

FAIRagro UC Submission Form (2nd Call)

1. UC – General information contact details

1.1. Title & Keywords

Title of the project	Unlocking Multifunctional Insights with Near-Surface Geophysical Data Harmonization in Agriculture
Short-Title / Acronym	MUFUDAT.agrio
Keywords <i>(min. 3, max. 5.)</i>	Near-surface geophysics, precision agriculture, cross-domain, harmonization, FAIR

1.2. Contact details

Main UC applicant's name (and role)	Ulrike Werban (PI, president of DGG)
Main UC applicant's Institution ¹	Helmholtz Zentrum für Umweltforschung - UFZ
FAIRagro (co-) applicant or participant	yes
Main UC applicant's E-Mail	ulrike.werban@ufz.de
Main UC applicant's ORCID <i>(optional)</i>	0000-0003-4700-5258
<i>Further persons involved from the main applicant's institution and their respective roles</i>	
UC-Co-applicant institution ¹ first name, last name, ORCID <i>(optional)</i>	UFZ, Claudia Schütze, 0000-0001-9562-8965
Additional associated partner ² first name, last name, ORCID <i>(optional)</i>	Till Sonnemann, 0000-0003-2632-7282 (Bonn Center for Digital Humanities, Rheinische Friedrich-Wilhelms-Universität Bonn)
Additional associated partners	Deutsche Geophysikalische Gesellschaft (DGG), NFDI4Objects, NFDI4Earth, Deutsche Bodenkundliche Gesellschaft (DBG),

1.3. UC format and duration

- ☐ UC Pilot: _____ months, expected start month/year:
☒ UC Project: 12 ____ months, expected start month/year: 01/2026

¹ All UC applicants and co-applicants must be part of the FAIRagro Plenary (Co-applicants or Participants) or become FAIRagro Participants in case they want to receive FAIRagro funding

² Associated partners who do not need to become FAIRagro participants are, however, excluded from receiving FAIRagro UC funding.

2. UC – Detailed description

2.1. Short UC summary (Abstract)

Near-surface geophysical methods are increasingly used in precision farming, providing rapid, cost-effective assessments of soil moisture, texture, and nutrient status. With advancements in sensor-based monitoring, AI-driven analysis, and automated machinery, the volume and complexity of agricultural data will continue to grow. However, these datasets hold value beyond agriculture, offering insights into archaeological features, soil processes, and environmental dynamics. A harmonized, cross-disciplinary framework will maximize their usability across scientific domains. The UC project “MUFUDAT.agrio” aims to enhance the usability of geophysical datasets obtained in precision farming through a structured workflow ensuring harmonization, quality assurance, and long-term accessibility. This workflow will address three key components: data acquisition, processing (including QA/QC), and archiving procedures. A dedicated agricultural pilot site will serve as a testbed and will also provide opportunities for archaeological prospection, allowing for the investigation of potential subsurface features. The project will implement Electromagnetic Induction (EMI), Gamma-Ray Spectroscopy (GRS), and optical spectroscopy as exemplary methods, demonstrating the structured workflow and refining data integration processes. By developing standardized metadata structures and controlled vocabularies, the project will create the basis to facilitate cross-disciplinary collaboration between agriculture, archaeology, and Earth System Sciences, promoting interoperability and long-term data usability. MUFUDAT.agrio forms the first phase of the broader “Multifunctional Data in a Multifunctional Landscape” initiative, a cross-consortium partnership between FAIRagro, NFDI4Objects and NFDI4Earth.

2.2. UC concept and objectives

Precision farming introduces a new level of high-resolution data collection, enabling detailed soil condition mapping and crop growth monitoring on farms based on e.g., geophysical methods, remote sensing techniques, and autonomous robots (among others). As technology advances, the volume, velocity and variety of data generated through precision farming is expected to grow significantly, driven by the increasing adoption of sensor-based monitoring, automated machinery, and AI-driven decision support systems. Farmers' motivation to adopt precision farming methods, despite the associated initial costs, is steadily rising (Webber et al., 2019). This trend is largely influenced by practical experience with the technology, the ability to integrate new systems into existing farm machinery, and growing confidence in the effectiveness of data-driven agricultural strategies.

Near-surface geophysical methods have become increasingly important tools in applied agricultural practices and studies (Garré et al., 2021). The great advantage of “agrogeophysical” methods is their potential rapidity, low cost, and spatial coverage and thus can easily be integrated in precision farming practices both in terms of prospection and monitoring. Agricultural geophysics investigations commonly focus on obtaining information concerning properties, conditions and related processes in soils, whose depths generally do not extend much beyond 2 meters beneath the ground surface. Covered areas can vary widely in scale, from experimental plots (several square meters), to farm fields (several hectares), up to the size of watersheds (several square kilometers).

Beyond their application in agriculture, the near-surface geophysical datasets generated in agricultural investigations often contain valuable information that extends far beyond precision farming and management decisions. These datasets can reveal subsurface anomalies indicative of archaeological remains, such as buried structures, former settlement areas, or ancient land-use modifications. Additionally, they provide critical insights into broader soil processes, including erosion patterns, hydrological dynamics, and long-term soil formation, which are highly relevant to environmental sciences and Earth system research. Consequently, the need for structured data management and standardization will become even more critical in the future. By structuring and archiving these datasets in a harmonized, cross-disciplinary framework, their usability can be maximized across multiple scientific domains. This will expand the research community and foster stronger interdisciplinary collaboration.

The main objective of the UC project is to maximize the usability across multiple scientific domains of near-surface geophysical prospection datasets obtained in precision farming based on the implementation of a structured workflow concept. This workflow will ensure harmonization, quality assurance, and long-term data accessibility, facilitating cross-disciplinary data integration in order to achieve multimodal datasets. The proposed **workflow consists of three key components**:

- 1) **Data Acquisition:** Establishing standardized protocols for data collection, ensuring consistency in sensors / instruments deployment, measurement procedures, and data formats. This phase focuses on raw data generation and the documentation with sufficient metadata in a structured manner to enable reproducibility and interoperability.
- 2) **Data Processing:** Implementing comprehensive documentation of quality assurance (QA) and quality control (QC) measures, including the transparent documentation of processing steps and validation procedures. This ensures that processed datasets and data products are traceable and meet high scientific standards.
- 3) **Data Archiving and Publication:** Defining best practices for metadata curation, data storage, and accessibility in metadata portals and open repositories. By aligning with FAIR principles, this phase enhances data discoverability, reusability, and long-term availability for applications beyond precision farming.

To establish such a workflow a detailed description of tasks is given in section 5. By integrating these workflow components, the project aims to create a harmonized data framework that supports multi-purpose usability, cross-domain collaboration, and scalable data-driven research (Werban et al., 2025).

Ensuring long-term and cross-discipline reusability requires comprehensive and well-structured metadata, which captures essential details on data acquisition, processing, and contextual factors. Hence, the definition and prioritization of metadata entries is a critical aspect in the development of proposed workflow. Based on previous studies (e.g. Ködel et al., 2022; Schütze & Dietrich, 2025), metadata can be categorized related to (1) observation and measurements, (2) sample and data history, (3) sensors and devices, (4) methods and processing, (5) environmental characteristics (spatial and temporal). Here, we identified different levels of importance: core metadata (essential and mandatory, including fundamental descriptors) and extended metadata (providing crucial contextual and methodological details enhancing the reusability of datasets beyond their original scope). A well-structured metadata framework must strike a balance between compulsory core metadata and additional metadata layers that facilitate comprehensive, cross-domain data integration. To support and enhance metadata provision, the use of controlled vocabularies is essential. These vocabularies ensure consistency, interoperability, and clarity across datasets. As part of this UC project, they will be developed, refined, and continuously updated through a curated process, ensuring their alignment with evolving research needs and cross-domain applicability.

The practical implementation of the UC project to demonstrate FAIR practices will be conducted using an agricultural pilot site, where all involved disciplines—agriculture, archaeology, and Earth System Sciences—can address their discipline-specific research questions. At the same time, the site will serve as a connecting platform for generating a harmonized, cross-disciplinary dataset, reusable beyond individual research domains. One potential site, an agricultural area with a size of approx. 30 ha, is selected in collaboration with the State Office for Heritage Management and Archaeology Saxony-Anhalt. The site under current consideration is of particular interest due to its location along the planned SuedOst Link DC power corridor in Saxony-Anhalt (section A2, municipality Kabelsketal) and the high potential for neolithic and medieval archaeological features, which require systematic mapping beyond agricultural research questions.

This controlled setting allows for systematic testing and refinement of standardized protocols while ensuring data quality and interoperability. The focus will be laid on geophysical methods that are widely applied in precision farming, particularly Electromagnetic Induction (EMI), Gamma-Ray Spectroscopy (GRS) and optical

spectroscopy (e.g., in the NIR range for plant stress and soil characterization), also by including multi-sensor platforms. These techniques provide rapid, high-resolution assessments of soil properties through proxy relationships. By implementing and evaluating the workflow at the pilot site, the project ensures practical applicability while building the foundation for scalable and cross-domain geophysical data integration. Additionally, the structured data generated through this approach will enhance the applicability of AI-driven models, enabling automated pattern recognition, adaptive learning, and predictive analytics for soil characterization and archaeological feature detection.

Multifunctional Data in a Multifunctional Landscape: Multi-Purpose Near-Surface Geophysical Prospecting

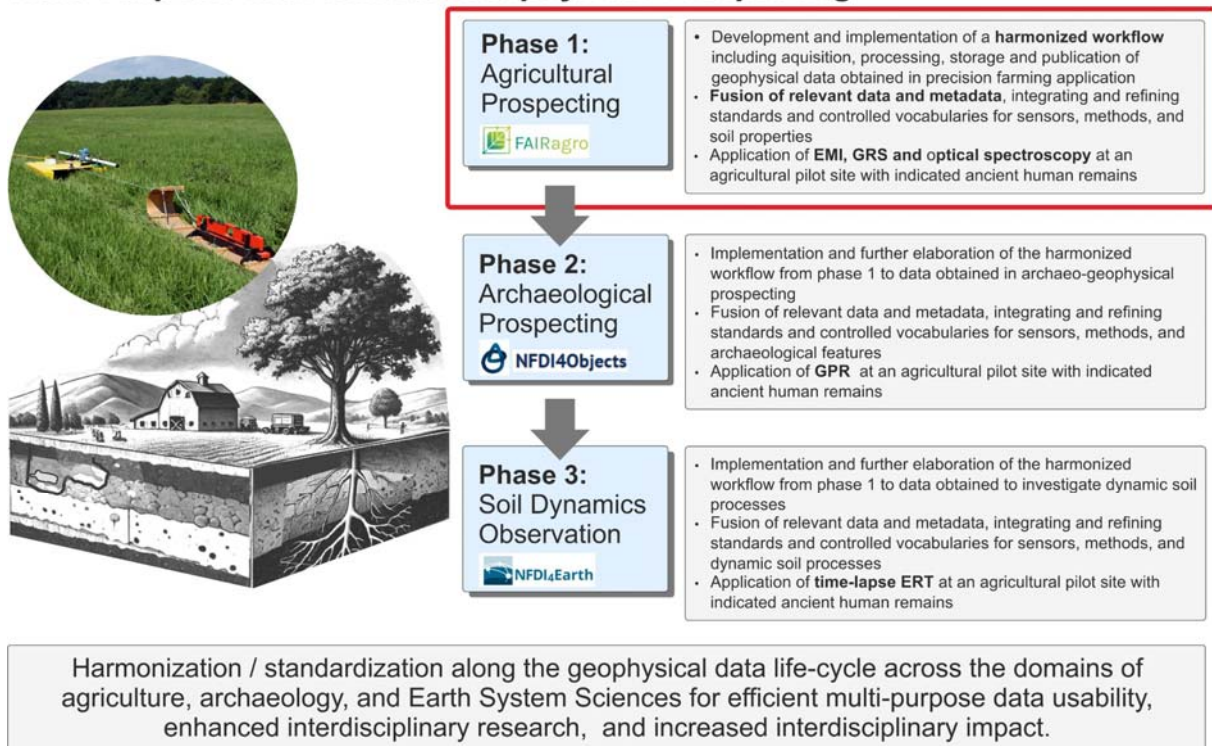


Fig.1: The UC project “MUFUDAT.agrio” is part of the overarching three-phases concept “**Multifunctional Data in a Multifunctional Landscape**” which is planned to combine the strengths of three NFDI-initiatives (FAIRagro, NFDI4Objects, NFDI4Earth). The overall objective of this approach is to harmonize the cross-domain generation of near-surface geophysical data, fostering data usability across broader user communities, interoperability, and long-term research data management impact (Werban et al., 2025). In the first phase covered by this proposal, the work focuses on the development and implementation of a structured data workflow, including data and metadata fusion, to enhance the cross-discipline reusability of geophysical datasets acquired in precision farming applications.

2.3. Added expertise, scientific background, and preliminary work

The Department Monitoring and Exploration Technologies at UFZ has particular expertise in near-surface geophysical methods enabling rapid, large-scale assessment of soil moisture and other soil properties. These methods are actively applied, validated and continuously refined for precision agriculture and digital soil mapping. The resulting datasets were FAIR-aligned processed, archived in public repositories, and often reused beyond the original scope, demonstrating their long-term value. There is an enhanced expertise in comprehensive FAIR data management based on work in initiatives like Helmholtz Metadata Collaboration, as a participant in NFDI4Earth and on the operation of large-scale research infrastructures (TERENO, MOSES). The UFZ is participant in NFDI4Objects and involved in the development of workflows for the processing, evaluation

and long-term storage of remote sensing data and geophysical sensor information in geoinformation systems based on FAIR principles (TRAIL 1.2).

Bonn University / Bonn Center for Digital Humanities (associated partner) is co-applicant of the NFDI4Objects consortium and also a partner in TRAIL 1.2.

- Dierke, C., **Werban, U.** (2013): Relationships between gamma-ray data and soil properties at an agricultural test site, *Geoderma* 199, 90 – 98
<https://doi.org/10.1016/j.geoderma.2012.10.017>
- Garré, S., Hyndman, D., Mary, B., **Werban, U.** (2021): Geophysics conquering new territories: The rise of “agrogeophysics”, *Vadose Zone J.* 20 (4), e20115 <https://doi.org/10.1002/vzj2.20115>
- Koedel, U., **Schuetze, C.**, Fischer, F.P., Bussmann, I., Sauer, P.K., Nixdorf, E., Kalbacher, T., Wiechert, V., Rechid, D., Bouwer, L.M., Dietrich, P. (2022): Challenges in the evaluation of observational data trustworthiness from a data producers viewpoint (FAIR+), *Front. Environ. Sci.* 9 , art. 772666
<https://doi.org/10.3389/fenvs.2021.772666>
- Krüger, J., Franko, U., Fank, J., Stelzl, E., Dietrich, P., Pohle, M., **Werban, U.** (2013): Linking geophysics and soil function modeling — an application study for biomass production, *Vadose Zone J.* 12 (4)
<https://doi.org/10.2136/vzj2013.01.0015>
- Pohle, M., **Werban, U.** (2024): Near surface geophysical data (Electromagnetic Induction and Electrical Resistivity Tomography) from the Loosbach valley at Pestenacker, a Late Neolithic wetland site, northern Alpine forelands, Germany [dataset publication series], PANGAEA
<https://doi.org/10.1594/PANGAEA.972418>
- Pohle, M.; Bauckholt, M.; **Werban, U.** (2025): Near surface geophysical data (Electromagnetic Induction and Electrical Resistivity Tomography) from the Ahr floodplain at Mayschoß, Germany [dataset publication series]. PANGAEA, <https://doi.pangaea.de/10.1594/PANGAEA.974990>
- Rentschler, T., **Werban, U.**, Ahner, M., Behrens, T., Gries, P., Scholten, T., Teuber, S., Schmidt, K. (2020): 3D mapping of soil organic carbon content and soil moisture with multiple geophysical sensors and machine learning, *Vadose Zone J.* 19 (1), e20062 <https://doi.org/10.1002/vzj2.20062>
- **Schütze, C.**, & Dietrich, P. (2025): Why is the reproducibility of data generation so important for geoscientists? Zenodo. <https://doi.org/10.5281/zenodo.14918261>
- **Sonnemann, T., Werban, U., & Schuetze, C.** (2024). NFDI4Objects - Survey Results on Data Management in Geophysical Prospecting in Archaeology. Zenodo. <https://doi.org/10.5281/zenodo.12793252>
- von Suchodoletz, H., Pohle, M., Khosravichenar, A., Ulrich, M., Hein, M., Tinapp, C., Schultz, J., Ballasus, H., Veit, U., Ettel, P., Werther, L., Zielhofer, C., **Werban, U.** (2022): The fluvial architecture of buried floodplain sediments of the Weiße Elster River (Germany) revealed by a novel method combination of drill cores with two-dimensional and spatially resolved geophysical measurements, *Earth Surf. Process. Landf.* 47 (4), 955 - 976 <https://doi.org/10.1002/esp.5296>

2.4. Involvement disciplines, institutions and cooperation with other initiatives/ projects

The UC project is embedded in an overarching three-phases concept “**Multifunctional Data in a Multifunctional Landscape**” which is planned to combine the strengths of three NFDI-initiatives: FAIRagro, NFDI4Objects, NFDI4Earth (Werban et al., 2025; see also appendix). UFZ plays a key role in all three initiatives as a participant, contributing its expertise in environmental research, data management, and geophysical methods. The overall objective of this approach is to harmonize the cross-domain generation of near-surface geophysical data, fostering data usability across broader user communities, interoperability, and long-term research data management impact. With the presented concept the authors identify key challenges in multi-purpose geophysical data usage and present a conceptual framework to address these obstacles effectively. Hence, the

targeted disciplines and research communities integrated in the Use Case are precision agriculture, near-surface geophysics, archaeology and Earth System Sciences. For that purpose several stakeholders and institutions will be involved with their specific roles, such as:

- NFDI4Objects (Task Area 1, Dr. Matthias Lang) - stakeholder, contribution of perspectives relevant for the archaeological community
- NFDI4Earth (Dr. Jan Bumberger) - stakeholder, contribution of perspectives relevant for the Earth System Sciences community
- Deutsche Geophysikalische Gesellschaft: AK Angewandte Geophysik (Dr. A. Schuck), AK Hydro- und Ingenieurgeophysik (PD Dr. Ernst Niederleithinger) - stakeholder, contribution concerning metadata and data standards in geophysics
- Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt (Dr. Susanne Friedrich) - stakeholder, contributions to find optimal pilot site with agricultural + archaeological features
- Deutsche Bodenkundliche Gesellschaft: AG Bodensensorik und Pedometrie (Dr. M. Möller) - stakeholder, contribution concerning metadata and data standards in soil sciences
- Leibniz-Institut für Agrartechnik und Bioökonomie e.V. (ATB) Bornim (Asim Khawaja, WetNetBB project) - stakeholder, contribution in terms of wetland agricultural aspects and FAIR data management plans
- FAIRagro Use Case 2 (ZALF et al.) - planned contribution and collaboration concerning cross-disciplinary usability of data products for model-validation
- FAIRagro Use Case 5 PhenoRob (FZ Jülich, Uni Bonn) - planned contribution and collaboration concerning sensor systems metadata and cross-disciplinary usability of data products

3. UC - RDM specifications and FAIRagro connection

3.1 UC inventory and specification of characteristics relevant for RDM

Category	Description: UC specification and examples
Disciplines	Agronomy, Soil science, Geophysics, Archaeology, Data Science and Artificial Intelligence
Scales (gene, plant, field, farm, landscape, region)	plot to landscape (small catchment)
Data domains (e.g. weather, soil, crop management)	near surface geophysical data, soil, yield information
Data types (e.g. tabular, images, gene sequences)	tabular, images, ...
File formats (open/ proprietary; e.g. xlsx, csv)	csv, json, xml, GeoTiff
Source data / database / repositories (proprietary/ public RDI/ FAIRagro RDI/ other; e.g. DWD, OpenAgrar)	UFZ data investigation portal, PANGAEA, BonaRes Repository
Processing workflows (concept/ prototype/ application/ ...)	concept, prototype and testing on pilot site use case
Tools/software (open/ proprietary; e.g. R, Python, QGIS)	Python, R, RDMO, QGIS, GitLab

The maturity of the UC can be described in respect to the technology readiness levels (TRL) as follows (see table below):

	Description: UC specification
TLR of UC today	- intra-disciplinary: TRL 3 (recommendations for structured data management in progress) - interdisciplinary: TRL 1 (no structured data management, no open and joint use of the data)
TRL of UC after completion of UC Project/ Pilot	- intra-disciplinary: TRL 5 (structured data management for different methods validated n at a demo field site) - interdisciplinary: TRL 3 (recommendations developed for structured data management)

3.2. RDM practices & FAIRness status quo

- UC will enhance the interoperability (I) and reusability (R) of near-surface geophysical data across disciplinary boundaries and develop reusable workflows facilitating comprehensive data integration across precision agricultural, archaeological and Earth System Sciences applications.
- Data acquisition, processing, and publication will follow a structured Data Management Plan (DMP); tools like RDMO are provided by the DMP4NFDI service.
- Newly derived datasets obtained at the pilot sites will be
 - published in FAIR and trusted data repository (e.g. PANGAEA)
 - with a unique and persistent identifier (e.g. DOI),
 - described with rich metadata and keywords tailored to the overarching cross-disciplinary needs,
 - using FAIR vocabularies or ontologies in a FAIR data repository.
- Datasets will address the FAIR principles F1, F2, I1, I2, R1, A1 and A2.
- Developed prototype tools will be made available as open-source on GitLab.

3.3 UC contributions and benefits

FAIRagro Connection through respective TAs and focal points	Synergies/ collaboration	Short explanation (in bullet points)
TA 1: Use Cases		
UC2 - Optimal crop nitrogen management	✓	synergies due to complementary benefit concerning cross-disciplinary usability of data products for model-validation
UC5 - Noninvasive phenotyping with robots	✓ ✓	contribution, synergies and collaboration concerning sensor systems metadata and cross-disciplinary usability of data products; developing cross-disciplinary multimodal datasets
TA 2: Community Involvement & Networking		
Communication and dissemination (e.g. content production and dissemination, organization of networking events such as workshops and conferences)	✓ ✓ ✓	support is required to network with agro-community and to present the UC results to stakeholders for successful implementation (M2.1)

Training and education (e.g. events, workshops, trainings, open educational resources)	✓✓✓	collaboration with existing training programs, providing of tailored training material, joint activities in specialized workshops (M2.4)
TA 3: Standardization, Interoperability & Quality		
Standards for data management	✓✓✓	collaboration concerning the available expertise in creation and development of an inventory of established (meta-)data standards, vocabularies and ontologies (support from M3.1)
Standards for Data Management, FAIRness and Discoverability	✓✓✓	collaboration and contribution based on UC developments in terms of common protocols and data management plans (M3.2)
Measures for data quality and fitness for use	✓✓✓	contribution and collaboration in terms of the establishment of standard criteria for data quality geophysical prospecting on the basis of our pilot datasets (M3.3)
Data quality annotation and curation	✓✓✓	utilization of the in M3.4 developed metrics and tools to annotate our pilot site data sets
FAIR workflows and FAIR Digital Objects	✓✓✓	utilization of the in M3.5 developed services and frameworks for describing research data workflows
TA 4: Services		
Central Service ('FAIRagro Portal')	✓✓✓	support through the FAIRagro Infrastructure services facilitating community engagement and capacity building; central services (e.g. RDMO) are required for implementation of UC tasks (M4.1)
Networked RDI	✓✓	support, collaboration and contribution for the implementation of best practises concerning FAIR and cross-disciplinary data publications (M4.2)
Scientific Workflow Infrastructure (SciWin)	✓✓	utilization of existing tools for a harmonized workflow generation (M4.4)
FAIRagro Task Area 5: Overarching activities		
Cross-NFDI networking	✓✓✓	support to ensure a seamless cross-consortia exchange between the involved initiatives is crucial for UC success in terms of the overall objective

3.4 UC requirements

For a successful implementation of the proposed UC, FAIRagro will play a crucial role in facilitating:

- support of a seamless cross-consortia work based on the overarching concept (in cooperation with TA5) including the provision of platforms for regular exchange and communication (in cooperation with TA2)
- support in gathering core and extended metadata entities and relevant standards that have to be considered (in cooperation with TA3)
- support in best practises for publication in cross-disciplinary relevant repositories and the findability in related metadata portals (in cooperation with TA4)

4. UC outcomes and outreach

4.1 Expected outcomes and impact

The UC will provide curated and quality-checked near-surface geophysical datasets with a comprehensive documentation for reanalyses and cross-disciplinary usability. With the practical implementation to demonstrate FAIR practices the UC will contribute to overcoming the four primary challenges of effective cross-domain geophysical data reuse identified by Werban et al. (2025).

Improved Data Discovery & Accessibility

- Establishment of FAIR-aligned workflows for data acquisition, processing, and publication.
- Integration of geophysical datasets into open-access repositories with standardized metadata.

Standardized Use of Public Repositories

- Development of best practices for repository use, aligning with existing infrastructures such as PANGAEA or NFDI metadata portals.
- Provision of guidelines for structured data archiving, ensuring consistency across repositories.

Harmonized Metadata Standards & Documentation

- Definition of a core and extended metadata model, integrating controlled vocabularies for sensors, methods, and soil processes.
- Development of training materials and workshops to support adoption of standardized metadata practices.

Enhanced Data Processing & Interoperability

- Implementation of standardized processing pipelines for geophysical methods such as EMI and GRS.
- Demonstration of multi-purpose data workflows at a pilot site, showcasing metadata fusion, quality control, and AI-ready data products.

Performance indicators to measure the UC success could be the number of data publications in FAIR-aligned repositories following the developed metadata model and the number of research studies relating to the UC results and datasets.

Since the overarching concept is structured across three NFDI initiatives (FAIRagro, NFDI4Objects, NFDI4Earth), there is a possibility that funding will be limited resulting in limited resources for full implementation. However, the here proposed UC will provide useful deliverables and a strategy concerning standardized data workflows and metadata models as well as FAIR-compliant datasets. This is giving guidance and insight for future near-surface geophysical applications beyond agriculture on how to enrich their metadata towards the generation of FAIR data products. Furthermore, there is a strong requirement to align the UC with existing and future projects to integrate findings in non-funded collaborations.

4.2 Outreach & community engagement

- UC results will demonstrate the added values of the distinct implementation of the FAIR principles across several disciplines and related communities.
- Based on the practical implementation at a pilot site, engagement with researchers and practitioners will take place in an interdisciplinary working group, inviting feedback and refinements.
- UC results including best practices for interdisciplinary data sharing will be presented in workshops and specialized conferences to the targeted communities.
- UC will provide training material on data and metadata handling for all involved NFDI consortia to contribute to a culture change towards FAIR and collaborative RDM.
- UC is planned to serve as the first step in a role model for future cross-disciplinary cooperation focused on data handling and re-usability approaches and is an initial application-related cornerstone towards "oneNFDI".
- The developed workflows, metadata standards, and best practices will serve as a sustainable foundation for FAIR RDM, ensuring long-term impact through their integration into repository infrastructures, interdisciplinary collaborations, and future geophysical data initiatives - even beyond the project duration.

5. Work plan

5.1. Actions (Work packages)

#	Action	Responsible Institution	Contributing institution/partner
1	Development of standardised protocols and DMPs compiling core and extended metadata for the considered methods EMI, GRS and optical spectroscopy including QA/QC standards and alignment with existing geophysical metadata models (consideration and adaptation of available discipline-related geophysical standards), covering: 1.1 Data acquisition 1.2 Data processing 1.3 Data publication and archiving	UFZ	Uni Bonn (BCDH) Deutsche Bodenkundliche Gesellschaft; Deutsche Geophysikalische Gesellschaft; NFDI4Earth, NFDI4Objects
2	2.1 Development and refinement of common controlled vocabularies through a curated process ensuring compatibility with existing metadata standards in geophysics, soil science, and archaeology concerning the application-related different metadata aspects: a) sensors and instruments, b) methods, c) data structure and content, d) data processing, and e) considered phenomena and processes. 2.2 Development of a metadata model including core and extended metadata entries (focus on a broad and cross-disciplinary applicability, ensuring interoperability with international metadata frameworks e.g., INSPIRE, ISO 19156, OGC).	UFZ	Uni Bonn (BCDH) Deutsche Bodenkundliche Gesellschaft; Deutsche Geophysikalische Gesellschaft; NFDI4Earth, NFDI4Objects
3	Demonstration of FAIR implementation at an agricultural pilot site with archaeological indication to obtain multi-purpose datasets for the methods EMI, GRS and optical spectroscopy including data curation and the implementation of automated metadata compilation streamlining data documentation.	UFZ	Uni Bonn (BCDH) Landesamt für Denkmalpflege und Archäologie SA
4	Outreach and capacity building 4.1 Best practices for archiving and data publication, interfaces to metadata portals and generation of machine-readable metadata to support AI-driven geophysical data applications. 4.2 Tailored workshops using dedicated training datasets obtained from the pilot site (including hands-on geophysical data processing and metadata structuring). 4.3 Interfaces and collaboration with other UCs.	UFZ	<i>all partners</i>

5.2. Milestones

#	Milestone	Action #	Achieved after ...
<i>M1</i>	Finalized Standardized Protocols & Data Management Plan for selected methods available	<i>1</i>	<i>6 months</i>
<i>M2</i>	First release of a harmonized metadata model and curated controlled vocabulary available	<i>2</i>	<i>8 months</i>
<i>M3</i>	Near-surface geophysical data acquisition at agricultural pilot site completed	<i>3</i>	<i>8 months</i>

5.3. Deliverables

#	Deliverable	Action #	Achieved after ...
<i>D1</i>	Curated, quality-checked near-surface geophysical dataset package with comprehensive documentation for reanalyses and integration into archaeological prospection phase	<i>3</i>	<i>10 months</i>
<i>D2</i>	Publication of metadata model covering core and extended metadata for selected methods in a FAIR-aligned repository	<i>2, 4</i>	<i>12 months</i>
<i>D3</i>	Provision of training material based on datasets from pilot site and presentation on a targeted workshop	<i>4</i>	<i>12 months</i>

6. Cost planning

6.1. FAIRagro funding

Type of Funding	Description/ justification	Institution	Estimated costs [€]
Personnel	PostDoc (1.0 FTE)	UFZ	81.800€
Material/Travel	4000€ (per calendar year per UC as fixed rate)		4.000€
Total estimated funding [€]			85.800€

6.2. UC in-kind contribution

Type of in-kind contribution	Description/ justification	Institution	Estimated Value [€] <i>(optional)</i>

7. Policies and Permission rights

This section contains an overview of the consent, policies, and permissions rights that the submitter is consenting to when applying with the Use Case submission form.

Acceptance of FAIRagro Use Case application procedure

By submitting your Use Case application, you hereby expressly confirm that you have read and understood the FAIRagro UC call published on the FAIRagro website: [‘Onboarding new Use Cases’](#)

Only UC applications are accepted, which were submitted on time, latest until March 3 2025 6pm to UC.fairagro@listserv.dfn.de. The use of the FAIRagro UC Submission form and its completeness is a prerequisite for the formal acceptance of the UC application.

Acceptance of FAIRagro Privacy Policy

By submitting your Use Case application, you hereby expressly agree to the [FAIRagro Privacy Policy](#).

We will process the following data from you:

- Surname, first name
- contact details
- Description of the use case and other related information, as shown in the form
- Further comments from you

We use this data to check your submission for suitability and to contact you if necessary for consultation and queries. In the course of the evaluation, the FAIRagro Community Advisory Board (CAB) and all members of the FAIRagro Steering Committee (SC) will have access to your submission in order to evaluate it. If your submission is successful, we will process your data for project implementation. The legal basis for data processing is Art. 6 para. 1 lit. b GDPR. If we accept your Use Case, we will retain your data until the end of the project in 2028. In the event of rejection, we will delete your data immediately.

Publication on the website

If your use case submission is successful, we will publish your name and details (UC title, participating institutions, UC summary and, if available, image/graphic) of your use case on the FAIRagro website. The legal basis for data processing is Art. 6 para. 1 lit. f GDPR. We have a legitimate interest in the transparent presentation of our activities. Once the project has been completed, we will cease publication.

You have the right to object to the processing (Art. 21 GDPR), your particular situation causes you to object to the processing for this reason, as you consider your fundamental rights and freedoms to be impaired. In some cases, we may demonstrate compelling legitimate grounds for the processing which override your rights and freedoms.

Upon successful acceptance, we will reach out to you for specific input for your Use Case subpage and graphic(s) and or pictures.

By submitting your Use Case application now, you agree to further communicate with FAIRagro to provide curated information about project details of this Use Case and you agree to openly publish this on the FAIRagro webpage using a [Creative Commons by 4.0 licence](#) thus ensuring that the FAIRagro community can effectively contribute to this Use Case. You will receive assistance from FAIRagro in this regard.

8. Appendix

☐ Letter of Commitment (LoC) of all institutions involved as applicant and co-applicant(s), recommended if they are not yet FAIRagro (co-)applicants or participants

☒ Letter of Interest (LoI) of associated partners, if applicable

- LoI NFDI4Objects
- LoI NFDI4Earth

☒ References

- Werban, U., Hoffman, C., Seegert, J., Keller, C., Schütze, C. (2025). Multifunctional Data in a Multifunctional Landscape - A Concept Paper for Cross-Community Research Data Management for Near-Surface Geophysical Data. Zenodo. <https://doi.org/10.5281/zenodo.14919049>

☐ Other:



NFDI4Objects

Research Data Infrastructure
for the Material Remains of
Human History

LETTER OF INTEREST

To whom it may concern

On behalf of NFDI4Objects, we are pleased to express our interest and support for the proposed Use Case project “Unlocking Multifunctional Insights with Near-Surface Geophysical Data Harmonization in Agriculture – MUFUDAT.agrio”. We recognize the project's importance in advancing interdisciplinary and cross-consortia research and ensuring the harmonization and interoperability of geophysical data across multiple scientific domains. Although the methodology and sensor technology of near-surface geophysics is often similar or even the same, data acquisition, processing methodologies, (meta)data handling and long-term archiving practices remain highly fragmented. This limits cross-domain research, data interoperability, comparability and accessibility, as well as reusability. To address these challenges, this approach seeks to integrate efforts across three key NFDI consortia: FAIRagro, NFDI4Objects, and NFDI4Earth.

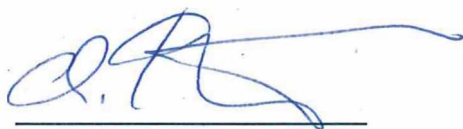
NFDI4Objects is committed to actively supporting the project's objectives by contributing expertise, collaboration opportunities and knowledge exchange in the areas of FAIR data management, common standards, development of controlled vocabularies. We particularly appreciate the project's focus on establishing standardized workflows, structured metadata integration and enhancing cross-disciplinary data usability, which aligns well with our ongoing efforts in Archaeology and Cultural Heritage Protection.

We would like to support MUFUDAT.agrio through the following appropriate collaborative measures:

- promoting and coordinating cross-consortia exchange in general
- contributing expertise, collaboration opportunities and knowledge exchange in the areas of FAIR data management, common standards and development of controlled vocabularies and metadata standardization
- Provision of funding for the UC depending on a positive approval of the UC in the 2nd Call for TRAILS in NFDI4Objects for the year 2027 (as part of its flexible funding)

In conclusion, NFDI4Objects fully supports MUFUDAT.agrio and looks forward to a fruitful collaboration with FAIRAgro as a significant contribution to answering novel interdisciplinary research questions.

Yours sincerely,

A handwritten signature in blue ink, appearing to be 'C. Keller', written over a horizontal line.

Berlin, 3 March 2025

Dr. Christin Keller, Deutsches Archäologisches Institut, NFDI4Objects Managing
Director

NFDI4Earth c/o Technische Universität Dresden, 01062 Dresden

Helmholtz Centre for Environmental Research - UFZ
Dr Ulrike Werban

Leipzig

Dresden, 28 February 2025

Letter of Interest

To whom it may concern

The Consortium for the establishment of a National Research Infrastructure (NFDI) for Earth System Sciences (NFDI4Earth) addresses the digital needs of Earth System Sciences. NFDI4Earth is a community-driven process providing researchers with FAIR, coherent, and open access to all relevant Earth System data, to innovative research data management and data science methods.

One ambition of the NFDI4Earth is the cross-consortia exchange with other NFDI consortia - in particular the specialised initiatives by so-called multidisciplinary use cases for integrating research, software and methods across different disciplines to address research questions that cannot be effectively addressed by a single discipline or method alone in order to highlight the added value of the NFDI.

In this context, NFDI4Earth and TUD Dresden University of Technology resp. as its applicant institution explicitly supports the efforts of the Helmholtz Centre for Environmental research – UFZ to submit a Use Case (UC) for the project 'FAIR Data Infrastructure for Agrosystems' (FAIRagro). The FAIRagro consortium is part of the NFDI focusing on research data management for the agrosystems research community.

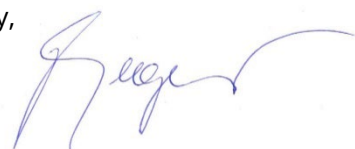
The proposed UC 'Unlocking Multifunctional Insights with Near-Surface Geophysical Data Harmonization in Agriculture – MUFUDAT.agrio' aims to develop a harmonized framework for geophysical data workflows, ensuring FAIR principles are consistently applied across disciplines. By leveraging expertise from agricultural research (FAIRagro), archaeology (NFDI4Objects) and environmental and Earth System Sciences (NFDI4Earth), this initiative will help to establish workflows for standardized data formats and metadata schemas, and best practices for geophysical data handling.

We would like to support MUFUDAT.agrio through the following appropriate collaborative measures:

- promoting and coordinating cross-consortia exchange in general
- contributing expertise, collaboration opportunities and knowledge exchange in the areas of FAIR data management, common standards and development of controlled vocabularies
- examining financial resources for the UC depending on a funding commitment of NFDI4Earth for a 2nd phase (as part of its flexible funding)

In conclusion, NFDI4Earth fully supports MUFUDAT.agrio and looks forward to a fruitful collaboration with FAIRagro as a significant contribution to answering novel interdisciplinary research questions.

Yours sincerely,



Jörg Seegert, TU Dresden
NFDI4Earth Managing Director

Multifunctional Data in a Multifunctional Landscape

A Concept Paper for Cross-Community Research Data Management for Near-Surface Geophysical Data

U. Werban¹, C. Hoffmann², J. Seegert³, C. Keller⁴, C., Schütze¹

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³ TUD Dresden University of Technology

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Near-surface geophysical data play a crucial role in multiple scientific domains, including precision agriculture, archaeological prospecting, and Earth System Sciences. Although the methodology and sensor technology used is often similar or even the same, data processing methodologies, (meta)data handling and long-term archiving practices remain highly fragmented. This limits cross-domain research data interoperability, comparability, accessibility, and reusability. To address these challenges, this approach seeks to integrate efforts across three key NFDI consortia: **FAIRagro**, **NFDI4Objects**, and **NFDI4Earth**.

The primary objective of this initiative is to develop a harmonized framework for geophysical data workflows, ensuring FAIR (Findable, Accessible, Interoperable, and Reusable) principles are consistently applied across disciplines. By leveraging expertise from agricultural research (FAIRagro), archaeology and cultural heritage protection (NFDI4Objects) and environmental and Earth System Sciences (NFDI4Earth), this initiative will help to establish workflows for standardized data formats and metadata schemas, and best practices for geophysical data handling. Additionally, it will foster interoperability between existing research infrastructures and promote sustainable data management. Hence, this approach aligns with the overarching goals of the NFDI by enhancing data accessibility and reusability, fostering interdisciplinary collaboration, and supporting data-driven research. By bridging domain-specific methodologies and establishing common standards, this initiative will significantly improve the integration of geophysical datasets across scientific fields, ultimately benefiting researchers, policymakers, and stakeholders engaged in environmental monitoring, heritage conservation, and precision agriculture.

The above-mentioned multiple scientific domains share significant overlap in their use of near-surface geophysical investigations to describe and analyze subsurface structures and processes. Despite their distinct primary objectives, the bridging elements among these disciplines include methods, instruments, and research goals, which allow for cross-disciplinary data reuse and methodological integration. The considered research fields rely on the use of geophysical methods as a proxy for soil properties, functional characteristics and state variables. Geophysical datasets can help to describe the targeted subsurface phenomena, albeit with different interpretations for each field. The same geophysical instruments are applied in the different communities and generate datasets relevant to multiple disciplines (e.g. Doolittle & Brevik, 2014; Boaga, 2017; De Smedt et al., 2014). Hence, sharing datasets maximizes research efficiency and broadens interdisciplinary insights (Webber et al., 2017; Cuenca-Garcia et al., 2018).

Recently, four primary challenges hinder to achieve effective cross-domain geophysical data reuse.

(1) Data discovery and accessibility (finding and getting the data):

Geophysical data are often collected for project-specific purposes and remain stored in local or inaccessible repositories. Even when funding agencies mandate data availability, the lack of standardized publication workflows means datasets are often only accessible through informal

networks. Access restrictions due to proprietary concerns (e.g., industry-funded agricultural projects) or data sensitivity (e.g., cultural heritage protection) further complicate data sharing.

(2) Inconsistent use of public repositories:

While open-data repositories (like Zenodo, PANGAEA, ...) exist, there is no widely adopted, discipline-specific protocol for archiving geophysical data in a way that supports cross-disciplinary discovery and reuse. Different research groups use varied metadata standards and file formats, making it difficult for potential users from other fields to find, interpret, and integrate the data into their own research.

(3) Lacking standards in metadata and documentation:

Even when data are uploaded to open-access repositories, they often lack sufficient contextual metadata (e.g., instrument settings, georeferencing information, acquisition context) and information about (environmental) boundary conditions (e.g., soil type, land-use, meteorological situation) making it impossible to assess the validity of the data or even the fit-for-purpose evaluation for new research questions. Different scientific communities use varying terminologies and classification schemes, making cross-domain data interpretation difficult. Without structured and standardized metadata and vocabularies, datasets become difficult to interpret or integrate with other research domains, reducing their reuse potential.

(4) Differences in data processing and interoperability:

Data formats, covered scales, depths, spatial and temporal resolution, and applied processing pipelines differ between disciplines, creating challenges in direct data exchange. For some research questions (e.g. in soil sciences) additional environmental data (such as soil properties, meteorological conditions, vegetation coverage, ...) might be required in terms of an increased data and process understanding.

To start a process to overcome the mentioned challenges, we propose a **structured three-phase concept**, demonstrated at a characteristic pilot site. This site will serve as a testbed for acquiring and systematically analyzing comprehensive near-surface geophysical data across three disciplines. The selected pilot site is of particular interest to all relevant fields, as it features characteristics suitable for agricultural, archaeological, and Earth System Sciences investigations. The focus will be on developing harmonized workflows from data acquisition to archiving, establishing standardized data and metadata structures, and defining cross-disciplinary best practices to ensure multi-purpose dataset usability. This could follow a hierarchical approach integrating different geophysical methods in a stepwise manner. Each phase introduces new geophysical methods based on the specific needs of the considered disciplines, while leveraging existing datasets from previous steps. This ensures that data acquired in a specific domain remains useful for other user groups, enhancing the collateral benefit of multi-purpose usability.

Phase 1 - Agricultural Prospection: The objective of agricultural prospection ("agrogeophysics") is to assess e.g., soil variability, soil moisture distribution, and nutrient status, which are essential for precision farming (Garré et al., 2021; Rhymes et al., 2023). The great advantage of "agrogeophysical" methods is their potential rapidity, low cost, and spatial coverage and thus can easily be integrated in precision farming practices both in terms of prospection and monitoring. In this phase, Electromagnetic Induction (EMI) will be used to map soil conductivity, while Gamma-Ray Spectroscopy (GRS) will provide insights into soil texture or salinity and can thus support management decisions. Another promising approach is represented by multiple proximal sensing technologies with integrating multi-sensor platforms, enabling simultaneous measurements and sensor data fusion. Thus, a broader range of soil properties can be rapidly assessed, enhancing the size of the covered areas and the soil property estimation accuracy (Tavakoli et al., 2024). These geophysical measurements also reveal distributed subsurface anomalies indicating past human activity or cultural remains, providing a valuable foundation for subsequent archaeological investigations. At this step the implementation of a harmonized workflow is required, ensuring that the data and metadata generated in this phase are structured, standardized, and properly documented for their integration into archaeological prospection. This includes the availability of standardized protocols essential for the structured acquisition, storage, and processing of the EMI, GRS or multi-sensor platform data and metadata as well as the consideration and further

development of common standardized vocabularies for sensor metadata and soil property description. The activities in Phase 1 are particularly relevant to the *FAIRagro consortium*.

Phase 2 - Archaeological Prospection: Archaeogeophysics will be applied to enhance structural analysis by high-resolution methods and to identify subsurface archaeological structures (walls, roads, and ditches). The data from EMI, GRS and multi-sensor platforms from agricultural prospection derived in phase 1 will be utilized to pre-identify areas with potential anthropogenic soil disturbances in order to design Ground Penetrating Radar (GPR) surveys and to optimize their efficiency and precision. GPR surveys are the preferred method to provide high-resolution 3D-imaging of buried features (Wunderlich et al., 2024). In this phase the further elaboration of standardized protocols and workflow harmonization is required and the degree of cross-disciplinary FAIRness (mainly re-usability) will be tested and further improved. Existent vocabularies will be enhanced concerning relevant terminologies concerning method and discipline to ensure consistency in data description.

The activities in Phase 2 are particularly relevant to the *NFDI4Objects consortium*.

Phase 3 - Observation of Soil Dynamics: Monitoring the dynamic subsurface is essential for understanding processes in soil science, hydrology, hydrogeology, including anthropogenic influences over time. Geophysical methods - especially the time-lapse concepts - can capture temporal variations in soil moisture, soil stability, soil temperature, and soil integrity; enabling a more comprehensive approach to long-term environmental assessments beyond agricultural requirements. A widely used method is Electrical Resistivity Tomography (ERT) providing 3D subsurface imaging of e.g., water infiltration, root penetration, and soil degradation (Garré et al., 2011; Perrone et al., 2014; Dimeche et al., 2022). In this phase the workflow harmonization will be further elaborated with special focus on the time-lapse methods including the expansion to incorporate the perspectives of soil processes. Moreover, the comprehensive integration of all applied method data holds immense potential for generating deeper insights, improving data reliability, and uncovering previously undetectable subsurface patterns. In the final phase all pilot data will be provided resulting in a comprehensive subsurface model that unites agricultural, archaeological, and soil science perspectives, while also generating an AI-ready dataset for multi-purpose geophysical modeling.

The activities in Phase 3 are particularly relevant to the *NFDI4Earth consortium*.

The three-phase concept is designed to **enable bidirectional data reuse**, ensuring that datasets generated in later phases also provide added value to earlier research fields. For example, high-resolution GPR data from archaeological investigations (Phase 2) can contribute to agricultural soil assessments or model validation if properly described and archived. Similarly, ERT datasets from Earth System Sciences (Phase 3) can offer critical insights for both archaeology and precision farming, supporting a more comprehensive understanding of subsurface structures and processes across all disciplines. In addition, if a geophysical dataset acquired for agricultural purposes are structured and archived in a way that makes them accessible to archaeological research and Earth System Science, benefits will emerge in (1) increased data availability and cost efficiency, (2) enhanced knowledge generation through multi-purpose data, (3) improved AI-driven predictive modeling by leveraging diverse datasets across disciplines, enabling automated pattern recognition, adaptive learning, and cross-domain insights for applications such as soil property mapping, archaeological feature detection, and land-use change analysis, and (4) interdisciplinary insights and holistic landscape understanding.

However, the aim to provide multifunctional near-surface geophysical data also means raising awareness, capacity building and fostering a willingness among communities to embrace broad usability of this data. Achieving this requires effective communication and tailored training efforts across the different user groups. This can be achieved, for example, through presentations at specialized conferences or through targeted workshops where different user groups can share knowledge, gain hands-on experience with cross-domain geophysical data, and develop a common understanding of best practices for data management and joint interpretation. These efforts will be integrated into all three phases of the proposed concept, ensuring that awareness-raising, communication, and training accompany each phase.

The harmonization of geophysical data across the three domains of agriculture, archaeology, and Earth System Sciences presents a major opportunity for efficient data reuse and interdisciplinary research. With the proposed initiative we will foster harmonization and standardization along the geophysical data life-cycle across the three disciplines, enhancing multi-purpose usability through FAIR and TRUST principles, while bridging natural and social sciences for greater interdisciplinary impact. Furthermore, **cross-disciplinary data is a unique selling point for the development of data-driven models and the application of AI approaches**. AI models, particularly in geosciences, agriculture, archaeology, and soil science, benefit significantly from diverse datasets that capture a wider range of environmental and subsurface features. Providing harmonized geophysical datasets will ensure the embedding of AI-readiness into our standardized geophysical data framework as well as a valuable integration into future AI-driven applications.

This showcase is connecting three branches of science and addresses the research data domains: Life Science (FAIRagro), Humanities (NFDI4Objects) and Natural Sciences (NFDI4Earth). It is intended to serve as a role model for future cross-disciplinary cooperation and esp. data handling and re-usability approaches and is an initial cross-consortia application-related cornerstone towards "oneNFDI".

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