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Informal Urban Biodiversity in the Milan Metropolitan Area: The Role of Spontaneous Nature in the Leftover Regeneration Process

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Abstract: The present study reflects on spontaneous nature's agency to reclaim abandoned urban areas in Italian urban brownfields, providing a focused analysis of the Metropolitan Area of Milan. These spaces are the products of phenomena, such as deindustrialization, demilitarization, and uncontrolled urban expansion, which have produced a compromised heritage and challenges to regeneration. Such abandonment sometimes produces new forms of urban nature, which suggests a possible path for ecological regeneration and coexistence, as affirmed by the multidisciplinary literature. The related informal urban biodiversity grows regardless of future planning provisions, triggering unexpected transformations of the urban environment and producing socio-ecological value, as demonstrated by citizens' recognition of these places. The present study maps informal urban biodiversity in the Milan territory, identifying the presence of large contaminated sites, relevant urban voids, vacant lots, and former agricultural spaces. This study also reflects on possible paths for urban planning and policies to integrate informal urban biodiversity within the urban ecological structure by analyzing the main features and challenges of the corresponding regeneration processes.

Keywords: informal biodiversity; abandoned areas; spontaneous nature

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1. Introduction

For decades, the city and nature have been conceived as separate systems, establishing a marked dualism between the urban environment and the external environment, which is rural and wild [1,2]. Starting in the 18th century, cities began integrating urban green spaces to satisfy human leisure and needs, producing a subordinated relationship in which anthropogenic actions carefully control natural urban elements. Parks, gardens, and rows of trees represent "domesticated" nature shaped for human needs [3,4]. Today, the benefits related to the presence of nature in cities are well known. These natural spaces impact human health and well-being [5–7] and facilitate the mitigation of and adaptation to external extreme conditions [8,9]. In a changing world, the importance of urban biodiversity led policies and policymakers to integrate programs for the implementation and preservation of such spaces [10,11], with related difficulties in planning for biodiversity in environments traditionally hostile to wild nature, such as cities.

The present research investigates the potential integration of urban planning into ecological urban systems, where nature, far from human control, arises spontaneously, generating what we define in the paper as places of informal urban biodiversity.

Urban studies name these spaces differently [12], referring either to their neglect or nature-hosting capabilities. Generally, these areas are characterized by abandonment and neglect, resulting in what public opinion calls "degraded" spaces [13]. Notably, the related expressions "wasteland" and "brownfield" recall the concept of the brown economy that

produces non-recyclable waste, representing a market failure of the city, as such spaces do not contribute any value or function to the urban system [14]. Indeed, these places usually result from socioeconomic processes, such as deindustrialization and demilitarization or uncontrolled urban expansion, which produce residual spaces [15]. Depending on the related economic interests, regeneration can be a relevant issue in the urban debate, as such spaces represent an "opportunity" for urban development. Nevertheless, administrative authorities struggle to begin regeneration processes due to high costs, bargaining with private investors, and a preference toward areas with high real estate value [16,17]. This condition leaves many areas perennially waiting for their future "valorization", which may never happen. Conversely, areas with low real estate interest are relegated to inevitable abandonment, experiencing only occasional risk management.

In places that have been released from their previous function or were never functional for the urban system, natural activity could act as a resignifier, beginning an ecological succession that could yield precious biodiverse areas [18,19]. The resulting "urban woodlands" or "novel ecosystems" constitute informal urban biodiversity that could be recognized and integrated into the urban green system due to its ecological contribution [20,21]. Investigating the spontaneous urban natural system is at the core of relevant research in ecological studies [22,23] and social studies [24,25], with potential for the urban planning discipline. Within the context of ecosystem functions, several studies revealed the benefits of such spaces for the urban environment [26,27], as well as the possible threats that should be managed and addressed [28]. However, public administration plans often do not consider this unintentional [29] urban condition and refer to these sites as potential areas for valorization or further abandonment.

In addition to scientifically demonstrating the invisible functions of these areas, citizen recognition could play a crucial role in reclaiming these spaces. Existing practices affirm how these spaces could induce a new sense of reappropriation by the population, creating a common space of coexistence between humans and non-humans [30,31].

Aside from the different characteristics related to economic interests or location, the literature confirms that urban leftovers could represent a resource for biodiversity in cities, setting the challenge of how to integrate and manage this element through public policies and plans [20,32,33]. The present research focuses on the presence of urban leftovers and their potential for urban biodiversity integration in an Italian context. In Italy, the extent of urban abandonment is unknown, making it difficult to investigate the possible trajectories and coherence of proposed policies [34]. Like other contemporary cities, Italian cities present several conditions of abandonment, including large contaminated sites [35], relevant urban voids [36], and vacant lots or residual spaces [37].

Previous studies carried out on Italian cities [38,39] underlined the presence of relevant urban spontaneous woodlands and their socio-ecological trajectories that sometimes lead public administrations to recognize such spaces as ecological hubs. Analyzing these interesting experiences and the related policies allows us to investigate a new ecological approach to regenerating leftover spaces.

The current study proposes an analysis of and a reflection on a selected territory, namely the Metropolitan Area of Milan, to explore the potential of natural succession as a regenerator and possible policies to implement the integration and management of this phenomenon.

1.1. Leftovers of Italian Cities: An Opportunity for Urban Informal Biodiversity

The lack of knowledge about the urban abandonment phenomenon in Italy hinders the fostering of related policies for the regeneration and reintegration of such spaces within the urban system [34]. The only available data, presented in a Draft Legislation (Disegno di Legge) proposed by the Association of Italian Municipalities (ANCI, Associazione Nazionale Comuni Italiani), refer to the presence in of 9.000 km^2 of abandoned industrial sites in 2012, covering 3% of the national land surface [40]. These data provided by the

National Statistical Institute (ISTAT, Istituto Nazionale di Statistica) underscore the urgent need to understand this phenomenon

One of the main issues related to abandonment in urban systems is the deindustrialization process, which transformed cities, beginning in the 1980s. This process left behind related industrial and logistic settlements [41], creating challenges for their regeneration [42]. This process occurred most noticeably in traditional Fordist cities, such as Turin and Milan, where entire neighborhoods were designed over the sediments of former factories, such as the Michelin (in Turin) and Pirelli (in Milan) settlements. As the deindustrialization process began four decades ago, this category includes, among others, historical buildings with an industrial archaeological heritage. Industrial disposal refers to the abandonment not only of large factories but also of smaller areas, such as warehouses [43] and logistics centers.

Another relevant category of abandonment relates to military structures, which lost their function following demilitarization, which abolished mandatory military service in 2000. Regeneration of the remaining dismantled structures became the issue of several policies intending to restore public value through privatization. The complexity of the bureaucratic system and the extent of these areas resulted in only partial regeneration and many ongoing processes [44].

In addition to the more consistent areas of decommissioning, cities also contain smaller patches whose functions are not defined and remain neglected due to uncontrolled urban expansion. This category includes "vacant lots", i.e., non-managed sites located in urban and peri-urban contexts [45].

Lastly, cities located in an agricultural context face the phenomenon of agricultural abandonment [46]. These two last categories are strictly related to the spontaneous passive rewilding phenomena as they are usually composed of open and unbuilt spaces, leaving open the possibility for nature to begin ecological succession, which should be carefully managed [47].

Mapping the multitude of these spaces is a significant steppingstone in understanding the phenomenon's magnitude and proposing coherent policies for spontaneous rewilding management. Establishing a collective database is necessary to analyze the trajectories of natural succession that occur in urban contexts free from anthropogenic control. This measure involves drawing from heterogeneous sources, such as existing databases indicating land use, decommissioning and contamination, development plans, and citizen science as an urbex activity [48]. The heterogeneity of these sources reflects the differences in ecological successional spaces. Formerly functional areas, such as industrial and military spaces, are sometimes collected in procedural databases, while residual spaces and agricultural remnants are more challenging to identify.

The present research mapped these spaces in a selected area while considering some essential elements to capture their regeneration processes. We first used a database with spaces of existing and potential spontaneous rewilding processes in the Milan Metropolitan Area. Then, we selected some specific sites to investigate and improve their development processes.

1.2. Investigating Regeneration and Informal Biodiversity in Urban Contexts

Analysis of the available literature [47,49–53] and relevant case studies [38,39,54–58] enabled us to define the most relevant elements to be considered when exploring informal biodiversity in leftover urban areas and the corresponding transformations. The development of urban leftovers is strictly connected with real estate interest, which is a relevant driver of urban development and regeneration. Developers usually do not consider the ecological significance when these processes involve areas featuring informal biodiversity.

The main characteristics influencing these processes are as follows:

- The dimension;
- The location;
- The property;
- The presence of contamination;

- The presence of social conflict between citizens and administrations or private owners in the area's transformation.

1.2.1. The Dimension

Considering real estate value, sites with large dimensions are often subject to urban development projects due to the possibility of establishing multi-functional areas. Generally, the transformation of these large areas is subject to public opinion, while land-use competition decreases when referring to more contained areas.

At the same time, the dimensional element is crucial for the juridical recognition of the informal nature established in these spaces. The Italian Law for Landscape and Cultural Heritage (Codice dei Beni Culturali e del Paesaggio, D.lgs. 42/2004) places juridical constraints on the woodland system, preserving it from uncontrolled transformation, which is allowed only through specific authorization. As a guiding principle, the Law Decree for Forestry and Forest Chain (Testo unico in materia forestale e filiere forestali, D.Lgs. n. 34/2018) defines the main characteristics of "woodland", requiring a minimum dimension of 2000 square meters, a minimum width of 20 m, and a minimum canopy cover of 20%. The juridical definition of a woodland enables administrations to formally recognize and manage novel ecological systems [47].

1.2.2. The Location

Position is another relevant element because of its ability to impact real estate value and the resulting interest in urban development. Positional distinctions can be made at the national level based on the different trends between major and minor cities. The cities with higher indexes in Italy are Milan, Rome, Turin, Bologna, and Bari [50]. Consequently, leftovers in these cities have a greater possibility to experience urban development interest than those in less-attractive cities. Moreover, within the urban system, market values can vary based on differences between the central and peripheral areas, as well as other site characteristics that can influence interest [59].

1.2.3. The Property

The type of property involved strongly influences the future of spontaneously rewilded areas in development projects. As informal biodiversity grows regardless of zoning constraints and boundaries, ecological successional activity can occur in both public and private areas.

Private properties tend to maximize profits and transform their land according to market logic, as seen in the cases of former industries and private lots. Public property developments can seek public interest according to the logic of the commons, transforming these sites for public utility. However, due to the financial and economic pressures in Italy, public authorities have acted according to market logic in recent decades, selling public assets for economic returns [60]. This situation has been particularly notable in military areas, such as Bologna and Milan [56], where the real estate market strongly influences public ownership.

1.2.4. The Presence of Contamination

Soil and groundwater pollution is a recurrent problem affecting leftover areas caused by past anthropogenic activities, mainly by former industries. In Italy, according to the Environmental Protection National Agency Data (ISPRA; Istituto Nazionale per la Protezione Ambientale), more than 16,000 sites are undergoing remediation processes or environmental analysis, with the maximum concentrations located in the Lombardy, Campania, and Tuscany regions. The inaccessibility of conditions related to contamination and the delay of remediation for economic reasons represent a growth driver for nature. In this sense, it is relevant to note the presence of more than 450 "orphan sites" whose culpability in contamination remains unidentified or wanting [61]. The inaccessibility condition related

to contamination represents a growth driver for nature, as attested by the spontaneous woodland raised in some relevant contaminated sites [62,63].

A direct consequence of contamination related to remediation intervention in the regeneration process is increased costs. This condition impacts economic affordability for administrations and private owners, resulting in perennial abandonment of the site or maximizing the developing indexes to cover remediation costs [49].

1.2.5. The Social Conflict

The fifth element to consider is related to the social conflict that could arise to protect the ecological value of sites that administrators and owners consider development areas. Citizen associations have a crucial influence on the political debate over urban transformation. Indeed, the sense of appropriation led by groups of people could represent the first step in recognizing the ecological potential of such systems under dismantlement risk [54,55]. The level of conflict is usually related to economic interests and may or may not end in negotiation processes.

This process is reflected in the history of Berlin's "Stadtbrachen", which refers to leftovers produced by the WWII disruption that created an informal green infrastructure recognized by the citizens who found a locus of expression in that space [51,52]. Starting in the 1950s, the specificity of the natural species settled in these areas attracted the interest of urban botanists, who created new common knowledge related to urban ecology and were able to influence political interventions to preserve these species [53]. The most famous example of this ecological knowledge production is the Südgelände Nature Park, a former railyard area where a spontaneous 18 ha woodland was raised after decades of abandonment. The ecological awareness of citizens and scientists protected this area from urban development, leading to a nature park being established in 2000 [57].

2. Materials and Methods

2.1. Study Site: The Metropolitan Area of Milan

Our analysis was conducted in the Milan Metropolitan region. The area of interest is located in the Lombardy Region in the northern part of Italy, covering a surface of 1575 km^2 organized into 133 different municipalities. The Milan Metropolitan region is Europe's sixth most populated urban area, with 4.3 million citizens (Eurostat, 2023). The central city is Milan, which contains a population of 1.3 million people (ISTAT, 2023) and is the region's main economic center, with daily commuters from the whole hinterland area. Because of its socioeconomic interdependency, the distinction between central and peripheral and urban and non-urban areas is narrowed, allowing the area to be defined as a post-metropolis [64].

According to data in the ISPRA [65] report, the Milanese territory is one of the Italian metropolitan regions with the highest percentage of soil consumption due to the proliferation of economic activities. In particular, the northern area of Milan is characterized by compact urbanization.

Because of its industrial past, the area presents a massive decommissioning phenomenon related to contamination. According to data from the Regional Environmental Agency (Agenzia Regionale per la Protezione Ambientale, ARPA), 5000 sites are undergoing a remediation process in the area of interest. Almost 500 sites (i.e., more than 750 hectares) are officially categorized as "contaminated" (AGISCO data, 2023).

Due to the relevance of abandonment and urban expansion, this region is an interesting case study for investigating the presence of informal biodiversity in an urban context. Starting from a mapping activity, we developed the first state-of-the-art analysis of this phenomenon, which intersects different domains of information.

2.2. Data Collection

The analysis was conducted by collecting data from existing databases indicating spontaneous woodlands or possible future ecological succession growth.

The first part of the analysis involved constructing a mixed database of land use indicating the presence of recent woodlands and wild systems, which was then combined with databases indicating procedural abandonment.

The principal investigated data were as follows:

- The Regional Land-Use Cover Database (Destinazione d'Uso dei Suoli Agricoli e Forestali (DUSAF)), which was updated in 2021. This regional database is provided by the Regional Agency for Agriculture and Forestry Services (ERSAF, Ente Regionale per Servizi a Agricoltura).

Other data accessed to apply the comparison were as follows:

- The Regional Dismissed Area Database, provided by the Mapping and Urban Data Laboratory (MaudLab) from Politecnico di Milano University, which was updated in 2022.
- The Regional Database of Contaminated Sites (AGISCO, Anagrafe e Gestione Integrata dei Siti Contaminati), provided by the Regional Environmental Agency (ARPA Lombardia) and updated in 2023.
- Orthophoto images updated in 1954, 1975, 1998, 2003, 2007, 2012, 2015, 2018–2019, and 2021, provided by the Regional Geoportal. These images were used to visualize vegetation growth and the transformation of the areas.
- The Metropolitan Forestry Plan (PIF, Piano d'Indirizzo Forestale), updated in 2016 by the Città Metropolitana di Milano Authority.
- Local development plans from the Piano di Governo del Territorio (PGT). The PGT Development Plan was introduced in the Lombardy Region by Regional Law n. 12 in 2005.

We also considered data from the gray literature, such as local newspapers, blogs, and social networks. These data were mainly used to investigate the social involvement in processes related to spontaneously rewilded urban leftovers, indicating the presence of social conflict.

2.3. Data Analysis

This section explains the methodology used to process the available data, as shown in Figure 1. The first operation was applied to the Land-use Database (DUSAF) to select spaces where natural succession could occur.

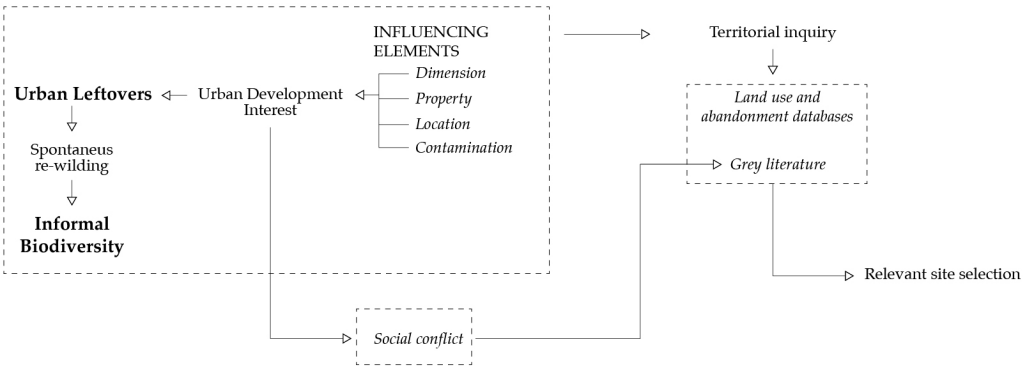

Figure 1. Relevant elements of urban biodiversity of leftovers and territorial analysis methodology.

We selected the following three primary levels from the DUSAF databases:

- The level of "Uncultivated green areas" (code 1412, DUSAF 2021) includes spaces within the urban context that are not considered agricultural or are experiencing transformation. This level collects areas with different characteristics that are generally traceable as leftovers, such as early-stage spontaneous woodlands and residual spaces where cuttings and management occur. However, this level sometimes includes managed green spaces, such as green private condominiums.

- The level of "Degraded and underutilized areas with no function or vegetation" (code 134, DUSAF 2021) includes degraded sites and areas experiencing transformation processes. This level collects such degraded spaces as abandoned factories, blocked construction sites where pioneer species grow, and underutilized paved areas where spontaneous vegetation arises.
- The comparison between the levels of "Anthropized areas" (the elements of code level 1) and "Agricultural areas" (the elements of code level 2) uses the DUSAF from 1999 and 2007, and the levels considered as "Wooded and seminatural areas" (the elements of code level 3) were taken from the DUSAF 2021. This comparison was carried out using the "Intersection" QGis tool to identify recently grown woodlands (a 3.1 level of the DUSAF) and semi-natural areas (3.2 level, DUSAF). The operation result was then modified by selecting areas following the Regional Law on Forestry (Testo Unico in materia di foreste e filiere forestali, d.lgs. n. 34/2018) for sites with a total area > 2.000 m^2 and a median width > 25 m.

To exclude new wooded areas with certain anthropogenic origins, we erased those considered "Green service and forestry interventions" from the PIF, which indicates recent woodlands planted through project interventions. This level collects several conditions: spontaneous woodlands with different dimensions and locations and former agricultural land undergoing rewilding. This level also includes some areas whose rewilding was the focus of restoration projects, such as systems of former quarries that were transformed into protected natural areas. Therefore, this level also considers intentionally restored and rewilded areas.

Thus, the initial stage of the study defined a vast database to explore spontaneous natural succession. The heterogeneity of the collected data is notable, as shown in Table 1. The categories of "Uncultivated green areas" and "Degraded areas" mainly contain areas whose lack of maintenance engendered recent processes of spontaneous ecological succession and areas where this process could potentially start. The "Recent spontaneous woodland and semi-natural systems" category includes spontaneous rewilded areas whose revegetation processes are more developed, as well as intentionally restored areas resulting from focused recovery projects. This heterogeneity underscores the importance of not considering the resulting data as spontaneous woodlands but instead as a preliminary database to investigate the relevant phenomena.

After collecting the data, we further analyzed the site characteristics to more deeply analyze significant sites.

First, we calculated the dimension using the QGis "area calculation" tool.

Then, we engaged in data framing of the location by intersecting the database with a buffer of 50 mt from the "urban tissue" shapefile provided by the Prevision Plans of the PGTs, available from the Regional Geoportal. In this way, we identified areas embedded in and surrounding the urban tissue.

The third operation concerned the intersection of the calculated database with available data on dismission and contamination, combining the resulting database with the Regional Dismission Areas Database and AGISCO to better understand the sites' characteristics.

Simultaneously, we conducted research based on the existing scientific literature and the gray literature regarding contested informal biodiverse spaces. The indication we used to assess this information mainly included the presence of local committees and public petitions to preserve spontaneous rewilding.

Based on these results, we conducted the analysis by identifying paradigmatic sites with different characteristics to deepen the discourse on specific areas and investigate how and if informal biodiversity is considered in the development discussion. We investigated the relative urban development plans (PGTs), the actors involved as owners and developers, and information from the gray literature (newspapers and social networks) to assess the role of informal biodiversity in the relevant regeneration processes.

Table 1. DUSAF categories. Sources: Google Satellite 2023, Google Street View 2023, 2021.

Data	Typology		
Uncultivated green areas (code 1412)			
			
	Early-stage spontaneous woodlands	Occasionally cut leftovers	Private green spaces (Managed and unmanaged)
Degraded and underutilized areas with no function or vegetation (code 134)			
			
	Abandoned factories	Paved underutilized areas	Blocked construction sites
Recent spontaneous forest and seminatural systems (code 1,2/1999–2007—code 3.1,3.2/2021)			
			
	Interstitial spontaneous woodland	Relevant spontaneous woodland	Rewilded former agricultural sites
			
	Restored former quarries		

3. Results

3.1. Land-Use Analysis Results

Figures 2 and 3 show the spatialization of the processed data listed in Table 2 in the Metropolitan Area of Milan. More detailed data are reported in the Supplementary Materials File S2.

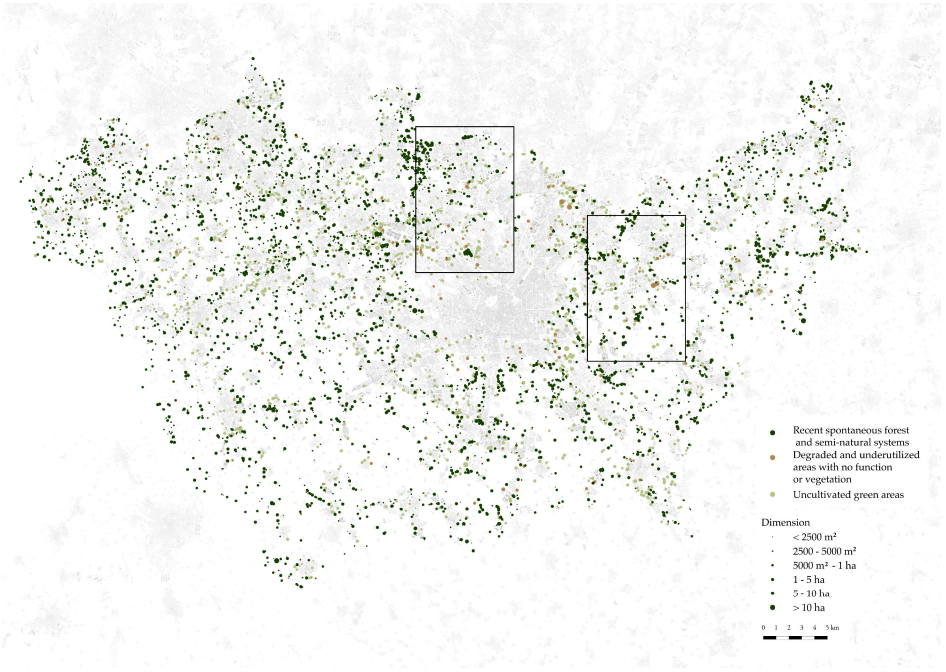

Figure 2. Detailed representation of uncultivated areas, degraded areas, and recent forest and semi-natural land of zoomed areas underlined in Figure 3.

Figure 3. Location of uncultivated areas, degraded areas, and recent forest and semi-natural land.

Table 2. Recent forest and semi-natural, uncultivated, and degraded areas in the study area.

Recent Woodlands and Semi-Natural Areas	Uncultivated Green Areas	Degraded and Underutilized Areas
3476 ha	1980 ha	326 ha

The analysis reported a 3.476 ha extension of recent forest and semi-natural systems whose original land use was mainly agricultural. Among the rewilded areas, 2.501 total hectares resulted from agricultural abandonment, while 975 hectares were originally considered anthropogenic areas. Looking at the time span, a large increase in the growth of new natural systems occurred during the last analyzed period from 2007 to 2021. From 1999 to 2007, 359 ha was rewilded, while from 2007 to 2021, the amount was 3117 ha.

Notably, the map does not only indicate spontaneous rewilding processes, as some of the shown areas could have been rewilded for intentional purposes even if such processes were not recorded in the PIF. Even if we erased the rewilded areas resulting from funded forestry projects as indicated in the PIF (Funded new woodlands and green systems, art.42, comma 1b, L.R. n. 31/08), the data could also include intentional rewilding. For example, some former quarries underwent processes of recovery after their disposal according to the Metropolitan Management Plan of the Quarries (Piano Cave), and some areas were restored by the WWF [66,67].

The uncultivated areas occupied 1980 ha, while the degraded areas encompassed 326 ha, showing the relevant presence of areas with potential for spontaneous rewilding.

The data show that most sites have dimensions from 2.500 m^2 to 5 ha, including former agricultural sites located next to woodland systems, former quarries, and industrial areas whose dimensions are relevant.

More than 51% of the recent forest and semi-natural areas are located in urban and peri-urban contexts according to our method, with a higher percentage among uncultivated and degraded areas (92% and 86%, respectively).

The data show that 125 sites are undergoing remediation proceedings for contamination. Among these sites, 43% present pollution due to industrial activities, 20% due to waste deposits, 12% due to the accidental release of pollutants, and 20% for unspecified reasons.

The comparison between the resulting database and the shapefile for regional dismissed areas showed the presence of vegetation in 226 dismissed sites out of a total of 1129. This result strengthens and reinforces the evidence that the phenomena of spontaneous rewilding affect areas officially recognized as "abandoned", occurring in one out of five of these sites. Among these dismissed sites, 44% are the result of productive activity, 22% are vacant lots, and 15% are the products of agriculture. The remainder resulted from infrastructure and other former use cases. This is a relevant data point for those municipalities that have abandoned sites on their premises, and during potential regeneration process there is a need to deal not only with abandoned areas but also with an ongoing rewilding process.

The present analysis revealed how particular areas experienced significant ecological succession processes, such as the ex-Falck factories in Sesto San Giovanni, ex-Italgas area in Bovisa, ex-SISAS area in Pioltello–Rodano, and ex-SNIA in Varedo–Paderno Dugnano. The relevance of these woodland systems is recorded in the Forestry Plan (PIF), which identifies a portion of them in ex-SISAS and ex-SNIA areas. The inclusion of these data enabled us to comprehensively represent the rewilding phenomena in former productive areas. In contrast, other rewilding processes were represented only through the land-use analysis.

3.2. Social Conflict

The inquiry over social involvement that emerged from spontaneous vegetation in the Milan Metropolitan area highlighted the most well-known experiences in the central city of Milan. The most complex and enduring situations were identified in the former military area of Piazza d'Armi and the former Italgas factory known as "La Goccia", where

local committees and associations helped preserve spontaneous relevant ecological hubs grown over abandoned sites, influencing the regeneration processes that were threatening informal biodiversity [68,69]. Another interesting case in Milan is the Parco POP, a former community-cultivated area [70]. All of these cases represented a community contesting the transformation of the area and intercepting the administration's intentions with open negotiation processes to preserve the region.

Apart from the Milan municipality, the present research revealed the presence of two open conflicts related to the "Bosco Urbano Spontaneo di San Donato" [71], a spontaneous woodland threatened by new construction, and Cava Gabbana, a former spontaneously rewilded quarry that will be subject to soil transformation, even if its final form is an urban park [72].

Other conflicts regarding the development of leftover spaces hosting informal biodiversity have been observed in a more general perspective related to the presence of grassroots movements advocating for city development and environmental issues related to remediation and regeneration interventions.

3.3. Selected Areas

The analysis revealed many areas with different regeneration or abandonment trajectories. We selected 20 cases, ensuring a variety of typologies and parameters, showed in Table 3 and in the Supplementary Materials File S1. We considered sites with different dimensions, located both in Milan and in the hinterland municipalities, while also considering both urban and peri-urban contexts and the presence of contamination and social conflict.

These parameters allowed us to divide the cases into three main typologies:

- Urban voids, relevant areas whose dimensions or strategic locations usually lead administrations to discuss their development.

These sites are characterized by real estate discussions or plans that last many years (particularly in the case of Milan), primarily previsions for new settlements and plans for developments. Among the analyzed cases, cases 1 and 2 were ultimately selected to become urban parks, while the end goal remained open in the other cases, sometimes generating conflict (cases 4, 5).

- Contaminated sites, whose redevelopment costs increase because of remediation, relegating them to further abandonment or dense transformation projects.

These sites differ in several features. Some of them have similar characteristics to the urban voids, as testified by local newspapers, which consistently discuss the related development and environmental threats (7, 8, 9). Due to the economic implications of remediation, most of these areas are planned, tentatively or concretely, to become residential or commercial areas.

- Vacant lots, small leftovers whose economic interest varies according to location.

These sites feature a more variegated typology, as their common factor is their contained dimension and more peripherical location, which could create conflicts over their transformation (16, 18, 20). However, for the majority of sites, these processes lasted for several years, and their impact on public opinion was not relevant.

Table 3. Analysis of selected sites: urban voids, contaminated sites, and vacant lots.

Urban Voids											
Name and former use	**Location**	**Area**	**Property**	**Planning prevision**	**Social Conflict**	**Name and former use**	**Location**	**Area**	**Property**	**Planning prevision**	**Social Conflict**
1. Linen factory	Cassano d'Addaperi-urban	5 ha	Private	Park	No	**4.** Military area Piazza d'Armi	Milan, urban	33 ha	Public	Residential and park	Yes
2. Scalo San Cristoforo railway yard	Milan, urban	11 ha	Public	Park	Yes	**5.** Ex Cava Lucchini quarry	Milan, urban	12 ha	Private	Residential and park	Yes
3. Former construction site	Melzo, urban	5 ha	Public	Residential and Park	No						
Contaminated sites											
6. Former sporting ground (Clug Cristina)	Pero, Peri-urban	4 ha	Private	Commercial and Service	No	**9.** Gas production Ex Italgas, La Goccia	Milan, urban	40 ha	Public	Services and urban forest	Yes
7. Ex SISAS factory	Pioltello-Rodano, peri-urban	38 ha	Private-Public	Industrial	Yes	**10.** Ex Raffineria factory	Cologno Monzese, Peri-urban	3 ha	Private	Residential and Park	No
8. EX SNIA factory	Paderno Dugnano, urban	30 ha (partial)	Private	Urban Park (partial)	Yes						
Vacant lots											
11. Vacant lot	Basiglio, Peri-urban	6 ha	-	Residences and park	No	**16.** Bosco spontaneo di S.D. factory	SanDonato Milanese, urban	5 ha	Private	Commercial	Yes
12. Former construction site	Rozzano, peri-urban	4 ha	Public	Services	No	**17.** Former agricultural	Magnago, Peri-urban	1 ha	Private	Agricultural	No
13. Former agricultural area	Cologno Monzese, Peri-urban	3 ha	Private	Residential and park	No	**18.** Parco POP, community garden	Milano, urban	6 ha	Public	Urban park	Yes
14. Former construction site	Milano, urban	1 ha	Public	Urban park	No	**19.** Former Quarry Cava Gabbana Lake	Vimodrone, Peri-urban	7 ha (lake)	Private	Urban park	Yes
15. Former factory	Legnano, urban	1 ha	Private	Commercial park	No	**20.** Former Factory Fonderie Stefanoni	Castano Primo, peri-urban	2 ha	Private	Residential and park;	No

4. Discussion

The present results revealed the heterogeneous presence of successional processes in the area of investigation.

We focused on sites located in urban and peri-urban contexts, which resulted in half of the sites showing the growing presence of rewilding close to the urban tissue. However, agricultural abandonment was found to be a consistent driver of ecological succession, with peculiar characteristics and management demands [73]. In this context, the restoration of protected WWF-managed natural oases [66,67] and former quarries [74] also revealed the presence of virtuous practices in managing abandonment outside of the urban context, resulting in dense biodiverse protected sites.

Our focus on an urban territory showed a more heterogeneous context composed of spontaneous woodlands and degraded areas in different stages, which could be subject to natural succession. An interesting aspect is represented by the context and the dimensions of these sites. These areas can be seen as interruptions within the dense urban fabric and de facto informally contributing to the ecological connectivity of the region and serving as a habitat for urban biodiversity, as studies implemented in other areas testify [19,20,26]. However, particularly in those areas located in the urban system and in the presence of consistent vegetation, the land use frequently remains unchanged, as the analysis conducted on the 20 selected sites revealed. This is a relevant aspect to be further investigated, eventually by considering the opportunity to include these areas in a permanent vegetation layer to be preserved, managed, and protected.

Another aspect of relevance is the recognition and spatialization of these spaces. The development of this database integrating multiple data sources can spur the interest of scientists that can measure the urban biodiversity defined in this study as "informal". These natural spaces in cities revealed the presence of relevant areas whose ecological functionality and biodiversity are unknown. Proper studies on their biodiversity functionality could endorse their strategic importance in the Milanese urban ecological system. This analysis could represent a relevant step towards formally recognizing this type of nature and assessing its implications in territories related to both socio-ecological benefits and costs [26,28]. In this sense, the literature highlights the importance of addressing the management of natural successional processes, particularly to support the coexistence of new species and existing nature. When handling biodiversity, the urban planning discipline needs to operate using the most multi- and inter-disciplinary approach to correctly address its management, drawing from the contributions of different fields. In this sense, the contribution aims to draw up a basis framework for further discussion and analysis with other field experts.

The study proposed a recognition of the phenomena on a specific territory, analyzing data regarding land use and contributing to creating a common database. Due to the impossibility of validating all the resulting sites, we focused on analyzing specific cases. Given the amount of processed and available data, it remains difficult to understand some elements, such as the properties and presence of social implications, such as open conflicts, whose analysis could be better conducted in specific areas and with proper research focus. Moreover, the data composition could influence information regarding dimensionality, as composed geometries sometimes characterize the data of recent woodland and semi-natural areas, resulting in possible invalidation of these data.

However, the analysis of selected cases allows us to comprehend the regeneration path these spaces could undergo and the consideration of informal biodiversity in these processes.

4.1. The Role of Informal Biodiversity in the Regeneration Processes

The analysis and observation of the main contents on the debate generated by the regeneration processes in the selected areas demonstrated the lack of consideration of spontaneous ecological succession processes in the discussion. These sites are indeed often seen merely as a leftover, and future provision and (when available) projects do not entail the preservation or management of spontaneous nature. Even if these areas are characterized by relevant spontaneous rewilding processes, their presence and importance

is enhanced only in some cases by citizens' demands. For example, the regeneration trajectories in cases 4, 9, and 18 were influenced by citizen associations and committees seeking to preserve spontaneous biodiversity. The role of citizens in these experiences is, therefore, crucial to formalize the ecological contributions of these spaces, which cannot be considered merely "transformation areas". Cases 16 and 19 represent interesting open conflicts that treat informal biodiversity as the main feature of the discussion. The other instances reclaimed by citizens are more closely related to general discussions on urban transformations, rights to the city, and environmental threats that contamination could induce (2, 5, 7, 8).

Among the over twenty analyzed cases of novel ecologies located in urban and peri-urban contexts, eleven are intended for future urbanization, four are intended for future parks, three have been defined as future parks after citizens' protests and engagement, two are currently being protested by citizens, and one is considered an agricultural area. While relevant urban voids and contaminated sites are more likely to be transformed into multi-functional areas, vacant lots and residual spaces are more often considered for future green areas, depending on their strategic locations. However, even when the areas are apt for future green provision, the preservation of spontaneous nature is not a foregone conclusion. For example, in cases 1 and 8, transformations into urban parks will be followed by the replacement of existing biodiversity.

Relevant data were confirmed by the length of the corresponding regeneration procedures (see the Supplementary Materials), as demonstrated by data regarding the abandonment time and data provided by the urban development plans (PGT), when available. Regeneration processes could last decades, particularly for urban voids and contaminated sites, resulting in further abandonment.

This planning approach, except for the particular and virtuous cases mentioned above, reinforces the widespread conceiving of these spaces as "wastelands" and "opportunities" for future valorization without considering their existing ecological value.

4.2. Urban Planning Perspectives

Considering the territory and bibliographic research inquiry, the following section provides some possible paths for urban planning to recognize and manage spontaneous urban biodiversity. These elements are represented by different forms of planning and design tools working synergically at different scales.

- Legal recognition.

The juridical protection of novel ecologies is critical to preserve the ecological value they informally represent from further urbanization. This measure inevitably requires inter-disciplinary analysis to recognize the contribution and importance of such ecologies to the urban system and ensure their protection. The ecological formalization of informal biodiversity can lead to other forms of coexistence between humans and non-humans by shifting the utilitarian view of nature as merely a resource [75]. Protected urban wild systems differ from traditional urban green spaces and require a cultural shift among the administrations and citizens in living and accessing these spaces differently from traditional urban parks [76]. The legal formalization of informal biodiversity is a crucial step in protecting this aspect of nature from further urbanization and testifies to the power and potential of nature in reclaiming abandoned spaces.

- Local and territorial environmental management plans.

Local and territorial environmental plans could support the management of these spaces by boosting their wilderness features as a potential driver for the growth of biodiversity. The application of softer management approaches, such as avoiding radical cuttings, could favor the onset and growth of novel ecologies. This lighter management style could affect citizens' perceptions of these spaces, thereby reducing feelings of degradation. The approach could integrate private and public areas, whose management could be planned according to the specific needs resulting from the site's characteristics.

However, it is also necessary to consider the wider territorial ecological succession phenomenon in non-urban areas. Implementing management plans at the metropolitan level could support the comprehensive acknowledgement of this phenomenon [47]. At a wider scale, the spontaneous development of woodland systems could be integrated into existing management tools, such as forestry plans, to simultaneously address the management, restoration, and development of new forestry projects [77].

- Citizen–administration–municipality agreements.

As attested by the existence of several urban conflicts to preserve nature, citizens can act as recognizers and signifiers of spontaneous natural urban systems. This function can sometimes result in informal actions of care towards these spaces, as shown by the Berlin experience [52], which led some municipalities to apply planning tools to formalize green space management with citizens [78]. The urban devices to manage community gardens and orchards also represent potential applications in informal practices [79] as wild, spontaneous urban systems.

- Integrated project.

Regeneration projects for unfunctional spaces usually use an approach that involves designing on a white sheet, i.e., considering the territory of intervention as a homogeneous space to be redrawn from scratch. In particular, when remediation is requested for decontamination, traditional remediation techniques disrupt soil assets. A multi-disciplinary approach for designing abandoned areas could support the definition of "adaptive" projects that integrate remediation necessities, existing nature, and future functions. The shift toward this approach involves based on the length of the whole regeneration process, not only the final result, as well as considering innovative forms of governance [49,80,81]. This approach involves testing experimental technologies for remediation, such as bio- and phytoremediation, and offers the ability to implement flexible projects over time [57,68].

5. Conclusions

This study analyzed a selected territory, the Metropolitan Area of Milan, within the context of broader research on the Italian national territory, to identify urban planning approaches for integrating informal biodiversity within the urban ecological system. As urban transformations could reveal certain leftovers, spontaneous natural activity in these spaces should be observed and investigated as part of the corresponding transformational processes.

The present analysis in the Milanese region revealed a heterogeneous ecological succession phenomenon emerging in unmanaged spaces at urban and non-urban levels, suggesting the need to investigate the region's ecological features and implications. A deeper analysis of some cases revealed the presence of spontaneous urban woodlands, whose regeneration processes are different and call for further experimentation to be integrated into the urban green network. The relevance of the spontaneous natural system is generally not included in related discussions. However, in some cases, this system has been explored in relation to social conflict implications in urban contexts, with researchers advocating for its preservation. This condition increases the need to mix different approaches and planning tools for managing and integrating these spaces, suggesting a new trajectory for coexistence with nature under informal biodiversity. The application of a new comprehensive approach could overcome the understanding of these spaces as loci of degradation or development potential by resignifying their value.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land13081123/s1, File S1: Selected sites; File S2: Tables.

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