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Editorial correspondence
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"
Piazzale Tecchio, 80
80125 Naples
web: www.tema.unina.it
e-mail: redazione.tema@unina.it

The cover image is a photo of the 1966 flood of the Arno in Florence (Italy).

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A GIS-based automated procedure to assess disused areas

Identification methods and regeneration opportunities

Mauro Francini [a]*, Nicole Margiotta [b], Annunziata Palermo [c], Maria Francesca Viapiana [d]

[a] Laboratory of Environmental and Territorial Planning (LabPAT) of the Department of Civil Engineering
University of Calabria, Arcavacata di Rende (CS), Italy
e-mail: mauro.francini@unical.it
ORCID: https://orcid.org/0000-0002-0943-8936
* Corresponding author

[b] Laboratory of Environmental and Territorial Planning (LabPAT) of the Department of Civil Engineering
University of Calabria, Arcavacata di Rende (CS), Italy
e-mail: nicole.margiotta@unical.it
ORCID: https://orcid.org/0000-0002-0660-111X

[c] Laboratory of Environmental and Territorial Planning (LabPAT) of the Department of Civil Engineering
University of Calabria, Arcavacata di Rende (CS), Italy
e-mail: annunziata.palermo@unical.it
ORCID: https://orcid.org/0000-0003-2879-0174

[d] Laboratory of Environmental and Territorial Planning (LabPAT) of the Department of Civil Engineering
University of Calabria, Arcavacata di Rende (CS), Italy
e-mail: mf.viapiana@unical.it
ORCID: https://orcid.org/0000-0003-4012-8052

Abstract

Regeneration of disused sites represents a significant opportunity. The scientific interest in their redevelopment possibilities has grown considerably in recent years. Despite this, a shared definition of disused sites which goes beyond that of brownfields and allows recognition the size of the problem on a transnational scale is still lacking. This study provides an overview of the main definitions provided by scientific literature and on this basis, it proposes a parametric definition of *functionally disused areas*. Subsequently, a GIS-based operational tool able to map functionally disused areas through a progressive screening of the local territory is introduced. The proposed methodology is tested on two Italian municipalities. It is the first step of a research aimed at defining a wider process able to assess the possibility of converting disused areas into multifunctional or monofunctional "smart" districts. They could be, indeed, characterized by a mixed use – contributing to soil consumption reduction – or by a single use – "social infrastructures" – linked to the needs that emerged as result of Covid-19 pandemic. This assessment process, hence, could support urban planning both at ordinary and emergency phase, allowing to identify in very short time areas where temporary facilities could be installed.

Keywords

Soil consumption; Sustainable development; Urban regeneration; Disused areas; GIS.

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1. Introduction

Due to the rapid environmental emergency progress, policy makers have made considerable efforts to agree international climate targets in the last few years (Bauer & Menrad, 2019). One of the most important programmatic initiatives is the Paris Agreement (2015), through which the United Nations agreed to limit global warming below 2 °C compared to pre-industrial levels, to reduce greenhouse gas emissions by 40% by 2030 and to improve energy efficiency, as well as to use 27% of energy from renewable sources (Amanatidis, 2020). In summary, the EU's climate change adaptation strategy aims to make Europe more resilient to climate change by promoting coordinated and shared measures between member States (Zucaro & Morosini, 2018). Globally, cities have emerged as leading climate change adaptation and mitigation actors (Grafakos et al., 2020). Indeed, today about 55% of the world's population lives in urban areas and it is expected that the population rate will increase to 68% by 2050 (ONU, 2018). Due to the high concentration of human activities, contemporary cities are (and will be) highly energy-intensive organisms, responsible for most of the consumption of non-renewable resources (Gargiulo & Russo, 2017). One of these is soil; to protect uncontaminated habitats and ensure sustainability we must ensure that it is used as efficiently as possible (Bartke, 2013). The EU aims to achieve zero soil consumption by 2050, avoiding the new sealing of natural areas (European Commission, 2016). Among the short-term strategies outlined by the member States of the European Commission, the highest potentialities concern the recovery of disused areas, which identify a wide range of urban properties that include areas, individual artifacts or entire compendiums, characterized by different dimensions, intended uses and intensity of degradation (Morano & Tajani, 2018). These are spaces and containers which are no longer used for the activities for which they were originally designed and built; they are in need of urgent intervention plans whose purpose should be the re-definition of spatial, social and economic functions (Krzysztofik et al., 2013). Their regeneration can take very different forms, providing a wide variety of land uses – residential, commercial, productive, open spaces (Loures et al., 2016) – without involving further consumption of greenfields. Disused areas recovery, indeed, can be for hard reuse (buildings and infrastructures), soft reuse (e.g. green space or biomass production), or a combined approach. The soft reuse such as recreation and amenity has become increasingly common due to the demand for the potential environmental, social and economic benefits that it can deliver (Bardos et al., 2015; Li et al., 2019). On the other hand, hard or – better – combined use would contribute to achieve the goals for urban development agreed-upon at the global level: compactness, polycentrism, mixed use, and prioritization of urban renewal (UN General Assembly, 2016).

In addition, the need for additional social urban services emerged as result of Covid 19 pandemic has amplified potential of disused areas, which could be converted into permanent or temporary "social infrastructures".

Regardless of the end-use chosen, therefore, disused areas regeneration entails benefits for both present and future populations.

The district scale of interventions would allow innovative solutions, regarding the saving and the intelligent use of resources, to be tested. The district size, indeed, is intermediate between that of the single building (understood as an autonomous entity) and that of the entire city (of which the district is a subsystem). This territorial level overcomes the individualistic approach of the single building and facilitates the experimentation and optimization of practices that could then be replicated on an urban scale. While the potential offered by the recovery and the conversion of disused spaces are many, there is currently no methodology for the systematic mapping of these areas. They are often erroneously assumed as coincident with the so-called brownfields for which intervention possibilities are often limited by the problems related to their reclamation. The disused area concept is wider, also including areas that were not previously connected to industrial functions (greyfields).

The aim of this paper, which corresponds to the first phase of our research, is to propose a parametric definition of this type of area, introducing the "disuse function". The theoretical proposal is translated into an

operational tool through the building of an automated GIS-based process, able to perform a first discretization of the territories, identifying potentially disused areas within them. With the goal of developing a census of these areas, the results obtained would constitute a useful starting point for local technicians, who would then just have to conduct a subsequent verification and refinement procedure. The proposed methodology uses only open-source data, and it has been developed in the operational environment of the QGIS desktop application, freely available to any user category. The assessment process, in addition to supporting urban planning at ordinary phase, could be used at emergency phase such as that of Covid 19 pandemic, allowing to identify in very short time areas where temporary facilities could be installed.
Model validity has been tested through two case studies, the municipalities of Rende (Calabria, Southern Italy) and of Voghera (Lombardy, Northern Italy).

2. Background and theoretical model development

2.1 Definition of the research application field

Disused areas constitute a substantial portion of the land area in post-industrial cities (Martinat et al., 2018). The *European Environmental Agency* (EEA) estimates the presence of over three million disused sites in Europe (EC, 2013) and this figure is, however, related only to areas with a previous industrial use (brownfields). The continuous activities of degradation, abandonment and dismantlement require rethinking the city, focusing on renewal, regeneration and recycle (Punziano & Terracciano, 2018). In the last decade, the number of literature studies concerning the effective reuse of disused and underused sites has grown exponentially. These areas, indeed, represent an enormous capital of stored grey energy (Paolella, 2013) and giving priority to their redevelopment can contribute to more sustainable land regeneration and management (Bartke, 2016). Nevertheless, less attention has been paid to the correct way of identifying them. Knowledge about the quantitative and qualitative dimensions of the "disuse phenomenon" are still fragmentary. The few local-scale inventories refer to criteria that are not comparable and they often have little influence on subsequent planning choices and, therefore, on the reduction of land consumption (Filpa et al., 2013).
In addition, despite the universally recognised generic definition of disused area as including all sites that have lost their original functional characteristics, the literature almost always focuses exclusively on the analysis of *vacant lands* with previous productive use. The definitions of British *derelict lands*[1] and of the French *frinche industrielle*[2], as well as that of the most recent *brownfields*[3], all refer to sites whose degrade condition is consequential to the processes of de-industrialization and for which contamination (presumed or confirmed) is the decisive indicator in most European countries (Poland, Belgium – Flanders, Italy, Bulgaria, Spain, etc.). Hence, these expressions exclude from the assessment all the interurban voids consisting of abandoned residential, commercial and tertiary areas, in state of neglect, underused or never completed, resulting from urban processes such as decentralisation linked to demographic change, urban expansion or citizens' preference for new types of residential choices (Johnson et al., 2014). The British *National Planning Policy Framework* refers to these areas with the expression *previously developed lands*, which includes "*lands which are or were occupied by a permanent structure, including the curtilage of the developed lands (although it should not be assumed that the whole of the curtilage should be developed) and any associated fixed surface infrastructure. This excludes: lands that are or were last occupied by agricultural or forestry buildings; lands*

1 The expression *derelict lands* was introduced by the British Department of Environment in 1979 and indicates "degraded areas so damaged by its industrial or other productive uses that it is unsuitable for any use without prior treatment" (DoE, 1979).

2 The expression *frinche industrielle* is used to describe all those spaces, built and not, previously occupied by industrial activities and then abandoned or underused (Iaurif, 1988).

3 The term *brownfield* refers to "sites and immovable property the upgrading and re-use of which may be complicated by the presence of a dangerous substance, pollutant or contaminant" (Davis & Sherman, 2010).

that have been developed for minerals extraction or waste disposal by landfill, where provision for restoration has been made through development management procedures; lands in built-up areas such as residential gardens, parks, recreation grounds and allotments; and lands that were previously developed but where the remains of the permanent structure or fixed surface structure have blended into the landscape" (NPPF, 2019). There are still a small number of studies extending the concept of disused area beyond that of brownfield sites. Indeed, while recent attention has largely focused on contaminated industrial sites, relatively little research or political work has considered the vast potential represented by the different types of *vacant urban lands* present in the most economically depressed urban districts (Goldstein et al., 2001). Few examples can be mentioned in this regard. The CABERNET (*Concerted Action on Brownfields and Economic Regneration*) Network Report (2006) defines different types of *previously developed lands*, according to the current site conditions (Fig.1). Kim et al. (2017) catalogue the vacant urban sites distinguishing between *post-industrial*, *abandoned*, *unattended land with vegetation*, *natural* and *transport related*. Loures & Vaz (2018) classify brownfields into five different types: *abandoned lands*, *contaminated lands*, *derelict lands*, *underutilized lands and vacant lands* (Fig.2). Krzysztofik et al. (2013) define the *functionally derelict areas*, divided into *derelict greenfields*, *greyfields*, *brownfields* and *blackfields*.

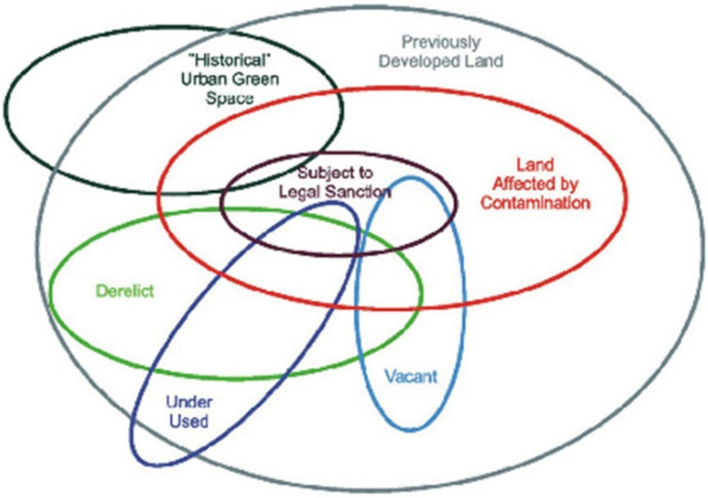

Fig.1 Previously developed lands types

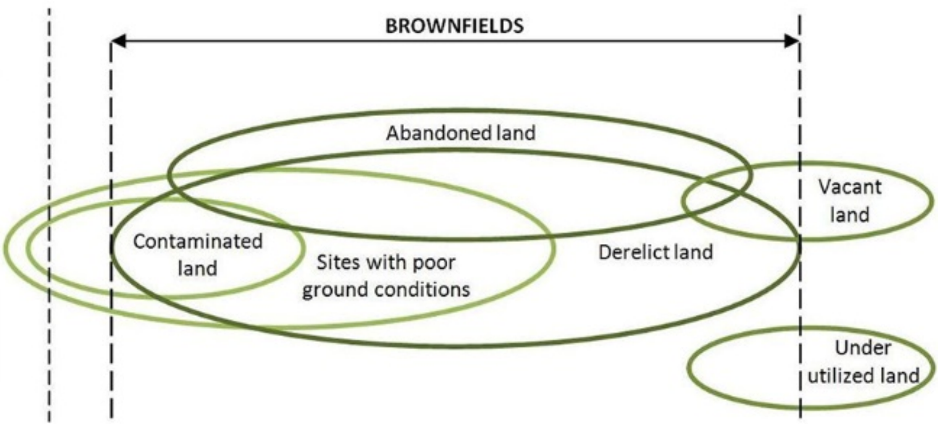

Fig.2 Brownfields types

Referring to the literature review (Tab.1), in the present study it was decided to consider the sites within the greyfields and brownfields categories (grey in the Tab.1) as "disused areas".

Types and references		Greenfields	References	Greenfields	References	Greenfields	References	Greenfields	References
Former use	No one	X	European Commission, 2013; Gallagher et al., 2019; Krzysztofik et al., 2013; Municipality of Rende, 1971; Regione Lombardia, 2014	-	-	-	-	X	Tang et al., 2020
	Farming	X	European Commission, 2013; Krzysztofik et al., 2013; Municipality of Rende, 1971	-	-	-	-	X	European Commission, 2013; Hou et al., 2016; Song et al., 2019; Tang et al., 2020
	Residential	-	-	X	Krzysztofik et al., 2013; NICOLE, 2002; Newton, 2010; Newton, 2011	-	-	X	Tang et al., 2020
	Industrial	-				X	Note 4; European Commission, 2013; Krzysztofik et al., 2013; Loures, 2016; NICOLE, 2002	X	Alker, 2000; European Commission, 2013; Krzysztofik et al., 2013; Munafo & Tombolini, 2014; Salvati et al., 2016; Tang et al., 2020
	Tertiary	-	-	X	Clarinet Project, 2002; Krzysztofik et al., 2013; Sobel et al., 2002	-	-	X	Krzysztofik et al., 2013; Tang et al., 2020
Relevant sealing[5]	No	X	Bartke, 2016; European Commission, 2013; Gallagher, 2019; Li, 2019; Municipality of Rende, 1971; Regione Lombardia, 2014	-	-	-	-	X	Hou et al., 2016; Song et al., 2019, Tang et al., 2020; UN General Assembly, 2016
	Yes	X	Krzysztofik et al., 2013	X	Krzysztofik et al., 2013; Newton, 2010; Sobel, 2002	X	Notes 4; 6; 7; 8; 9; 10; Bauer & Menrad, 2019; European Commission, 2013; Ferber, 2006; Krzysztofik et al., 2013; NICOLE, 2002	X	Alker et al., 2002; Krzysztofik et al., 2013; Munafo & Tombolini, 2014; Salvati et al., 2016; Tang et al., 2020
Contamination (presumed or confirmed)[11]	No	X	European Commission, 2013; Hou et al., 2018; Krzysztofik et al., 2013; Municipality of Rende, 1971; Regione Lombardia, 2014	X	NICOLE, 2002; Newton, 2010; Newton, 2011	X	Notes 6; 7; 10; Coutinho Guimaraes, 2019; European Commission, 2013; Ferber et al., 2006; Krzysztofik et al., 2013; loures et al., 2020; Paolella, 2020	-	-
	Yes	-	-	-	-	X	Notes 4; 8; 9; Bauer & Menrad, 2019; NICOLE, 2002	X	Alker et al., 2002; European Commission, 2013; Hou et al., 2016; Krzysztofik et al., 2013; Loures, 2016; Munafo & Tombolini, 2014; Salvati et al., 2016; Song et al., 2019; Tang et al., 2020; UN General Assembly, 2016

Tab.1 Main characteristics of the different types of disused site according to the literature

Fig.3 summarizes the disused site typologies characteristics and outlines the application field of the present work.

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[4] Brownfield definition provided by French Ministry of Environment.

[5] In this study soil sealing resulting from the building of agricultural structures and/or infrastructure is considered as *not relevant*.

[6] Brownfield definition provided by Danish Environmental Protection Agency.

[7] Brownfield definition provided by Direction Generale des Ressources Naturelles et de l'Environment (DGRNE).

[8] Brownfield definition provided by Openbare Afvalstoffenmaatschappij voor het Vlaamse Gewest (OVAM).

[9] Brownfield definition provided by Polish Ministry of Environment.

[10] Brownfield definition provided by Romanian Ministry of Waters and Environment.

[11] With regards to the brownifields sites, the distinction of literature references is made between definitions that indicate contamination – presumed or confirmed – as a necessary characteristic in order to identify a site as brownfield, and definitions for which it is a probable but not a discriminating feature.

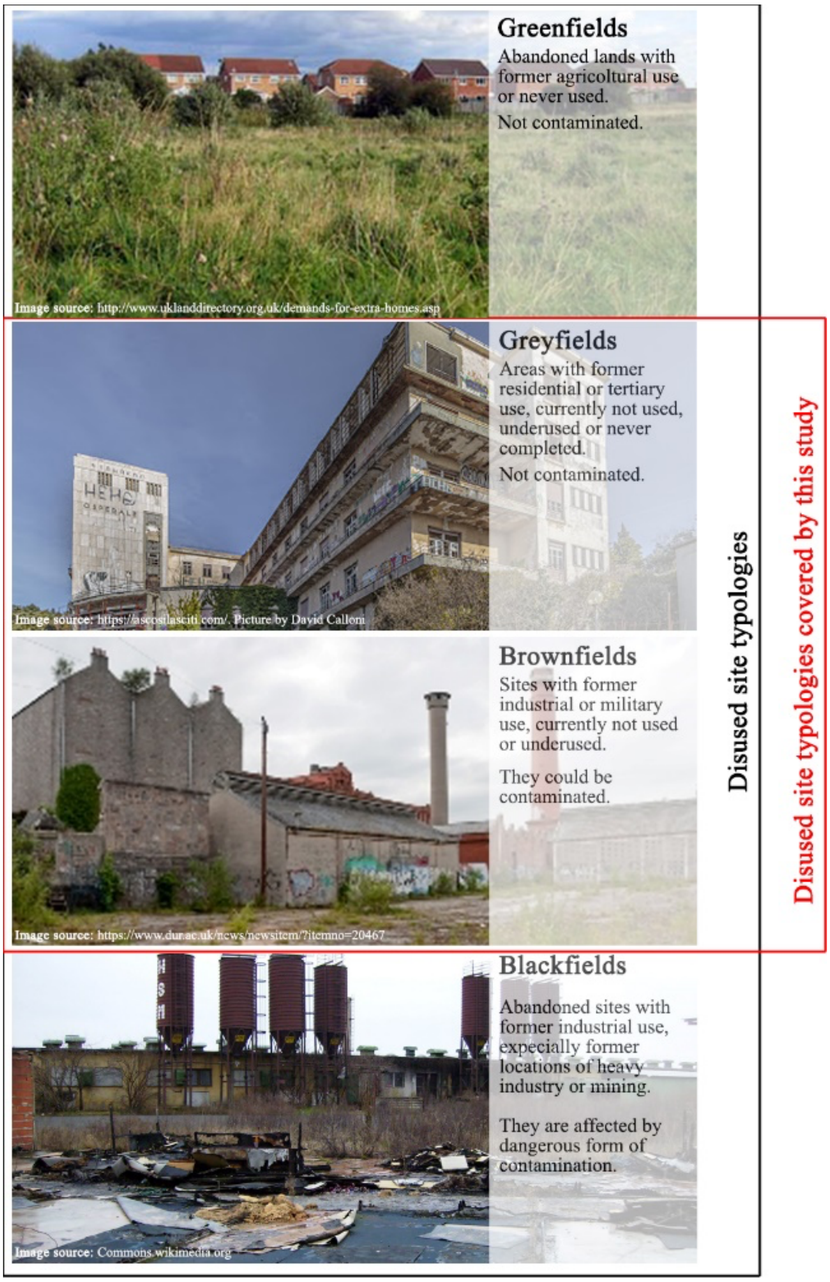

Fig.3 Schematic representation of disused site typologies and research application field identification

2.2 Theoretical model development

After the application field definition, the research focus shifted to determining parameters useful to identify disused areas. Providing objective criteria is necessary not only to avoid misunderstandings, but also to create a common language between the different people involved in regeneration processes (Loures & Vaz, 2018). Regarding the subject of this work, the definition of quantitative metrics is essential for a threefold purpose:

- to facilitate the disused areas census by the technical offices of the different municipalities, providing a unified identification code free from the various local specificities;
- to allow the development of a GIS-based automated process for the detection of potential disused areas;
- to make the results of the two detection methodologies comparable.

The critical literature review has allowed identification of the most influential parameters in the characterization of a disused area and their threshold values (Tab.2).

Parameter	**Symbology** *(Italian parameters acronyms)*	**Description**	**References**	**Included in the "functionally disused area" definition**	**Used for the GIS-based process development**
Soil sealing	Ss	Sites with a soil sealing percentage ≥ 30% (discontinuous medium density urban fabric)	European Commission, 2016	-	X
Zoning	Du	Consolidated or consolidation areas for residential, productive or service use. New expansion areas are excluded	Note 12	X	X
Population density	Dp	Census areas with population density ≤ 1,500 ab/m² (urban clusters)	Department of the Environment; 1979	-	X
Not used buldings	Ev	Census areas in which the presence of at least one unused building is recorded	Note 13	-	X
Total surface area	S	Disused areas with a total surface ≥ 10,000 m² (1 ha)	Grassi, 1989; POST, 1988; Taylor & Lewin, 1966	X	X
Covered surface area	Sc	For industrial areas the covered surface must be ≥ 1,000 m²; for areas with a different use covered surface must be ≥ 3,000 m²	European Commission, 2016; POST, 1988; Taylor & Lewin, 1966	X	X
Decommission year	Ad	Areas not used for at least one year with regards to brownfields and for at least three years with regards to greyfields	CzechInvest 2008; Grassi, 1989; Krzysztofik et al., 2013; Loures et al., 2016; POST, 1988	X	-
Buildings rated life (linked to degradation)	Vn	If more accurate information is not available, the potential building degradation is estimated referring to the ordinary structures rated life, which is equal to 50 years[14]. The parameter is not discriminatory	MIT, 2018; Regione Lombardia, 2010	-	X

Tab.2 Key disuse parameters in accord with the definition proposed by authors

It is possible, hence, to define the "disuse phenomenon" as a function of Eq.1:

$$Disuse = f(Ss, Du, Dp, Ev, S, Sc, Ad, Vn) \tag{1}$$

Some parameters have been included in the proposed definition of "functionally disused area" (explained below) reported in the census form sent to the municipal offices. Other ones have been used to develop the GIS-based detection process, allowing a progressive discretization of the analysed territories. The criteria relating to the zoning, the minimum total surface area and the minimum covered surface area have been used in both cases.

The brief definition of functionally disused area proposed in this research work, as result of the analyses and reworkings carried out, is the following:

"*The "functionally disused areas" are sites and building complexes which are no longer used to carry out the activities for which they were designed and built. They are artificially shaped spaces, totally or partially abandoned, already provided with at least primary urbanization works (roads, power grid and sewage, etc.),*

[12] Any disused or underused area definition provided by the literature assumes that this falls into previously developed areas.
[13] Any brownfield and/or greyfield definition provided by the literature assumes that the site is disused or underused, that is at least one of the buildings in the area is not currently in use (or, at most, abusively occupied).
[14] The NTC2018 (Technical Standards for Construction, which are the equivalent of the Eurocode in the Italian national legislation) define the rated life as the number of years in which it is expected that the buildings, subjected to necessary maintenance, maintain specific performance levels. Due to the uncertainty of the parameter in absence of documentation relating to the individual building, it is not considered discriminatory.

but characterized by building, urban and/or socio-economic degradation. The disuse condition must have been for at least one year with regards to brownfields (disused industrial areas) and for at least three years with regards to greyfields (disused residential and/or commercial areas). The total surface area must have a minimum size of 10,000 m² (1 ha); the covered surface area must have a minimum size of 1,000 m² with regards to industrial sites and of 3,000 m² with regards to sites with a different use".

3. Methods

3.1 A GIS-based automated process for the detection of functionally disused areas

The purpose of the development of a GIS-based automated process is to provide a tool to support municipalities during the early stages of the functionally disused areas census and mapping. Briefly, the tool develops a progressive discretization of the territory identifying the areas which, respecting the conditions described in Tab.2, are potential disused sites. A subsequent verification procedure by local authorities is however necessary, due to two main reasons:

- data used in the process are not constantly updated by the relevant sources[15], so any territorial changes may not have been recorded and need to be checked;
- some disuse parameters (e.g. the decommission year) cannot be found from open source data, so it is essential to integrate the data.

3.2 Input data homogenization

QGIS is an open source, cross-platform desktop GIS application written in C++ and Python and used by a wide variety of users (Meyer & Riechert, 2019). The wide range of functionalities that it provides makes it a valid alternative to the most popular commercial GIS software, while maintaining its free character. Linking with this feature, which greatly simplifies its use, we have developed a code that uses exclusively open source and easily available input data. To standardize all the input data, a regular grid of 100x100 meters was used as the only cartographic base. Each cell has an area of 1 ha, that is the defined minimum size for the total surface of a disused area (Tab.2).

QGIS plugins are tools for the execution of all the spatial operations necessary to translate the data from the various relative bases to the regular grid, whose use involves several advantages (Istat, 2018):

- cells have the same size so that they can be easily compared to each other;
- grids are stable over time and the data within them integrate very easily;
- a grid-based system can be subdivided and aggregated regardless of hierarchical subdivisions into administrative units.

The reference system used for the data-processing is that used by Eurostat for the GEOSTAT population grid ((EPSG: 3035) ETRS89/LAEA). This simplifies the use of the proposed tool and the comparison of the results provided by different European countries.

3.3 The workflow in QGIS

As mentioned, the proposed methodology operates a progressive screening of the territory, analysing data on an increasingly smaller scale as the process progresses.

Figure 4 outlines the discretization process workflow. The methods for calculating the parameters and the sources of necessary dataset are provided in Tab.3.

15 For instance, Istat (the Italian National Institute of Statistics) carries out regular censuses every 10 years.

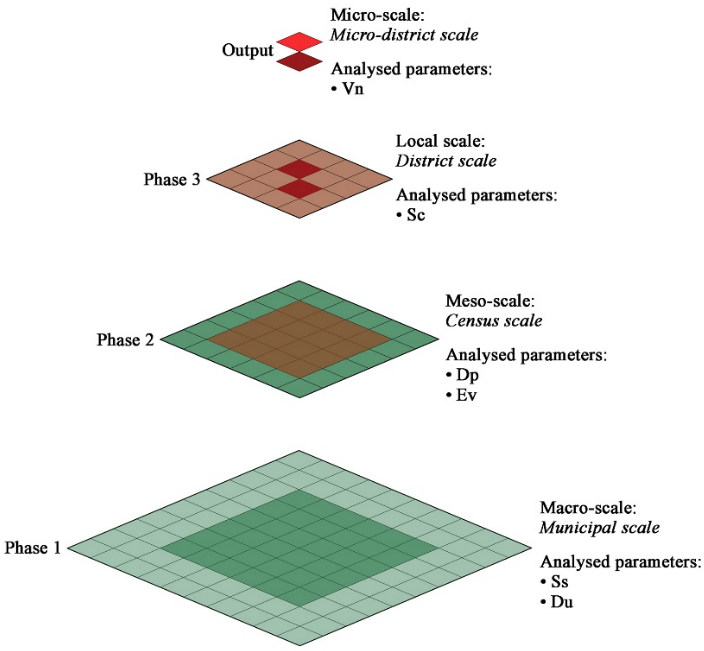

Fig.4 Schematic representation of the workflow in QGIS

Scale of analysis	Parameter	Method for calculating	Source
Macro-scale	Ss	-	Copernicus Degree of Imperviousness HR Layer
	Du	Zonal statistics algorithm	Municipal urban planning reference tool
Meso-scale	Dp	Zonal statistics algorithm	Istat – GEOSTAT population grid
	Ev	Zonal statistics algorithm; calculation code by using "aggregate","sum" and "contains" or "intersects" function	Istat census data; OpenDemanio georeferenced data
Local scale	Sc	Contiguous cells aggregation; calculation code by using "aggregate", "sum" and "intersects" functions	Updated municipal cartography
Micro-scale	Vn	Calculation code by using "aggregate", "sum" and "intersects" functions	Buildings conservation status map / Municipal historical maps
		Zonal statistics algorithm (on not industrial cells aggregations only)	Istat census data (regarding residential buildings)

Tab.3 Methods for calculating parameters used in QGIS process and sources of related dataset

3.3.1 Phase 1: macro-scale analysis

In this study the macro-scale is equivalent to the municipal scale.

The first parameter to be examined is the percentage of soil sealing (Ss) within municipal administrative boundaries. The sealing percentage is indeed indicative of the irreparable degradation of the soil resulting from human activities (Munafo & Tombolini, 2014). For this analysis the *Copernicus Degree of Imperviousness HR Layer* was used, which has been developed by the *European Environmental Agency* (EEA) under the Copernicus project to monitor land cover at the continental level and at a high level of detail (Istat, 2017). The cell layer with a soil sealing percentage of less than 30% are hidden. Following literature studies and a comparison of the Layer with the cartographic results of the European project *Corine Land Cover*, it has been verified that above this threshold the soil can reasonably be considered *artificially shaped*.

Subsequently, the zoning (Du) of the municipal territory is examined. Using the urban planning reference tool, cells totally falling into agricultural or newly expanding areas are hidden.

3.3.2 *Phase 2: meso-scale analysis*

The reference meso-scale is that of the census areas used for the processing of statistical data.
In this phase data concerning population density (Dp) and the presence of not used buildings (Ev) are analysed. Istat makes the data concerning the population distribution available using the Eurostat grid with cells size of 1 km^2 (GEOSTAT population grid), aligning with the European trend. The non-demographic data, on the other hand, still refer to the census areas[16].
Referring to the procedure used by Istat, the proposed methodology resamples all input datasets on the regular grid with cells size of 100x100 meters, using the QGIS algorithm *Zonal statistics* iteratively. For each cell, the algorithm returns a single output value concerning the Dp parameter and a single output value concerning the Ev parameter. Ev values are increased if one or more not used public real estate are located into the analysed aggregation cells. In Italy, georeferenced data regarding not used public real estate are freely downloadable by the State Property Agency website (OpenDemanio).
These values are compared with the relevant threshold values (Tab.2); cells that do not comply the disuse criteria examined are hidden.

3.3.3 *Phase 3: local scale analysis*

In phase 3, district scale (local scale) parameters are examined.
Contiguous surviving cells are aggregated using a specific algorithm. The definition of *contiguous cells* refers to that provided by Eurostat for *moderate-density urban clusters* (Eurostat, 2019). For this reason, cells connected only along a diagonal are also aggregated.
The parameter concerning the minimum total surface area (S) is theoretically already verified, because each cell has size equal to 1 ha. This parameter will have to be checked subsequently by municipal technicians, when the real boundaries of the disused areas have been precisely defined (disused areas can be included in the single cells, but not occupy them totally).
The covered surface area (Sc) falling in each aggregation of contiguous cells is determined by the software, setting a special calculation code. It is necessary to provide a polygonal *Shapefile* containing all the buildings falling within the municipal territory, referring to an updated cartography, as input. The value of Sc contained in each cell aggregation is compared with its threshold value, depending on whether the aggregation falls in an industrial area or in an area with a different use (Tab.2). Aggregations in which the Sc value is inferior to the relative threshold value are hidden.

3.3.4 *Phase 4: micro-scale analysis*

The cell aggregations resulting from the discretization operated in phase 3 constitute the set of potential functionally disused areas within the municipal territory.
A subsequent refinement of the results can be carried out on a micro-district scale (micro-scale), using an algorithm to identify the aggregations in which buildings whose construction period is before 1970 (Vn ≥ 50 years) fall. The necessary input data is the same polygonal *Shapefile* used in phase 3, in which buildings have been classified according to the age of construction. This data can be obtained by comparing the updated cartography with the municipal historical maps. Regarding residential buildings, Istat provides census data concerning with their conservation status and construction period. Since these data refer to dwellings, they are resampled only on the *not industrial* cells aggregations by using the QGIS *Zonal statistics* algorithm.
The Vn parameter is definitely more uncertain than the others for three main reasons:

- historical maps of periods of interest are not always available;

[16] The census areas constitute the minimum survey unit of the municipal territory. A census area is a homogeneous part of the territory in which the environmental and socio-economic characteristics are similar.

- although the building was built before 1970, it may have undergone restoration works which have improved its conservation status;
- buildings built after 1970 could also be in a poor conservation status.

For these reasons the Vn parameter is not considered as discriminatory. The presence of buildings with Vn ≥ 50 years is indicative of a *higher* probability that the area is currently in a disuse condition.

4. Cases studies – methodology test on the municipalities of Rende (Southern Italy) and Voghera (Northern Italy)

The validation process of the proposed methodology provides for the comparison of output data obtained in the GIS environment with the data collected through appropriate census forms send to the staff of local authorities and filled out by them. The general procedure is described in Fig.5.

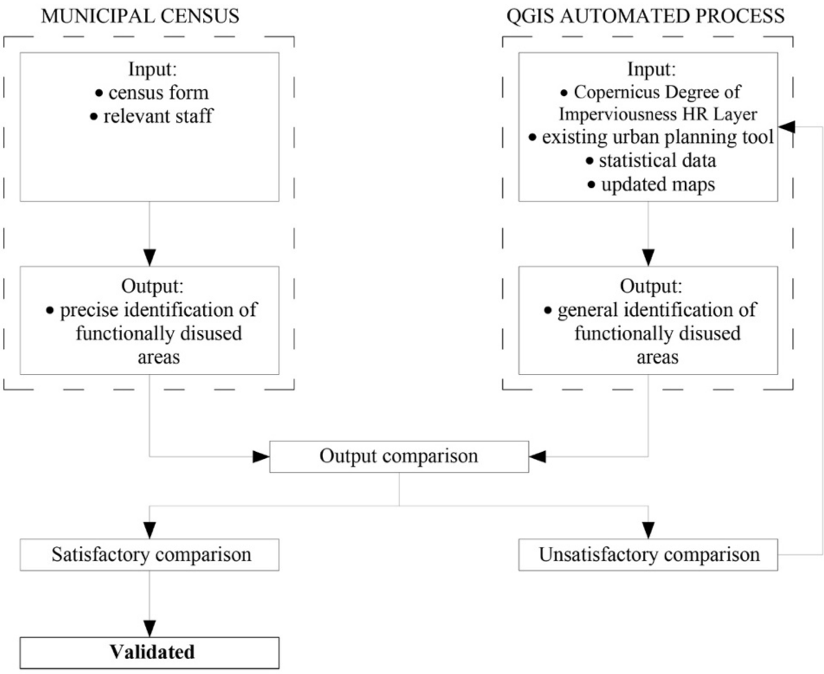

Fig.5 General description of the model validation procedure

Validation has been carried out on two sample municipalities which have been selected according to the criteria that will be described in paragraph 4.1.

4.1 Case studies selection

For the selection of the two municipalities, three criteria were adopted:

1. significance of the comparison;
2. data availability;
3. comparability of the two case studies.

The Italian municipalities of Rende (Calabria, Southern Italy) and Voghera (Lombardy, Northern Italy) (Fig.6) were chosen due to the following reasons:

1. the choice of two case studies, one located in the extreme South and the other in the extreme North of the Italian peninsula makes the comparison particularly relevant, because of the numerous differences and disparities existing between northern and southern Italy[17];

[17] For istance, the strong industrial vocation of Northern Italy, compared with the widespread tendency to abandon small villages or unfinished buildings in Southern Italy, would suggest a preponderance of brownfields in the first case and of greyfields in the second one.

2. in order to validate the methodology results it was necessary to compare them with data obtained by a municipal census. The choice of a Lombard municipality was, in this regard, prompted by the fact that Lombardy is the only Italian region to have carried out a census of the disused areas in its territory[18]. The choice of the municipality of Rende is linked to the authors' possibility to have a direct discussion with municipal technicians;
3. Voghera has been selected among the various Lombard municipalities because: (i) it belongs to the same size class as Rende according to Istat classification[19]; (ii) the municipal censuses have detected a comparable total surface of the functionally disused areas.

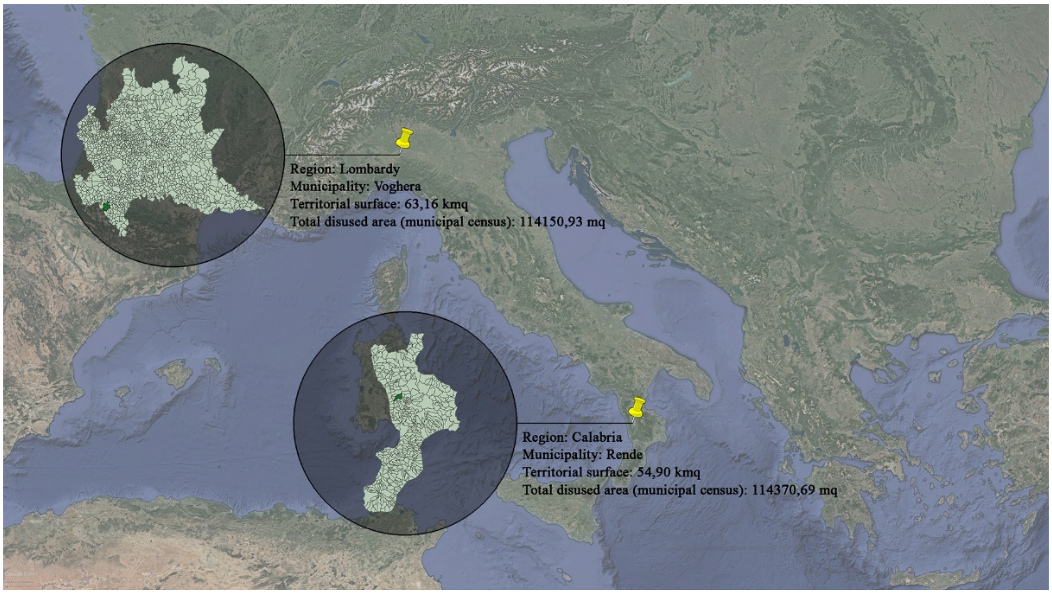

Fig.6 Cases study localization and their main features

4.2 Comparison data retrieval: the municipal census

In order to assess the validity of the experimental results, it is necessary to compare them with those provided by "certified sources". In this study, the output data obtained by the GIS-based automated process are compared with the data acquired following the censuses of functionally disused areas carried out in the two municipalities analysed. Regarding to the municipality of Voghera, the useful information was taken from the website of the Lombardy Region. In Voghera there are nine functionally disused areas, for a total surface area of 114,150.93 m^2. Seven of these sites were characterized by a former industrial use and two of these by a former commercial use.

Regarding the municipality of Rende, the lack of data has been remedied by transmitting the format of a census form of the functionally disused areas to municipal technicians.

The format has been structured by referring to the form that was used by the Lombardy Region and to the indicators proposed by the CABERNET European project for the brownfields classification[20] (CABERNET Network Report, 2006) with particular reference to those relating to the location characteristics (position

[18] The census was carried out between 2008 and 2010. The format of a survey form made by the Region was sent to the various Lombard Provinces, which in turn forwarded the document to all municipalities falling within their jurisdiction. The Lombardy Region makes available the results of the survey on the site: https://www.regione.lombardia.it/wps/portal/istituzionale/HP/DettaglioPubblicazione/servizi-e-informazioni/Enti-e-Operatori/territorio/sistema-informativo-territoriale-sit/aree-dismesse/aree-dismesse.

[19] Istat divides Italian communes into 5 classes, according to their territorial extension. The data from the last census (2011) highlight that communes with a territorial surface between 50 km^2 and 250 km^2 cover more than half of Italian territory (50.7%) (Istat, 2013).

[20] The classification recommended by the European project CABERNET, similar to that used by the United Kingdom National Brownfield Regeneration Strategy, divides brownfields into three categories A-B-C according to their development potential (Doleïelová et al, 2014). Some of the indicators proposed by the CABERNET project have been included in the census form because they will be useful in the second phase of research (under development).

relative to the city center, distance from the highway) and the potential for redevelopment (properties, risk of contamination).

The format is organized as following:

- *Functionally disused area* definition (according to authors)
- *Section 1: area description*
  - location (address)
  - disuse characteristics of the area
  - urban and disuse parameters
- *Section 2: physical feauteres*
  - building typological features
  - building conservation status
- *Section 3: location characteristics*
  - position and accesibility
  - area connectivity
- *Section 4: regeneration potential*
  - urban data
  - cadastral data
  - restrictions

The census forms completed by the municipal technicians initially highlighted the presence of eight functionally disused areas in the territory of Rende.

From the forms received, the territory of Rende was initially found to present eight functionally abandoned areas. Following verification, it was noted that of these areas: (i) one is currently used; (ii) one does not meet the minimum total surface area requirement (S); (iii) two do not meet the minimum covered surface area requirement (Sc); (iv) the remaining four can be classified as functionally disused areas, for a total surface area of 114,370.69 m^2.

Fig. 7 summarizes the relevant data of phase 4.

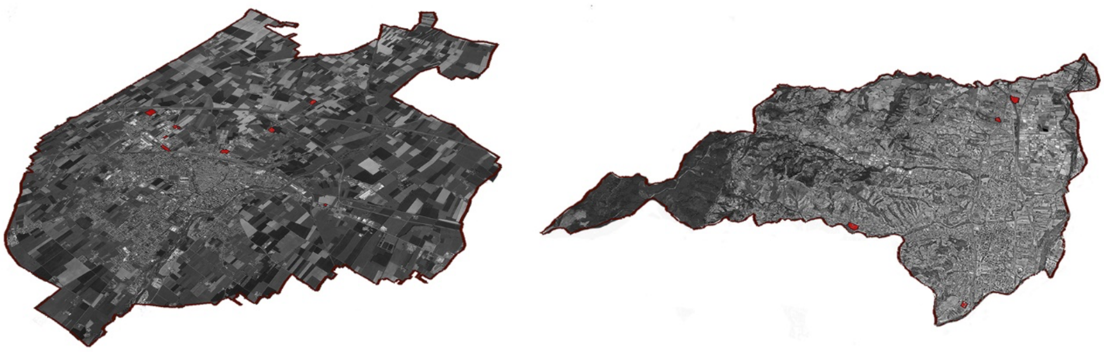

Fig.7 Functionally disused areas location, resulting from the census carried out in the municipalities of Voghera (left) and Rende (right)

4.3 GIS-based automated process results

The proposed methodology was applied on the two sample municipalities. The data collection was a rather simple operation because all data are open source and easily available. The acquisition of Voghera historical maps, necessary for the Vn parameter determination, was the only difficulty encountered. However, it has not been a problem because the Vn parameter is not discriminatory. The figures below illustrate the different GIS-based process phases carried out on the municipality of Voghera (Fig.8) and on the municipality of Rende (Fig.9).

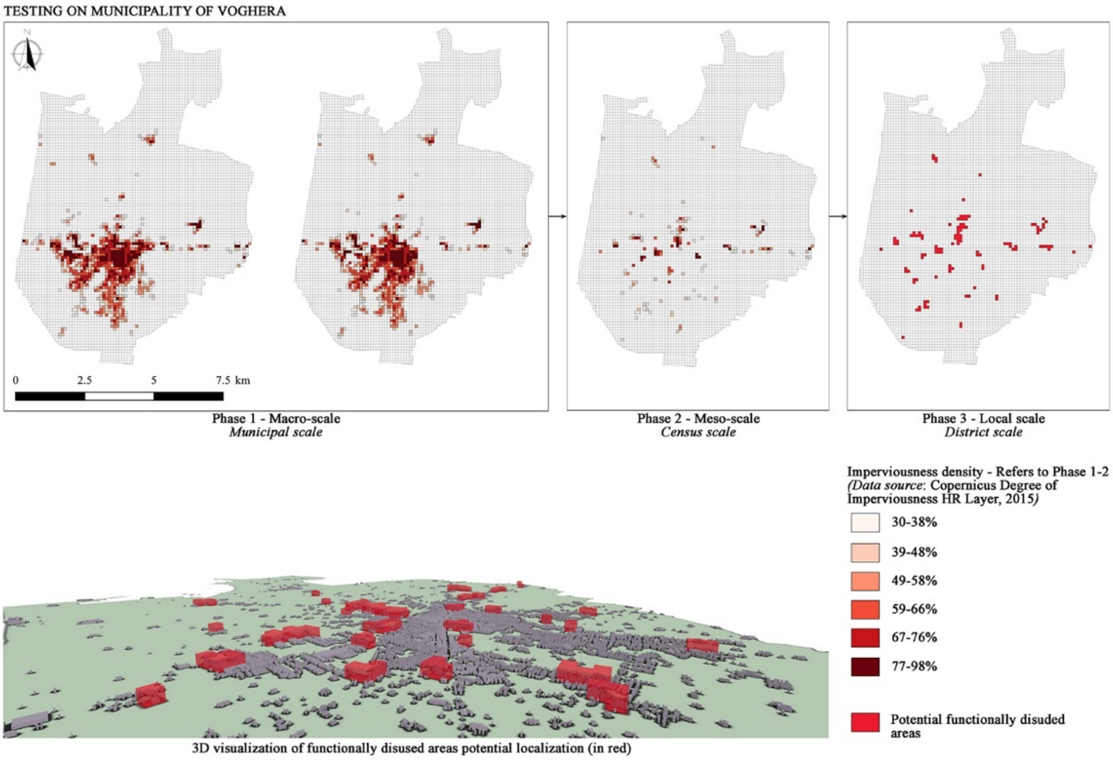

Fig.8 Results in GIS environment regarding the municipality of Voghera

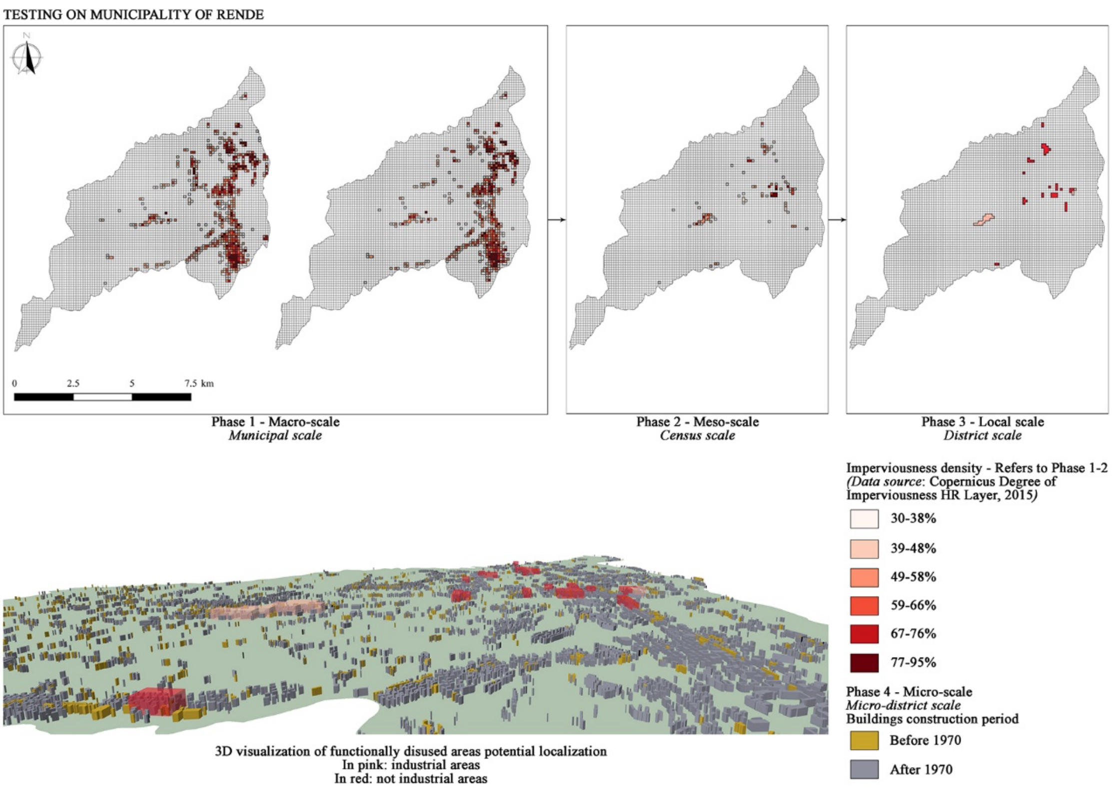

Fig.9 Results in GIS environment regarding the municipality of Rende

4.4 Discussion of the results

The comparison between data obtained from the local census and results obtained from the proposed methodology shows satisfactory similarities in both case studies.

The resulting remarks are similar for the two municipalities.

It is interesting to note firstly that the GIS-based process identifies a total surface of potential functionally disused areas greater than that indicated by local authorities. This aspect reflects expectations, because the aim of the tool is to provide a general localization of the areas, which local technicians have to "refine" using their in-depth knowledge of the territory. Moreover, this result underlines the usefulness of the methodology from two point of view. On one hand, with regards to the municipality of Voghera – in which QGIS process results were compared to disused areas regional census results – it should be considered that traditional local census are complex proceedings that involves various professionals and therefore need rather long technical time to be completed. Consequently, results are not constantly updated, and they often no longer reflect current situation. On the other hand, with regards to the municipality of Rende – in which QGIS process results were compared to data obtained by the filled-out census forms – the result confirmed that often local technicians do not have complete knowledge concerning with disused real estate existing in the municipal territory. An anomaly is recorded in the case study of Voghera: three of the nine areas indicated by the municipality are not detected by the GIS-based process. However, this mismatch is due to a forcing present in the census form, because despite the regional format requiring exclusive consideration of sites in which the covered surface area is greater than the explicit thresholds[21], this parameter is not respected in the three areas concerned[22].

It is necessary to audit the cell aggregations that do not cover the areas indicated by the municipalities. This operation has been performed through in situ surveys in the Municipality of Rende and by visual analysis through the Google Earth software regarding the municipality of Voghera.

Tab. 4 summarizes the results.

	Nr. of detected areas	**Nr. of disused or underused areas[23]**		**Nr. of areas devoid of current or prior disuse features**	**Nr. of areas regarding which no useful data are available (no data)**
		Industrial	**Not industrial**		
Voghera	33	15	10	3	5
Rende	14	4	7	2	1
Total	47	36		5	6
Percentages	100%	76.60%		10.64%	12.76%

Tab.4 GIS-based process results regarding the two case studies

5. Conclusions and future developments

In the context of sustainable densification of European cities, the regeneration of disused urban areas offers an important potential of surfaces to be recaptured (Laprise et al., 2015). The knowledge gap related to the nature and scale of the disused areas in Europe is the cause of the main problems related to the recovery of these sites. This lack is a significant aspect, as knowledge is essential for any regenerative policy (CABERNET Network Report, 2006). Most of the current research focuses on the evaluation and definition of the intervention methods to be implemented in disused areas; a much smaller number of studies investigate how to identify these areas.

21 The Lombardy Region under the census carried out between 2008 and 2010 asked the various municipalities to identify disused areas in which the covered area was greater than 2000 m^2 with regards to industrial areas, and greater than 5000 m^2 with regards to areas with different uses (note that threshold values are more restrictive than those imposed by the GIS-based process).

22 In the census forms, indeed, reference is made to the paved surface area instead of the covered surface area.

23 The column refers both to areas currently affected by disuse or underuse phenomena and to areas that have been affected by these phenomena in the past and have undergone redevelopment (reuse of existing buildings, new construction, etc.) at a later date than the reference data collection period.

The research proposes a general definition of functionally disused areas, resulting from a critical review of the existing literature and based on objective parameters. The main aim is to expand the concept and not to make it coincide (as often happens) with that of brownfields, also including all those sites with a different use than the industrial one that are currently in state of abandonment or underuse in the definition.

The proposed definition is used to develop the described operational methodology. The second aim of the research is indeed to provide an operational tool developed in GIS environment able to support planners during the identification phase of disused areas located in the municipal territory.

Even though verification by competent professionals is necessary, the tool offers them a valuable help by operating a substantial screening of the territory that allows a much more immediate identification of sites potentially affected by disuse phenomena.

The application of the methodological approach on the municipalities of Voghera and of Rende has shown positive results, which can be summarized as follow:

- over 75% of the cell aggregations detected by the GIS-based process actually contain areas that are (or were, at the time of the reference data collection) in disuse conditions. This shows that the methodology allows the data obtained through local census not only to be verified but also to be increased. The proposed automated procedure provides results much faster than standard census, and this allows to update information more frequently. In this way, even the most recently disused areas are detected by the procedure. In addition, particularly interesting is the case of Rende, in whose territory the GIS-based process has allowed the identification of a functionally disused area that had not been reported in the filled-out census forms. This area has larger surface than all the others and enjoys a favourable position, because it is located only a few minutes from the city centre and close to one of the main roads. As mentioned in the previous paragraph, this result underlines methodology usefulness. Through the QGIS process, indeed, a strategic disused site that had not been mentioned by local technicians has been detected;
- almost all the areas indicated by the two censuses are correctly identified by the GIS-based process. The only exceptions are due to the non-updating of data concerning the number of not used buildings (Ev parameter);
- the percentage of areas devoid of current or prior disuse features, which is of just over 10%, is due to the particular conditions of the incorrectly detected sites (for instance, a museum/school complex in the municipality of Voghera which, while respecting all the required parameters, cannot be considered a disused area).

In conclusion, it can be said that the proposed methodology provides results that are useful for the rapid identification of potential functionally disused areas.

This study contributes to the scientific discussion on the definition and identification of disused areas and aims to open new perspectives to be investigated to transform these sites into "smart" urban districts. Pursuing this goal, next research phases will be concerned with identification of indicators useful to assess the "quality" of the detected sites (in order to determine the intervention priority) and with analysis and definition of urban parameters that allow optimization of the energy efficiency of districts to be built in disused areas. These sites could be transformed into mixed-use districts – contributing to the soil consumption reduction – or into mono-use districts where specific "social infrastructures" could be realized, contributing to the urban density reduction. Recent Covid-19 crisis, indeed, questioned the dense urban model and underlined the dematerialization of services happened in the last years (Angiello, 2020), which involved misuse of collective spaces and, therefore, the dissatisfaction of city users needs (Esopi, 2018). The identification of these urban fragilities could represent a new first step in order to develop and to propose methodological and operative innovations for the planning and the management of the urban transformations (Papa, 2018). Research aim,

hence, is to help in the realization of smart, sustainable, and resilient districts, with special attention also to the energy saving issues.
Exploiting the many environmental, social and economic benefits that the recovery of these areas may entail is both our right and a moral duty to our planet.

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Author's profile

Mauro Francini

Full Professor of Urban Engineering at the University of Calabria, his research activities include the study of models, techniques and tools for urban and territorial planning and management. Tel. +39 0984.49.67.66.

Nicole Margiotta

PhD Student at Department of Civil Engineering at University of Calabria. Her research activity is focused on the analysis, study and definition of models and tools for regeneration of distressed urban areas. Tel. +39 0984.49.67.67.

Annunziata Palermo

Associate professor of Urban Engineering at the University of Calabria. She is interested in the strategic planning of integrated territorial systems, sustainable regeneration of "marginal" areas and urban resilience. Tel. +39 0984.49.67.50.

Maria Francesca Viapiana

Associate Professor of Urban Engineering at the University of Calabria. She is interested in urban design and planning with particular attention to the role of sustainability in regeneration processes. Tel. +39 0984.49.67.64.