

Article

Innovation and Research to Support Policies on Sustainable Development Goals: An Integrated ICT Platform for the Definition and Monitoring of Programs in Puglia Region, Italy

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Abstract: The 2030 Agenda for Sustainable Development, approved by the international community, represents a global strategic guide with 17 Sustainable Development Goals (SDGs) and 169 interconnected targets, aimed at promoting equitable economic, social and environmental development. In this context, innovation and research can play a crucial role in supporting policies for the achievement of SDGs, especially at local and regional levels. This article reports what was developed in the Puglia Region according to a double action. On the one hand, the creation of an IT platform to improve collaboration between legislative institutions and research centres facilitates the collection and transfer of data as best practices to support political decisions. On the other hand, practical experimentation on issues related to regional development is conducted, with particular attention to sustainability-oriented partnerships, legislative needs, and knowledge of the territory. The new information system, based on a geo-database and developed entirely with open source software, collects regional regulatory data on SDGs, cooperation projects, and technical and scientific documents contributing to the knowledge of the application of plans and programmes applied to the territory. This tool, in addition to mapping relevant projects, represents an important resource for monitoring progress and supporting sustainable development policies, facilitating the sharing of information between local, national, and European actors.

Keywords: geo-database; sustainable development goals; Puglia region; open-source software



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1. Introduction

Halfway through the imagined path to the fulfilment of the Agenda 2030, initiated in 2015, national governments and international institutions are striving to assess progress in the implementation of Sustainable Development Goals (SDGs) and the distance from the planned targets.

At the international level, it is observed that such progress is unsatisfactory, due to obstacles posed by several factors (climatic change-related events, the COVID-19 pandemic, armed conflicts, and the general economic crisis with the resulting impacts on the costs of living), making the need to intensify efforts more and more evident [1]. As a consequence,

calls are being made to international institutions to improve activities and strengthen efforts to guarantee overcoming crises due to global occurrences [2].

Indeed, more sources underscore the ultimate political nature of the problem [3–6], naturally leading to reflections on process governance. The consensus on the need to approach sustainable development from a systemic perspective, rather than by single objectives [7], stresses how an integrated and multi-governance approach is equally needed, which can make the implementation of that ‘unicum’ in different territorial contexts feasible, recognizing and respecting their structural characters and differences.

The monitoring of SDGs at the national level, for instance, reveals how, even in countries with limited geographic extension such as Italy, marked heterogeneities across local contexts exist, resulting in substantial differences in the progress of goals’ implementation [5,6,8,9].

It must be observed that Italy has been distinguishing itself, in the field of implementation monitoring, for the strong innovative nature of its approach to the revision process. This earned it the scene as one of the most ambitious and successful international practice examples. Indeed, its Voluntary National Report (VNR) 2022 [10] has drawn international attention as one of the first examples of integrated VNR/VLRs combining national and local perspectives. The main national document includes the following:

- A total of 12 Voluntary Local Reviews (VLRs) set up by 18 subnational institutions (Regions, Autonomous Provinces, and Metropolitan Cities);
- A Voluntary Subnational Review (VSR) elaborated by the AICCRE, the Italian Association for the Council of Municipalities and Regions of Europe [11];
- The Three-Year Programming and Policy Planning Document for International Development Cooperation drafted by the Ministry for Foreign Affairs and International Cooperation (MAECI, Ministero degli Affari Esteri e della Cooperazione Internazionale) [12] to monitor the external dimension of the Italian Agenda 2030.

In this way, the nation confirmed at the operational level, the stated purpose of its National Sustainable Development Strategy (SNSv, Strategia Nazionale per lo Sviluppo Sostenibile) [13], namely, the overcoming of the sectoral governance approach.

Nevertheless, the findings of monitoring activities still show a significant distance from expected progress, but, most importantly, the comparison of the latest national reports reveals how, even with changing priorities and paces in the fulfilment of different targets, differences across Italian regions persist, with alternating raising or lessening phases [6]. Reasonably, structural differences affect the way that sustainable development objectives can be put into practice and realized.

Indeed, the importance of the sub-national level has been explicitly acknowledged at different levels and by different institutions [14,15], primarily because national indicators fail to catch the territorial processes that take place at the local and regional scales. A growing attention to territory is being dedicated, in particular, by the European Commission, especially with reference to the topic of SDG monitoring in the European regions. In particular, in 2022, the Joint Research Center (JRC) of the Commission started as the coordinator of the “Regions2030: Monitoring the SDGs in the EU regions—Filling the data gaps” pilot project, supported by the European Parliament and developed in collaboration with EUROSTAT and the DG REGIO (the Directorate-General for Regional and Urban Policy). The project aims to develop the definition of a common indicator framework for SDGs’ monitoring at the regional level that will be used across the whole UE, alongside integrative indicators. Puglia, among the 10 European regions selected, played a pivotal role by offering, through its Regional Strategy, an enrichment of methods and practices of the whole country [16].

Once ascertained the key role of regions and local governments in the fulfilment of the Agenda 2030, it is easily understood that the implementation of SDG needs to be approached within a marked territorial perspective. It must be observed that much attention is currently focused on the local (mainly urban) dimension of the process. Nevertheless, on one hand, the centrality of political and institutional issues for the topic and the growing subnational (in Italy, regional) competency of key matters, such as environment and health, highlight the regional administrative level as the most relevant scale for dealing with the theme, thus deserving specific attention. On the other hand, the need to engage the stakeholders' system in strategies and actions, even when dealing with the urban processes and their actual distribution in a wider territory beyond the municipal borders in a "whole-of-government approach" [17], proves that the regional level is the most appropriate action sphere, in that it can effectively encompass the partnerships relevant for all the processes developing at the sub-national scale (local as well as regional).

The fifth edition of the State of the Voluntary Local Review series, carried out by the Institute for Global Environmental Strategies (IGES) [1] on 48 Voluntary Local Reviews (regional and urban) across the world, revealed emerging trends that the highest representation of regional VLRs comes from European countries. The report also suggests that cities generally tend to elect and pursue those goals that are more aligned with their specific priorities. For the purpose of this article, such attenuation of the desired systemic approach to the Agenda 2030 occurring at the urban scale suggests that the regional governance level is the most adequate for the implementation of SDGs as a whole.

As a direct consequence of the general awareness of the importance of the subnational dimensions, several tools in support of local authorities in the specific field of monitoring have been set up: the "2019 SDG Index and Dashboard Report on European Cities" by the Sustainable Development Solutions Network (SDSN) [18], the "Localized indicator framework for SDGs" [15], and the "European Handbook for SDG Voluntary Local Reviews" by the Joint Research Center (JRC) of the European Commission [19] are just a few examples of the efforts put in play at the international level. Many endeavours are directed to the definition of indicators of national and subnational validity.

In this respect, it can be observed that the prominent concentration of efforts towards tools and protocols for SDGs paves the way for a comfortable and oversimplifying identification of the sustainable development concept with the system of instruments supporting its achievement.

In particular, two factors have reasonably led to focus on tools and applications: the central role gained by the smart city concept in the race towards SDGs [20–26] and the practical need to measure their progress for process monitoring and reorienting [27–29] supported by global institutions themselves [30–32]. This has been gradually spreading an optimistic faith in the availability of a 'goals-applications-indicators-metrics-measuring tools' track map as an infallible condition, against which the SDGs' underachievement leaves planners and scholars unexpectedly puzzled. Thus, losing sight of the fact that, in the authors' opinions and in line with national and global reports' findings, the task is much more about a careful declination of sustainability objectives by distinguishing across global and local contexts.

Undoubtedly, sustainable development is a shared and crosscutting idea that cannot be identified with the set of tools made available as yet, which are clearly not sufficient, and the difficulties in its implementation, despite the plethora of metrics, protocols, methodologies, and frameworks, prove it. Many studies delve into the concepts and principles at the basis of the definition of sustainable development, including its diverse and possible interpretations [33–37]. In this respect, the work of Öztürk [36] is an emblematic and indicative example: his proposal of the Core Idea Innovation Policy Perspective Methodology

(CIIPPM) suggests tracing back the basic concept to general principles to guide the implementation of sustainability, by converting and reinterpreting all UN SDGs into scientific principles universally acknowledged, assigning each identified scientific principle to a core idea according to the CIIPPM and subsequently focusing on its practical realization.

However, two considerations should be made about tools. On one hand, their essential role is undeniable for the implementation and monitoring tasks in the processes towards SDGs, as an avoidable element. On the other hand, it is also important to observe that tools somehow represent the idea of sustainability at a simplified level. Some of the mentioned works [22,24] maintain that applications explain and encourage communities, for example, to practice rational resource use and a general adoption of environmentally aware behaviours and then bring sustainable objectives closer to them and within their capability. This means that, in some way, when dealing with the concept of sustainability in respect to non-skilled communities, the distinction between end and means, or between the high-level role of objectives and policies and the material triviality of tools, becomes questionable. Whereas that distinction maintains its sense for insiders, who establish objectives and have to measure their progress, from the point of view of larger communities it becomes feeble and, rather, can open an intriguing space for research. Applications can be considered, then, a sort of basic translation of the sustainability concept, on the community side.

On the decision and policymakers side, the support that is needed by the new multi-governance is not limited to indicators' systems for the monitoring of SDGs' progress and of policies' impacts but also encompasses the knowledge that is necessary for the upstream definition of those policies through the analysis and the evaluation of best practices' applicability to local contexts. Up to now, little has been done to deliver such kinds of support to regional governments.

In this respect, the potential role of scientific research is paramount, and the collaboration and interaction between decision-makers and the research community on a local basis deserve to be strengthened through adequate instruments, useful also to map competence centres and scientific partnerships that can be integrated into wider stakeholders' networks. Such awareness, at the basis of this work, is in line with Sikora's view of the collaboration between science and public administrations as a facilitating agent in implementing the idea of sustainable development and overcoming the related difficulties [37].

In recognizing and clarifying the mutual contribution between Agenda 2030 and scientific research, the extensive work by Trane et al. [38] has recently revealed how the commitment of the research community in the operational support to SDGs is still mainly of a sectoral nature, both in thematic terms (privileging environmental concerns in respect to social and economic issues) and with reference to the territorial scope, giving priority to the urban context and leaving wide unexplored space for the study of trade-offs across different goals.

Indeed, one main essential contribution that scientific research can bring to SDGs' progress lies in revealing the importance of the spatial component in the related processes. Actually, Szarek Iwaniuk [39] underscores how the conservation of spatial order is one of the key objectives of planning and a primary indicator of the sustainability of territorial development and how such order is put in danger through different local factors and dynamics, to the detriment of equity and common well-being. In fact, many authors have been investigating the relationship and the possible alignment between spatial planning and SDGs [40–43]. Moreover, Jabbari [44] suggests that, to the three classical pillars of sustainability—environmental, economic, and social—two other pillars must be added: the institutional and the spatial ones. Furthermore, the spatial dimension also proves to critically influence sustainable development, although little attention has been paid to it

in the definition of indicators. Anyway, the UN Agenda 2030 acknowledges its centrality by calling on geospatial information towards the monitoring framework of SDGs, enough to entrust to two dedicated working groups the tasks of data integration [45] and of the elaboration of the geospatial roadmap for SDGs [46].

At the strictly technological level, the definite territorial component of the topic naturally orientates towards IC and geospatial technologies. Sharing this view, we think that, making the most of geographic information systems, geo-referenced data can be used not only for the creation of maps (e.g., for indicator mapping) but also as decisional support for their capacity to integrate geographic data, statistics, and multi-format information.

This work presented here, in some respect in line with Sikora's and Jabbari's view and partially with the work of Allen [47] (as he advocates the cooperation of public administrations, among others, with the scientific domain), positions itself in a 'middle ground' between principles and tools, where the research findings are made available exactly to favour and orient policies towards the most effective operational strategies and tools. Such intermediate space does not rely on an optimistic automatism of the 'objective-tool-achievement' cycle but, rather, leaves space to upstream creativity and orientation to facilitate the matching of ideas and principles with territories' and local communities' exigencies. This work, which directly involved the Regional Administrative Institutions, is based on these two premises: the lack of the spatial dimension in tools and, on the other hand, the need to integrate the policy and the scientific spheres. Its two specific research questions refer, then, to the assessment of the possibility to

- Support with a concrete tool the collaboration between research and decision making;
- Systematize and encompass within a spatially based, operational tool a territory with its exigencies and priorities through its distinguishing features in terms of knowledge and regulatory equipment.

The present work illustrates an integrated IT platform in support of the dialogue between local decision-makers and scientific research, conceived to facilitate the collection and transfer of data related to best practices from ongoing or completed projects to support the definition of policies and decision tasks. A practical application is also proposed on issues related to regional development, with particular attention to the knowledge of the regional territory in terms of legislative set up, evolution and needs, and of the system of established partnerships.

In the following sections, the experience and advancements of the Puglia Regional Administration in the SDGs' implementation process are first described. Then, the IT platform is presented, based on a geo-database and fully developed with open source software, collecting data from regional regulations on relevant to SDGs, cooperation projects, and technical and scientific documents that contribute to the knowledge of the application of plans and programmes applied to the territory. The tool, alongside the mapping of relevant projects, represents an important resource for progress monitoring and the support of sustainable development policies, facilitating information sharing among local, national, and European actors.

2. The Case Study: The Commitment of the Regional Administration of Puglia for SDGs, the Environmental Research Registry, and the SDG-SGP

Agreements between public bodies, in particular, those between research bodies (EERR) and public administrations (PPAA), constitute a strategic opportunity to address complex objectives such as the SDGs [48]. These agreements promote evidence-based equity and sustainability policies, supporting anticipatory governance models capable of intercepting emerging trends and adapting future scenarios [49].

The Environmental Research Registry (ARAP, Anagrafe delle Ricerche Ambientali in Puglia) was created in the Puglia Region [50], an initiative conceived to promote the diffusion of environmental scientific knowledge, facilitate access to the data produced, explore the methodologies developed, and bring different stakeholders closer to the world of science. The project aims to foster dialogue between experts in the environmental sector, expanding the network of operators interested in understanding and using environmental data. One of the main functions of the ARAP is to stimulate technology transfer and enhance research results, contributing significantly to scientific and technical innovation in the regional environmental context.

The main features that characterize the ARAP are the possibilities to

- Highlight research experiences as they develop, providing visibility to research institutions and researchers;
- Demonstrate how scientific debate can promote the advancement of knowledge;
- Satisfy requests for information arising from the functions of the Environmental Authority and environmental reporting;
- Promote the diffusion of scientific knowledge in response to the growing demand for qualified information.

Thanks to its structure and the information it contains, the ARAP also represents an essential tool to support political choices, which are increasingly influenced by technical and scientific considerations.

The ARAP contains data from research bodies and institutions, organized into sections that refer to the various environmental sectors: air, water, marine and coastal environment, soil, waste, natural ecosystems, technological risk, urban environment, and cultural and landscape heritage.

Many administrations are involved, some of which are the Puglia Region, the National Research Council (CNR), the University of Bari, Foggia, and Lecce, the Polytechnic of Bari, ENEA, INEA, and private companies.

The new Italian Public Contracts Code constitutes an important regulatory reference which, in synergy with the provisions on collaboration between public bodies, promotes greater institutional cooperation. At the same time, the adoption of innovative tools, such as Geo-Content Management Systems (Geo-CMSs) and advanced platforms for data collection and management, is registering an increasing diffusion, often enhanced by the support of artificial intelligence. These tools represent a significant opportunity for public administrations, allowing them to systematize and enhance the knowledge derived from available data, thus contributing to the achievement of policy objectives in a more efficient and integrated way.

A concrete example of this synergy is represented by the implementation in the Puglia Region of the SDGs, the Spatial Governance Platform (SDG-SGP), a territorial information system developed to contextualize regional activities in relation to the Sustainable Development Goals of the 2030 Agenda. This ICT tool is particularly useful to support strategic planning on complex issues such as sustainability, ecological transition, and technological development. Through the adoption of advanced data management systems and innovative methodologies based on data analysis, the platform enables more effective and informed territorial monitoring. The SDG-SGP was born from the framework agreement between the Regional Council of Puglia and the National Research Council (CNR).

The SDG-SGP is a tool designed to enhance regional activities towards the SDGs, highlighting aspects that are difficult to measure with traditional indicators. It aims to enhance regional collaborations in the context of the Sustainable Development Goals, geo-localizing initiatives and partnerships to promote an integrated territorial vision. Through a targeted analysis, best practices and European cooperation projects that concretely contribute to

the achievement of specific SDGs are highlighted. Among the most relevant examples are actions related to SDG 6, with the promotion of innovative technologies for the sustainable management of water resources; SDG 12, through strategies for reducing the use of plastic materials; SDG 13, encouraging measures to adapt to climate change; and SDG 15, with interventions for the sustainable management of agro-industrial ecosystems. These initiatives aim to support a transition towards more responsible and sustainable development models, strengthening the territorial impact of regional policies.

The tool stands out for its advanced and integrated functionalities, offering powerful support to regional sustainable development strategies. The underlying database collects a wide range of data, including standards, scientific publications, statistics from the National Institute of Statistics (ISTAT) and SDG indicators, allowing a documentary integration that facilitates in-depth analyses. By using Hub Maps [51], with relational patterns and various thematic maps, the tool synthesizes complex information, highlighting the connections between local actions and global objectives.

This ability to synthesize makes it a valuable support for policymakers, helping them to identify gaps, guide strategies, and evaluate the effectiveness of the actions undertaken. Complementary to the Regional Sustainable Development Strategy, the tool allows for the survey of ongoing activities, highlights contributions to Equitable and Sustainable Well-being (BES), and supports the work of the Regional Committee for BES indicators, thus strengthening the effectiveness of local policies.

3. Materials and Methods

The geo-database created, on which the SDG-SGP is based, was designed to highlight the contribution of research to the achievement of the Sustainable Development Goals (SDGs). The technological choice fell mainly on MySQL, a Relational Database Management System (RDBMS) based on the GNU licence, guaranteeing flexibility, scalability, and compatibility with open standards.

The ARAP, the true beating heart of the SDG-SGP, acts as a strategic database for geolocating regional initiatives and partnerships, offering a territorial vision of activities and valorizing best practices and European cooperation projects, with a focus on relevant SDGs, such as the sustainable management of water resources (SDG 6), the fight against climate change (SDG 13), and the protection of natural ecosystems (SDG 15).

The ARAP database for managing scientific and research projects, created in SQL, has a modular structure in order to guarantee the accuracy, coherence, and completeness of the data. The ARAP database is structured in MySQL and consists of multiple interrelated tables. Data integrity and synchronization were ensured through a series of triggers that automatically updated the relevant tables whenever an insert, update, or delete operation was performed. This mechanism maintained consistency across the dataset and streamlined data processing. In addition, for data entry, a dedicated graphical user interface (GUI) was developed to facilitate the manual insertion of new records, including environmental projects and associated attributes. Upon data submission, predefined scripts populate the necessary relationships between tables, ensuring proper linkage and seamless visualization within the Geo-CMS environment. The Geo-CMS serves as the central platform for data storage, visualization, and analysis. It operates by dynamically retrieving information from the MySQL database through a combination of Python and PHP scripts, while the front-end interface is developed using HTML and JavaScript. This architecture allows users to efficiently access and interact with geospatial data, ensuring real-time updates and a cohesive integration of environmental research information.

Below is the structure of the database and its main tables. Pseudocode will be used instead of SQL to make the structure and relationships between tables easier to understand and replicate.

The database was divided into the following tables:

- Projects;
- Institutions;
- Researchers;
- Research Unit;
- Outputs;
- SDGs;
- Relationships between tables.

Table 'Projects'

This table contains all high-level data, i.e., general and descriptive information providing a comprehensive overview, relating to the individual research projects. Below is the pseudocode for the table Projects:

```
TABLE Projects:
- Project_ID: Unique project identifier.
- Title: Project name.
- Institution_Coordinator_ID: Reference to the public body
coordinating the project.
- Period_of_Realization: Project execution period.
- Application: Sector on which the project acts (e.g.,
Environmental Matrix, Urban Environment).
- Geographical_area: Geographical area of the project.
- Description: Project description.
- Website: Project website.
RELATION: Institution_Coordinator_ID → Institutions
(Institution_ID).
```

Table 'Institutions'

Institutions are the bodies involved in the projects, both as coordinators and as participants. The Institutions table centralized this information. Below is the pseudocode of the Institutions table:

```
TABLE Institutions:
- Institution_ID: Unique identifier of the entity.
- Institution_Name: Name of the Institution.
- Address: Contact information.
- Coordinate: Geographical coordinates of the Authority in
WGS84 format.
- Website: Website of the institution.
```

Table 'Researchers'

This table stores the personal data of the researchers involved in the projects. The relationship between researchers and projects will be managed through an association table. Below is the pseudocode for the table Researchers:

```
TABLE Researchers:
- Researcher_ID: Unique researcher identifier.
- Nome: Name of the researcher.
- Surname: Researcher's surname.
- Email: Email contact.
```

- Institution_ID: Reference to the researcher's institution.

RELATION: Institution_ID $\rightarrow$ Institutions (Institution_ID).

The other tables, Research Units, Outputs, and SDGs, were structured accordingly. More importantly, the relationships between these tables allow users to identify projects and institutions with potential thematic overlaps, facilitating more targeted searches. The following sections provide a detailed overview:

Association Table 'Project-SDGs'

Since a project can contribute to multiple SDGs, we used an association table to represent this relationship. Below is the pseudocode of the Projects–SDGs Association table:

TABLE Project_SDGs:

- Project_ID: Project reference.

- SDG_ID: Reference to SDG.

RELATION:

Project_ID $\rightarrow$ Projects(Project_ID).

SDG_ID $\rightarrow$ SDGs(SDG_ID).

Association Table 'Projects_Researchers'

A project can involve multiple researchers, and a researcher can participate in multiple projects. To handle this many-to-many relationship, we used an association table. Below is the pseudocode of the table Projects–Researchers Association:

TABLE Projects_Researchers:

- Project_ID: Project reference.

- Researcher_ID: Reference to the researcher.

RELATION:

Project_ID $\rightarrow$ Projects(Project_ID).

Researcher_ID $\rightarrow$ Researchers(Researcher_ID).

Below, we report the main relationships and interactions between tables (Figure 1):

- Projects and Institutions: Each project has a coordinating institution.
- Projects and Researchers: Researchers participate in multiple projects, and a project can have multiple researchers.
- Projects and Outputs: Each project produces one or more outputs.
- Projects and SDGs: A project can contribute to multiple SDGs, and the same SDG can be associated with multiple projects.

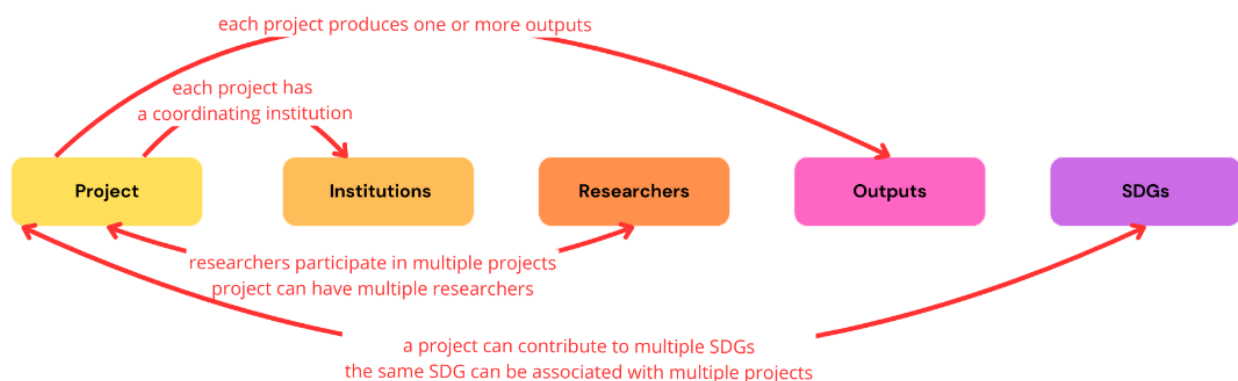


Figure 1. The main relationships and interactions between the database tables.

The SDG-SGP uses a Geographic Content Management System (Geo-CMS) developed entirely with open-source software under the General Public License Version 2.0. This approach allows the information contained in the research database to be made accessible,

highlighting active collaborations both within the regional territory and with external entities. The platform was designed to collect and organize, in a structured and usable way, documentation related to the themes of the SDGs, thus facilitating the sharing and use of knowledge on a territorial and thematic scale.

The basic components, derived from open-source communities, are represented by

1. **Autonomy:** As the back end allows for completely autonomous management of geo-referenced data through an administration interface accessible from the web and therefore from any location where there is an internet connection;
2. **Versatility:** The mapping engine allows you to manipulate complex data from various sources, such as MySQL databases, Postgres, GeoJSON files, CSV, etc., with a wide choice of functions;
3. **Scalability:** The ability of a system to increase or decrease in scale depending on needs and availability of resources;
4. **Locator:** Detailed features relating to the contents;
5. **OpenData:** Through the exclusive use of data from different communities of developers and actors.

The GIS and WebGIS functionalities were implemented through the design and creation of interfaces based mainly on JavaScript libraries capable of developing fully responsive and interactive geographic maps supported by most browsers and HTML5 and CSS3 standards. OGC standards for the exchange of WMS, WFS, and WCS data have also been implemented [52], through the geoserver application [53].

This work also involved the creation of thematic maps in digital format, developed using themes derived from specific project data, existing information systems, and sources such as OpenLayers [54]. Each map was created using distinct layers, configured to represent targeted geospatial information on various topics (e.g., environmental, socio-economic data). Subsequently, an interactive HTML page for managing and viewing maps was designed, integrating advanced filtering options, such as selecting specific SDGs, partners, or geographic regions, that allow the user to view single or combined thematic maps. At the backend level, server resources were optimized through caching and resource compression, reducing loading times and improving rendering efficiency. The system was finalized to offer efficient memory management and distributed load, ensuring fast navigation even on large geospatial databases.

To represent the geographical distribution of institutions, we developed a mapping approach based on the Hub Map model. This method enables the clustering of geographic data related to institutional headquarters, facilitating the identification of spatial patterns and relationships. The creation of clustered geographic maps, carried out through QGIS version 3.28 [55], requires various technical steps, from data import to clustered visualization. First of all, it was necessary to import the dataset, containing the geographic coordinates and attributes to be clustered, in GeoJSON format [56]. Next, a clustering tool, such as K-means, was used using the Leaflet.markercluster library [57], available in the QGIS toolbox in the qgis2web plugin [58], to segment data into homogeneous groups based on distances. The distance radius used to cluster markers is configurable, allowing the customization of the clustering granularity level based on the map zoom or geographic extent of the study area.

Once clustering is performed, users can visualize the results on a map. QGIS allows us to apply different symbols for each group through categorized symbolization, which associates a specific colour to each cluster, making it easier to identify groups. To further improve the readability of the map, labels, colour gradients, and background layers, such as satellite images or raster layers, can be added to contextualize the spatial distribution of the clusters. The final output is a thematic map that highlights the environmental or

anthropogenic characteristics of the territory, supporting advanced spatial analysis and informed decisions on environmental management.

Further implemented features are related to the introduction of a search box for the contents present in the dataset which, once filtered, were made clickable, and the fit-to-extend functionality makes it possible to centre the map on the area of interest for the selected SDGs.

All features were developed using existing JavaScript libraries, integrated with custom code. This approach improved interoperability between libraries while ensuring optimal support for most browsers and full compatibility with HTML5 and CSS3 standards.

The SDG-SGP was integrated into a framework produced by the voluntary and collaborative Joomla! Community [59], whose main features are (1) user-friendly backend interface to manage all aspects and functions of a website; (2) compliance with the best security standards; (3) options to allow indexing on search engines, from URLs to metatags; and (4) presence of over 8000 extensions between components, modules, and plugins to extend the functionality. The chosen theme is based on T3 framework [60].

Other advanced technological tools for the management and analysis of a large legislative database were implemented to link each law to specific Sustainable Development Goals (SDGs) and related targets. To achieve this goal, tools such as JooDatabase [61] and Plotalot [62] were adopted and integrated into a system based on the Joomla platform, which guaranteed flexibility, customization, and scalability.

JooDatabase played a central role in data management, allowing us to effectively import, organize, and display information related to the analyzed laws. This tool allowed us to extend the structure of the ARAP database in a detailed and easy-to-consult way, through which it was possible to associate each law with one or more specific objectives and targets. JooDatabase's intuitive interface enabled in-depth data search and analysis, giving users the ability to explore complex information quickly and easily.

As for the graphical representation of the results, Plotalot was used, an extension dedicated to the creation of interactive graphs and diagrams. Thanks to this tool, it was possible to visually represent the assignment of objectives to SDGs and targets, facilitating the understanding of the relationships between the different components of the database. The generated graphs highlighted the aggregation of the data, clearly showing the distribution of the laws with respect to the sustainable development targets and providing a synthetic and immediate vision of the results obtained.

3.1. Methodological Approach

The methodological framework adopted for the development of the SDG-SGP was structured around a combination of database management, geospatial analysis, and system validation techniques following a three-step approach:

- (1) Data collection and structuring: The system was designed to integrate structured environmental research data within a relational database, ensuring consistency and interoperability;
- (2) Data processing and integration: The collected information was systematically processed through the Geo-CMS, which dynamically retrieves, analyzes, and visualizes data ensuring real-time accessibility;
- (3) Validation and system effectiveness assessment: A multi-level validation approach was applied, involving data consistency checks, expert validation, and real-world case studies to assess system performance and usability.

3.2. Validation Methodology

To ensure the effectiveness and reliability of the SDG-SGP and the ARAP database, we implemented a structured validation process consisting of the following:

- (1) Database consistency checks: Automated SQL queries and integrity constraints (e.g., foreign keys, triggers) were applied to verify data coherence and prevent redundancy;
- (2) Comparative analysis with existing repositories: The database content was cross-checked with other environmental data repositories to assess its completeness and accuracy;
- (3) User testing and feedback: The system was tested in real-world scenarios, particularly in monitoring regional environmental projects related to SDG 6 (water resource management), SDG 13 (climate change mitigation), and SDG 15 (ecosystem protection), confirming the platform's ability to geolocate, categorize, and interconnect research initiatives effectively.

Below, we report in Figure 2 the entire operational workflow for reasons of synthesis and understanding.

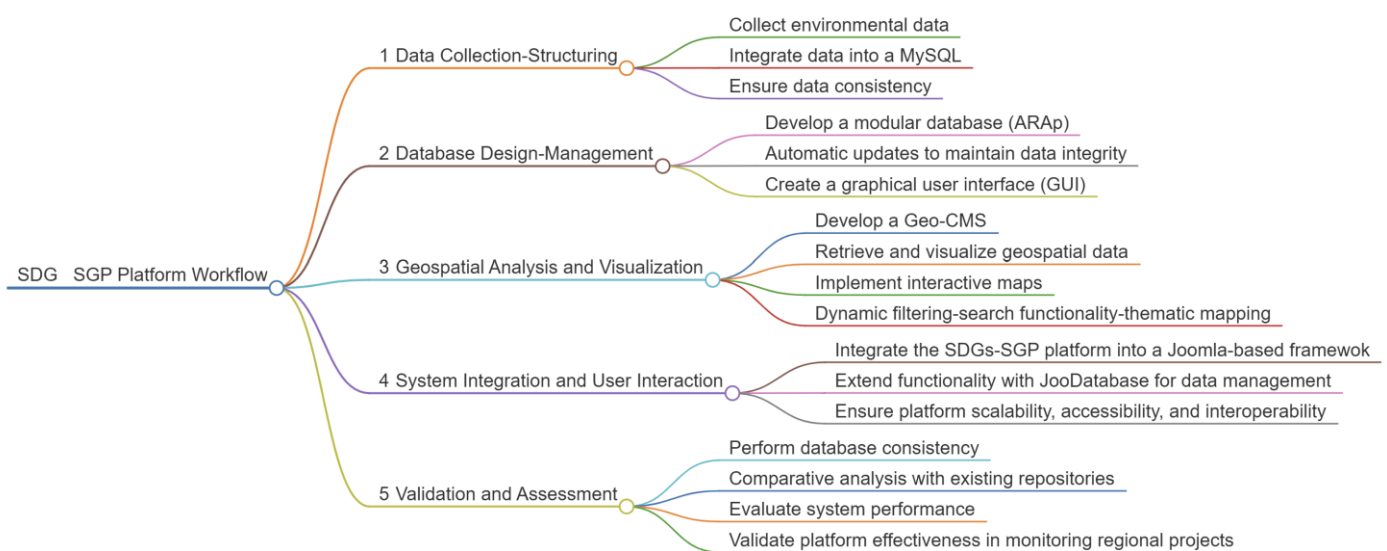


Figure 2. The entire operational workflow.

4. Results

In general terms, the aim was to create a collection, restitution, and research tool aimed at deepening and systematizing information on collaborative study activities and good practices conducted in the regional territory and oriented (categorized) towards sustainable development objectives.

In this context, the SDG-SGP and the Environmental Research Registry (ARAP) serve as invaluable tools, enabling companies to apply key research findings effectively. Simultaneously, they support universities and research institutions by fostering the advancement of ongoing studies while minimizing duplication and redundancy.

The SDG-SGP is configured as a dynamic element for the concrete implementation of the “European Research Area” and to give a local dimension to research policies, as well as representing a further tool to support the regional development of research, as it

- Provides a clear and accessible definition of research outcomes in the environmental field, enabling swift and straightforward utilization by a broader audience. This approach indirectly fosters the dissemination and enhancement of the scientific heritage of universities and research centres in the Puglia Region, contributing to greater visibility and impact in the environmental sector;

- Allows us to highlight and interrelate research projects and studies that, activated on the same themes in different centres, can develop synergistic or complementary relationships, favouring the verification of the disciplinary areas in which in-depth efforts are necessary both on a methodological and content level;
- Provides visibility to researchers and research structures in order to promote the exchange and valorisation of the know-how present in the regional territory;
- Allows us to ascertain the coherence of the research themes with the policies and initiatives of the European Structural Funds;
- Promotes users' interest in science and research, the value of research as a tool for quality of life;
- Considers the strategic value of research as a competitive advantage of the knowledge society;
- Highlights the importance of research on new knowledge methodologies and their diffusion.

On the technological–informational level, the SDG-SGP also allows for the direct and updated management of data relating to research activities carried out in the environmental sector. To date, the SDG database contains over 120 projects belonging to 16 coordinators for a total of 74 partners. All SDGs are mapped with at least one project activity. The creation of the Hub Map allowed us to obtain an immediate and graphical visualization of the existing connections between partners and coordinators who took part in this research (Figure 3). Other fully responsive and interactive geographic maps, compatible with most modern browsers and built using HTML5 and CSS3 standards, are presented in Figure 4.

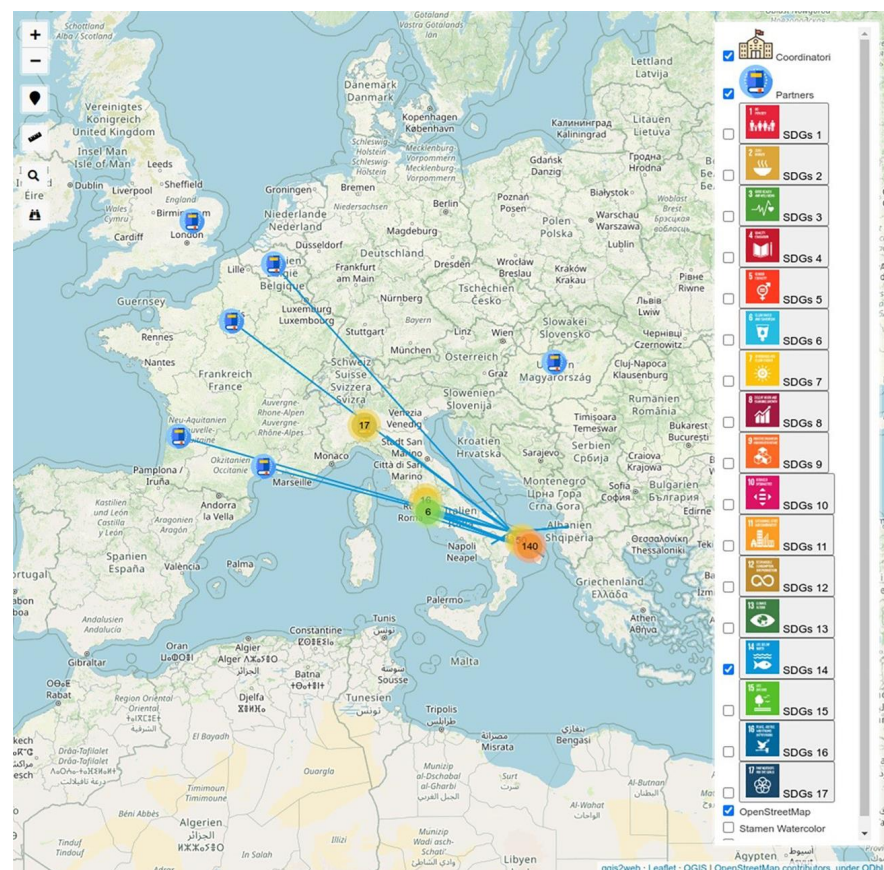


Figure 3. SDG-SGP screenshot of the Hub Map for SDG 14. The dots represent the locations of project partners, clustered by proximity; colored lines show connections between them, corresponding to the SDGs they address.

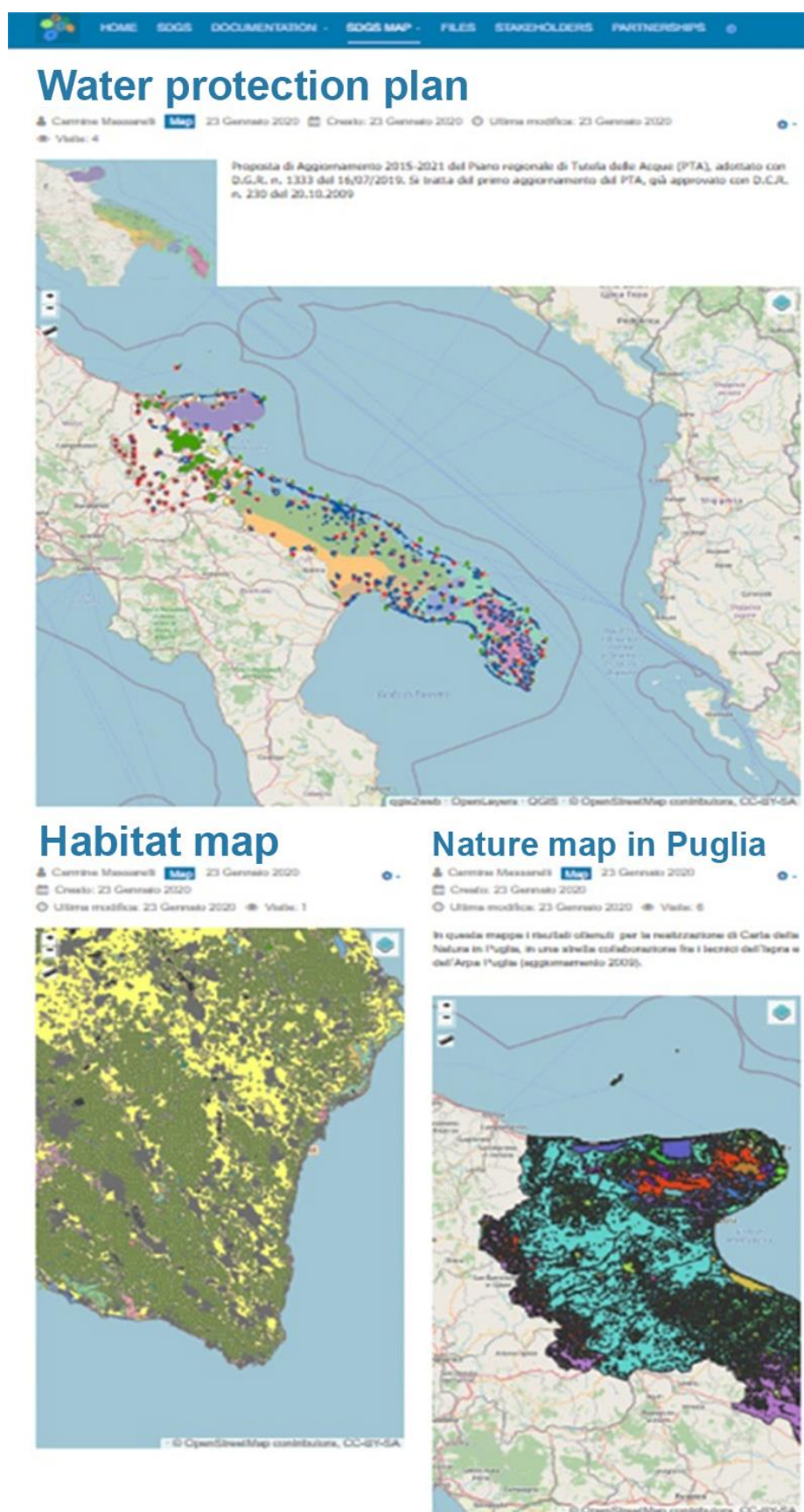


Figure 4. Example of other fully responsive and interactive geographic maps created.

The analysis of the frequencies of projects associated with the primary and secondary SDGs highlights a significant picture of the environmental priorities and the strategies adopted to address them.

SDG 15 (Life on Land) is particularly central, with 42 projects as a primary goal and 25 as a secondary goal. This reflects a priority focus on the sustainable management of terrestrial ecosystems, such as forests, soils, and biodiversity, which are essential to mitigate climate change and support environmental resilience.

SDG 14 (Life Below Water), with 30 projects as a primary objective and 21 as a secondary, reveals a strong interest in protecting marine and coastal ecosystems, which are essential for biodiversity and the livelihoods of many communities. This indicates a growing awareness of the urgency of preserving aquatic habitats, often threatened by pollution and unsustainable fishing.

SDG 6 (Clean Water and Sanitation), with 26 projects as its primary target, highlights the need to ensure equitable and sustainable access to water resources. This is particularly relevant in the context of increasing pressure on water resources due to urbanization and climate change.

Among the secondary SDGs, SDG 13 (Climate Action) also stands out, with 18 projects, demonstrating the growing commitment to adopting mitigation and adaptation strategies to climate change.

These frequencies show a strong interconnection between the objectives, suggesting that many projects address complex environmental issues in an integrated and multidisciplinary approach. For example, a project focusing on SDG 14 as a primary goal can also contribute to SDG 15 as a secondary goal, reflecting the close relationship between the health of marine and terrestrial ecosystems. This synergistic approach is essential to address global environmental challenges and ensure long-term sustainable development.

In a specific section, it is possible to consult a sample of Apulia Regional Laws classified according to their consistency with the SDGs. The implementation of this technological infrastructure has produced significant results. Researchers from the Department of Law, University of Bari, analyzed over 1100 laws (issued in the period 1974–2019), attributing a total of 1800 specific objectives and targets. This work allowed us to automatically aggregate the data according to relevant criteria, such as the frequency of assignment to specific SDGs (Figure 5a) and the correlation between targets (Figure 5b). These analyses have allowed us to identify the areas of greatest political and legislative attention, offering a concrete basis for further investigations and strategic decisions.

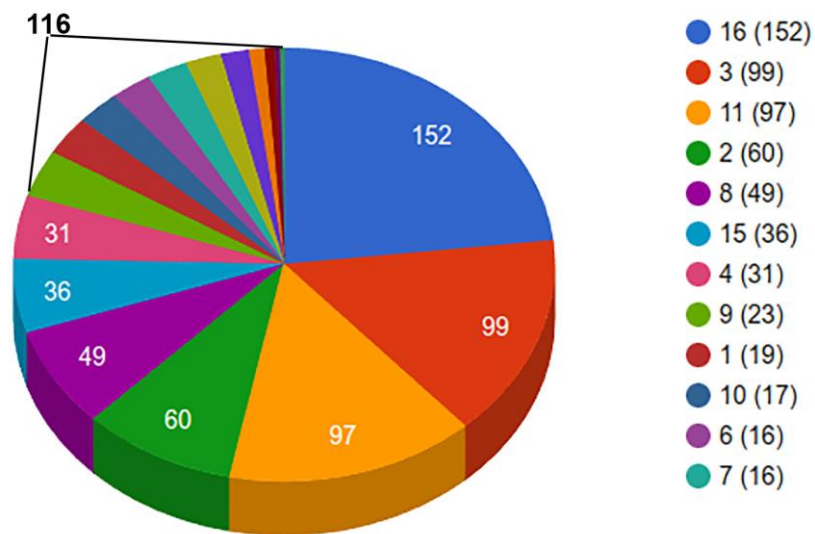
The analysis of laws and targets associated with the Sustainable Development Goals (SDGs) highlights regulatory commitment in various priority areas consistent with the 2030 Agenda. The 152 laws related to SDG 16 (Peace, Justice, and Strong Institutions) reflect a significant push towards strengthening transparent, just, and accountable institutions, which are essential for social cohesion and sustainable development. In parallel, the 99 laws associated with SDG 3 (Health and Well-being) indicate the importance given to improving the quality of life and equitable access to health services.

Regarding SDG 11 (Sustainable Cities and Communities), the 97 laws highlight the focus on more inclusive, safe, and resilient urban management, a crucial aspect given increasing urbanization and the challenges associated with climate change.

From a target perspective, the presence of 126 combined references to SDG 16 and 6 (Clean Water and Sanitation) highlights a synergy between the need to ensure equitable access to water resources and that of building institutions that can support the sustainable management of these resources. The 47 targets linked to SDGs 3 and 8 (Decent Work and Economic Growth) highlight the importance of a balance between public health and sustainable economic development. The 29 targets shared between SDG 11 and 3 reflect

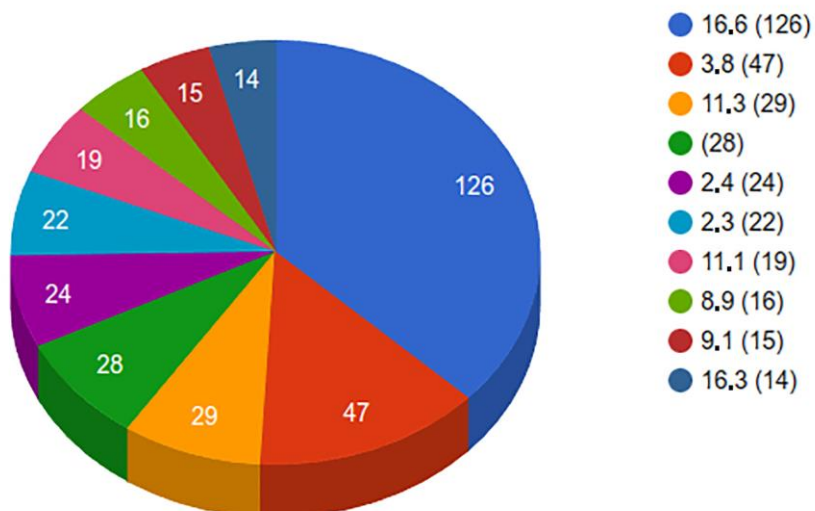
the link between well-being and the quality of urban environments, underlining the need for integrated policies for more liveable cities.

Puglia Region law catalog: Aggregated data by SDGs



(a)

Puglia Region law catalog: Aggregated data by Targets



(b)

Figure 5. Aggregated data illustrating (a) the association between laws and SDGs and (b) the correlation between specific targets.

These data demonstrate the crucial role of regulations in guiding the implementation of the SDGs but also highlight the importance of a synergistic and coordinated approach between objectives. The 2030 Agenda calls for a holistic vision, in which progress in one sector supports and strengthens progress in others, to ensure truly sustainable development.

The developed system has proven to be a valuable tool to support political decisions and plan sustainable strategies. The possibility of updating and enriching the database in real time guarantees the continuous topicality of the information, while the accessibility and interactivity of the visualizations allow it to involve a wide audience, even outside

the scientific community. This integrated approach has made the project a key tool for understanding and promoting progress towards the Sustainable Development Goals.

5. Discussion

The developed tool represents a significant innovation for the development of evidence-based policies. One of its main features is the ability to categorize projects, such as those funded at the European level, based on their coherence with one or more Sustainable Development Goals (SDGs). For example, a project aimed at sustainable water management could be associated with SDGs 6 (Clean Water and Sanitation) and 13 (Climate Actions), with the indication of the related territorial partnerships. This type of categorization, already tested with the initial dataset seeding of the platform, allows for the immediate visualization of existing collaboration networks, offering useful indications for planning new initiatives.

The SDG-SGP is a strategic tool for both public decision-makers and researchers. For the public decision-maker, it is a valuable information support, useful for selecting priority interventions, monitoring their progress and evaluating the results with respect to the SDGs. For the researcher, it is a resource that facilitates the identification of relevant areas of study and the connection with other institutions engaged in similar projects. For example, a map showing territorial initiatives related to reducing plastic use (SDG 12) can reveal clusters of projects in specific areas, highlighting any synergies or gaps. Thanks to this technology, it is possible not only to geolocalize initiatives and partnerships but also to create interactive maps. These tools make information easily accessible not only for experts but also for citizens, increasing transparency and public involvement. For example, the interactive maps could allow users to explore active projects in a specific region, filtering them by SDGs, targets, or year of launch. Another practical example could be the creation of maps that overlay CO₂ emissions data onto reforestation projects, to assess the environmental impact of ongoing initiatives.

The SDG-SGP is integrated with Open Data portals, which allow transparent data sharing. This approach promotes collaboration between public and private entities, reducing duplication and encouraging synergy. A concrete example is given by platforms such as that of the European Environment Agency, which aggregates data and indicators from all Member States, offering an effective model for transnational cooperation.

One of the key challenges in developing the SDG-SGP lies in ensuring data integration and interoperability across multiple sources. Given the heterogeneous nature of environmental, legislative, and research data, issues such as data quality, consistency, and standardization must be carefully addressed. The platform aggregates information from various stakeholders, including regional institutions, universities, and research centres, each of which may use different formats, classification systems, and levels of detail.

To tackle these issues, automated validation procedures have been implemented to detect missing, duplicated, or inconsistent data. Additionally, metadata standards, such as INSPIRE guidelines for spatial data and Dublin Core for metadata management, have been adopted to ensure semantic compatibility.

For the platform to be effective, it must be accessible and user-friendly for diverse stakeholders, including policymakers, researchers, and the general public. The SDG-SGP features a graphical user interface (GUI) designed to facilitate data exploration and visualization, with interactive maps and relational graphs. To enhance usability, a multi-tiered access system has been implemented, allowing different levels of interaction depending on user expertise. Moreover, a set of tutorials and user guides has been developed to support onboarding and training.

5.1. Prospects

The approach developed in collaboration with the Department of Law of the University of Bari was based on an experiment that involved the entire corpus of over 1500 regional laws of Puglia issued between 1970 and 2019. The text of the laws was analyzed with the expert contribution of a team of jurists, identifying the reference objectives to evaluate the possibility of reinterpreting provisions, even those before the 2030 Agenda, in light of the SDGs.

This action allows, among other things, us to verify how the sensitivity of the decision-maker changes over time with respect to the themes that, since 2015, have been incorporated into the 2030 Agenda.

Today, the European Commission Research Centre (JRC) is working on fully automated tools that facilitate this type of processing, but it is necessary to compare a massive analysis based on “expert judgement”. At the moment, this comparison is not possible because the tool developed by the JRC allows analysis only on English-language documents (<https://knowsdgs.jrc.ec.europa.eu/>, accessed on 1 December 2024). However, it would be an interesting activity, considering that, to our knowledge, there are no manual analyses extended to several documents comparable to those examined in the activity conducted in Puglia.

The activities reported, started in 2018 and still ongoing, aim to develop a method to assess legislative proposals in advance against the SDGs. A practical example could be the analysis conducted by the Italian Alliance for Sustainable Development (ASviS), which, however, examines national budget laws only after their approval [63].

At its current application state, the platform focuses on three specific themes: the sustainable management of water resources (SDG 6), climate change (SDG 13), and the protection of natural ecosystems (SDG 15).

From a full-integration perspective, further applied research on the tool would find an interesting challenge in the definition of a possible cross-cutting categorization of projects on the region’s built heritage. Although it is formally addressed in the Agenda 2030 only with reference to the 11.4 and 8.9 targets, some recent studies delivered evidence of how the built heritage, and the built environment in general, have the peculiar and strategic ability to contribute to all 17 Sustainable Development Goals [64–67].

On the other hand, the case-study region’s built heritage, though including world-famous cultural sites such as Lecce (the city of Baroque) and UNESCO sites (e.g., Alberobello, Castel del Monte), distinguishes itself against a European scene dominated by a discrete number of ‘heritage cities’, in that it has a highly distributed character, with an unquantifiable wealth of ‘minor’ heritage assets scattered across the whole regional territory, whether urban or rural, often in a network-system mode. This diverse heritage has, over the years, attracted equally multifaceted attention from local, national, and international research communities through numerous collaborative projects, each offering architectural, social, or cultural interpretations.

Such application of the SDG-SGP to the region’s built environment would allow the formation of an articulated representation of relevant partnerships’ networks and thematic interrelation systems that could greatly enhance the positioning of Puglia in the national and European path towards SDGs as a showcase of manifold and variegated experiences and best practices useful for the whole of European cities, regions, and Member States. Besides supporting a useful multiscale perspective (single building, neighbourhood, urban, and territorial levels), this would, on one hand, go in the direction of the desired systemic consideration of all Sustainable Development Goals and, on the other hand, maximize the exchange of knowledge that is expected, and now more than ever necessary, for the SDGs’ implementation.

The scalability of the SDG-SGP is a crucial aspect of its broader applicability. While initially designed for the Puglia Region, the architecture allows for expansion to additional regions and even cross-national implementations. This will require the harmonization of taxonomies and classification systems across different administrative and legislative contexts. In the future, the integration of artificial intelligence (AI) and machine learning (ML) techniques will enhance the platform's ability to analyze complex data patterns and automatically generate insights on sustainable development trends.

A fundamental objective of the SDG-SGP is to support evidence-based policy making by providing real-time data and impact assessments on sustainable development initiatives. The classification and analysis of regional laws and policies have already highlighted significant alignment patterns between legislative priorities and SDG targets.

Future research will focus on conducting longitudinal studies to measure the effectiveness of policy interventions, integrating qualitative and quantitative impact assessments.

5.2. Limitations of This Study

Despite the significant potential of the SDG-SGP in supporting regional sustainability efforts, several limitations should be acknowledged.

The platform's effectiveness is dependent on the availability, completeness, and quality of data provided. Variability in data collection processes and differences in classification may introduce gaps or biases in the analysis, potentially affecting the accuracy. Addressing these issues requires data validation protocols to enhance reliability.

In addition, while the platform integrates automated mind-mapping and relationship-exploration features, their interpretability and accuracy rely on the robustness of the underlying algorithms. Current natural language processing (NLP) and clustering techniques may struggle with contextual nuances, particularly when analyzing legislative texts or complex environmental data.

We have also considered the scalability and adaptability of the platform to other regional, national, or international contexts. This aspect is a challenge related to data standardization, interoperability, and governance frameworks.

Last but not least, although the SDG-SGP aims to support evidence-based decision making, its actual impact on policy formulation and implementation requires further empirical validation. Longitudinal studies, policy impact assessments, and stakeholder engagement processes will be necessary to quantify the platform's contribution to sustainable development efforts and ensure its continued evolution as a strategic tool for governance and research.

6. Conclusions

The importance of acting at a regional level for the monitoring, dissemination, and advancement of proposals related to the Sustainable Development Goals established by the United Nations emerges clearly in the use of the Exhibitor tool. This innovative model, already conceived to support the 2030 Agenda, aims to consolidate the role of Puglia as an example of sustainability in the national and international context. The SDG-SGP is configured as a dynamic and constantly evolving platform, capable of generating automated mind maps to explore relationships between actors, problems, and solutions, and of expanding its database to include other regional and national realities, thus encouraging comparison and adoption of good practices.

The integration of advanced indicators will provide additional tools for monitoring and evaluating public policies, promoting a holistic and territorial approach to the SDGs. With integrated management and a long-term vision, the SDG-SGP represents a strategic resource for environmental monitoring, policy planning, and the

valorization of scientific heritage, strengthening the regional positioning on the path towards sustainable development.

The work presented here positively met the initial research questions, particularly through the validation phase. Capitalizing on the direct involvement of the Regional Administrative Institution, the platform can be fully integrated with the other existing instruments; the following phases will concern its adoption and incorporation into the administrative practice.

While the SDG-SGP offers valuable support for regional sustainability, certain limitations must be considered. Its effectiveness depends on the availability and reliability of data from institutional sources, which may result in gaps or inconsistencies. Furthermore, the automated mapping and relationship-exploration tools, though useful for knowledge dissemination, rely on algorithmic accuracy, which may require further refinement. Lastly, expanding the platform to other regions presents challenges in data standardization and interoperability, requiring targeted solutions to facilitate broader integration into global sustainability frameworks.

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