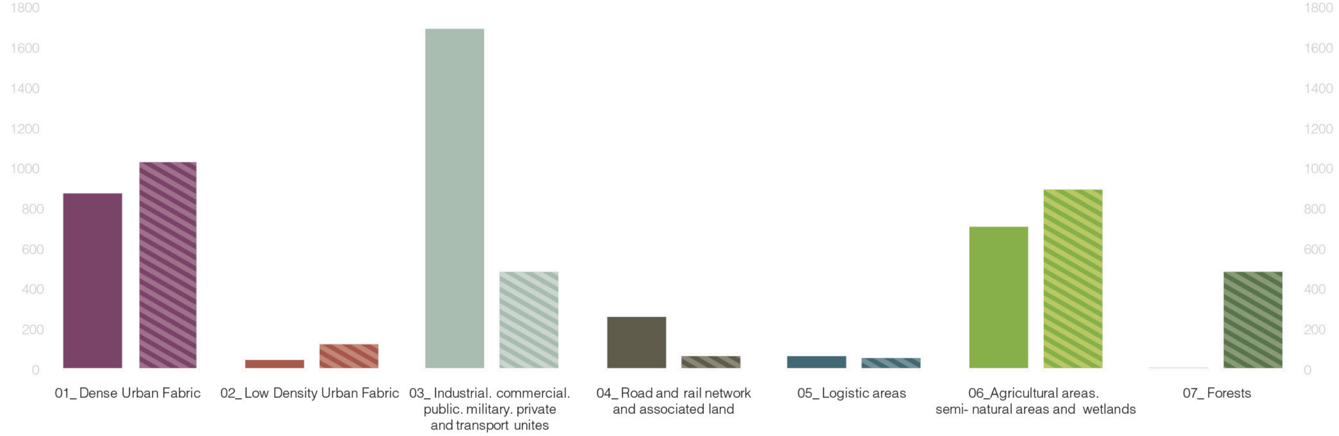
Shannon's Diversity Index (SDI)



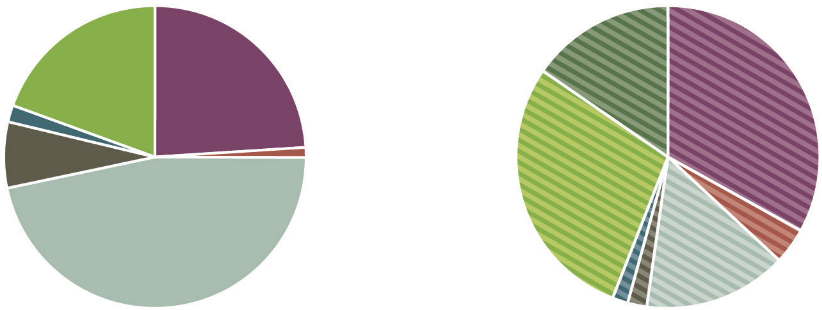
Total Class Area (CA)

	sub-basin 1	sub-basin 2
01_ Dense Urban Fabric	871.63	1029.55
02_ Low Density Urban Fabric	39.33	119.83
03_ Industrial, commercial, public, military, private and transport unites	1694.24	478.08
04_ Road and rail network and associated land	256.06	63.91
05_ Logistic areas	65.36	51.91
06_Agricultural areas. semi-natural areas and wetlands	707.01	891.98
07_ Forests	0	479.62

Total Class Area (CA)

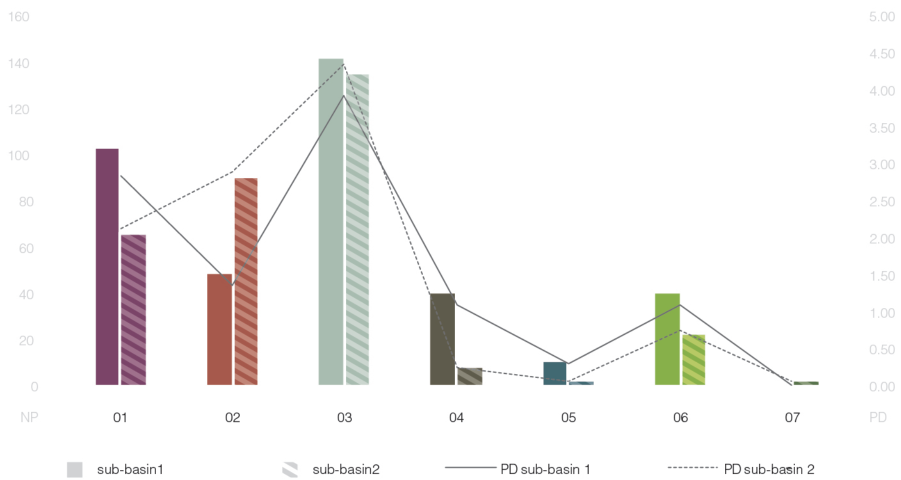


Percentage of Landscape (PLAND)



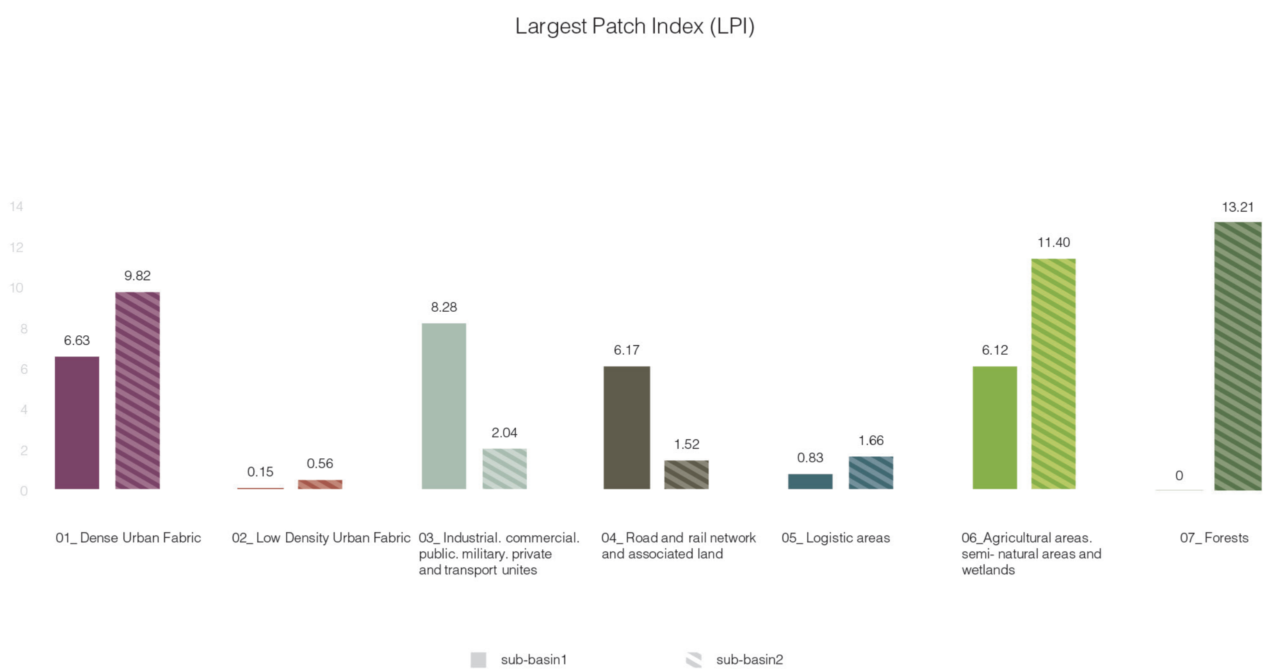
	sub-basin1	PLAND
	01_ Dense Urban Fabric	23.99
	02_ Low Density Urban Fabric	1.08
	03_ Industrial, commercial, public, military, private and transport unites	46.63
	04_ Road and rail network and associated land	7.05
	05_ Logistic areas	1.80
	06_Agricultural areas. semi-natural areas and wetlands	19.46

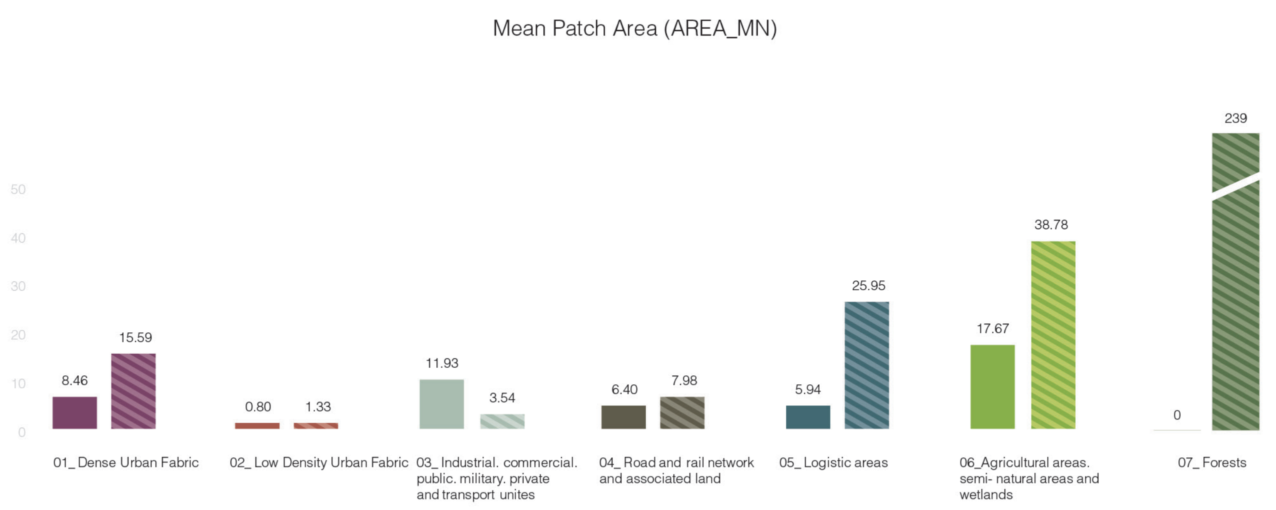
Number of Patches (NP) I Patch Density (PD)



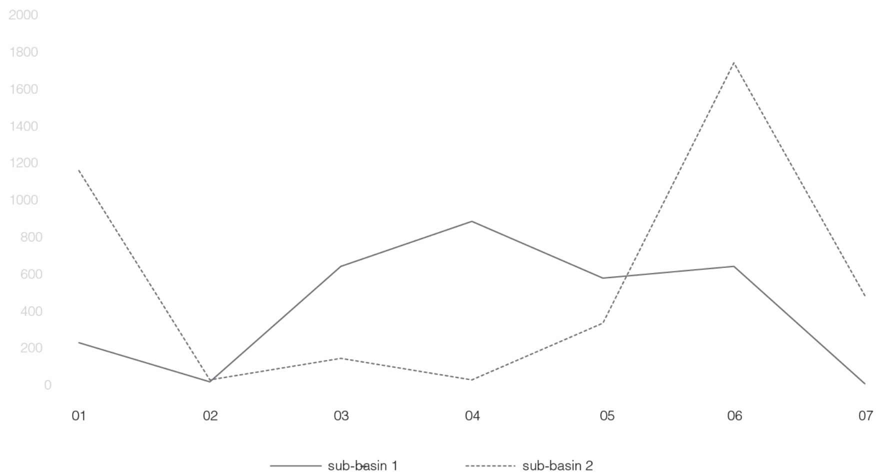
sub-basin1	NP	PD
01_ Dense Urban Fabric	103	2.83
02_ Low Density Urban Fabric	49	1.35
03_ Industrial, commercial, public, military, private and transport unites	142	3.91
04_ Road and rail network and associated land	40	1.10
05_ Logistic areas	11	0.30
06_Agricultural areas. semi-natural areas and wetlands	40	1.10

sub-basin2	NP	PD
01_ Dense Urban Fabric	66	2.12
02_ Low Density Urban Fabric	90	2.89
03_ Industrial, commercial, public, military, private and transport unites	135	4.33
04_ Road and rail network and associated land	8	0.26
05_ Logistic areas	2	0.06
06_Agricultural areas. semi-natural areas and wetlands	23	0.74
07_ Forests	2	0.06


Largest Patch Index (LPI)
14
12
10
8
6
4
2
0
6.63
9.82
0.15
0.56
8.28
2.04
6.17
1.52
0.83
1.66
6.12
11.40
0
13.21
01_ Dense Urban Fabric
02_ Low Density Urban Fabric
03_ Industrial. commercial. public. military. private and transport unites
04_ Road and rail network and associated land
05_ Logistic areas
06_Agricultural areas. semi- natural areas and wetlands
07_ Forests
sub-basin1
sub-basin2


Mean Patch Area (AREA_MN)
50
40
30
20
10
0
8.46
15.59
0.80
1.33
11.93
3.54
6.40
7.98
5.94
25.95
17.67
38.78
0
239
01_ Dense Urban Fabric
02_ Low Density Urban Fabric
03_ Industrial. commercial. public. military. private and transport unites
04_ Road and rail network and associated land
05_ Logistic areas
06_Agricultural areas. semi- natural areas and wetlands
07_ Forests

Proximity Index (PROX_MN)



PROX_MN	sub-basin 1	sub-basin 2
01_ Dense Urban Fabric	222.6652	1148.557
02_ Low Density Urban Fabric	6.2326	17.6931
03_ Industrial, commercial, public, military, private and transport unites	639.0583	138.2675
04_ Road and rail network and associated land	877.6777	25.0865
05_ Logistic areas	576.024	324.4375
06_Agricultural areas. semi-natural areas and wetlands	635.7241	1734.7994
07_ Forests	0	479.62

6.7 | Drosscape comparison

After performing the morphological analysis for the sub-basins, the same process has been applied to drosscape in the study area. The final spatial map of drosscape has been elaborated starting from the mapping made within the P.R.I.N. Re-Cycle Italy by the research unit of Naples. The areas that constituted wasted land have been extended and integrated with the information emerging from the Urban Atlas, and successively reclassified according to the categorisation proposed in paragraph 5.2.

Concerning drosscape, morphological analysis has been implemented exclusively at the class level. In fact, this level is the most appropriate for the identification of possible correlation between land use and the morphological features of drosscape as a proper typology of landscape. Consequently, the mapped areas were analysed in Fragstats considering the remaining landscape as background.

Comparing the information derived from Total Class Area index (CA) and Percentage of Landscape (PLAND), it becomes clear that the amount of drosscape in the sub-basin 1 is much higher than in the sub-basin 2. Polluted soils class (01) has a total area of 144,75 ha, and this is a direct consequence of the massive presence of industrial areas in the sub-basin 1. In total, drosscape in the sub-basin 1 constitutes the 12.18 % of the area. This is partially due to the associated land use.

Besides CA and PLAND, Mean Patch Area (AREA_MN) gives back the grain of each category. The elaboration of this index highlights that within the sub-basins, patches of class 01 and class Critical urban fabric (04) are bigger than patches belonging to the Compromised ecosystems (03) and Abandoned infrastructures and interstitial areas (06). Patches' area is similar for both the sub-basins. Nonetheless, the Number of Patches (NP) shows that the amounts of classes 03 and 06 patches are the highest.

Concerning the extent of each class, GYRATE_MN shows a certain homogeneity in both the sub-basins. ENN_MN shows that class 01 patches are more isolated in the sub-basin 1 than in the sub-basin 2, while patches related to the infrastructure network are more connected, as well as patches belonging to class 03.

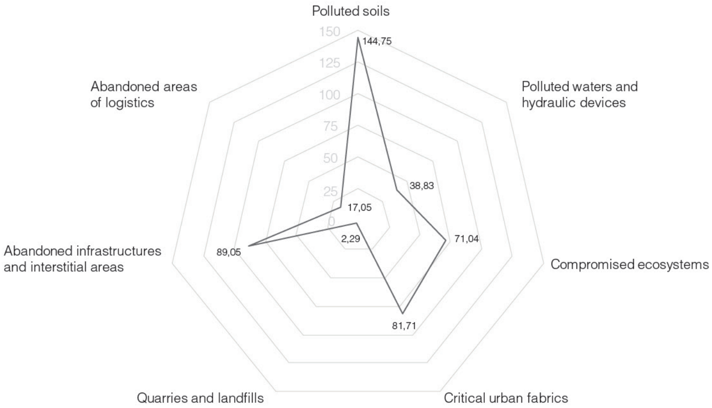
Total edge contrast index (TECI) is a measure of the degree of contrast between a patch and its immediate neighbourhood. In this work, this index is normalised according to the maximum value, showing that in the sub-basin 1 the average TECI is lower than the one in the sub-basin 2. The highest value is represented by class 01 in the sub-basin 2.

fig. 6.10 a-g | In the following pages: morphological analysis of drosscape

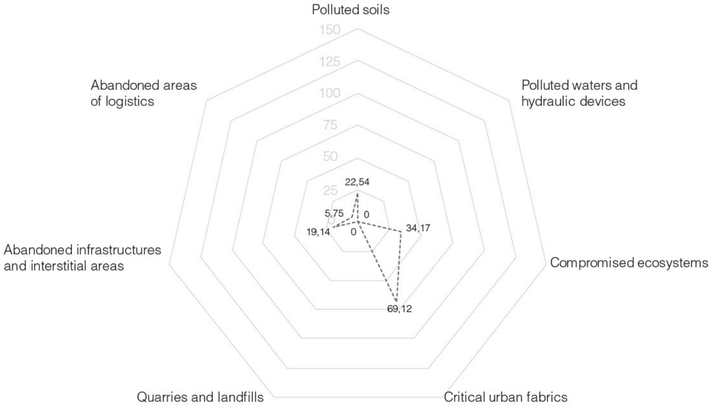
Total Class Area (CA)

	sub-basin 1	sub-basin 2
Polluted soils	144,75	22,54
Polluted waters and hydraulic devices	38,83	0
Compromised ecosystems	71,04	34,17
Critical urban fabrics	81,71	69,12
Quarries and landfills	2,29	0
Abandoned infrastructures and interstitial areas	89,05	19,14
Abandoned areas of logistic	17,05	5,75

sub-basin 1

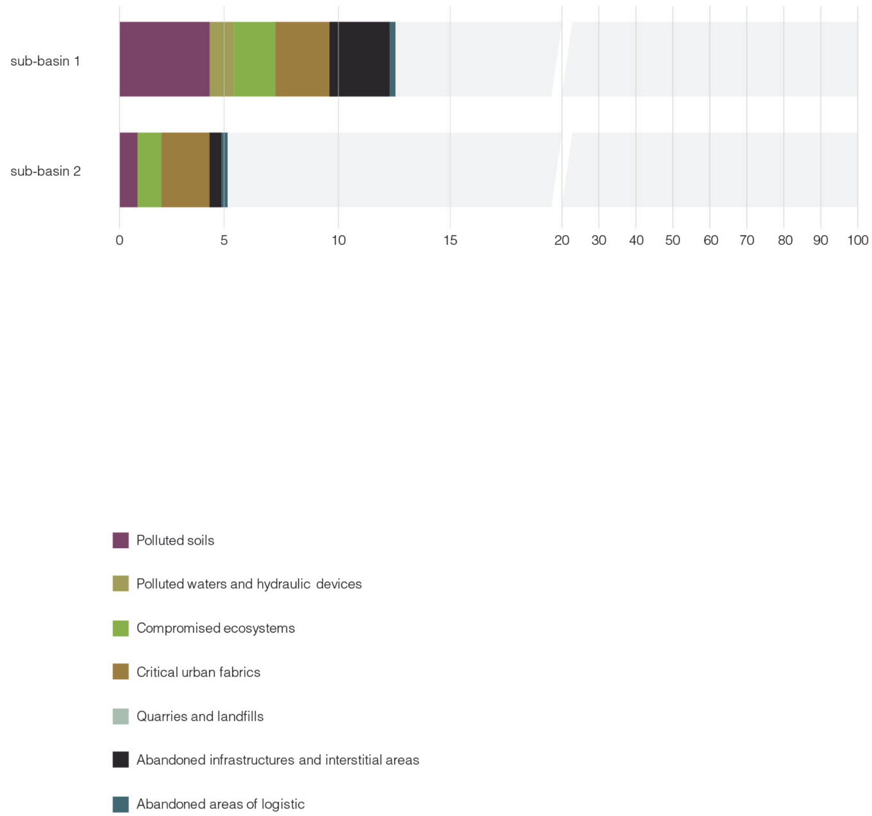


sub-basin 2



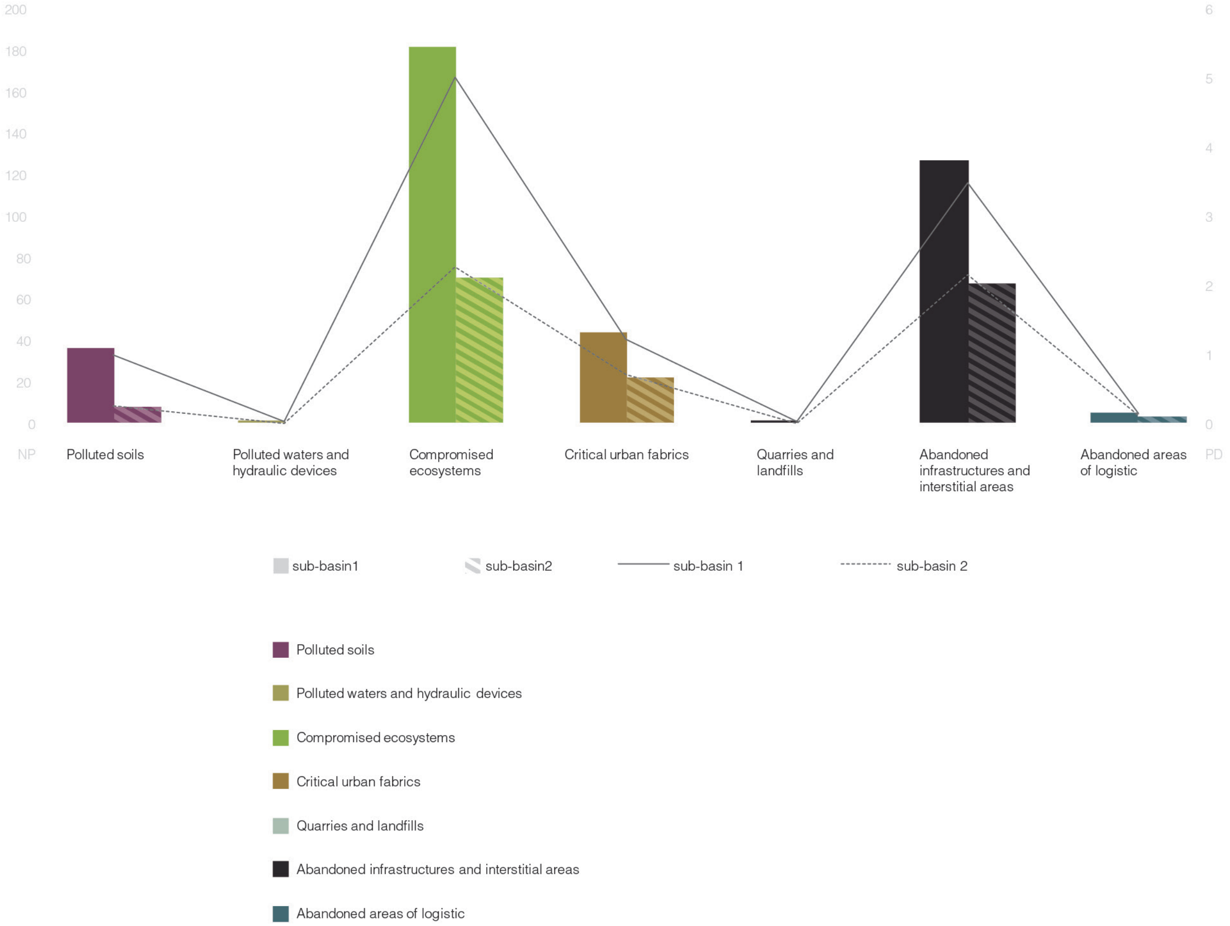
Percentage of Landscape (PLAND)

	sub-basin 1	sub-basin 2
1_Polluted soils	3,9796	0,7235
2_Polluted waters and hydraulic devices	1,0676	0
3_Compromised ecosystems	1,9531	1,0968
4_Critical urban fabrics	2,2465	2,2185
5_Quarries and landfills	0,063	0
6_Abandoned infrastructures and interstitial areas	2,4483	0,6143
7_Abandoned areas of logistic	0,4688	0,1846



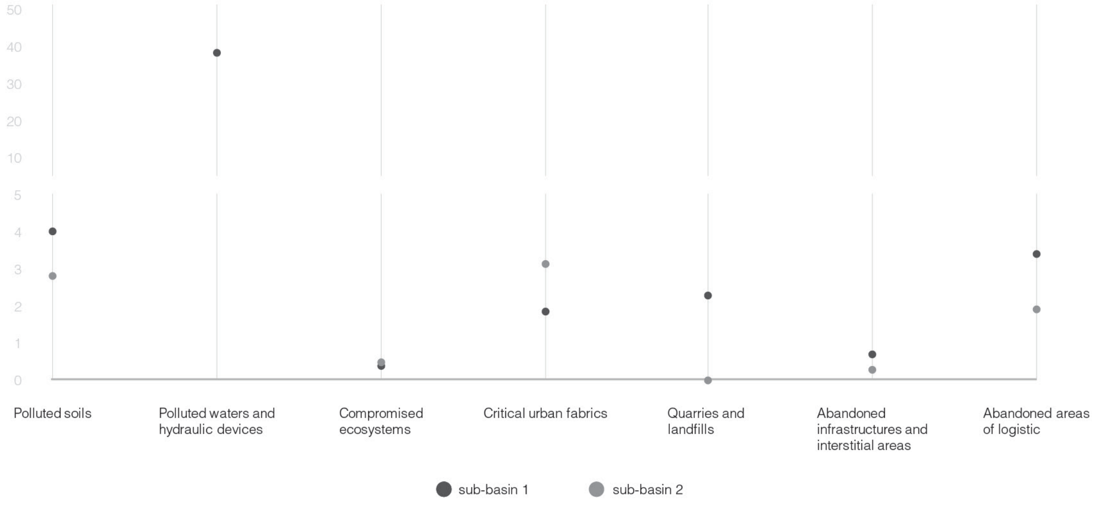
Number of Patches (NP) I Patch Density (PD)

	NP sub-basin 1	NP sub-basin 2	PD sub-basin 1	PD sub-basin 2
1_Polluted soils	36	8	0,9898	0,2568
2_Polluted waters and hydraulic devices	1	0	0,0275	0
3_Compromised ecosystems	182	70	5,0037	2,2468
4_Critical urban fabrics	44	22	1,2097	0,7061
5_Quarries and landfills	1	0	0,0275	0
6_Abandoned infrastructures and interstitial areas	127	67	3,4916	2,1505
7_Abandoned areas of logistic	5	3	0,1375	0,0963



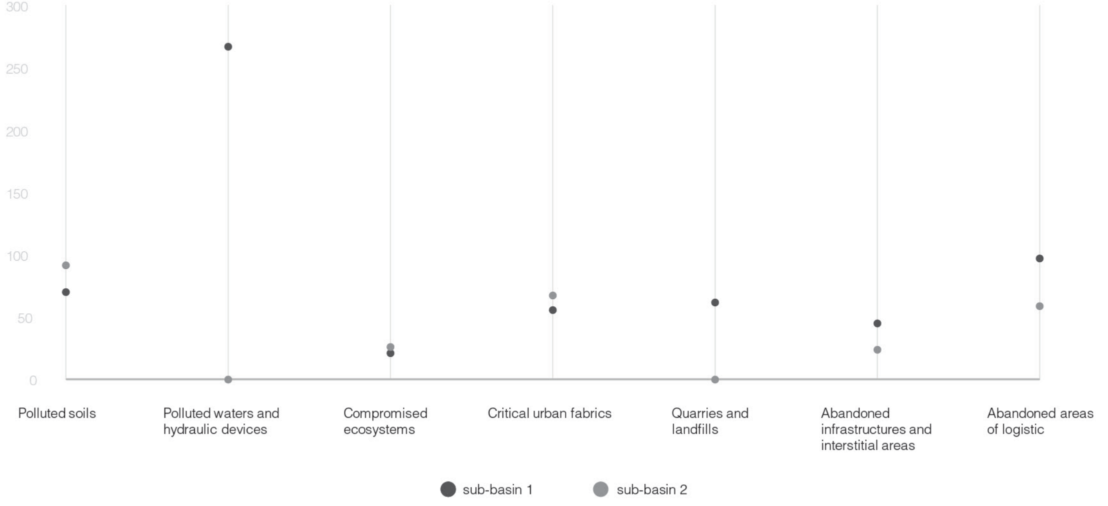
Mean Patch Area (AREA_MN)

	sub-basin 1	sub-basin 2
1_Polluted soils	4,0208	2,8175
2_Polluted waters and hydraulic devices	38,83	0
3_Compromised ecosystems	0,3903	0,4881
4_Critical urban fabrics	1,857	3,1418
5_Quarries and landfills	2,29	0
6_Abandoned infrastructures and interstitial areas	0,7012	0,2857
7_Abandoned areas of logistic	3,41	1,9167



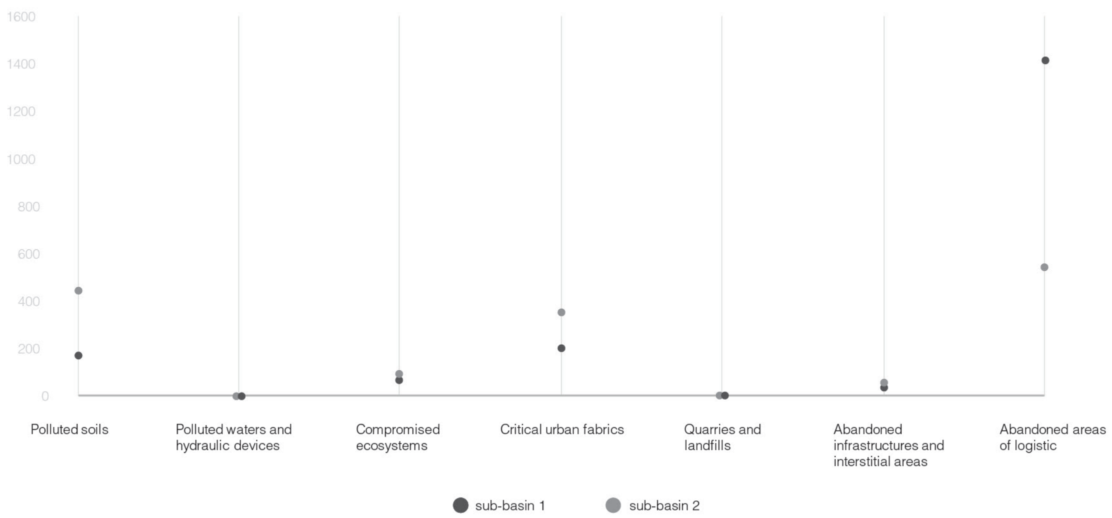
Mean Radius of Gyration (GYRATE_MN)

	sub-basin 1	sub-basin 2
1_Polluted soils	70,233	91,7336
2_Polluted waters and hydraulic devices	267,2475	0
3_Compromised ecosystems	21,1963	26,1481
4_Critical urban fabrics	55,8102	67,4992
5_Quarries and landfills	61,8971	0
6_Abandoned infrastructures and interstitial areas	45,1026	23,9427
7_Abandoned areas of logistic	97,2295	58,926



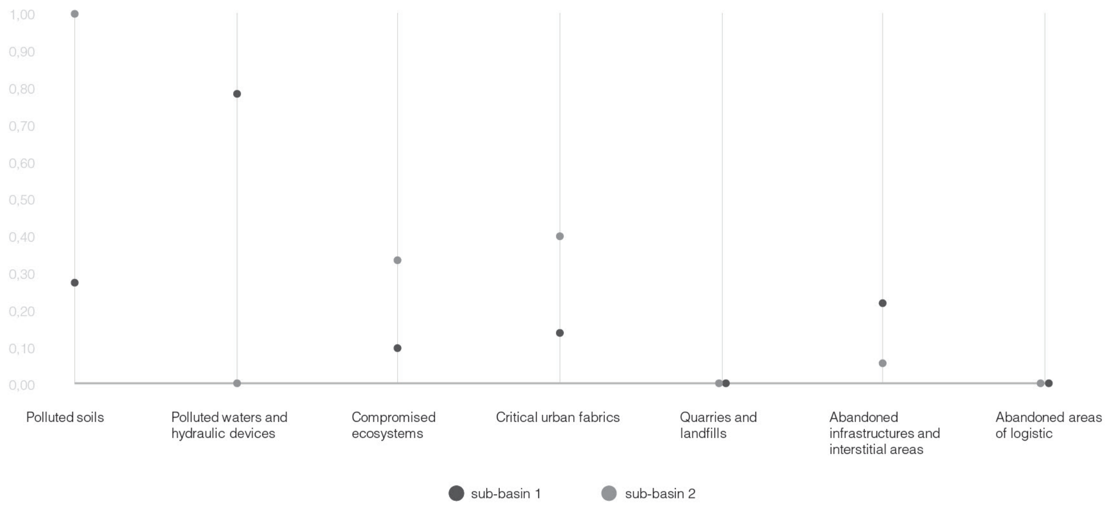
Mean Euclidean Nearest-Neighbour Distance (ENN_MN)

	sub-basin 1	sub-basin 2
1_Polluted soils	171,7898	445,4588
2_Polluted waters and hydraulic devices	N/A	N/A
3_Compromised ecosystems	67,782	94,3203
4_Critical urban fabrics	202,5031	353,8938
5_Quarries and landfills	N/A	N/A
6_Abandoned infrastructures and interstitial areas	36,5215	57,4144
7_Abandoned areas of logistic	1417,0807	544,3213



Total Edge Contrast Index (TECI)

	sub-basin 1	sub-basin 2
1_Polluted soils	0,27	1,00
2_Polluted waters and hydraulic devices	0,78	0,00
3_Compromised ecosystems	0,10	0,34
4_Critical urban fabrics	0,14	0,40
5_Quarries and landfills	0,00	0,00
6_Abandoned infrastructures and interstitial areas	0,22	0,06
7_Abandoned areas of logistic	0,01	0,01



6.8 | Conclusions

The morphological analysis was conducted on the two sub-basins that compound the sub-basin of Volla, for the study case of Napoli Orientale.

The set of data employed for the analysis allows the replicability of the methodology in other European metropolitan areas, at an urban scale. However, the classification proposed by the Urban Atlas is not exhaustive enough for the purpose of drosscape's analysis, since the classification proposed should be more disaggregated. Specifically, in order to implement a more accurate calculation, the elements belonging to the nomenclature 'Industrial, commercial, public, military, private and transport units' should be splitted. The reason lies in the multiple nature of drosscape, and the different shades of relationships that it generate with the other subsystems. For instance, wasted lands associated with industrial areas are different from the ones related to commercial units, as well as from military units, both from a morphological and relational perspective (see paragraphs 2.2, 5.2).

Nonetheless, interesting correlations emerged from the comparison between the sub-basins.

The tables below shows the ratio between land use and corresponding drosscape typology. For this purpose, some drosscape categories have been excluded because of the inconsistency of the number of patches, while some land use classes were aggregated.

table 6.3 | Comparison of drosscape in the two sub-basins

Sub-basin 1

Land Use	CA (ha)	Drosscape	CA (ha)	%
01_ Dense Urban Fabric	871.63	Critical urban fabrics	81.71	
02_ Low Density Urban Fabric	39.33			
	910.96		**81.71**	**8.96 %**
03_ Industrial, commercial, public, military, private and transport unites	1694.24	Polluted soils	144.75	
		Polluted waters and hydraulic devices	38.83	
	1694.24		**183.58**	**10.83 %**
04_ Road and rail network and associated land	**256.06**	Abandoned infrastructures and interstitial areas	**89.05**	**34.77 %**
06_Agricultural areas, semi-natural areas and wetlands	**707.01**	Compromised ecosystems	**71.04**	**10.04 %**

Sub-Basin 2

Land Use	CA (ha)	Drosscape	CA (ha)	%
01_ Dense Urban Fabric	1029.55	Critical urban fabrics	69.12	
02_ Low Density Urban Fabric	119.83			
	1149.38		**69.12**	**6.01 %**
03_ Industrial, commercial, public, military, private and transport unites	478.08	Polluted soils	22.54	**4.71 %**
		Polluted waters and hydraulic devices	0	
	478.08		**22.54**	**4.71 %**
04_ Road and rail network and associated land	**63.91**	Abandoned infrastructures and interstitial areas	**19.14**	**29.94 %**
06_Agricultural areas, semi-natural areas and wetlands	**891.98**	Compromised ecosystems	**34.17**	**3.83 %**

The results highlight that the land use category to which a higher amount of drosscape is associated is the road and rail network in both the sub-basins. Agricultural areas in higher urbanised landscapes tend to quickly produce drosscape, while the percentage of critical urban fabrics is similar for the sub-basins.

Endnotes

1 In the original version: Amministrazione borbonica delle Bonifiche

2 the track of the surface of separation between two successive formations is parallel to the performance of the contour lines. This favors, in the subsoil, circulation “for slopes superimposed”, interconnected.

3 The Regi Lagni are a grid of straight ditches and waterways, mostly artificial, which basin has an area of 1095 square kilometres, in 99 municipalities within the provinces of Napoli, Caserta, Avellino and Benevento, made by the Bourbon Kingdom, during the XVII century.

4 PTCP: in Italian, Piano Territoriale di Coordinamento Provinciale

5 The Irpinia earthquake took place on November, 23th, 1980 mainly hitting the towns in the province of Avellino, hardly damaging them and causing hundreds of deaths.

6 This datum refers to the 15th polulation census, made in 2011, by the Italian National Institute of Statistics (ISTAT).

7 ARPAC: in Italian, Agenzia Regionale per la Protezione Ambientale Campania

8 In Italian: Industrie a Rischio di Incidente Rilevante

9 http://www.consorziobonificanapoli.it/

10 LIDAR quadrants are open-source data, available at http://sit.cittametropolitana.na.it/lidar.html

11 The shapefiles representing the hydrographic system are open-source, and they are available at http://www.adbcampaniacentrale2.it/psai-download/

12 Data are available at http://www.eea.europa.eu/data-and-maps/data/urban-atlas

13 Fragstats is an open-source software developed by McGarigal and Marks, of Oregon State University. It is downloadable at https://www.umass.edu/landeco/research/fragstats/fragstats.html

07 Conclusions

7.1 | Results

Drosscape, and more generally derelict and discarded areas, is an intrinsic product of urbanisation processes. In its development and its growth, city undergoes transformation due to external or internal drivers that generate as a result the total or partial abandonment of some of its parts. Such condition represents a proper opportunity for cities to deal with flooding, and this is particularly true for densely urbanised areas. Indeed, trends in global urbanisation processes highlight the increasing tendency of world population to move towards highly vulnerable areas, with the consequent raise in the risk and the exposition of people and goods to flood events. Consequently, dealing with water in order to reduce vulnerability and enhance resilience is one of the main challenges for cities worldwide. Redevelopment processes that involve drosscape, then, can be a useful tool for adaptation and mitigation.

On the other hand, involving abandoned areas and former industrial sites entails facing a number of criticalities. Due to previous land use, air, soils and water within abandoned industrial sites are often polluted and call for reclamation processes; moreover, they do not interact with the other parts of the city, as their heritage of fenced monofunctional areas separated them ideally and morphologically from the rest of the city. Marginality and liminality, then, are not only a spatial condition, but also a social issue: indeed, derelict industrial sites often host unformal and/or on the fringes of legality activities.

Nevertheless, these sites represent a real resource to start from for the enhancement of urban systems' resilience, for several reasons. Firstly, for their strategic position: former industrial areas are very often close to the denser city. Secondly, for the environmental and socio-economic opportunities that they can trigger. From an ecological perspective, they are a form of interstitial wilderness (Haid, 2011), characterised by the presence of spontaneous vegetation due to the slow reconquer by nature after the man's withdrawal, and thus they offer high degrees of biodiversity. At the same time, they are places in which creativity and a sense of freedom can drive exploration and growth (Lynch, 1990), and not rarely they are subjected to a series of bottom-up processes (Berger, 2006). Additionally, the built heritage and the industrial archaeology act as a physical and cultural landmark as they contributed in time to shape the identity of some places, and frequently these areas are the object of masterplans and projects.

Including derelict industrial areas within adaptation strategies involving nature-based solutions unavoidably implies developing transcalar approaches both in space and in time. From a spatial perspective, connecting them to a wider network of green and open spaces in order to improve environmental conditions offers a clear opportunity to enhance resilience of urban areas to flooding while providing multiple benefits to citizens. In fact, drosscape offers the possibility to experiment new ways to think and design the network of open spaces, acting positively on the adaptive capacity of open spaces. This is particularly true when the voids are put in relation among them, and treated as a proper landscape. Hence, a multiscalar approach can be adopted, embracing the idea of a dynamic and ever-changing landscape in which its parts accumulate new meanings over time.

Multiscalarity, then, finds its reasons in space and time. Drosscape exists in variable but limited timeframes, and is the byproduct of dynamics which are internal and external to the urban system. Even though its reintroduction in the metabolism of the city can take years, it still can play a substantial role in the implementation of GBI, according to different level of direct utilisation by man. Its heterotopic condition related to its being a gap within the well-functioning parts of the city can have tangible repercussions on the design of GBI, as it provides those set of spaces that can be planned in order to reach multifunctionality.

This is potentially the most virtuous act in its systemic recycle: converting a leftover of a tangible sign of failure of the obsolete monofunctional production models to a device able to supply a multitude of new functions, able to adapt to new emerging needs in time and to contribute to cope with flooding risk, creating a new variety of possible landscapes.

7.2 | Main novelties and reflections on research questions and hypotheses

A more comprehensive definition of drosscape

Drosscape is the byproduct of the capitalistic system's crisis, a leftover of an economic regime which is no more sustainable. Nonetheless, the main lens through which this phenomenon is interpreted and explained is still too closely tied to the economic aspects. Such interpretation can be useful for the identification of abandoned areas within the urban tissue, simply labelling them as portions of city whose life cycle is ended or almost at the end. Nonetheless, it is a restricting perspective. In fact, despite their dereliction state, they still present features that make them not completely 'exhausted'. Such features represent the potential of these areas for their reintroduction in the urban system with the aim of enhancing its resilience. From an ecological perspective, these areas play a fundamental role as they offer a high degree of biodiversity that is hard to find in the other parts of the city. Furthermore, the cultural value and the social aspect of these places can contribute to redefine the state of drosscape's life cycle, as there are places in which novelty and innovation exist and can be nurtured. Consequently, there is not a unique point of view from which to observe and define the life cycle of an abandoned area. Rather, it depends on the spatial scale of analysis, and on the elements that time after time are chosen to describe it. Nonetheless, a total anthropocentric perspective is not enough sufficient and comprehensive. In fact, shades of meanings emerge when the focus is shifted from a direct and immediately tangible profit, used to describe the life-cycle of a portion of city, to the range of direct and indirect synergistic benefits that it can deliver.

From this perspective, considering drosscape can facilitate such comprehension: when the shared idea of main and total use disappears, then we need to force ourselves to investigate more deeply and assign new interpretations and meanings to those that at a first sight can be named as void.

Aside this aspect, wasted lands can be intended as a temporary manifestations within the city and which, therefore, they exist only in their suspension state, between a land use and another. In addition, such suspension makes drosscape a phenomenon hard to catch. In fact, on the one hand, cartographic production is not sufficiently frequently updated and neither the consolidated scales of representation nor the classifications proposed by institutional maps are completely adequate to describe this peculiar landscape.

Drosscape as descriptor of degrees of resilience

As urban systems undergo crisis, they can collapse and easily be subjected to sudden shocks provided by both socio-economic development and natural events. Nonetheless, the processes that lead to those thresholds beyond which a system can collapse have tangible repercussions on the urbanised environment. One typology of 'symptom' is drosscape itself. It is indeed a clear signal of fragmentation condition of a complex adaptive system. On the other hand, fragmentation is an obstacle for adaptation processes that can be overtook through the definition of values, goals and actions in different timeframes.

Furthermore, albeit Berger states that drosscape is an indicator of healthy urban growth, according to panarchy theory, after an exploitation phase – which is comparable to the growth phase of an urban system – then there are the release phase and the reorganisation one. The latter prepares the system providing new resources that become available for a new phase of exploitation. This phase is the most delicate, as it gives the opportunity and stimulates novelty and experimentation. From this perspective, within urban system drosscape can be intended as a resource to be exploited through its reintroduction in urban systems.

As its formation is related to the progressive reduction or to the total absence of any use, drosscape belongs to the occupation layer (see paragraph 3.7), characterised by a faster pace of transformation. Nonetheless, It directly interacts with the elements of subsystems belonging to different layers, affecting them or being affected by them. A clear example are the depletion or the pollution of vital resources like water, air and soils – both top-soils and deep soils – inherited by former land uses of drosscape, such as industry or some typologies of agriculture. The network layer, as well, generates empty spaces and voids. It is the case of elevated railways and highways, which need wide areas in order to protect the urban environment from approaching them, and consequently create spaces that are not able to interact with the city.

Drosscape and redevelopment processes for green-blue infrastructures

Drosscape can play an important role in implementing adaptation strategies to flood risk, for several reasons. Firstly, it constitutes an ideal field in which experiment multidisciplinary approaches involving urban planners, architects, engineers and policy makers, as the importance of designing flexible and adaptive systems is more and more acknowledged. Through the implementation of GBI, trans-disciplinary and community-based approaches can take place, by activating co-design, co-development and co-implementation processes.

Secondly, it provides the opportunity to steer the future development of cities toward the 'nature as infrastructure' paradigm, incrementally introducing ecological processes and multiple-values approaches. However, in order to achieve this goal, it is necessary to recognise the importance of open spaces as a networked, multiscalar and multifunctional system. This is a key point in order to facilitate the transition of stormwater management from the underground piped drainage to multifunctional systems mainly above ground through green-blue infrastructures.

Using drosscape as raw material for green-blue infrastructure finds its acknowledgement in the growing relevance that landscape is getting within the domain of risk and adaptation, as it is able to intertwine ecological performance and design culture. Furthermore, GBI can enhance water resilience of cities, generating at the same time inclusivity and liveability and improving quality of life for the citizens. However providing a robust evidence of the direct and indirect benefits of GBI, it is not easy yet.

From this perspective, the approach proposed and tested on the study case of Napoli Orientale can represent an interesting insight on a possible multiscalar approach based on the morphology of voids, that aims to understand their spatial processes of formation, and the tools for a strategy based on the potential provided by their composition and configuration. Such approach moves from the idea that the complexity of urban landscape is a proper ecologic condition that plays a relevant role in the implementation of green-blue networks, and it can be exploited when synergistically tied to the other intrinsic and relational aspects of drosscape.

7.3 | The need for a new research approach

This study takes place from the PRIN Re-Cycle Italy research, within which a multidimensional methodology was developed in order to assess drosscape life cycle. The work done within the PRIN highlighted the importance of the relational aspects in evaluating discarded and derelict areas. Such methodology has constituted the premises from which this research moves, reframing it in the light of Complex Adaptive Systems theories, through the lens of the Dutch Layers Approach. Here, such approach is applied as a model able to describe reality, to understand and categorise the possible relations that drosscape establishes with the wide range of subsystems that form an urban system. This framework is useful to highlight the different characteristics of drosscape, which are specifically reinterpreted in order to identify what are the main features that allow or obstacle their use for the implementation of a green-blue infrastructure.

The employment of drosscape in the design of a ‘nature-oriented city’ is important for two reasons. The first is that, in order to maximise benefits coming from the redevelopment of drosscape, a multidisciplinary approach should represent an unavoidable condition. Nonetheless, due to the multidimensional issues of both wasted lands and GBI, together with the variety of geographical and institutional contexts across Europe, a clear, replicable methodology is hard to be defined. Instead, a set of parameters through which to assess the potential of an urban system can support its steering to other and more preferable states and guide a flexible and incremental design.

The second is related to the opportunity of identifying hierarchies among the sets of detected objectives and selected elements, pinpointing the various degrees of flexibility according to the level of indispensability of both. This framework can help to better address strategies and tactics that consider temporary uses as well as structural and non-structural actions able to strengthen the implementation of green-blue infrastructures through the acknowledgment of the different aspects that are involved.

7.4 | Limits of the research

In the light of the previous considerations, some limits emerge from this research work.

The first limit is represented by the extreme heterogeneity of data. They differ from grain, resolution, extension, scale – and thus accuracy – and year of production. The accuracy of spatial data depends on the scale of representation and on the care with which the features were digitized from maps or photos. For this reason, a certain degree of approximation needs to be considered, in particular when thematic maps are involved. Furthermore, it was remarkably hard to reconstruct trends of some phenomena in time. This happened for two reasons. In some cases, data were absent or partial and incomplete within different timeframes; in some other cases, the excessive cost of data has impeded their retrieval.

The second limit is constituted by the scale of representation of spatial data. This limits the application of the methodology to the urban scale, although this work recognises the substantial importance of transcalarity. Nonetheless, it is possible to up-scale or down-scale the indicators matrix – and consequently the spatial maps. Nonetheless, a multiscalar approach is still evident here, as some indicators describing systems and phenomena at different scales are present.

The third constrain is the essence of the mapping process. As Alan Berger (2006) points out, drosscaping might be conceived as 'a sort of scavenging of the city surface for interstitial landscape remains', but still it needs some rules in order to make this process transferable and scalable. Furthermore, the multiscalarity of this phenomenon must deal with the rigidity of representation scales, both concerning raw data and output maps.

The fourth and last limit is a direct consequence of the third. Since it is very hard to define precisely – both in term of spatial features and intangible factors – which areas can undergo abandonment processes and thus become drosscape, the methodology takes into consideration a set of drosscape, which is the input at the time of the survey.

The formulation of the proposed classification was made selecting and re-elaborating the one proposed within the P.R.I.N. research. This means that it could be partially modified if applied in other contexts. Hence, it should be tested in different study areas in Italy and, more generally, in developed countries. Similarly, the methodology should be tested in study cases presenting different conditions of environmental degradation and flood risk, in order to verify the real potentiality of the proposed model.

7.5 | Recommendation for future research

The first step in order to validate the methodology in this research project is a comparative study in another area. It can be further promoted and strengthened in a number of aspects. For instance, the proposed performance parameters are developed starting from a set of data selected according to different criteria in order to avoid data redundancy; furthermore, it is strictly dependent on the classification process of each information. This process can be improved if exposed to stakeholders and experts from different disciplines and domains. Parameters are chosen in order to make the results easily comparable with other areas which can differ in size and quantity of drosscape. Enhancing comparative studies in this direction, either in broader aspects and diverse scale levels will be purposeful and substantial.

In order to better understand the social and cultural values of drosscape, more qualitative research should be developed. Different contexts within Europe can reveal the presence of different uses and formal and unformal activities that can broaden the palette related to the social sphere. Furthermore, a more structured analysis should be done to highlight those aspects related to the perception and the cultural values that drosscape can present. According to this perspective, introducing qualitative aspects to the proposed methodology could contribute to validate it.

The application of CAS theories on drosscape is a useful exercise for the identification of the relations that occur among the parts of the city. In this sense, the heterotopic aspect of wasted lands facilitates the implementation of a model for the understanding of such dynamics. The model represents a starting point to be implemented at the different spatial and temporal scales.

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Annexes

Annex 1 | Landscape Metrics

Definitions taken from the software Fragstats

AREA	**Patch Area**
Description	AREA equals the area (m2) of the patch, divided by 10,000 (to convert to hectares).
Units	Hectares
Range	AREA > 0, without limit. The range in AREA is limited by the grain and extent of the image; in a particular application, AREA may be further limited by the specification of a minimum patch size that is larger than the grain.
Comments	The area of each patch comprising a landscape mosaic is perhaps the single most important and useful piece of information contained in the landscape. Not only is this information the basis for many of the patch, class, and landscape indices, but patch area has a great deal of ecological utility in its own right. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

GYRATE	**Radius of Gyration**
Description	GYRATE equals the mean distance (m) between each cell in the patch and the patch centroid.
Units	Meters
Range	GYRATE ≥ 0, without limit. GYRATE = 0 when the patch consists of a single cell and increases without limit as the patch increases in extent. GYRATE achieves its maximum value when the patch comprises the entire landscape.
Comments	Radius of gyration is a measure of patch extent (i.e., how far-reaching it is); thus, it is effected by both patch size and patch compaction. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

CA	**Total (Class) Area**
Description	CA equals the sum of the areas (m2) of all patches of the corresponding patch type, divided by 10,000 (to convert to hectares); that is, total class area.
Units	Hectares
Range	CA > 0, without limit. CA approaches 0 as the patch type becomes increasing rare in the landscape. CA = TA when the entire landscape consists of a single patch type; that is, when the entire image is comprised of a single patch.
Comments	Class area is a measure of landscape composition; specifically, how much of the landscape is comprised of a particular patch type. In addition to its direct interpretive value, class area is used in the computations for many of the class and landscape metrics.

PLAND	**Percentage of Landscape**
Description	PLAND equals the sum of the areas (m2) of all patches of the corresponding patch type, divided by total landscape area (m2), multiplied by 100 (to convert to a percentage); in other words, PLAND equals the percentage the landscape comprised of the corresponding patch type. Note, total landscape area (A) includes any internal background present.
Units	Percent
Range	0 < PLAND ≦ 100 PLAND approaches 0 when the corresponding patch type (class) becomes increasingly rare in the landscape. PLAND = 100 when the entire landscape consists of a single patch type; that is, when the entire image is comprised of a single patch.
Comments	Percentage of landscape quantifies the proportional abundance of each patch type in the landscape. Like total class area, it is a measure of landscape composition important in many ecological applications. However, because PLAND is a relative measure, it may be a more appropriate measure of landscape composition than class area for comparing among landscapes of varying sizes.

LPI	**Largest Patch Index**
Description	LPI equals the area (m2) of the largest patch of the corresponding patch type divided by total landscape area (m2), multiplied by 100 (to convert to a percentage); in other words, LPI equals the percentage of the landscape comprised by the largest patch. Note, total landscape area (A) includes any internal background present.
Units	Percent
Range	0 < LPI ≦ 100 LPI approaches 0 when the largest patch of the corresponding patch type is increasingly small. LPI = 100 when the entire landscape consists of a single patch of the corresponding patch type; that is, when the largest patch comprises 100% of the landscape.
Comments	Largest patch index at the class level quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a simple measure of dominance.

AREA_MN	**Patch Area Distribution**
Description	AREA equals the area (m2) of the patch, divided by 10,000 (to convert to hectares).
Units	Hectares
Range	AREA > 0, without limit. The range in AREA is limited by the grain and extent of the image; in a particular application, AREA may be further limited by the specification of a minimum patch size that is larger than the grain.
Comments	Mean patch size (AREA_MN) at the class level is a function of the number of patches in the class and total class area. Importantly, although mean patch size is derived from the number of patches, it does not convey any information about how many patches are present. A mean patch size of 10 ha could represent 1 or 100 patches and the difference could have profound ecological implications. Furthermore, mean patch size represents the average condition. Variation in patch size may convey more useful information. For example, a mean patch size of 10 ha could represent a class with 5 10-ha patches or a class with 2-, 3-, 5-, 10-, and 30-ha patches, and this difference could be important ecologically. For these reasons, mean patch size is probably best interpreted in conjunction with total class area, patch density (or number of patches), and patch size variability. At the landscape level, mean patch size and patch density are both a function of number of patches and total landscape area.

PAFRAC	**Perimeter-Area Fractal Dimension Index**
Description	PAFRAC equals 2 divided by the slope of regression line obtained by regressing the logarithm of patch area (m2) against the logarithm of patch perimeter (m). That is, 2 divided by the coefficient b1 derived from a least squares regression fit to the following equation: ln(area) = b0 + b1ln(perim). Note, PAFRAC excludes any background patches.
Units	None
Range	1 ≦ PAFRAC ≦ 2 A fractal dimension greater than 1 for a 2- dimensional landscape mosaic indicates a departure from a Euclidean geometry (i.e., an increase in patch shape complexity). PAFRAC approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, plane-filling perimeters. PAFRAC employs regression techniques and is subject to small sample problems. Specifically, PAFRAC may greatly exceed the theoretical range in values when the number of patches is small (e.g., < 10), and its use should be avoided in such cases. In addition, PAFRAC requires patches to vary in size. Thus, PAFRAC is undefined and reported as “N/A” in the “basename”.class file if all patches are the same size or there is < 10 patches.

Comments	Perimeter-area fractal dimension is appealing because it reflects shape complexity across a range of spatial scales (patch sizes). However, like its patch-level counterpart (FRACT), perimeter-area fractal dimension is only meaningful if the log-log relationship between perimeter and area is linear over the full range of patch sizes. If it is not (and this must be determined separately), then fractal dimension should be computed separately for the range of patch sizes over which it is constant. Note, because this index employs regression analysis, it is subject to spurious results when sample sizes are small. In landscapes with only a few patches, it is not unusual to get values that greatly exceed the theoretical limits of this index. Thus, this index is probably most useful if sample sizes are large (e.g., $n \geq 20$), although FRAGSTATS computes the index for moderate sample sizes as well (i.e., $n \geq 10$). In addition, it is important to realize that the perimeterarea fractal dimension computed in FRAGSTATS is based on the regression of log area on log perimeter; that is, ln(area) = b0 + b1ln (perim). It is equally valid to compute fractal dimension by regressing log perimeter on log area; that is, ln(perim) = b0 + b1ln(area), in which case the fractal dimension (D) is equal to 2 times the slope (b1). These two approaches give slightly different answers and it is not clear that one is superior to the other. Both approaches are used in practice, so it behooves you to note the manner by which fractal dimension is computed when comparing among studies.

ENN	**Euclidean Nearest-Neighbour Distance**
Description	ENN equals the distance (m) to the nearest neighboring patch of the same type, based on shortest edge-to-edge distance. Note that the edge-to-edge distances are from cell center to cell center.
Units	Meters
Range	ENN > 0, without limit. ENN approaches 0 as the distance to the nearest neighbor decreases. The minimum ENN is constrained by the cell size, and is equal to twice the cell size when the 8-neighbor patch rule is used or the distance between diagonal neighbors when the 4-neighbor rule is used. The upper limit is constrained by the extent of the landscape. ENN is undefined and reported as “N/A” in the “basename”.patch file if the patch has no neighbors (i.e., no other patches of the same class).
Comments	Euclidean nearest-neighbor distance is perhaps the simplest measure of patch context and has been used extensively to quantify patch isolation. Here, nearest neighbor distance is defined using simple Euclidean geometry as the shortest straight-line distance between the focal patch and its nearest neighbor of the same class.

ECON	**Edge Contrast Index**
Description	ECON equals the sum of the patch perimeter segment lengths (m) multiplied by their corresponding contrast weights, divided by total patch perimeter (m), multiplied by 100 (to convert to a percentage). Edge segments along the landscape boundary are treated like background (as specified in the edge contrast weight file) unless a landscape border is present, in which case the boundary edge types are made explicit by the information in the border.
Units	Percent
Range	0 ≦ ECON ≦ 100 ECON = 0 if the landscape consists of only one patch and the landscape boundary consists of all background (i.e., in the absence of a border) and is give a zero-contrast weight (d = 0). Also, ECON = 0 when all of the patch perimeter segments involve patch type adjacencies that have been given a zero-contrast weight in the edge contrast weight file. ECON = 100 when the entire patch perimeter is maximum contrast edge (d = 1). ECON < 100 when a portion of the patch perimeter is less than maximum-contrast edge (d < 1).
Comments	Edge Contrast Index is founded on the notion that all edges are not created equal. To account for this, the notion of edge "contrast" was created. This index is a relative measure of the amount of contrast along the patch perimeter.

NP	**Number of Patches**
Description	NP equals the number of patches of the corresponding patch type (class).
Units	None
Range	NP ≥ 1, without limit. NP = 1 when the landscape contains only one patch of the corresponding patch type; that is, when the class consists of a single patch.
Comments	Number of patches of a particular patch type is a simple measure of the extent of subdivision or fragmentation of the patch type. Although the number of patches in a class may be fundamentally important to a number of ecological processes, often it has limited interpretive value by itself because it conveys no information about area, distribution, or density of patches. Of course, if total landscape area and class area are held constant, then number of patches conveys the same information as patch density or mean patch size and may be a useful index to interpret. Number of patches is probably most valuable, however, as the basis for computing other, more interpretable, metrics.

PD	**Patch Density**
Description	PD equals the number of patches of the corresponding patch type divided by total landscape area (m2), multiplied by 10,000 and 100 (to convert to 100 hectares). Note, total landscape area (A) includes any internal background present.
Units	Number per 100 hectares
Range	PD > 0, constrained by cell size. PD is ultimately constrained by the grain size of the raster image, because the maximum PD is attained when every cell is a separate patch. Therefore, ultimately cell size will determine the maximum number of patches per unit area. However, the maximum density of patches of a single class is attained when every other cell is of that focal class (i.e., in a checker board manner; because adjacent cells of the same class would be in the same patch).
Comments	Patch density is a limited, but fundamental, aspect of landscape pattern. Patch density has the same basic utility as number of patches as an index, except that it expresses number of patches on a per unit area basis that facilitates comparisons among landscapes of varying size. Of course, if total landscape area is held constant, then patch density and number of patches convey the same information. Like number of patches, patch density often has limited interpretive value by itself because it conveys no information about the sizes and spatial distribution of patches. Number of patches is probably most valuable, however, as the basis for computing other, more interpretable, metrics. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

PROX_MN	**Proximity Index**
Description	PROX equals the sum of patch area (m2) divided by the nearest edge-to-edge distance squared (m2) between the patch and the focal patch of all patches of the corresponding patch type whose edges are within a specified distance (m) of the focal patch. Note, when the search buffer extends beyond the landscape boundary, only patches contained within the landscape are considered in the computations. In addition, note that the edge-to-edge distances are from cell center to cell center.
Units	None
Range	PROX ≥ 0. PROX = 0 if a patch has no neighbors of the same patch type within the specified search radius. PROX increases as the neighborhood (defined by the specified search radius) is increasingly occupied by patches of the same type and as those patches become closer and more contiguous (or less fragmented) in distribution. The upper limit of PROX is affected by the search radius and the minimum distance between patches.
Comments	Proximity index was developed by Gustafson and Parker (1992) and considers the size and proximity of all patches whose edges are within a specified search radius of the focal patch. Note that FRAGSTATS uses the distance between the focal patch and each of the other patches within the search radius, similar to the isolation index of Whitcomb et al. (1981), rather than the nearest-neighbor distance of each patch within the search radius (which could be to a patch other than the focal patch), as in Gustafson and Parker (1992). The index is dimensionless (i.e., has no units) and therefore the absolute value of the index has little interpretive value; instead it is used as a comparative index.

TECI	**Total Edge Contrast Index**
Description	TECI equals the sum of the lengths (m) of each edge segment involving the corresponding patch type multiplied by the corresponding contrast weight, divided by the sum of the lengths (m) of all edge segments involving the same type, multiplied by 100 (to convert to a percentage). Edge segments along the landscape boundary are treated like background (as specified in the edge contrast weight file) unless a landscape border is present, in which case the boundary edge types are made explicit by the information in the border.
Units	Percent
Range	0 ≦ TECI ≦ 100 TECI = 0 when there is no class edge in the landscape; that is, when the entire landscape and landscape border, if present, consists of the corresponding patch type and the user specifies that background edge be given a zero-contrast weight (d = 0). TECI approaches 0 as the contrast in edges involving the corresponding patch type lesson (i.e., contrast weight approaches 0). TECI = 100 when all class edge is maximum contrast (d = 1).
Comments	Total edge contrast index is similar to the edge contrast index at the patch level, only here it is applied to all edges of the corresponding patch type.

TA	**Total Area**
Description	TA equals the total area (m2) of the landscape, divided by 10,000 (to convert to hectares). Note, total landscape area (A) includes any internal background present.
Units	Hectares
Range	TA > 0, without limit.
Comments	Total area (TA) often does not have a great deal of interpretive value with regards to evaluating landscape pattern, but it is important because it defines the extent of the landscape. Moreover, total landscape area is used in the computations for many of the class and landscape metrics.

LSI	**Landscape Shape Index**
Description	LSI equals .25 (adjustment for raster format) times the sum of the entire landscape boundary (regardless of whether it represents 'true' edge or not, or how the user specifies how to handle boundary/background) and all edge segments (m) within the landscape boundary involving the corresponding patch type, including some or all of those bordering background (based on user specifications), divided by the square root of the total landscape area (m2). Note, total landscape area (A) includes any internal background present.
Units	None
Range	LSI ≥ 1, without limit. LSI = 1 when the landscape consists of a single square patch of the corresponding type; LSI increases without limit as landscape shape becomes more irregular and/or as the length of edge within the landscape of the corresponding patch type increases..
Comments	Landscape shape index provides a standardized measure of total edge or edge density that adjusts for the size of the landscape. Because it is standardized, it has a direct interpretation, in contrast to total edge, for example, that is only meaningful relative to the size of the landscape.

CONTAG **Contagion Index**

Description: CONTAG equals minus the sum of the proportional abundance of each patch type multiplied by the proportion of adjacencies between cells of that patch type and another patch type, multiplied by the logarithm of the same quantity, summed over each unique adjacency type and each patch type; divided by 2 times the logarithm of the number of patch types; multiplied by 100 (to convert to a percentage). In other words, the observed contagion over the maximum possible contagion for the given number of patch types. Note, CONTAG considers all patch types present on an image, including any present in the landscape border, if present, and considers like adjacencies (i.e., cells of a patch type adjacent to cells of the same type). All background edge segments are ignored, as are landscape boundary segments if a border is not provided, because adjacency information for these edge segments is not available and the intermixing of the classes with background is assumed to be irrelevant. Cell adjacencies are tallied using the double-count method in which pixel order is preserved, at least for all internal adjacencies (i.e., involving cells on the inside of the landscape). If a landscape border is present, adjacencies on the landscape boundary are counted only once as are all adjacencies with background. Note, Pi is based on the total landscape area (A) excluding any internal background present.

Units: None

Range: $0 < CONTAG \leqq 100$ CONTAG approaches 0 when the patch types are maximally disaggregated (i.e., every cell is a different patch type) and interspersed (equal proportions of all pairwise adjacencies). CONTAG = 100 when all patch types are maximally aggregated. CONTAG is undefined and reported as "N/A" in the "basename".land file if the number of patch types is less than 2, or all classes consist of one cell patches adjacent to only background.

Comments: Contagion is inversely related to edge density. When edge density is very low, for example, when a single class occupies a very large percentage of the landscape, contagion is high, and vice versa. In addition, note that contagion is affected by both the dispersion and interspersion of patch types. Low levels of patch type dispersion (i.e., high proportion of like adjacencies) and low levels of patch type interspersion (i.e., inequitable distribution of pairwise adjacencies results in high contagion, and vice versa.

DIVISION **Landscape Division Index**

Description: DIVISION equals 1 minus the sum of patch area (m2) divided by total landscape area (m2), quantity squared, summed across all patches in the landscape. Note, total landscape area (A) includes any internal background present.

Units: Proportion

Range: $0 \leqq DIVISION \leqq 1$ DIVISION = 0 when the landscape consists of single patch. DIVISION is achieves its maximum value when the landscape is maximally subdivided; that is, when every cell is a separate patch.

Comments	Division is based on the cumulative patch area distribution and is interpreted as the probability that two randomly chosen pixels in the landscape are not situated in the same patch. Note, the similarity with Simpson's diversity index, only here the sum is across the proportional area of each patch, rather than the proportional area of each patch type in the landscape. Note, DIVISION is redundant with Effective mesh size (MESH) below, i.e., they are perfectly, but inversely, correlated, but both metrics are included because of differences in units and interpretation. DIVISION is interpreted as a probability, whereas MESH is given as an area. In addition, as described below (see MESH), DIVISION is perfectly redundant with Area-weighted mean patch size (AREA_AM) when there is no background.

PR	**Patch Richness**
Description	PR equals the number of different patch types present within the landscape boundary.
Units	None
Range	PR ≥ 1, without limit
Comments	Patch richness is perhaps the simplest measure of landscape composition, but note that it does not reflect the relative abundances of patch types. Note, this metric is redundant with both patch richness density and relative patch richness.

PRD	**Patch Richness Density**
Description	PRD equals the number of different patch types present within the landscape boundary divided by total landscape area (m2), multiplied by 10,000 and 100 (to convert to 100 hectares). Note, total landscape area (A) includes any internal background present.
Units	Number per 100 hectares
Range	PRD > 0, without limit
Comments	Patch richness density standardizes richness to a per area basis that facilitates comparison among landscapes. Note, this metric is redundant with both patch richness and relative patch richness.

SHDI	**Shannon's Diversity Index**
Description	SHDI equals minus the sum, across all patch types, of the proportional abundance of each patch type multiplied by that proportion. Note, Pi is based on total landscape area (A) excluding any internal background present.
Units	Information
Range	SHDI ≥ 0, without limit SHDI = 0 when the landscape contains only 1 patch (i.e., no diversity). SHDI increases as the number of different patch types (i.e., patch richness, PR) increases and/or the proportional distribution of area among patch types becomes more equitable.
Comments	Shannon's diversity index is a popular measure of diversity in community ecology, applied here to landscapes. Shannon's index is somewhat more sensitive to rare patch types than Simpson's diversity index.

Annex 2 | Description of Mapping Units for the Urban Atlas

Code	Nomenclature	Definition
1	Artificial surfaces	Surfaces with dominant human influence but without agricultural land use. These areas include all artificial structures and their associated non-sealed and vegetated surfaces.
1.1	Urban Fabric	Built-up areas and their associated land, such as gardens, parks, planted areas and non-surfaced public areas and the infrastructure.
1.1.1	Continuous Urban Fabric (S.L. > 80%)	Land Use: Predominant residential use: areas with a high degree of soil sealing, independent of their housing scheme (single family houses or high rise dwellings, city centre or suburb). Included are downtown areas and city centres, and central business districts (CBD) as long as there is partial residential use.
1.1.2	Discontinuous Urban Fabric (S.L. 10% - 80%)	Land Use: Predominant residential usage. Contains more than 20% non-sealed areas, independent of their housing scheme (single family houses or high-rise dwellings, city centre or suburb). The non-sealed areas might be private gardens or common green areas.
1.1.2.1	Discontinuous Dense Urban Fabric (S.L. 50% - 80%)	Average degree of soil sealing: > 50 - 80% Residential buildings, roads and other artificially surfaced areas.
1.1.2.2	Discontinuous Medium Density Urban Fabric (S.L. 30% - 50%)	Average degree of soil sealing: > 30 - 50% Residential buildings, roads and other artificially surfaced areas. The vegetated areas are predominant, but the land is not dedicated to forestry or agriculture.
1.1.2.3	Discontinuous Low Density Urban Fabric (S.L. 10% - 30%)	Average degree of soil sealing: 10 - 30% Residential buildings, roads and other artificially surfaced areas. The vegetated areas are predominant, but the land is not dedicated to forestry or agriculture.
1.1.2.4	Discontinuous Very Low Density Urban Fabric (S.L. < 10%)	Average degree of soil sealing: <10 % Residential buildings, roads and other artificially surfaced areas. The vegetated areas are predominant, but the land is not dedicated to forestry or agriculture. Example: exclusive residential areas with large gardens.
1.1.3	Isolated structures	Isolated artificial structures with a residential component, such as (small) individual farm houses and related buildings.
1.2	Industrial, commercial, public, military, private and transport units	Land cover: Artificial structures (e.g. buildings) or artificial surfaces (e.g. concrete, asphalt, tar, macadam, tarmac or otherwise stabilised surface, e.g. compacted soil, devoid of vegetation), occupy most of the surface. Included are associated areas, such as roads, sealed areas and vegetated areas, if these areas are not suitable to be mapped separately with regard to the minimum mapping unit size.

1.2.1	12100 Industrial, commercial, public, military and private units	Land use: Industrial, commercial, public, military or private units. The administrative boundaries of the production or service unit are mapped, including associated features. This class contains: a) Industrial uses and related areas > Sites of industrial activities, including their related areas; > Production sites; > Energy plants: nuclear, solar, hydroelectric, thermal, electric and wind farms; > Sewage treatment plants; > Farming industries > Antennas, even with predominant vegetated areas. The vegetated areas may be predominant, but the land is not dedicated to forestry or agriculture; > Water treatment plants; > Sewage plants; > Seawater desalination plants. b) Commercial uses, retail parks and related areas > Surfaces purely occupied by commercial activities, including their related areas (e.g. parking areas even larger than the MinMU); > High-rise office buildings; > Petrol and service stations within built-up areas. c) Public, military and private services not related to the transport system Surfaces purely occupied by general government, public or private administrations including their related areas (access ways, lawns, parking areas).Included are: > Schools and universities; > Hospitals and other health services or buildings; > Places of worship (churches / cathedrals / religious buildings); > Cemeteries; > Archaeological sites and museums; > Administration buildings, ministries; > Penitentiaries; > Military areas including bases and airports; > Military exercise areas fenced and under current use; > Castles, etc. not primarily used for residential purposes (building management, gardeners, etc. living there is not residential use in this sense); > Private storage areas without a residential component, such as compounds of garages. d) Civil protection and supply infrastructure > Dams, dikes, irrigation and drainage canals and ponds and other technical public infrastructure, to be mapped with the roads, embankments and associated land included; > Includes also breakwaters, piers and jetties, sea walls and flood defences; > (Ancient) city walls, other protecting walls, bunkers; > Avalanche barriers.

1.2.2	Road and rail network and associated land	Associated lands are: > Slopes of embankments or cut sections; > Areas enclosed by roads or railways, without direct access and without agricultural land use; > Fenced areas along roads (e.g. as for protection against wild animals); > Areas enclosed by motorways, exits or service roads with no detectable access; > Noise barriers (fences, walls, earth walls); > Rest areas, service stations and parking areas only accessible from the fast transit roads; > Railway facilities including stations, cargo stations and service areas; > Foot- or bicycle paths parallel to the traffic line; > Green strips, alleys (with trees or bush
1.2.2.1	Fast transit roads and associated land	Roads defined as “motorways” in the COTS navigation data, and motorway rest and service areas and parking areas, only accessible from the motorways. Motorways that are not included in the COTS navigation data are to be mapped by the service provider.
1.2.2.2	Other roads and associated land	Roads, crossings, intersections and parking areas, including roundabouts and sealed areas with “road surface”.
1.2.2.3	Railways and associated land	Railway facilities including stations, cargo stations and service areas.
1.2.3	Port areas	Administrative area of inland harbours and sea ports. Infrastructure of port areas, including quays, dockyards, transport and storage areas and associated areas.
1.2.4	Airports	Administrative area of airports, mostly fenced.Included are all airport installations: runways, buildings and associated land.
1.3	Mine, dump and construction sites	
1.3.1	Mineral extraction and dump sites	> Open pit extraction sites (sand, quarries) including water surface, open-cast mines, inland salinas, oil and gas fields; > Their protecting dikes and / or vegetation belts and associated land such as service areas, storage depots; > Public, industrial or mine dump sites, raw or liquid wastes, legal or illegal, their protecting dikes and / or vegetation belts and associated land such as service areas.
1.3.3	Construction sites	Spaces under construction or development, soil or bedrock xcavations for construction purposes or other earthworks visible in the image. Clear evidence of actual construction needs to be identifiable in the ata, such as actual excavations and machinery on site, or ongoing construction of any stage, etc.

1.3.4	Land without current use	Areas in the vicinity of artificial surfaces still waiting to be used or re-used. The area is obviously in a transitional position, "waiting to be used". Waste land, removed former industry areas, ("brown fields") gaps in between new construction areas or leftover land in the urban context ("green fields"). No actual agricultural or recreational use. No construction is visible, without maintenance, but no undisturbed fully natural or semi-natural vegetation (secondary ruderal vegetation). Also areas where the street network is already finished, but actual erection of buildings is still not visible.
1.4	Artificial non-agricultural vegetated areas	Vegetation planted and regularly worked by humans; strongly human-influenced. Sporting facilities as functional units independent of being non-sealed, sealed or built-up.
1.4.1	Green urban areas	Public green areas for predominantly recreational use such as gardens, zoos, parks, castle parks. Suburban natural areas that have become and are managed as urban parks. Forests or green areas extending from the surroundings into urban areas are mapped as green urban areas when at least two sides are bordered by urban areas and structures, and traces of recreational use are visible
1.4.2	Sports and leisure facilities	All sports and leisure facilities including associated land, whether public or commercially managed: e.g. Theresienwiese (Munich), public arenas for any kind of sports including associated green areas, parking places, etc.: > Golf courses; > Sports fields (also outside the settlement area); > Camp grounds; > Leisure parks; > Riding grounds; > Racecourses; > Amusement parks; > Swimming resorts etc.; > Holiday villages ("Club Med"); > Allotment gardens1; > Glider or sports airports, aerodromes without sealed runway; > Marinas.

2	Agricultural areas, semi-natural areas and wetlands	a) Arable land > Fields under rotation system. Can be non-irrigated or permanently irrigated. Also includes rice fields; > Fields laid in fallow are included. b) Permanent crops: > Fruit orchards, scattered fruit trees with pasture; > Vineyards and their nurseries; > Roses; > Olive groves; > Berries and hop plantations. c) Pasture & natural grassland: > Grassland; > Pasture and meadow under agricultural use, grazed or mechanically harvested. d) Shrubs and / or herbaceous vegetation including transitional woodland > Vegetation cover more than 50%, ground coverage of trees with height > 5 m: < 30%, areas with minor / without artificial or agricultural influence; > Sclerophyllous vegetation; > Bushy sclerophyllous vegetation (e.g. maquis, garrigue); > Abandoned arable land with bushes; > Woodland degradation: storm, snow, insects or air pollution; > Areas under power transmission lines inside forest; > Fire breaks; > Steep bushy slopes of eroded areas; > Abandoned vineyards or orchards, arable land and pasture land under natural colonisation; > Dehesas with bush proliferation indicating no agricultural or farming use for a rather long time; > Bushy areas along creeks. e) Moors and heathland: > Bushes, shrubs and herbaceous plants, dwarf forest in alpine or coastal regions (Pinus Mugo forests). Height is maximum 3 m in climax stage. f) Beaches, dunes, sand: > 10% vegetation cover; > Beaches, dunes and sand plains, (coastal or inland location), gravel along rivers; > Seasonal rivers, if water is characteristic for a shorter part of the year (< 2 months). g) Bare rocks: > 90% of the land surface of bare rocks, (i.e. < 10% vegetation); > Rocks, gravel fields, landslides; > Scree (fragments resulting from mechanical and chemical erosion. Weathering rocks forming heaps of coarse debris at the foot of steep slopes), cliffs, rocks. h) Sparsely vegetated areas i) Burnt areas j) Snow and ice k) Inland wetlands l) Coastal wetlands

3	Forests	> With ground coverage of tree canopy > 30%, tree height > 5 m, including bushes and shrubs at the fringe of the forest; > Included are plantations such as Populus plantations, Christmas tree plantations; > Forest regeneration / re-colonisation: clear cuts, new forest plantations.
5	Water	The visible water surface area on the EO data is delineated. EO data should be considered as a primary (guiding) data source. > Sea; > Lakes; > Fish ponds (natural, artificial); > Rivers, including channelled rivers; > Canals.