# 3. TOWARDS THE IMPLEMENTATION OF THE GO-FAIR AGRO BRAZIL NETWORK: THE EXPERIENCE OF A RD&I ORGANIZATION IN THE IMPLEMENTATION OF THE FAIR PRINCIPLES

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## 3.1 INTRODUCTION

Agricultural Science is a multi and interdisciplinary Science due to the integrative nature of knowledge about the physical, biological, social and economic environments. This means that the production, trade, and consumption of food are closely related to human and environmental health, and the ability to connect knowledge on these themes, which are often controversial, is essential to overcome complex problems in agriculture (Hilimire, 2016). Considered the basis of the scientific method (Heidorn, 2008), data are essential for the integrated analysis of the several disciplines that are part of agricultural science, and which must be treated as valuable products of the Research, Development, and Innovation (RD&I) activity.

In this context, the amount of data to be analyzed has increased dramatically, with the transition to a much more data-intensive science in all areas of knowledge (Hey; Tansley; Tolle, 2009). In Agricultural Science, large amounts of data are being generated from remote and proximal sensing technologies, which are used to monitor variables of interest in real time – such as soil, climate, atmosphere, or organism variables – as well as from genomic or natural language processing technologies. At the same time, long-tail data, that is, data that are heterogeneous, diverse, poorly structured, and difficult to be obtained (Heidorn, 2008; Borgman *et al.*, 2016) are accumulated for decades — these records of immeasurable value about production systems and environmental assets are at risk of being lost if not properly treated and preserved.

Reliability and reproducibility are also important pillars of the scientific method, which require sound research data management practices to be ensured. In this respect, the FAIR principles (*Findable, Accessible, Interoperable, Reusable*)

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(Wilkinson *et al.*, 2016) are being increasingly adopted as guidance for research data management and enablers of their reuse. Applications and metrics for adopting and evaluating FAIR principles have been developed worldwide through standards, metadata, controlled vocabulary, ontologies and persistent identifiers that bring accurate meaning to data and other research outputs (Henning *et al.*, 2019).

The recognition by the scientific community of the importance of making data management practices adherent to FAIR principles led to the emergence of initiatives such as 'GO FAIR', which articulates communities of practice from thematic and regional Implementation Networks (INs)[102]. One of those networks, named *Food Systems*, aims at supporting the implementation of FAIR principles in agri-food sciences[103]. Brazil is part of this initiative with a national office[104], to which several INs are associated – among them, the GO FAIR Agro Brazil Network, which will contribute to the adoption of the FAIR principles by institutions that produce agricultural data (Go-Change); provide training in partnership with other national INs (Go-Train); and collaboratively build and implement infrastructure and interchangeable patterns (Go-Build).

This chapter aims at reporting the experience of Embrapa in incorporating the FAIR principles into institutional policies, as well as into data governance and management processes and practices. The narrative was built from an exploratory case study, with Embrapa as a single unit of analysis and data collected through documentary research. With its theoretical foundation on conceptualizations of Open Science, e-Science and Research Data Management domains under the perspective of the FAIR principles, the analysis herein serves as a basis for the GO FAIR Agro Brazil Implementation Network, thus benefiting the entire national agricultural RD&I system.

The following chapters present contextual information on Research Data Management (RDM) at the Brazilian Agricultural Research Corporation (Embrapa), explaining its positioning in the global RDM system, describing current internal regulations, and reporting results obtained thus far. Finally, the challenges and future prospects are discussed, to make Embrapa's research data increasingly adherent to the FAIR principles.

## 3.2 A FEW WORDS ABOUT RESEARCH DATA MANAGEMENT AT EMBRAPA

The mission of Embrapa – a governmental research institution linked to the Brazilian Ministry of Agriculture, Livestock and Supply – is "to create research, development, and innovation solutions to ensure the sustainability of agriculture, for Brazilian society (Embrapa, 2020, p. 16). Organized in 43 research centers geographically distributed nationwide and with strong partnerships abroad, the company generates a large volume of data on the various strategic themes of agricultural research. Aware of the volume, velocity, variety, and value of the research data produced by its activities, Embrapa has mobilized efforts to properly govern and manage these assets throughout their life cycle, to make them findable, accessible, interoperable and reusable.

102 More information can be found in the GO-FAIR portal: https://www.go-fair.org.

103 More information on the Brazilian office can be found at: https://www.go-fair.org/go-fair-initiative/go-fair-offices/go-fair-brazil-office.

104 The portal for data access is available at: https://metabuscador.uspdigital.usp.br/.

Among those efforts, the corporate project entitled "Data and Information Governance for Knowledge at Embrapa: Model and Implementation Plan Development" is noteworthy, which aimed at designing, validating and proposing a systemic model for the governance of data and information at the organization. As a result of the project, several recommendations were made to improve research data governance and management (Table 1), which associate well with the GO Build, GO Change, and GO Train pillars of the GO FAIR Implementation Networks.

**Table 1 - Recommendations to improve research data governance and management at Embrapa, as related to the GO Build, GO Change and GO Train pillars of the GO FAIR Implementation Networks**

| Category | Recommendations |
|---|---|
| Related to corporate processes | • To model and implement corporate processes for research data management and open data publishing. *Change*<br>• To review the employees' performance evaluation and reward process with the aim of fostering the culture of data sharing and data reuse. *Change*<br>• O develop and implement the processes, competences, tools, and methodologies to enable semantic interoperability. *Build*<br>• To enable the linkage of scientific data to the publications and the projects that generated them. *Build*<br>• To adopt public licenses for digital assets. *Build* |
| Related to internal guidelines and norms | • To develop and publish a corporate Open Data Plan. *Change*<br>• To develop, review, update, and implement policies and internal rules related to research data and information management . *Change*<br>• To add to the company's Master Strategic Plan, specific guidelines related to research data and information management. *Change*<br>• To establish and sustain a corporate model for research data. *Build* |
| Related to the organizational culture | • To ensure active participation in national and international forums and networks on research data management. *Change*<br>• To engage Information Science professionals on research data management processes. *Change*<br>• To train and communicate about research data management. *Train*<br>• To require Research Data Management Plans. *Change* |
| Related to tools, instruments, and technologies | • To develop and implement technological infrastructure for research data management through consistent and interoperable platforms. *Build*<br>• To adopt persistent identifiers for data, datasets, and authors. *Build*<br>• To ensure the alignment of data management plans and information architectures with epistemologically systematized and globally used conceptual models for agriculture. *Build*<br>• To build an open data infrastructure, interconnected with the Brazilian Open Data Portal. *Build*<br>• To implement terminology management and conceptual alignment technological tools. *Build* |

| Category | Recommendations |
|---|---|
| Related to structure, roles and responsibilities | • To define rules and responsibilities for research data management within the organization. *Change* |

Source: Authors (2024).

It is evident that cultural changes (Go Change), training (Go Train), and building and implementing infrastructure and interchangeable patterns (Go Build) permeate the 19 recommendations in Table 1. The recommendations related to corporate processes align to the Change (1 and 2) and the Build pillar (Build: 3, 4 and 5), while the normative recommendations fit the Change (6, 7 and 8) or the Build category (9). Recommendations related to the organizational culture associated with the Train (12) or the Change pillars (10, 11 and 13). All recommendations related to tools, instruments, and technologies align with the Build category (14, 15, 16, 17 and 18), and finally, the recommendation related to structure, roles, and responsibilities categorizes as Change. In total, nine recommendations were categorized as building and implementation (Build), the other nine as cultural change (Change), and one as training (Train). One of the recommendations categorized as cultural change (10 - "To ensure active participation in national and international forums and networks on research data management") is explored in the next section.

## 3.3 INTRODUCING EMBRAPA IN THE GLOBAL RESEARCH DATA MANAGEMENT ECOSYSTEM

The Big Data phenomenon and the new e-Science and Open Science paradigms have promoted a transformation in the scientific system, with practices, rules, and behaviors reconfiguration especially, in research data organization and management (Algabli *et al.*, 2015). To better understand and benefit from this transformation, Embrapa has exchanged knowledge through participation in national and international initiatives, networks, groups, and forums addressing RDM. As part of these efforts, Embrapa coordinated, between October 2018 and July 2020, the Commitment 3 of the 4th National Action Plan for Open Government, known as the 'Brazilian Commitment towards Open Science', which aimed at "establishing mechanisms for scientific data government for the advancement of Open Science in Brazil" (Brasil, 2018a, 2018b). The Commitment was carried out in partnership with several government agencies and civil society, including the Ministry of Science, Technology, and Innovations (Ministério da Ciência, Tecnologia e Inovações - MCTI), Oswaldo Cruz Foundation (Fundação Oswaldo Cruz - Fiocruz), Brazilian Institute of Information in Science and Technology (Instituto Brasileiro de Informação em Ciência e Tecnologia - Ibict), Ministry of Agriculture, Livestock and Food Supply (Ministério da Agricultura, Pecuária e Abastecimento - MAPA), National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq), Coordination for the Improvement of Higher Level Personnel (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Capes), National Education and Research Network (Rede Nacional de Ensino e Pesquisa -RNP), University of Brasília (Universidade de Brasília - UnB), and Open Knowledge Brazil (OKBR). Among the results of this Commitment, the following stand out a diagnosis of the Open Science developments in the world and in Brazil, a guidance document about interoperability patterns; indicators for evaluating organizational maturity for research data openness; the development and implantation of pilot institutional data repositories; awareness and training actions on the topic; liaising with scientific editors and funding agencies; and the creation of an inter-institutional network on the topic.

The Open Government agenda turned out to be a suitable environment for strengthening and expanding partnerships among the various actors of the national scientific system, thus avoiding duplicate efforts.

Furthermore, noteworthy is Embrapa's participation in the working group for the implementation of a Network of Scientific Data Repositories in the State of São Paulo, created by the Foundation for Research Support of the State of São Paulo (Fundação de Apoio à Pesquisa do Estado de São Paulo - Fapesp), contemplating data and information from state public universities[105]. Embrapa Digital Agriculture, one of Embrapa's research centers, integrates the WG, focusing on sharing data and information generated by the company, which can be used for scalability tests and integration of agricultural data to repository networks. Furthermore, the Company shares technical knowledge and contributes to speeding up the activities developed by WG in matters such as scalability tests, evaluation of tools or data curation procedures, among others.

In the international context, Embrapa integrates the GODAN (*Global Open Data for Agriculture and Nutrition*) initiative, which aims at promoting global efforts for providing, accessing and reusing relevant data in agriculture and nutrition[106]. As part of the network with more than 1,110 partners, the Company has worked on the translation to Portuguese of instructional materials about open data management in agriculture. The company has also contributed to the *Research Data Alliance* (RDA[107]) - a global initiative started in 2013 to foster open sharing and reusing of research data. Currently, RDA has more than 11,000 members, including data producers, users, and managers who contribute to the development of RDM solutions and good practices. Specialists meet in thematic groups, one of which is the *Improving Global Agricultural Data (IGAD) Community of Practice* (IGAD), coordinated by FAO, USDA, GFAR (Global Forum on Agricultural Research and Innovation), and Embrapa representatives. Another international group with Brazilian coordination is *Professionalizing Data Stewardship*, which brings together professionals from all continents to achieve a common goal regarding the professionalization of research data stewardship. The Data Observation Network for Earth (DataOne[108]) is one more initiative that has contributed to the development and adoption of strategies and best practices for RDM at Embrapa. DataOne aims at a deeper understanding of life on Earth and the environment supporting it; it is held by the community and provides data for several of the members' repositories, promoting the best practices in data management through educational resources and materials. The interface between Science and politics is the focus of action of *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (IPBES[109]), which has a task force for data and knowledge that, among other actions, proposes the data policy of the platform and monitors its adoption. Jointly, such initiatives helped to disseminate and adopt RDM best practices and thus, data can be reused, leading to the advance of frontiers of knowledge and subsidizing decision-making in various spheres. The participation of Embrapa in these discussion forums makes it possible to exchange experiences, continuous update and review of strategies and activities, described in the following sections.

105 More details on the Godan initiative can be found in: https://www.godan.info/

106 RDA portal contains information on members and work groups: https://www.rd-alliance.org/.

107 More information in: https://www.dataone.org/.

108 IPBES portal contains details on the platform: https://ipbes.net/.

109 More information in: http://www.embrapa.br/siexp.

## 3.4 EMBRAPA DATA GOVERNANCE, INFORMATION, AND KNOWLEDGE POLICIES

One of *GO Change* recommendations, among the normative measures presented in Table 1, is number 7: "Elaborate, update and implement policies and internal rules for the management of data and information generated during research developed by the Company". An essential action in this regard was the enactment of Embrapa Data Governance, Information, and Knowledge Policy that establishes principles, guidelines, and responsibilities to "strengthen the mechanisms for generating, organizing, treating, accessing, preserving, retrieving, disseminating, sharing and reusing Embrapa's information assets" (Embrapa, 2019, p. 10).

Guided by the principles of the Constitution of Federative Republic, the Declaration of Human Rights and the precepts of the Open Science movement, the policy established 17 principles for Embrapa's data, information and knowledge management, namely: (1) Data, information, and knowledge as corporate assets; (2) Strategic alignment; (3) Development of capacities and competences; (4) Federated infrastructure; (5) Analysis, intelligence, and innovation based on data; (6) Efficiency and economics; (7) Compliance and risk mitigation; (8) Interoperability; (9) Licensing; (10) Preservation and memory; (11) Privacy, protection, and confidence; (12) Safety; (13) Quality and integrity; (14) Epistemological specificity; (15) Organizational learning, continuity and knowledge retention; (16) Openness and transparency; (16.1) Open Access to scientific information; (16.2) Open Data; (17) Monitoring and responsibility when disseminating relevant information.

Although FAIR principles are not directly stated in the guidelines and principles of the policy, the document's core is "well organized, documented, accessible and accuracy and validity checked data and information are easily shareable and reusable", providing several advantages to the administration (Embrapa, 2019). Notably, the publication responsible for introducing the FAIR principles (Wilkinson *et al.*, 2016) is one of the basic references of the policy and constitutes transversal elements to all its content. For instance, the following guideline should be highlighted: "implement and support processes that ensure that data and information produced by Embrapa are reliable and easily retrievable, accessible, interoperable and reusable" (Embrapa, 2019).

Among the principles of the policy, 'Interoperability' is the one which better means the need of applying the FAIR principles. To be covered by RDM best practices, this principle requires the use of semantic tools and widely established and widespread data and metadata standards . This principle is strengthened through the guideline described from the technological perspective that directs to the innovation and to the use of technologies allied to international trends, such as data sharing and reuse with broad adoption of interoperability services.

Thus, FAIR principles encompass a central reference for the development of the GDP Corporative Program, outlined in item 8.1 of the policy strategic guideline: "implement, support and monitor a Research Data Management Corporate Program and guide the development of data management plans in the context of Research, Development, and Innovation projects" (Embrapa, 2019, p. 13).

## 3.5 RESEARCH DATA MANAGEMENT (RDM) CORPORATE PROGRAM: ACTIONS IN PROGRESS

### 3.5.1 Diagnosis on data management practices

Throughout the history of Embrapa, several data management practices and information systems were created, according to the specificities of diverse thematic areas in different research centers at Embrapa. Thus, one of the initial actions of the RDM Corporate Program was to carry out a survey to diagnose them. To this end, an electronic questionnaire was elaborated to describe important points related to research data: data characterization, collection and documentation, data storage, backup, accessibility, sharing and reusing, and research data repositories. The questionnaire was answered by 854 data producers distributed among 43 research unities with the aim of supporting and guiding RDM corporate improvement actions of Emprapa, according to the better international practices and trends of data organization and publication.

### 3.5.2 Development and Implementation of a Reliable Data Repository and Persistent Identifiers Attribution

The current context requires a comprehensive strategy to establish the roots to make Embrapa data FAIR, considering the importance of strengthening solutions that already exist in the Company, such as the Embrapa Experiment Information System (SIExp[110]) and Embrapa Spatial Data Infrastructure – GeoInfo (Drucker *et al.*, 2017), as well as the need to accommodate data for which proper solutions have not been implemented yet. The complexity and multidisciplinary of Agricultural Sciences require technological solutions that allow adherence to FAIR data and, at the same time, accommodation of data from different domains and their representation models and standards, to obtain a central description core, as well as the treatment of specificities via small extensions of this core, so that the interoperability of scientific data repositories is enabled in general at different levels. Considering the best practices adopted worldwide, it was decided to implement a reliable research data repository as a solution for the organization, treatment, preservation, and publication of data produced by Embrapa.

Embrapa Data Repository, Redape[111], was launched in April 2022 and is based on *Dataverse*[112] open data software . Additionally, a computational infrastructure for storing research data was acquired and enabled, and a team responsible for the technical administration of the repository, located at Embrapa Scientific *Data Center*, was nominated. Embrapa Scientific *Data Center* is based in Campinas, SP, and has essential characteristics of information security, such as: restrict access to computers, servers and data storage disks, as well as defense against attacks to repository, prevent access to unauthorized individuals, among others.

110 Available from: https://dataverse.org.

111 Available from: https://www.redape.dados.embrapa.br/

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Redape supports the assignment of persistent identifiers, one of the fundamental requirements to make data products available to the scientific community. A persistent identifier (PID) enables the unique identification of a digital object and is addressed to be a permanent way of identifying and accessing this specific resource. The most widely known PID in the scientific community is the *Digital Object Identifier* (DOI), which generates a persistent link that points to the repository or to other digital location when including the URL in the metadata. It provides a system for persistent and actionable identification, as well as for interoperable exchange.

### 3.5.3 Knowledge Representation

According to Meadow *et al.* (2007), information retrieval is a communication process between record authors, creators, and readers. This process depends on a proper language control (code) between the sender and receiver and between users' documents and requirements (Janaite Neto; Ferneda, 2016). Building controlled vocabulary aims at information indexing, storing and retrieving activities, representing meaningful concepts of some domain of knowledge and, if possible, engaging with types and even subtypes of domain (Chandrasekaran *et al.* 1999; Cintra, 2002; Jacob, 2003; Fujita, 2004).

According to Lattes Platform (CNPq), Agrarian Sciences can be subdivided in the following subareas: Agronomy, Forest Resources and Forest Engineering, Agricultural Engineering, Zoo technics, Veterinary Medicine, Fishery Resources and Fishing Engineering, Food Science and Technology (CNPq, 2021). This diversity of subareas contributes to the high number of terms that can be used for indexing, storing and retrieving information. Agrovoc Multilingual Thesaurus, for instance, accounts for 33,388 main terms and 2,254 alternative terms, including food, nutrition, agriculture, forestry, fishing, scientific and common names of animals and plants, environment, biological concepts, plant cultivation techniques, among others. Agroterms – controlled vocabulary built by a permanent work group at Embrapa – gathered nearly 245 thousand terms pertinent to the agricultural knowledge domain from the gathering of terminologies in Portuguese found in national and international agricultural thesaurus. The expectation is of expanding Agroterms to a conceptual space of Brazilian agricultural knowledge and promoting a better interoperability between internal and external information systems.

### 3.5.4 Data management Plan

A Data Management Plan is one of the most important stages in the research development process, for it is at that moment that data treatment throughout its lifecycle is discussed. It is also discussed how to ensure that data is freely available – respecting privacy – and how it can be reused, under specific conditions and licenses clearly defined, and which can be properly cited and used as reference. A Data Management Plan (DMP) is, therefore, an essential tool so that best data management practices are applied during the research development until data publication. Aware of DMP importance, development agencies in the United States, European Union, United Kingdom, Australia, and Canada have demanded that research projects are accompanied by a DMP in line with FAIR principles (Aventurier, 2017). In Brazil, Fapesp was the first Brazilian funding agency to announce, in 2017, the obligation of having a DMP for research projects funding requests. Research institutions must insert DMP in their research development process, not only to obtain funding, but also to ensure that data is properly managed. At Embrapa, the obligation of attaching a DMP to all research projects started in January 2022, while it has been a practice adopted by Embrapa Digital Agriculture since 2018.

## 3.6 Final Considerations

This work described efforts that have been applied at Embrapa to implement research data management based on FAIR guiding principles, and it sought to fit the mapped measures according to the pillars of GO FAIR initiative. The section describing the insertion of Embrapa in the DMP global ecosystem showed that there are several actions in course related to this theme, which meet one of the recommendations characterized as cultural change (Go-Change), number 10: "Ensure Embrapa inclusion and active participation in national and international forums and networks in research data management.". The results obtained so far are remarkable and have the potential to be multiplied and expanded in the coming years, based on the strengthening of relationships and ties with partner institutions. This is a feature that substantiates the *Go-Change* pillar, as Community Building underpins the GO FAIR initiative.

Another significant action to encourage the adoption of practices adhering to the FAIR principles and to support the cultural change necessary to promote the pillars of the GO FAIR movement was the enactment of Embrapa's Data, Information and Knowledge Governance Policy, described herein. To incorporate those principles to the everyday activities of the organization, the company is implementing the Corporate Research Data Governance Program, which will ensure the necessary means, services, and tools so that data produced by projects are easily located, accessed, interoperated and reused. Among the actions for the implementation of this corporate program are the following: diagnosis of data management practices; implementation of a reliable data repository, with the attribution of persistent indicators and viability of data discovery, which were disconnected until then; the development of actions to enable the representation of Agricultural Science knowledge and the establishment of practices of elaborating data management plans in research projects developed by the company.

It is worth highlighting that the research data management process was mapped and formally described, allowing for a deeper understanding of the current practices, so that services and solutions are adherent to the organizational and epistemological culture. This process is not elementary, given the multidisciplinary nature of Agricultural Science and the need to involve different actors and competences to achieve a model of this complexity. In combination, training actions are essential for the successful implementation of the DMP Corporate Program.

Another challenge to be faced is to properly contemplate the interoperability principle by adopting data and metadata standards and semantic tools – essential requirements so that data is properly interpreted and, thus, allowing for its reuse. Once more, considering the great diversity and heterogeneity of data created and analyzed in the context of Agricultural Sciences, it is a challenge that requires the participation of several actors from different subjects that make up agricultural research. The attribution of licenses that clarify the terms of data use is also an essential condition.

As challenges and future perspectives, training, and education actions are crucial for the successful implementation of the DMP Corporate Program. Another challenge to be faced is to properly contemplate the interoperability by adopting data and metadata standards, as well as ontologies and semantic tools, essential requirements so that data is properly interpreted and, thus, enabled to be reused. Once more, considering the great diversity and heterogeneity of data created and analyzed in the context of Agricultural Sciences, it is a challenge that requires the participation of several actors from different subjects

Finally, the elaboration of monitoring strategies of the DMP Corporate Program with a view to adherence to FAIR principles, allowing for the incorporation of improvements, is an essential perspective to ensure its success. A reference base is the work performed in the scope of Goal 9 of the Commitment to Open Science of the Open Government Partnership, entitled "Proposition of a set of indicators for measuring maturity in Open Science". Although the FAIR principles do not necessarily entail data opening, the set of indicators for measuring the maturity level of scientific data opening provides objective criteria that can also be used for measuring the success in Governance, Organizational Culture, Scientific Data Management and Technological Infrastructure fields (Fortaleza *et al.* 2020). More specific indicators can be developed, such as metrics for cataloging research data in institutional repositories; quantity of access to available resources; description and implementation of processes; licensing; and establishment of reward mechanisms when sharing and reusing data.

As demonstrated in the case of Embrapa, the adherence to FAIR principles is crucial for the technological and semantic interoperability of data in the agricultural context. The strategy presented herein assumes that data are valuable products of the research activity, and denotes the transition to a praxis in which reusing data from the agricultural research based on the paradigm of FAIR principles is encouraged. In this regard, building the GO FAIR Agro Brasil network is critical so that the collaborative work mutually benefits the communities that manage agricultural data. Thus, encouraging the reuse of agricultural research data will contribute to the solution of problems not only for Brazilian society but also the society worldwide, considering the relevance of the country in the context of food systems.

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