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AN OPEN DIGITAL ARCHIVE FOR THE INTEGRATION OF HETEROGENEOUS DATA FOR TOPOGRAPHICAL RESEARCH

1. Introduction: the Digital Groma platform

The project In.Res.Agri – Investigating Resilient Roman Agricultural Landscapes in Southern Italy, funded under the PRIN 2022 program[1], involves the integrated use of traditional and innovative methods for the documentation, interpretation, and dissemination of archaeological and topographic information related to Roman land division in Southern Italy, based on selected case studies located in Campania and Puglia (Brancato *et al.* 2024). To support data collection, organization, and analysis activities within the project, a dedicated IT platform has been developed, named Digital Groma. This platform consists of three modules: a database with its open repository – composing the In.Res.Agri digital archive – and a geodatabase. This article aims to describe the approaches which guided the CNR-ISPC research unit in the modeling of the archive as a tool capable to integrate a whole range of heterogeneous data coming from different types of sources – topographical, archaeological, environmental and textual – and designed according to FAIR principles.

I.R.

2. The In.Res.Agri archive

2.1 *The applications – with a view to FAIRness*

The In.Res.Agri archive is built on a relational database designed for the recording, manipulation, and integration of both new and legacy data concerning archaeo-topographical research. The database builds upon an application, named Racoon, developed by the IT specialist V. Bellucci for archaeological databases, which has been customized to meet the project's specific requirements, both in terms of logical structure and table fields, and of data-entry and administrative functionalities. The application is based on a PostgreSQL relational database with the PostGIS extension, installed on a cloud server. This configuration is well established in the management of geospatial data, enabling direct upload of shapefiles and interoperability with the geodatabase (Guarnieri *et al.* 2016; Berzellini *et al.* 2024, 239-241)[2]. The

[1] Project code 2022SMJCHX. The project is coordinated by the University of Naples Federico II, in collaboration with the research units of the Institute of Heritage Science of the National Research Council (CNR-ISPC) and the University of Salento.

[2] The development of the geodatabase is under the responsibility of the research unit at the University of Naples. It will enable geospatial analysis and visualization.

web interface for data entry (https://digitalgroma.cnr.it/) was developed using PHP on the server side and JavaScript, HTML5, and CSS3 on the client side.

A public version of the archive has been also developed to enable the automatic publication of validated database records as static HTML pages, provided with a set of metadata tracking scientific responsibility, usage conditions, authorship and chronology of content, thus ensuring transparency and citability[3]. Although such public version was not a requirement of the project in this phase[4], it was deemed important to allow prompt accessibility to the project's archival data. Moreover, as an API endpoint was developed to ensure that the data collected could be reused by similar initiatives, associating each database record with a public URL allowed the necessary stable referencing for identification and linkability across machine-interoperable environments.

2.2 *A model for the integration of heterogeneous data*

The core of the In.Res.Agri informative system is concerned with topographical entities and the related archaeological features, including both movable and immovable monuments, as well as environmental and geomorphological features. These data primarily derive from the fieldwork conducted by the units involved in the project. However, a distinctive aspect of the project is the particular attention devoted to legacy data derived from pre-existing documentation, such as archival materials, and to the history of research available through previous publications, which often include a wide range of visual or, more broadly, multimedia content – especially maps and photographs, both aerial and satellite. Finally, textual information derived from epigraphic and literary sources was deemed essential for a complete reconstruction of the topographical landscape.

The implemented data model follows a relational structure organized around seven entities: Topographical Entity, Project, Archaeological Materials Table, Geomorphological Entity, Monument, Literary Source, and Archival Document (Fig. 1). Within this architecture, the Topographical Entity represents the central core and is responsible for collecting and organizing topographical information (Brancato 2020, 70-72). It maintains: recursive relations with itself, useful to represent possible connections and hierarchies among multiple topographical entities; many-to-many relations with the entities Monument, Literary Source, and Archival Document; a many-to-one

[3] Each record in the system is associated with an operational status (draft, private, public), defining its level of validation and visibility within the platform. An authentication system implements user profiling with differentiated roles (Admin, Read/Write, Read/Write Own Records, Read Only). This setup supports a workflow based on distributed responsibility, ensuring traceability, version control, and data integrity throughout the entire processing cycle.

[4] Contents will be publicly accessible and queryable through the geodatabase.

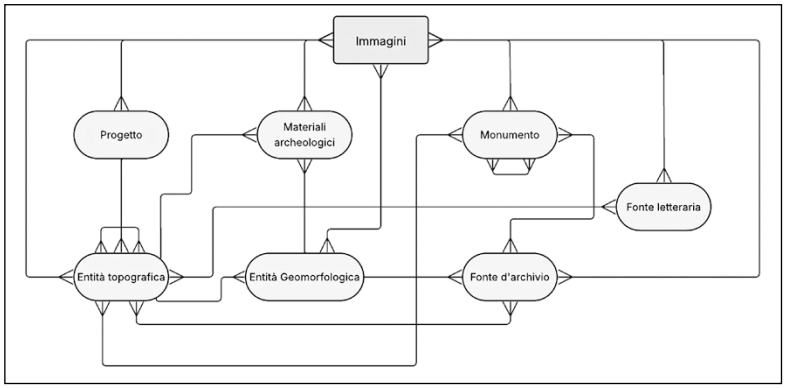

Fig. 1 – Model of the In.Res.Agri database.

relation with the Project entity; and one-to-many relations with the Archaeological Materials Table and Geomorphological Entity.

The Project entity is understood as the territorial reference unit within which field activities are organized – corresponding, in the context of the In.Res.Agri project, to the areas selected as case studies. Monument, Archival Document and Literary Source contribute to documenting the different interpretative dimensions of the Topographical Entity through material, archival and literary sources.

The Monument entity is conceived for the analytical characterization of both immovable and movable evidence; it includes a recursive relation useful for modelling hierarchical configurations among objects (for instance, the inclusion of an inscription on a wall within the relevant architectural unit).

The Archival Document entity, on the other hand, is devoted to integrating materials derived from previous research, including maps, drawings, written documents, as well as digitized or born-digital resources, not only in relation with Topographical Entities but also with Monuments and Geomorphological Entities.

One of the distinctive aspects of In.Res.Agri is its attention to the analysis of textual sources. For this reason, an autonomous Literary Source entity was defined to provide a structured description of textual attestations, following an information model consistent with the specific characteristics of this documentary typology. This results in a catalogue of sources related to Roman centuriation in the study areas. Textual sources which are not literary but epigraphic are described within the Monument entity (see *infra*).

The Archaeological Materials Table allows for the structured recording of material movable finds of a given Topographical Entity, while the Geomorphological Entity documents data obtained from coring carried out in

the relevant context. Both contribute to building an integrated and coherent interpretive and chronological framework of the associated Topographical Entity.

Within the relational database developed according to this model, the relationships among most entities are implemented through join tables, designed not only to formally link records but also to qualify semantically the nature of those relationships. Although the database does not formally adopt a semantic model, each join table is enriched with descriptive attributes that explicitly specify the type of relationship between connected entities. For instance, the recursive relationship between two Monument records can specify that an element classified as an 'inscription' *is included* within an 'architectural structure'. Further specifications of the relationships can be recorded as well: for instance, a Literary Source can be linked to a Topographical Entity by specifying as attributes of the join table the relevant toponym mentioned in the Source, where a citation of the textual passage containing the toponym appears. In this way, the system supports semantic traceability of connections, enhancing the integration of material and documentary evidence.

The system also includes bibliographic information and multimedia content. While technically treated as accessory components (see *infra*), they are fundamental from an informative perspective: the latter allows to integrate visual materials on monuments, archival documents, maps, aerial and satellite images, etc., while the former ensures to reference existing literature and trace the history of studies concerning a given territory.

I.R.

3. Selecting and organizing information

Since the outset, the project focused on designing a model able to address the diversity of the available information and bring it together within a coherent conceptual frame. Two were the principles guiding the organisation of information within the seven main record types described above: first, the effectiveness in the representation of the actual data produced and gathered by the In.Res.Agri project and the responsiveness to the project's research aims; second, the compliance with standards in view of interoperability – a commitment to ensuring that the dataset could be reused and extended within a broader research environment. The data were deliberately organised with the prospect of integration into the Geoportale Nazionale per l'Archeologia (GNA: https://gna.cultura.gov.it/; Calandra *et al.* 2021) and, wherever possible, aligned with the standards of the Istituto Centrale per il Catalogo e la Documentazione (ICCD, http://www.iccd.beniculturali.it/; Mancinelli 2018). To this aim, the adoption of controlled vocabularies has been a structural component of the data model, designed to guarantee descriptive

coherence, interoperability, and semantic quality. In total, 46 vocabularies have been integrated. A significant portion derives from nationally recognized repositories, such as those of the ICCD and the GNA, which together represent over three quarters of the total. To a lesser extent, vocabularies from the epigraphic domain were also included, notably from the Europeana Network of Ancient Greek and Latin Epigraphy (EAGLE) and the Epigraphic Database Roma (EDR). About one sixth of the vocabularies were newly developed by the project's research units in response to specific needs that emerged during the modelling process. Although the system is not formally based on an ontological model, the selection of vocabularies was guided by compatibility with existing information standards, making the model potentially alignable with infrastructures adopting semantic approaches.

3.1 *Project*

The Project table was developed to bring together the key information relating to the study area as a whole. For the In.Res.Agri project, this meant providing a concise framework for the selected case studies contributed by the various research units. The information is arranged into seven sections, grouped into three broad categories. The first category gathers general and administrative details, setting out the institutional and territorial framework of the project. The second one addresses methodological and technical aspects, describing the process of identifying study areas and the georeferencing methods applied. The third one presents descriptive and documentary information, ranging from the historical and archaeological overview to environmental and geomorphological features.

The structure closely follows the Modulo Progetto (MOPR) adopted by the GNA, which is used to record initiatives that have an impact on the territory (https://gna.cultura.gov.it/wiki/index.php/Compilare_il_MOPR). Nearly two-thirds of the fields of the relevant In.Res.Agri database table correspond directly to those defined in the MOPR, both in nomenclature and in the controlled vocabularies employed (see *infra*). At the same time, some modifications were introduced to the original specifications to better meet the research project's requirements (Fig. 2). These included the addition of fields, such as a numerical code assigned to the geometry of the study area to manage spatial information within the system[5], as well as fields allowing for the specification of the geometry type to represent geographical features and the coordinate reference system used, derived from the ICCD Modulo Sito/Area (MOSI) along with their associated vocabularies (https://iccd.beniculturali.it/getFile.php?id=9512). Other controlled vocabularies were

[5] It is comparable in function to the GEI code used in SIGECweb.

In.Res.Agri DB: Project entity		
Section	**Field**	**GNA MOPR / ICCD correspondence**
Identificazione		
	Codice progetto	GNA
	Ambito di applicazione	GNA (with vocab)
	Denominazione	GNA
	Modalità di individuazione	GNA (with vocab)
Localizzazione		
	Regione	GNA
	Provincia	GNA
	Comune	GNA
Georeferenziazione		
	Identificativo Geometria	
	Tipo di localizzazione	GNA (with vocab)
	Tipo di georeferenziazione	ICCD vocab
	Sistema di riferimento	ICCD vocab
	Tecnica di georeferenziazione	GNA (with vocab + new values)
	Grado di precisione del posizionamento	GNA (with vocab)
	Base cartografica di riferimento	GNA (with vocab + new values)
	Note al posizionamento	GNA
Opera in progetto		
	Categoria opera	GNA (with vocab)
	Fase di progetto	GNA (with vocab)
	Data della relazione archeologica	GNA
	Data della campagna di ricognizione	GNA
	Descrizione	GNA
Descrizione		
	Geomorfologia	GNA
	Caratteri ambientali storici	GNA
	Caratteri ambientali attuali	GNA
	Sintesi storico archeologica	GNA
	Note	GNA
Riferimenti		
- Bibliografia		
	Id record in Zotero	
	Riferimento	
- Risorsa esterna		
	URL	
Certificazione e gestione dei dati		
	Responsabili della redazione della scheda	GNA
	Responsabili del progetto e contenuti	GNA
	Data di redazione della scheda	

Fig. 2 – The Project table and its correspondences with the GNA 'MOPR' module and ICCD vocabularies.

also expanded to include additional georeferencing techniques and types of cartography employed, which are not provided in the MOPR module but reflect the operational practices adopted by the research units[6].

3.2 *Topographical Entity*

The Topographical Entity table was conceived to organise contextual information. It arranges data across thematic sections, covering the location and georeferencing of evidence, the methods applied to identify them, and their nature, all framed within their chronological setting (Fig. 3). Its design draws on the MOSI module of the GNA. Much of the architecture of MOSI is retained – over two-thirds of the fields correspond directly – yet the schema was not applied rigidly and was adapted and extended to address the specific

[6] The additional terms include georeferencing techniques such as 'Base rover, RTK, and TS', and reference cartographic bases such as 'Tavoletta IGM'.

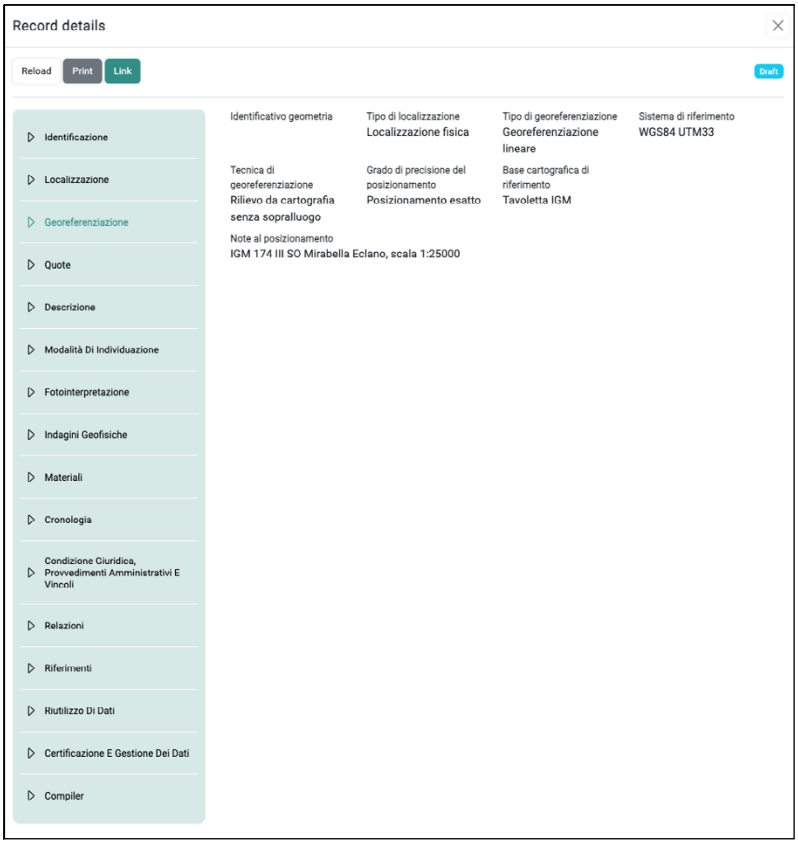

Fig. 3 – Example of a Topographical Entity record (Località Baricella) showing georeferencing information.

needs of the project. The photointerpretation section illustrates this balance between continuity and adaptation. The reliability field and its vocabulary were kept unchanged, while the existing field for type of image was preserved and its vocabulary broadened to better reflect the work in the field[7].

At the same time, new fields were introduced to record the type of traces and their visibility on the terrain, using vocabularies developed specifically for the project[8]. Other additions include a field recording the *Regio Antiqua*

[7] Values of 'Tipo di immagine' vocabulary: foto da drone, foto aerea, immagine satellitare.

[8] Values of the 'Tipologia di traccia' vocabulary: traccia da umidità, traccia da alterazione della composizione del terreno, traccia da anomalia, traccia da microrilievo, traccia da sopravvivenza, traccia da vegetazione; vocabulary of 'Situazione sul terreno' field: visibile, non visibile.

to which a site once belonged, with controlled terms taken from the corresponding field in the Epigraphic Database Roma (EDR, http://www.edr-edr.it/Download/EDR%20-%20Manuale%20v.1.pdf). Moreover, this table introduces a completely new section on geophysical surveys where it is possible to specify the methods applied by the research team.

3.3 *Archaeological material recovered during fieldwork*

This table was created to record the movable finds connected with the topographic entities investigated during the project. In shaping its structure, inspiration was drawn from two national standards: the Tabella Materiali Archeologici (TMA, version 3.0, https://iccd.beniculturali.it/getFile.php?id=207) and the Modulo per la Schedatura Preliminare dei Materiali Archeologici (https://iccd.cultura.gov.it/getFile.php?id=8936) developed by the ICCD. Both were originally designed to allow the rapid cataloguing of finds recovered during fieldwork, whether from surveys or excavations. From these models, a substantial set of fields was selected, to which a handful of additional ones were added in order to complete the framework.

The resulting table is organised into nine sections. These range from general and identifying information on the categories of material, to details of their location and discovery, chronology, and contextual information. A dedicated section is reserved for typological and quantitative description, designed to accommodate composite or complex collections.

3.4 *Geomorphological data*

As part of the In.Res.Agri project, selected areas were explored through pollen corings to identify indicators of past agricultural activity. A dedicated table was developed to document these interventions systematically. It records key information for each investigation, including location, elevation, depth, and geographic coordinates. A stratigraphy section enables each layer to be numbered and described in terms of relative elevation, thickness, and composition[9].

3.5 *Monuments (including inscriptions)*

The Monument table was developed to provide a detailed framework for describing monuments directly or indirectly associated with the topographic entities under study. Its design draws on a reasoned combination of three ICCD models: Monumenti Archeologici (MA, version 3.0, http://www.iccd.beniculturali.it/it/ricercanormative/38/ma-monumenti-archeologici-3_00),

[9] This table was specifically developed for this study by a group – coordinated by Prof. Elda Russo Ermolli – of the research unit of the University of Naples.

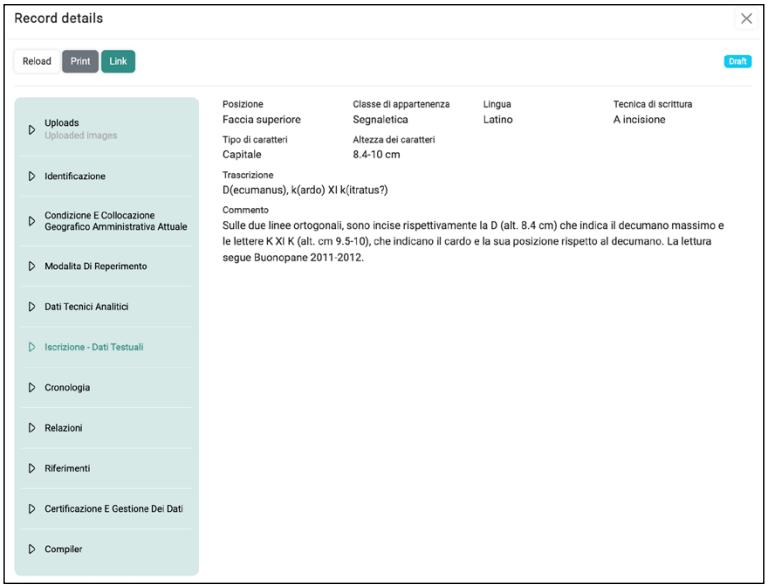

Fig. 4 – Example of a Monument record with inscription (Cippo RPAA-2010/11-326 = AE 2010, 00353).

Reperti Archeologici (RA, version 3.0, http://www.iccd.beniculturali.it/it/ricercanormative/4/ra-reperti-archeologici-3_00) and Beni Numismatici (NU, version 3.0, http://www.iccd.beniculturali.it/it/ricercanormative/18/nu-beni-numismatici-3_00). Information is organised into sections covering identification, location, circumstances of discovery, description of the monument, and chronological attribution. Terminology follows ICCD vocabularies wherever possible, complemented in some cases by other standards, such as the one provided by the Europeana Network of Ancient Greek and Latin Epigraphy (EAGLE) project for material classification (https://www.eagle-network.eu/resources/vocabularies/material/).

A particular focus is placed on epigraphic data, reflecting one of the broader aims of the In.Res.Agri project: to advance knowledge of Roman agrarian landscapes through an integrated approach that also includes literary and epigraphic sources. Inscriptions are recorded directly within the Monument, rather than as a separate entity, preserving their connection to the physical support (Fig. 4). This follows the ICCD RA model, which already includes a dedicated section for epigraphic information. Fields allow for the specification of inscription type, language, script, and text, and terminology in this section relies primarily on ICCD vocabularies, with additional terms introduced where necessary.

Fig. 5 – Example of a Literary source record (Cic., *De Lege Agraria*, II) with transcription of the relevant text passage.

3.6 *Literary sources*

In contrast to epigraphic data, which for their partly-material nature are described by means of the Monument table – a dedicated table was created for literary sources, with the aim of integrating ancient texts into the broader documentation framework of the project. It is organized into three principal sections, enabling the systematic recording of essential information for each work, including author, title, original language, and chronological framework. A dedicated field allows for the transcription of relevant textual passages, with particular attention to those containing toponymic references (Fig. 5). These references are systematically associated with the Topographic Entities, allowing textual evidence to be interpreted in relation to the geographical context under study.

3.7 *Archival sources*

Archival research constitutes a significant component of the project; accordingly, a dedicated table was developed to meet the specific requirements of documenting these sources. It is organised into sections for identification and general description, including fields for the type of support, the documentary unit, and chronological information. Particular attention is given to the archival location, with fields to record, for example, folder, file, and shelf, which enables precise tracing and referencing of the materials.

3.8 *Common features*

The tables share a number of structural features that strengthen the coherence of the overall modelling framework. For instance, a section for data

certification and management is systematically included, ensuring traceability, scientific accountability, and transparency in the process of compilation. Moreover, specific fields are provided for entering links to external digital resources matching the present record, thus allowing, for example, to associate the record describing an inscription with the relevant record in a specialized database such as EDR, or to connect a site to its corresponding entry in a gazetteer such as ToposText, Pleiades, or Geonames.

Bibliographical references are a key informative component of the archive; they are not recorded in an autonomous table but as attributes within each table, pointing to a widely-used external application, Zotero. Each publication retains complete metadata within the Zotero open library of the In.Res.Agri project (https://www.zotero.org/groups/5888666/in.res.agri) and is referenced in the database via its unique identifier given in the Zotero library. The effectiveness of this approach, chosen to facilitate data interoperability and reuse, was validated in previous experiences within the H2IOSC project (see *infra*), such as H-SeTIS (https://h-setis.cnr.it/; Scarpa, Valente 2024) and EpiHub (https://open-epihub.cnr.it/; Rossi, Salvador 2024).

Finally, the management of multimedia content, mainly images, is handled through a dedicated internal library; each file can be associated with one or more database records and described through a structured set of metadata documenting its content and context (Type, Year, Scale, Description), possible bibliographic references, and usage or reuse conditions (Rights, License).

G.B.

4. Final remarks

These final remarks focus on two key aspects of the information system described above: one looking back at automated cataloguing in Italy and its long-term observation by A&C, and a second focused on current perspectives in digital archaeology, which place data sharing and interoperability between systems at the core of research practices. The relational database created as part of the In.Res.Agri project, as noted, was designed in accordance with ICCD cataloguing standards, developed to ensure uniformity, coherence and interoperability among the different institutions involved in heritage management, through descriptive models, controlled vocabularies, and shared data structures. These standards are the result of a long and complex process, undertaken in the mid-1970s, aimed at progressively harmonizing documentation practices and establishing a common language for cataloguing Italian cultural heritage. Terminology played a central role in this process, being essential for achieving descriptive coherence and standardization, and leading to the establishment of controlled vocabularies and shared tools for semantic definition (Caravale 2022).

From its earliest stages, this process was designed as a comprehensive framework for knowledge, enabling each catalogued object to be placed within its historical, cultural, spatial, and temporal context, and in relation to other artefacts. From this perspective, cataloguing serves as an active interpretative tool, capable of reflecting the complexity of heritage objects and their relationships within broader systems of reference. A&C closely monitored ICCD's activities, documenting their progression over time, up to the most recent developments and the new opportunities offered by the Semantic web, with interoperability and data sharing playing an increasingly central role in the construction of archaeological knowledge (cf. e.g., Ferrari 1991; Papaldo, Ruggeri 1993; Mancinelli 2004; Mancinelli, Negri 2016; Moro *et al.* 2017). In this context, the In.Res.Agri database represents a recent example of the practical application of ICCD criteria in national projects, capable of managing multiple and heterogeneous cataloguing entities and providing effective tools to support the study and understanding of archaeological heritage.

Data sharing and resource interoperability have become fundamental principles for fostering truly collaborative knowledge, reflecting a research paradigm increasingly oriented toward cooperation among institutions, projects, and scientific communities. Within this framework, the In.Res.Agri digital archive was conceived in full compliance with established standards and with a strong emphasis on interoperability, aiming to facilitate its integration into broader research ecosystems, such as the GNA. At the same time, efforts are being made to connect the archive with one of the platforms developed by the CNR-ISPC research group Open Data, Open Knowledge, Open Science within the PNRR H2IOSC project (https://www.h2iosc.cnr.it/). More specifically, reference is made to the Open Digital Archaeology Hub (ArchaeoHub, https://open-archaeohub.cnr.it/), an advanced digital archaeology platform conceived as one of the pilot of Work Package 7 of the project (Caravale *et al.* 2025). Designed as an open and extensible environment, the system aggregates and interlinks metadata from collections of textual, visual, and bibliographic materials, digital archaeological projects, datasets, and interactive resources, providing access to information through a geographic interface. In its prototypical version, the platform has been populated with texts, bibliographic records, and images from A&C, as well as data from DHeLO (Digital Heritage Landscaping platfOrm; https://chloe.cnr.it/s/DHeLO/page/home), another H2IOSC digital product (Mancuso 2025). Following the recent TNA call (Trans-national and National Access to the H2IOSC RIs Cluster Services, July 2025), which promoted the advanced digital services developed within the PNRR project and aimed to gauge the level of interest among research communities, efforts are now underway to connect and integrate the datasets of ArchaeoHub and In.Res.Agri, advancing interoperability and promoting the coordinated use of the digital resources

produced. Moreover, some of the ArchaeoHub resources, particularly visual ones, have already been structured for harvesting by Europeana, the European digital library. This opens up broader perspectives for our project, which could benefit from integration into wider transnational infrastructures, further enhancing the visibility, accessibility, and reuse of its data within the European research landscape.

A.C.

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ABSTRACT

This paper presents the In.Res.Agri digital archive, developed within the PRIN 2022 project In.Res.Agri – Investigating Resilient Roman Agricultural Landscapes in Southern Italy. Conceived as part of the Digital Groma platform, the archive provides an open and FAIR-compliant environment for managing heterogeneous data related to topographical resources. Built on a PostgreSQL relational database, it integrates information from diverse sources – archaeological, geomorphological, textual, and archival – within a coherent data model structured around seven core entities. The system adopts national documentation standards to ensure semantic coherence, interoperability, and long-term sustainability.