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The Role of GIS Data Post-Processing in the Environmental Assessment: The Case of Umbria, Italy

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Abstract: The increasingly complex dynamics of urban planning require an innovative approach to land use suitability analyses and environmental assessments. Traditionally, these disciplines have provided a critical foundation for sustainable urban development, but the current acceleration of change requires renewed attention to technology and innovation. The integration of advanced territorial data is emerging as a key element to enrich the analysis and mapping of the landscape. This type of data allows for an updated and objective view of reality, providing urban planners and decision makers with a dynamic tool to quickly adapt to evolving urban needs. The use of new technologies increases the accuracy and effectiveness of these analyses, enabling more efficient and sustainable urban planning. This article explores how innovation and technology are transforming the field of land use suitability analyses and environmental assessments and provides real-life examples of how advanced territorial data can be used to model the landscape more accurately in the case of Umbria, a region in Italy characterised by a rich cultural history and picturesque landscapes. Umbria, with its unique geography and delicate environmental balance, provides a fertile ground for exploring how the implementation of territorial databases can contribute to the responsible management of industrial activities. This case study represents an important first step in applying a QGIS and Python geoprocessing approach to these issues. The methodology starts with the creation of territorial data and includes a post-processing phase using Python. This integrated approach not only provides an updated and objective view of the landscape but also represents the first instance in the literature of a study applied to such a small and environmentally rich region as Umbria.

Keywords: urban planning; environmental assessment; land-use suitability analysis; buffer zone; urban sustainability; sustainable development; cumulative impact mapping; Agenda 2030

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1. Introduction

Urbanisation changes demographic characteristics and transforms the physical landscape of the environment [1], and inadequate planning can have significant impacts on various environmental components [2]. The concept of sustainability [3] was introduced in response to general environmental degradation. In particular, this concept received serious attention in 1978 when the United Nations published “Our Common Future”, where the term is defined as “. . . [the] development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [4]. It is clear how the definition applies to the environmental but also to the social and economic spheres [5,6]. International leaders have been working for years on a sustainable development strategy, and on 25 September 2015, the UN General Assembly adopted a global programme of interrelated actions signed by the 193 Member States, called the 2030 Agenda for Sustainable Development, based on 17 Sustainable Development Goals (SDGs) finally divided into 169 targets to be achieved by 2030 [7–10]. Each country must define its own sustainable development strategy to achieve the goals and targets. In general, the European Union has adopted strategies and policies to achieve the goals of the 2030 Agenda, such as the circular economy, research and innovation, and sustainability of agriculture and food systems.

In Italy, the approach to implementing the 2030 Agenda is defined by the National Strategy for Sustainable Development (SNSvS), which is structured around five areas of intervention corresponding to the "5Ps" of sustainable development proposed by the 2030 Agenda [11]. Article 34 of Legislative Decree 152/2006 requires the regions to draw up regional strategies for sustainable development that define the contribution to be made to achieve the objectives of the national strategy. The same decree states that the regional sustainable development strategies are the basis for environmental impact assessments [12], which represent the environmental component in the decision-making process [13]. In particular, Environmental Authorisation regulates the impact of industry on the environment. Consequently, in the context of the 2030 Agenda, which aims to promote global sustainable development, an environmental impact assessment is a crucial element in achieving the ambitious goals outlined. In this context, the effective use of Geographical Information Systems (GISs) plays a key role in understanding and managing the environmental impacts of land-use planning decisions. In fact, decision makers and land-use planners use GISs to develop spatial environmental databases and carry out land assessments [14]. GISs can have many applications, but in the case of urban planning, the main uses can be visualisation and spatial analysis [15]; mapping provides the most powerful visualisation tools [14]. This study aims to explore the critical role of GIS data post-processing, with particular attention to the specific context of Umbria, Italy.

Umbria, with its extraordinary landscape diversity and rich cultural heritage, is a fertile ground for the application of new sustainable planning approaches. In particular, Umbria is characterised by a lack of territorial data processing in accordance with the INSPIRE Directive, which creates a gap in the assessment of Environmental Authorisation and hinders the formulation of an innovative and integrated approach to the sustainability policy. This study aims to fill this gap with a twofold objective. First, it aims to overcome the lack of territorial data through an innovative post-processing approach based on Python, an open-source programming language (the use of open-source tools ensures transparency, accessibility, and collaboration in data management). Furthermore, the approach of transparency and citizen participation in urban planning and land use suitability is also supported by the production of territorial data from public administration, easily available on a website. Secondly, interactive maps can be easily developed by using the Python Folium library (also open source), creating an efficient dynamic tool for sharing information between the public bodies involved in the decision-making process. This initiative, in line with Agenda 2030, is part of the broader objective of promoting the interoperability of territorial data. The introduction of Python, with its open-source flexibility and computational power, represents a significant step towards more efficient and sustainable territorial management. The interactive maps created by Folium not only provide a clear visual representation of the data but also facilitate more effective and objective communication between the stakeholders involved in territorial planning.

This paper aims to explain in detail how the use of Python and Folium can introduce a meaningful contribution in the context of environmental assessment, promoting sustainability and providing practical tools for information sharing. The implementation of interactive maps will significantly contribute to a more integrated and transparent vision, supporting efforts towards territorial planning based on accurate, interconnected, and sustainability-oriented data, in line with the goals of the 2030 Agenda.

2. Context

Land use suitability analysis is a very important task faced by urban planners and managers, with the aim of identifying the most appropriate spatial pattern for future land use [16,17] according to specific requirements, preferences, or predictors of some activities [18]. It has also been applied in a variety of situations, such as the definition of land habitats for animal and plant species [19,20], geological affordability [21,22], landscape evaluation and planning [23,24], and environmental impact assessment [25]. Methods of land use suitability analysis can be categorised as overlay mapping methods [26]. Environmental assessments can be divided into two categories: strategic analysis and environmental impact assessment. Both types are potential tools for policy making, although they have different areas of application. Strategic environmental assessments aim to facilitate the consideration of potential environmental impacts in strategic decision making and are therefore applied to plans and programmes [27,28]. On the other hand, environmental impact assessments are used to evaluate the impact of a proposed project [29,30]. Environmental assessments therefore have different areas of application, but both aim to contribute to sustainability. Environmental assessments are related to potential aspects, and therefore, it is important to examine the actual territorial conditions; environmental assessments of plans, programmes, and projects are closely related to Environmental Authorisation. Environmental Authorisation finally regulates the impacts of industry and promotes the concept of sustainability in industrial activities [31,32]. Figure 1 schematises what has been defined.

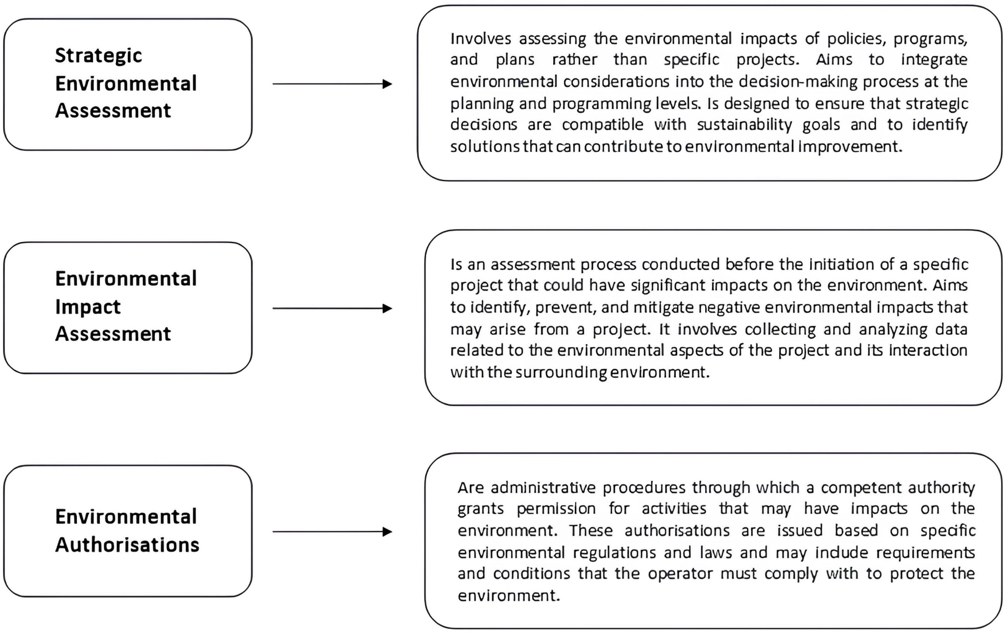

Figure 1. Difference between environmental impact assessment (EIA), strategic environmental assessment (SEA), and Environmental Authorisations.

The Italian Legislative Decree 152/2006 is the main Italian law on the subject. It implements European Directives such as:

- The Integrated Environmental Authorisation for intensive agricultural and industrial activities characterised by a higher risk for the environment [33];
- The Waste Unique Authorisation for waste disposal and recovery installations [32];
- The Environmental Unique Authorisation, which covers various Environmental Authorisations and applies to all categories of small- and medium-sized enterprises that are not subject to other forms of authorisation [32].

Environmental Authorisations are linked to specific locations, and territorial data allow for a detailed representation of the spatial distribution of these activities, facilitating precise cartographic representations of their respective locations. In fact, according to art. 59, paragraph 1 of the Legislative Decree 82/2005 "Digital Administration Code": "Territorial data means any geographically localised information". In this context, territorial data also play a crucial role in the analysis of environmentally sensitive or protected areas. Environmental Authorisation must include this analysis to ensure compliance with regulations and specific restrictions within designated geographical areas.

Territorial data facilitate the implementation of spatial analyses to assess the environmental impact of permitted industrial activities. This approach identifies areas of increased environmental sensitivity or potentially endangered natural resources. The knowledge gained from such analyses is essential for developing strategies for effective environmental management. Territorial data are essential for supporting decision making and must be shared and understood in a standardised format by all stakeholders involved in the environmental permitting process. The interoperability of territorial data refers to their ability to be used in various data management systems or platforms to facilitate efficient collaboration and information exchange. In particular, interoperability can be defined as a measure of the degree to which different systems, organisations, and individuals are able to work together to achieve a common goal [34]. For computer systems, interoperability is typically defined in terms of syntactic interoperability and semantic interoperability. Syntactic interoperability is based on specified data formats, communication protocols, and the way in which communication and data exchange are ensured [34]. Semantic interoperability, on the other hand, occurs when two systems have the ability to automatically interpret exchanged information meaningfully and accurately to produce useful results according to a common information-exchange reference model [34].

In 2007, the European Union adopted the INSPIRE Directive (INfrastructure for SPatial InfoRmation in Europe—Directive 2007/2/EC) to address issues related to the exchange, sharing, access, and use of interoperable spatial data and spatial data services across different levels of government and sectors. This Directive requires EU Member States to transpose the INSPIRE rules on metadata, interoperability, network services, data sharing, and coordination into their national legislation [35,36]. The INSPIRE Directive was implemented in Italy by Legislative Decree No 32 of 27 January 2010, which established a national infrastructure for spatial information and environmental monitoring in Italy as a Community infrastructure hub [37]. In Italy, the government agency responsible for the implementation of the INSPIRE Directive is AgID. Its role is to coordinate public administrations to achieve the objectives of the Italian Digital Agenda and to promote the digital transformation of the country. In addition, according to Article 59 of Legislative Decree 82/2005, the Geo-Topographic Databases (DGBTs) define the territorial information base for public administrations. The National Spatial Data Catalogue (RNDT) is a database that serves as a national reference research service for the implementation of the INSPIRE Directive [37]. The Ministerial Decree 11/2011 established the technical rules for creating, documenting, and using DGBTs. These rules are outlined in the 'Technical Rules for the Definition of the Specifications of the Content of Geo-Topographic Databases' and its annex the 'Catalogue of Territorial Data—Specifications of the Content of Geo-Topographic Databases'. These documents serve as a reference for creating territorial databases. In the past, regional technical maps were used to support territorial community analyses. However, with the evolution of technology and the spread of GIS software, it has become possible to move from technical maps to DGBTs. This allows for the acquisition of information and the ability to explore and visualise the territory. The DGBT is the tool that enables regional administrations and local authorities to have the basic cognitive elements for land management.

3. Methods

Geographic Information Systems (GISs) enable the capture, storage, analysis, visualisation, and processing of information derived from spatial data. The key feature of GISs is their ability to associate alphanumeric information with any geographical element located according to a given coordinate system [13]. Spatial tools such as GISs are extremely useful in supporting environmental assessments, land use suitability mapping, and analysis. They have the potential to facilitate efficient decision making by providing objective evidence. In this case, the GIS platform used is Quantum GIS (QGIS), an open-source program that can be downloaded directly from the internet without the need for a license. The desktop application is a GIS package that is comparable to other commercial tools in terms of usability and functionality.

One of its strengths is the ability to use advanced functionality and be compatible with plug-ins developed in the Python and C++ languages [38]. Processing is an object-oriented Python framework for QGIS [39]. In fact, Python, with its clear and flexible syntax [40], provides an ideal development environment to create scripts and tools to manage geographic information. Python-based geoprocessing therefore represents an advanced methodology for analysing and manipulating spatial data. This approach allows analysts and developers to automatically perform complex spatial processing operations, improving the efficiency and accuracy of geographic analysis. Much of Python's popularity is also due to its fully accessible programming libraries that can be used on all major operating systems and platforms [41]. In geoprocessing, Python's ability to handle vector data is enhanced by specialised libraries such as Json, Folium, and Shapely. These libraries enable Python to manipulate geometry, create buffers, perform spatial queries, and more. Python is increasingly recognised as a key language in the field of geoprocessing, providing a powerful and accessible solution for managing and analysing geographic data. The Json library facilitates communication between Python and GIS software. Geolocated data from GIS can be exported to GeoJSON format for processing in Python. The Folium library can be used to create interactive maps by inserting data in GeoJSON format. Alternatively, Shapely can convert geolocated data into editable polygons before visualisation. It is an interactive development environment (IDE) that enables users to create and share documents containing live code, equations, visualisations, and narrative text. JupyterLab is a valuable tool for spatial analysis. Its integration with Python and support for various data science libraries make it an excellent choice for analysts and developers. JupyterLab is used to integrate Python-based geoprocessing scripts, enabling a collaborative and interactive approach to geospatial analysis. The integration of JupyterLab can enhance the overall workflow by providing a versatile and dynamic interface for exploring, processing, and visualising geospatial information. All the maps and information analysed in the present work were generated by using the above tools. The produced maps provide a visual representation of geographic data that is interactive and easy to explore. Users can zoom in or out, click on map elements for additional information, or explore different areas.

4. Case of Study

The test case under consideration is located in Umbria, a region of Italy that covers an area of 8456 km^2 and has a population of 851,251 as of 2023. Umbria was selected due to its unique combination of geographical, environmental, and economic features. It is situated in the heart of Italy and provides a distinctive context characterized by a range of industrial activities combined with an important landscape. Umbria offers an excellent opportunity to study the impact of human activities on the environment due to its abundant natural resources and diverse industrial sectors. It is important to note that decisions related to industrial activities can affect every aspect of the landscape. Umbria, with its diverse environmental and landscape characteristics and various industrial sectors, provides an excellent opportunity for an in-depth analysis of environmental sustainability. The region faces pressing challenges related to urbanisation and spatial planning, which require a careful balance with environmental sustainability. The absence of precise territorial information on Environmental Authorisation presents a distinctive opportunity to develop a new approach that considers these crucial aspects. The aim is to introduce an innovative analytical method that streamlines the permitting process by utilising detailed territorial data and complex geoprocessing functionalities. The proposed approach aims to expand beyond the simplification of the permitting process and instead focuses on a broader, interdisciplinary perspective that encompasses urbanisation, spatial planning, and environmental sustainability. In conclusion, Umbria serves as a case study for environmental permitting and provides a unique context for developing innovative solutions. Solutions that integrate urbanisation, spatial planning, and environmental sustainability in a harmonious manner can contribute to a more comprehensive and sustainable approach to territorial management. Umbria serves as an excellent example of balanced coexistence between industrial development and the preservation of its natural heritage.

5. Data

The process of generating territorial data in compliance with the INSPIRE Directive and promoting a uniform and standardised comprehension of environmental planning commenced with a thorough analysis of the Environmental Authorisations issued by the Umbria Region. These authorisations, which are accessible on the Umbria Region website, were scrutinised through collaborative discussions with regional representatives and Environmental Authorisation evaluators. After completing this phase, the next step was to map the industrial activities that are subject to Environmental Authorisation in QGIS. The correct localisation was determined by using the land register sheet number and land register parcel number defined in the Environmental Authorisation available on the Umbria Region website. The Agenzia delle Entrate's Web Map Service (WMS) and the Google Satellite map, obtained by using the Quick Map Service QGIS plug-in, were used to spatially localise industrial activities subject to Environmental Authorisation in Umbria. It is important to note that the reference vector geometry chosen for this study is polygonal. The attributes associated with the defined geographical elements were then identified. The data for these attributes were obtained from the documents in the Environmental Authorisation. The project progressed from creating basic spatial data to a geolocated database with attributes. This phase is crucial because our goal was not only to implement spatial data but also to characterise them with attributes that enable a more precise interpretation of the spatial information. The spatial data produced must comply with the European-level infrastructure for spatial information, as defined above. This study refers to the 'Catalogue of Territorial Data—Content Specifications for Geo-Topographic Databases'. The Catalogue defines content specifications for territorial databases, specifically the identification of territorial data that represent and describe the natural and anthropogenic aspects of a territory. The data are organised in layers, themes, and classes, with explicit specification of the relationships and constraints that characterise them. The catalogue's structure comprises classes that define the representation of a particular type of territorial object, including its properties, data structure, acquisition rules, and its relationship with other objects. Layers and themes are not used for classification but instead group classes based on their morphology or function. This grouping simplifies the description or specification of the classes within them. Each layer is identified by a name, an alphanumeric designation, and a two-digit numeric code for encoding the classes and their attributes. A layer description is also provided, which describes the objects collected in the layer, their common properties, and the significant relationships between them. In the case of the theme, it is essential to define the theme name, the numeric code, and the description. The name is an alphanumeric designation, while the numeric code consists of two digits corresponding to a theme numbering within the layer. This code is used to numerically code classes and their attributes. The description provides information about the objects collected in the theme, their common properties, and the significant relationships between them. Each class is identified by an alphanumeric name; a geometric qualification; an alphanumeric code; and a six-digit numeric code composed of two digits from the layer code, two digits from the theme, and two digits corresponding to a class numbering within the theme.

Finally, the defined specifications were followed to produce comprehensive territorial data, which include spatial definitions and attributions in shapefile format.

6. Experiments and Results

The approach developed in this study can be described as a step-by-step approach. Firstly, the territorial data were defined and then converted to GeoJSON format for further processing in JupyterLab and Python. Additionally, the Python Folium library was used to create interactive maps, enabling the visualisation of the data on an interactive map. In fact, the resulting html file can be easily shared on a website. The maps created were exported into a static cartographic representation for this paper. This study's focus is to highlight the functionality of interactive maps and their potential for sharing information during the assessment and permitting process. Obviously, in order to create the best presentation of the interactive maps and to be able to show the potential behind them, it was necessary to start from the analysis of only two types of territorial data: industrial activities subject to Integrated Environmental Authorisation and Unique Waste Authorisation, as shown in Figure 2.

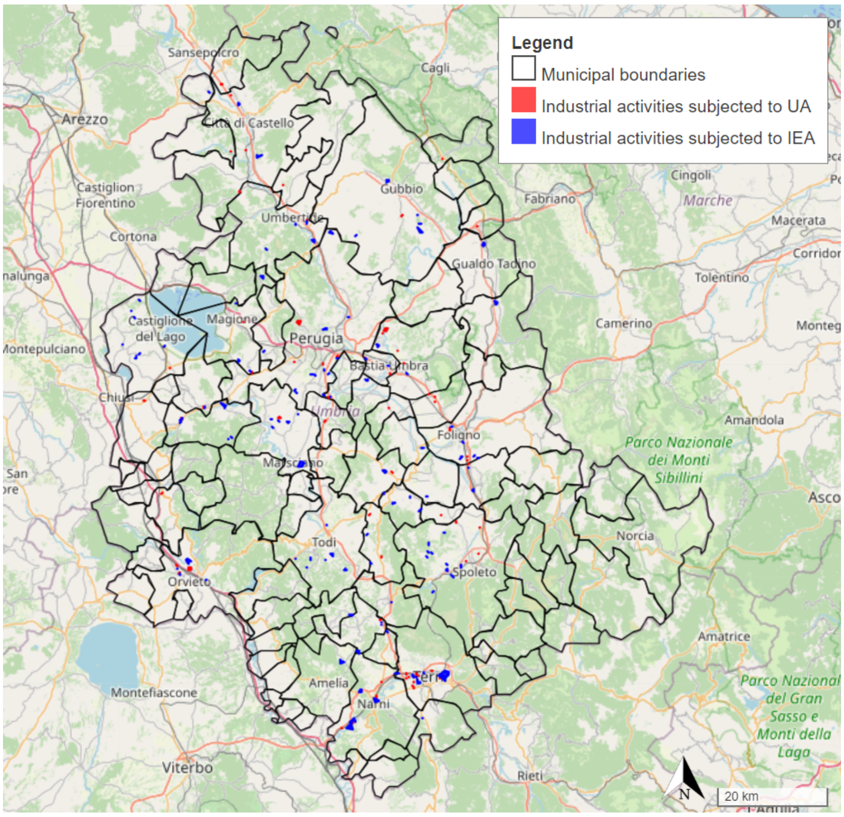

Figure 2. Industrial activities, subjected to Integrated Environmental Authorisation and Waste Unique Authorisation, geolocated in Umbria.

The visual representation of municipal boundaries provides a clear indication of the spatial distribution of geolocated industrial activities. In order to evaluate the territorial distribution, a new map was created. The map uses different colours to represent the specific numerical density of industrial activities. Figure 3 shows a section of the map from which it can be seen that Terni has a higher density of industrial activities subject to Integrated Environmental Authorisation and Unique Waste Authorisation, followed by Narni, Spoleto, and Perugia. Therefore, these municipalities require greater consideration in the decision-making process for new industrial activities.

The initial rapid processing and visualisation demonstrated the significant potential of this tool. Subsequently, new territorial data and other types of industrial activities subject to environmental permits were included. The final selection included the following activities:

- Waste disposal systems (operational landfills, post-operational landfills, and closed landfills);
- Waste recovery and/or disposal systems (simplified recovery, waste recovery and/or disposal installations subject to an Integrated Environmental Authorisation, and waste recovery and/or disposal installations subject to a Waste Unique Authorisation);
- Incineration and energy-recovery installations;
- Composting industries;

- Industries subject to an Integrated Environmental Authorisation;
- Intensive and non-intensive farming (intensive farming subject to an Integrated Environmental Authorisation, non-intensive farming subject to an Environmental Unique Authorisation, and non-intensive farming subject to General Authorisation for emissions into the atmosphere);
- Industries at risk of major accidents;
- Industries where emissions of substances used in production cycles are classified as carcinogenic, toxic for reproduction, mutagenic, or with high cumulative toxicity and persistence (art. 271, paragraph 7-bis, Legislative Decree 152/2006).

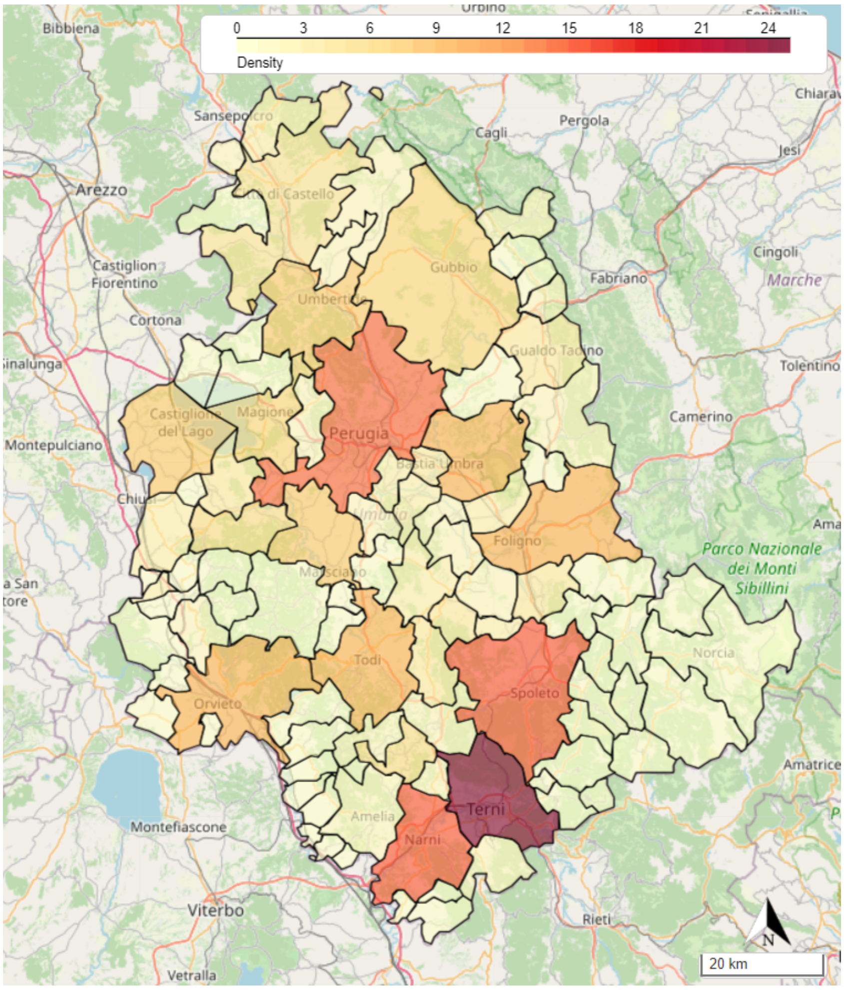

Figure 3. Density of industrial activities subjected to Integrated Environmental Authorisation and Unique Waste Authorisation located in Umbria.

However, regional Environmental Authorisation evaluators also suggested considering additional activities that require careful attention including mining activities (quarries and mines), purification plants, radio and video antennas, and industries producing energy from non-renewable and renewable sources. After completing the localisation process, it became evident that cumulative effects must be taken into account. The chosen approach was to consider a circular buffer around the polygonal geometries because circular buffer zones are commonly used in environmental assessments [42]. The buffer size of 1.5 km was chosen based on the experience of regional Environmental Authorisation evaluators and the dimensions of municipal boundaries. After establishing the buffers around the territorial data, a defined nomenclature was assigned to the considerable number of buffers generated. The definition of these codes can be found in Table 1. In order to visually quantify the amount of data, the map shown in Figure 4 was generated.

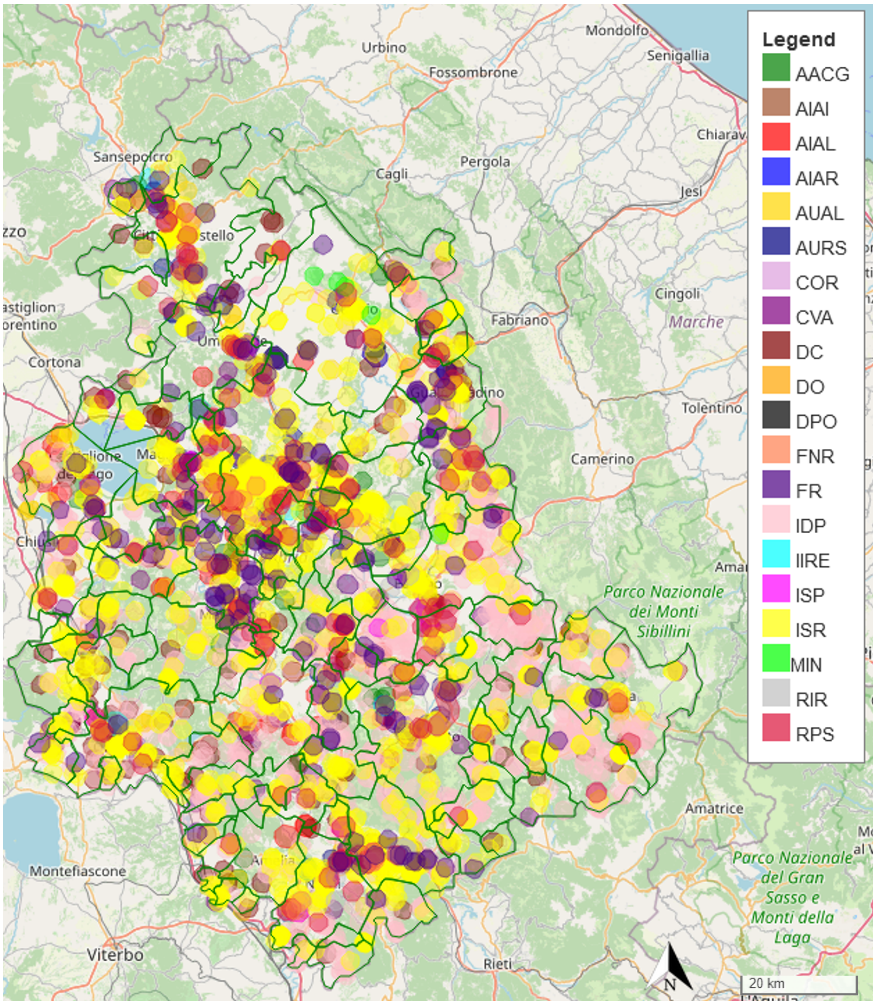

Figure 4. Buffers of industrial activities located in Umbria.

To conduct a more detailed local analysis, we chose a test case in the Umbria region. This will enable us to develop a cascade approach that can be applied to even the most complex cases. Our selected case is the municipality of Todi, which is situated in the province of Perugia and has an estimated population of 15,724 as of 2022. Todi is characterised by a range of industrial activities from farming to waste recovery. The previous analysis identified 64 industrial activities within the municipal boundaries. Table 2 summarises the types of industrial activities located in Todi and considered for this study.

Again, it was decided to create buffers of 1.5 km around the located industries. This choice was based on considerations relating to the specific characteristics of the data and the objectives of the analysis in order to obtain an accurate representation of the spatial relationships. At this point, it is important to analyse Figure 5.

Identifying the areas of intersection between the buffers is a crucial step as it provides detailed information on the degree of overlap. The red–brown colour in the visualisation was chosen to highlight different levels of overlap, allowing for a quick visual interpretation. The presence of overlap indicates a high industrial concentration in certain areas, emphasising the need for further investigation in these specific contexts. This methodology for spatial analysis offers a comprehensive and informative framework for comprehending the relationships between located geometries. It enables a thorough understanding of the geographical distribution of the data under consideration, providing a strong foundation for informed decision making and further research.

Table 1. Codes associated with industrial activities located in Umbria.

Code	Industrial Activities
AACG	Non-intensive farms subject to General Authorisation for emissions into the atmosphere
AIAI	Industries subject to Integrated Environmental Authorisation
AIAL	Intensive farming subject to Integrated Environmental Authorisation
AIAR	Waste recovery and/or disposal plants subject to Integrated Environmental Authorisation
AUAL	Non-intensive farming subject to Environmental Unique Authorisation
AURS	Waste recovery and/or disposal plants subject to Waste Unique Authorisation
COR	Waste composting industries
CVA	Quarries
DC	Closed landfills (Ante D. Lgs 36/2003)
DO	Operational landfills
DPO	Post-operational landfills
FNR	Industries that produce energy from non-renewable sources
FR	Industries that produce energy from renewable sources and not renewable sources
IDP	Purifiers
IIRE	Incineration and energy-recovery plants
ISP	Industries where emissions of substances used in production cycles are classified as carcinogenic, toxic for reproduction, mutagenic, or exhibiting high cumulative toxicity and persistence (Art. 271, paragraph 7-bis Legislative Decree 152/2006)
ISR	Radio and video systems
MIN	Mines
RIR	Industries at risk of major accidents
RPS	Recovery in simplified procedure

Table 2. Industrial activities located in Todi.

Industries Activities	Number
Quarries	6
Closed landfills (Ante D. Lgs 36/2003)	1
Purifiers	21
Industries subject to Integrated Environmental Authorisation	2
Intensive farming subject to Integrated Environmental Authorisation	7
Non-intensive farming subject to Environmental Unique Authorisation	3
Industries at risk of major accidents	1
Industries where emissions of substances used in production cycles are classified as carcinogenic, toxic for reproduction, mutagenic, or exhibiting high cumulative toxicity and persistence (Art. 271, paragraph 7-bis Legislative Decree 152/2006)	3
Radio and video systems	20
TOTAL	64

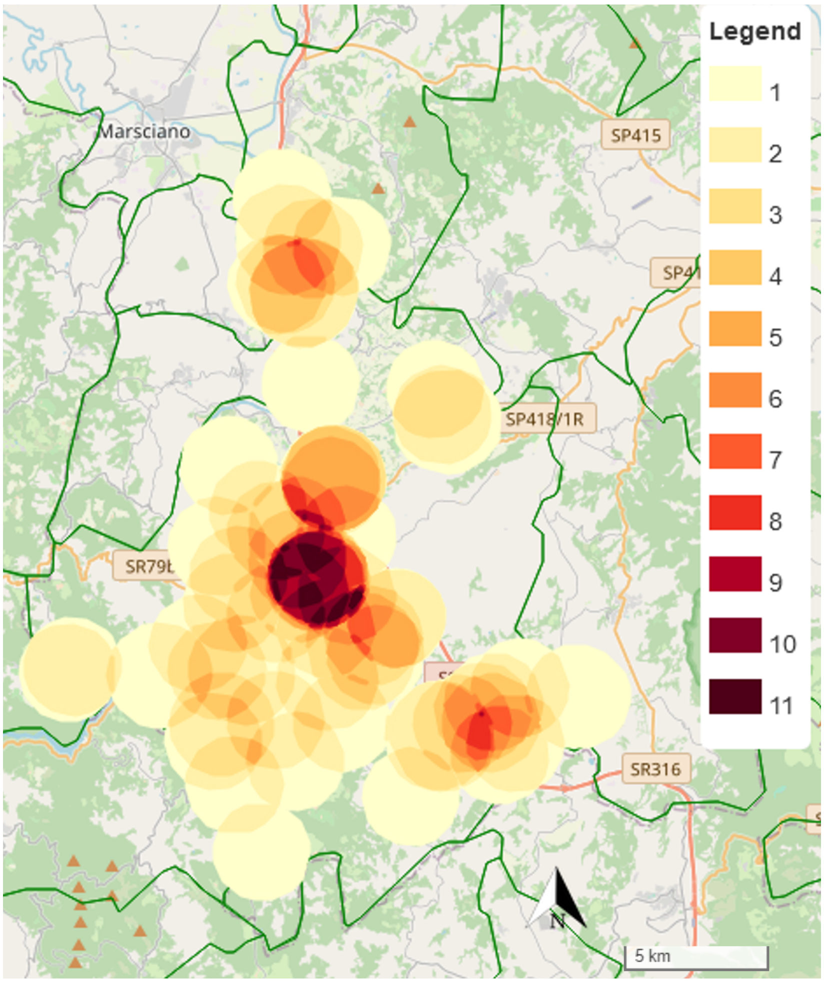

Figure 5. Geographical distribution of buffers for industrial activities located in Todi.

In Figure 5, the total number of intersections is shown by plotting the buffers on a chromatic scale. This helps to identify areas where multiple buffers intersect. Equation (1) was used to identify the number of intersections, where i and j represent the buffers. To assign a value to repeated intersections, the $N_0(\chi)$ was calculated for each point of the examined area. Within each buffer, different sections of different colours are created, taking into account the distance with respect to the coordinates of the centroid:

$$N_o(x) = \sum_{i}^{n} \rho_i(x) \quad (1)$$

where

- $\rho(x) = 1$ when x is in the ith buffer (0 otherwise).
- n is the actual number of polygons.
- x represents the vector of geographic coordinates.

However, it is important to remember that each buffer should be assessed according to its specific typology. Industrial activities have varying impacts on the environment, and it is important to assign danger values to each type. Initially, three danger values were defined, each associated with a specific type of Environmental Authorisation: Integrated Environmental Authorisation, Waste Unique Authorisation, and Environmental Unique Authorisation. However, a fourth value was necessary because intensive farming is included in the Integrated Environmental Authorisation but can be considered separately due to its high level of pollution. The permitting process includes a territorial analysis not only of activities that require Environmental Authorisations but also of other activities such as mining, purification, and radio and video systems. To achieve a comprehensive categorisation, we added a fourth danger value and extended the categorisation to other activities that regional instructors have deemed important for the permitting process. To summarise, value 1 is associated with industrial activities that require Environmental Unique Authorisation and other low-risk activities that, when considered together with industrial activities, are significant, such as radio and video systems. Value 2 has been assigned to activities that pose a higher degree of environmental risk than level 1. This value can be linked to activities such as mining or non-intensive farming, which have significant effects on the environment. Industrial activities that produce pollution and are subject to periodic checks on waste treatment or industrial emissions of hazardous substances are assigned a value of three. This includes activities such as waste treatment and large-scale industrial operations that fall under either a Waste Unique Authorisation or an Integrated Environmental Authorisation. These authorisations are often closely linked due to the high degree of pollution associated with both. Value 4 is associated with activities that require specific analyses of potentially polluting or hazardous substances produced by their operations for authorisation purposes; for example, intensive farming or industries that emit carcinogenic or toxic substances. It is important to note that these values should not be considered empirical. Rather, they should be seen as a preliminary assessment of the hazard levels in the cumulative impact assessment. This assessment is based on discussions with regional experts and is consistent with the level of complexity of the permitting process. As a result, they represent an important tool for risk quantification and cumulative impact assessment based on knowledge of the areas and industrial activities. Table 3 defines the danger values associated with the industrial activities located in Todi.

Table 3. Danger values associated with industrial activities located in Todi.

Industries Activities	Danger Values
Mining activities	2
Waste disposal systems	3
Purifiers	2
Industries subject to Integrated Environmental Authorisation	3
Intensive farming subject to Integrated Environmental Authorisation	4
Non-intensive farming subject to Environmental Unique Authorisation	2
Industries at risk of major accidents	4
Industries that emit carcinogenic or toxic substances	4
Radio and video systems	1

Specifically, a danger value of four indicates an industrial activity with high emissions and chemical risks, requiring a thorough Environmental Authorisation analysis. In this case, a new map was created to show the associated danger levels. The legend in Figure 6 uses a colour scale ranging from orange to red to indicate increasing danger values.

A deeper level of knowledge can also be obtained for each overlapping polygon considering the weighted total sum of overlaps N_{o_w} estimated by using the danger values according to Equation (2). In this way, the overlaps are weighted in terms of danger.

$$N_{o_w}(x) = \sum_{i}^{n} \rho_i(x) \cdot v_i(x) \tag{2}$$

where

- $\rho(x) = 1$ when x is in the ith buffer (0 otherwise).
- n is the actual number of polygons.
- x represents the vector of geographic coordinates.
- v is the danger value for each overlap.

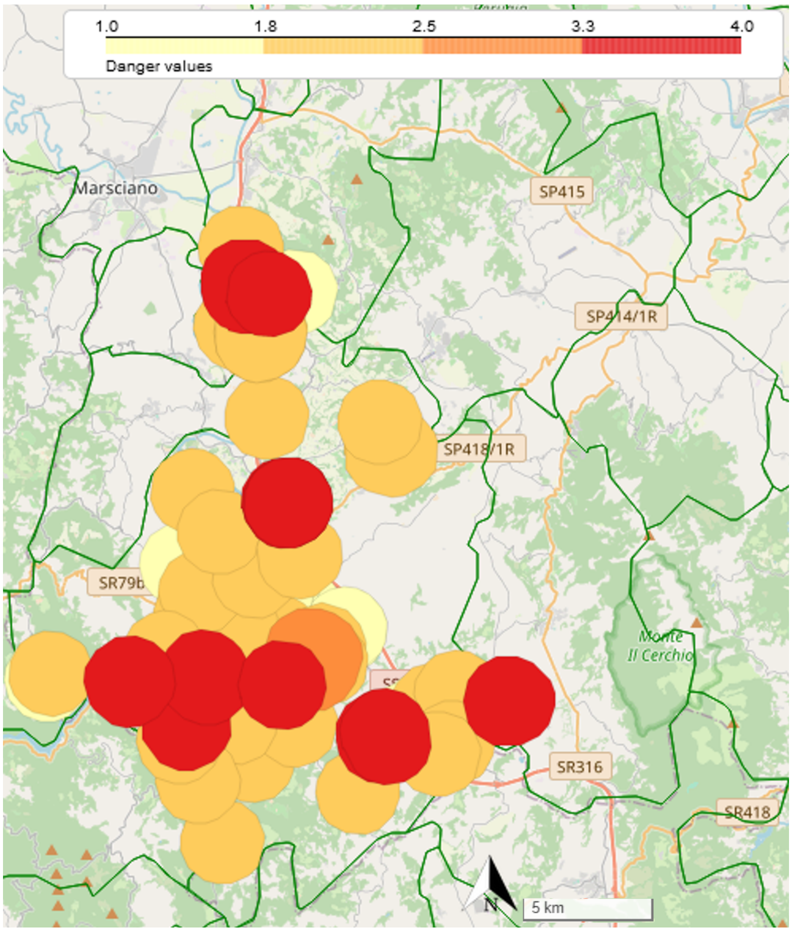

Figure 6. Danger values associated with the buffers of industrial activities located in Todi.

Figure 7 shows overlapping areas coloured according to their N_{o_w} values. Darker areas require special attention in the decision-making process as they represent locations where the environmental impacts of individual activities accumulate with those of nearby activities. Therefore, these areas deserve a higher level of attention in environmental assessments and permitting procedures. The establishment of new industries or anthropogenic activities in these areas may pose risks to both the environment and human health. Figure 7 is an updated version of Figure 5, providing a higher level of knowledge by taking into account the danger values of individual polygons.

In this way, Figure 7 can suggest which local area may require a detailed analysis. For example, Figure 8 shows a zoom of the N_{o_w} map overlaid with satellite imagery; this can be very useful to guide more detailed considerations.

Figure 9 shows the histogram of the danger values based on the function of surface area in square metres; this plot is useful for a deeper analysis of the global impact and to analyse the precision and usefulness of the overlap. The area scale is logarithmic for better visualisation. The maximum value of the affected area corresponds to a danger value of five, which is relatively low considering that the maximum danger value of an individual buffer can reach four. As also highlighted in Figure 7, the maximum value of N_{o_W} reached 25 and affects a relatively small area when considering the municipal extension. However, there are large areas affected by high danger values. It can be observed that, in general, the danger values tend to increase as the area affected decreases.

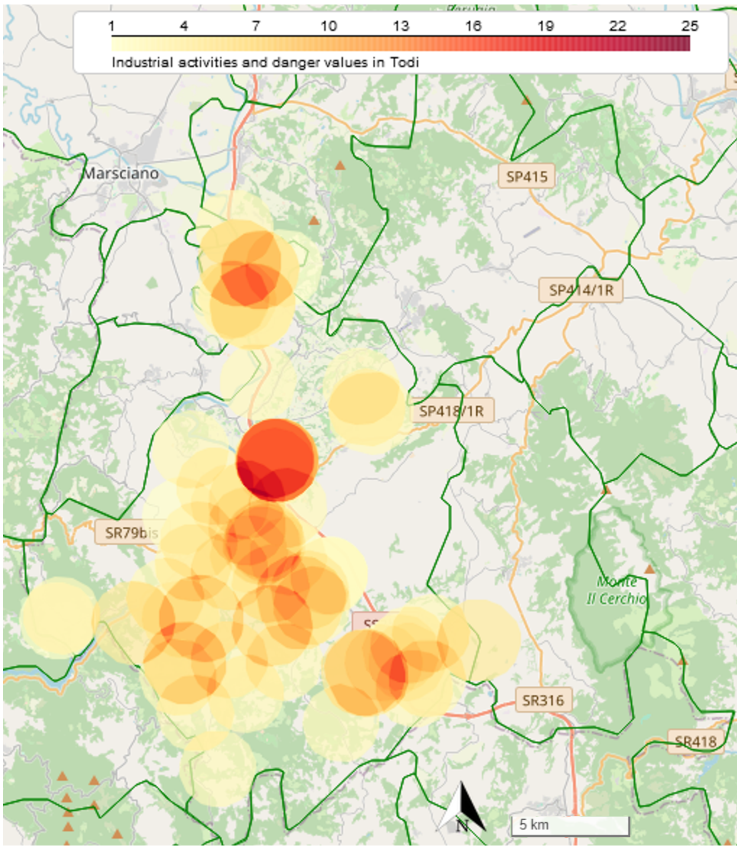

Figure 7. Calculated N_{o_w} for the intersections of industrial activity buffers in Todi.

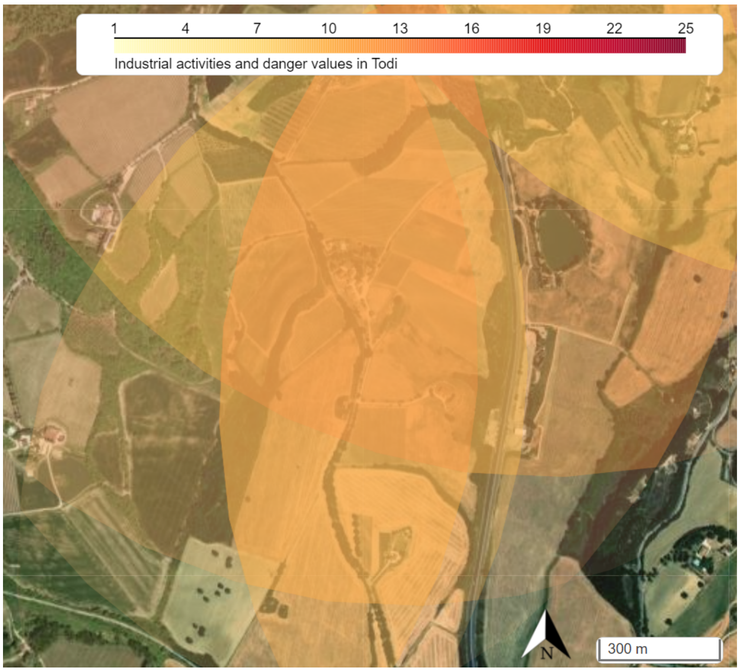

Figure 8. Detail of the calculated N_{o_w} for the intersections of a local area in Todi.

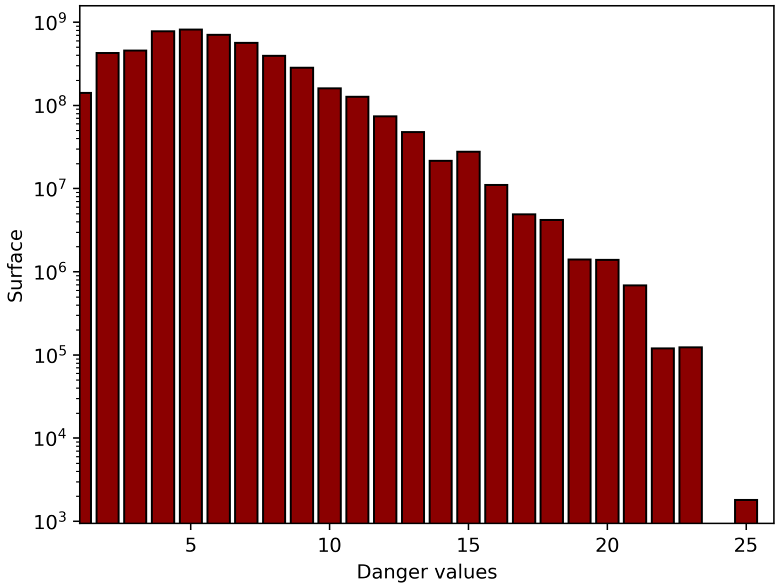

Figure 9. The histogram displays the affected surface area as a function of the calculated weighted total sum of overlaps N_{o_w} for the municipal area under investigation.

7. Conclusions

This study presents the crucial role of GIS data post-processing in environmental assessments, with a specific focus on the Umbria region in Italy. The initial lack of territorial data related to environmental licensing underlined a critical gap for effective territorial planning and targeted strategic assessments. This approach considers territorial data as a crucial element to define a comprehensive and objective view of environmental conditions, both qualitatively and quantitatively. The integration of geoprocessing has highlighted the significant potential of this type of data, supported by open-source platforms that facilitate free analysis and the sharing of work. The use of interactive maps was briefly introduced in this study, but it represents a powerful tool for simplifying the visualisation of territorial data and making it accessible without specific skills or software and will be considered in future work. The key is the ability to promote information sharing and an objective approach to environmental decisions, essential elements for integrated sustainable territorial management. Umbria has proved to be an ideal laboratory to demonstrate how new technologies can overcome the lack of relevant territorial data. The analysis of buffer overlaps in industrial areas has highlighted potential for further research and future development.

This study represents a first step towards a more comprehensive and innovative approach to land management. In order to further develop the current technique and contribute to sustainable and informed territorial management, it is necessary to carry out a more detailed analysis of aspects related to data sharing and the potential of interactive maps, as well as to consider new territorial data, such as landscape aspects. The implementation of innovative approaches can have a positive impact on the future of territorial policies and promote an integrated and conscious understanding of our environmental and industrial reality.

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