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Motivators and barriers of FAIR and open data practices in the German Earth System Sciences

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Abstract

To better understand the current attitudes, motivators and barriers surrounding FAIR and open data practices in the context of the German national research data infrastructure consortium for the Earth System Sciences (NFDI4Earth), an online survey was conducted (n = 114). The survey targeted researchers in the German Earth System Sciences community.

The main findings of the survey are as follows. The strongest motivators to perform FAIR and open data practices more often are better institutional support for FAIR and open data practices as well as more scientific recognition via dataset citation metrics. Only few participants think that awards for FAIR and open data practices are strong motivators. The most important drivers for data publication in particular are the perception that it improves science as a whole. This is contrasted by extrinsic drivers (such as requirements from publishers, funders, institutions), and data sharing norms, both ranking lower. The most important reasons for not sharing data are the consideration that the data are not suitable for sharing and the fear of scooping, i.e. somebody else may publish an analysis of the data earlier than the data's originator.

Recommendations for NFDI4Earth include to strengthen motivators for FAIR & open data practices in general and, in particular, for data publication, because the latter are highly important for survey participants. Barriers to data sharing should be assessed in order to identify actions to establish more incentivizing environments and structures, e.g. by forming stronger strategic partnerships with partners like academic societies. NFDI4Earth may further intensify training and education on data sharing and the use of DMPs as well as collaborate with NFDI4Earth member institutions and other partners to promote the introduction of data sharing policies and to strengthen existing services.

NFDI4Earth member institutions should take advantage of NFDI4Earth-developed instruments, e. g. the Help Desk and the OneStop4All, in providing better assistance and infrastructure to their researchers. Development of open data citation metrics and improved recognition of FAIR and open data practices should be supported by NFDI4Earth to drive the much-needed cultural change towards recognition of diverse research contributions and open sharing.

1 Introduction

In the rapidly evolving landscape of scientific research, the principles of FAIR data (FAIR = findable, accessible, interoperable and reusable; (Wilkinson et al., 2016)) and openness in research data management have gained significant prominence.

The FAIR data principles are valuable to support the practice of data publication for all research disciplines, including the Earth Sciences (Kinkade & Shepherd, 2021). The

core of the FAIR concept lies in its ability to be applied across both human and automated processes, with the aim of making data as easily usable by machines as possible.

As an additional concept, 'open data' comprises practices that make research data publicly available, accessible and reusable with minimal restrictions (Higman et al., 2019). Open data is a valued concept also in the Earth Sciences (Wildman & Lewis, 2022).

Applied together, the principles of FAIR data and open data are effective approaches for engaging researchers and fostering sound data practices from the very start (Higman et al., 2019). FAIR and open data practices for the Earth System Sciences (ESS) are described in the COPDESS "Commitment to Enabling FAIR Data in the Earth, Space, and Environmental Sciences" (Enabling FAIR Data Community, 2018) and, more recently, in the "NFDI4Earth FAIRness and Openness Commitment" (NFDI4Earth Consortium, 2024).

For researchers, FAIR and open data practices may comprise a variety of activities, with data sharing being the most central element of these practices. This is especially true for researchers from natural sciences (Enwald et al., 2022; Tenopir et al., 2020). FAIR and open data practices that are directly related to publication activities (data publication and linking research data to journal publications) may include:

- Publish fully documented research data with open licences in suitable repositories.
- Citation of data (created or reused) in publications.
- Including a data availability statement in journal publications.

Apart from that, FAIR and open data practices may comprise:

- Preparing, using, publishing, and updating data management plans.
- Educating colleagues in practices that enable FAIR and open research outputs.
- Supporting development and implementation of open and FAIR standards and practices in institutions and organizations, in academic societies, and in scholarly publishing as authors, reviewers, and editors.

1.1 Motivation and methods

While FAIR and open data is becoming more common through initiatives and guidelines, there are still significant gaps between data policies and researcher practices, also in the German research community (Hahnel et al., 2024). To understand and improve the uptake of FAIR and open data practices especially in the German ESS community it is crucial to first gain a better understanding of current attitudes and practices in the German ESS research community relating to FAIR and open data practices, and to learn specifically about the motivators and barriers related to such practices.

The research question was to evaluate whether there are discipline-specific aspects in the German ESS community that can be used to advance FAIR and open data practices in this community. For this purpose, an online survey was conducted. The complete survey and all anonymized results are available in Hübner (2024).

The current article focusses on a selection of the survey results: the motivators and barriers associated with FAIR and open data practices in general and with the sharing of research data in particular. This selection covers the most important aspects when it comes to reflecting about how to influence values, attitudes, and habits of researchers in the long run, driving the cultural change towards more FAIR and open data practices.

The German ESS research community is well represented by the NFDI4Earth consortium and thus, researchers of the NFDI4Earth member institutions were the main target group of the survey. The set of survey questions about motivators and barriers related to FAIR and open practices was developed and refined using input from the community consultation process that accompanied the development of the “NFDI4Earth FAIRness and Openness Commitment” (NFDI4Earth Consortium, 2024). A pretest of the survey was conducted with four researchers and two persons from a university research data management team and resulted in valuable feedback especially on the clarity of the questions.

The request to participate in the online survey was distributed in October 2023. It was sent via Email to all NFDI4Earth consortium members contact persons and, as far as know, to their institutional research data management teams of participant institutions. The invitation to participate in the online survey was also circulated via the NFDI4Earth Email list, in the NFDI4Earth newsletter and was prominently placed on the NFDI4Earth website. The online survey was open until 17 December 2023.

Overall, 151 persons participated in the online survey. 115 participants completed the survey, however, one of these answers stemmed obviously from the test phase of the survey and was excluded from the analysis. Therefore, 114 completed answers were considered in the analysis of the online survey.

1.2 Earlier work

Motivators and barriers for FAIR and open data practices in general and, in particular, for data sharing have been investigated by many studies (Borgman, 2012; Chawinga & Zinn, 2019; Fecher et al., 2015; Gomes et al., 2022; Iain et al., 2021; Kaiser & Brainard, 2023; Kim & Stanton, 2016; Kratz & Strasser, 2015; Tedersoo et al., 2021; Watson, 2022; Woods & Pinfield, 2021) and have also been investigated for the Earth System Sciences (Gilder et al., 2021; Meistring, 2023; Radosavljevic et al., 2019; Schmidt et al., 2016; Tenopir et al., 2018; Wu & Worrall, 2019; Yan et al., 2020). The three main influences on attitudes toward data sharing and reuse are individual motivations, social influences, and organizational support (Borycz et al., 2023). Researchers are more

likely to share their data when they see the potential benefits, such as increased citations and visibility of their work (Borgman, 2012). Kim and Stanton (2016) reported that the influence of regulatory requirements from journals, normative expectations within the discipline or community, and individual motivations such as career advancement and a sense of scholarly altruism all play a significant role in encouraging researchers to share their data.

In a study of Tenopir et al., (2020) the main challenge to sharing data was reported to be the pressure to publish research findings first, which was followed by concerns about data ownership and rights, the time and resources required to prepare data for sharing, and funding restrictions that limited their ability to prepare and deposit the data. Other studies found that the lack of recognition and rewards for sharing research data is a significant disincentive (David et al., 2020; Fecher et al., 2015).

Schmidt et al. (2016) reported that the main reasons for publishing data as open data were rooted in intrinsic research motivations, including both general considerations, such as speeding up scientific progress and enabling applications, and personal motivations, such as sharing and recognizing research findings, upholding a personal commitment to open data, and responding to requests from data users. The main hurdles to publishing data as open data were the need to publish research results before releasing the underlying data, concerns about legal restrictions, the risk of losing credit or recognition for one's work, and the potential for the data to be misinterpreted or misused (Schmidt et al., 2016).

Geophysicists were reported to have quite positive attitudes toward data sharing and data reuse, as long as there are assurances that data are cited properly and that researchers can specify which data they would like to share (Tenopir et al., 2018). Major concerns about data sharing were expressed towards the potential misuse or misinterpretation of data. Researchers in the earthquake engineering (EE) community were uncertain of data ownership (Wu & Worrall, 2019). This uncertainty can undermine the intentions of EE researchers to share their data, despite their generally positive attitude towards data sharing. The study also found that funding agency requirements and academic traditions had a strong influence on the data-sharing practices of EE researchers.

In a 2023 survey of the German ESS community, around 75% of all respondents fully agreed that the publication of research data should be taken into account in the evaluation of scientific performance (Meistring, 2023). A survey of Digital Data Management Practices at the GFZ Helmholtz Centre for Geosciences revealed that 65 % of the respondents would share their data publicly if they were given credit (e.g. via citation), while 62 % would request dedicated embargo periods or personal permission as a condition for data sharing (Radosavljevic et al., 2019).

2 Results

Motivators for FAIR and open data practices in general and, in particular, drivers and barriers for data sharing are presented in Figs. 1-3. To make it easier to recognize trends, only answers “always” and “often” are presented, sorted by cumulative percentage. The full results are available at Hübner (2024).

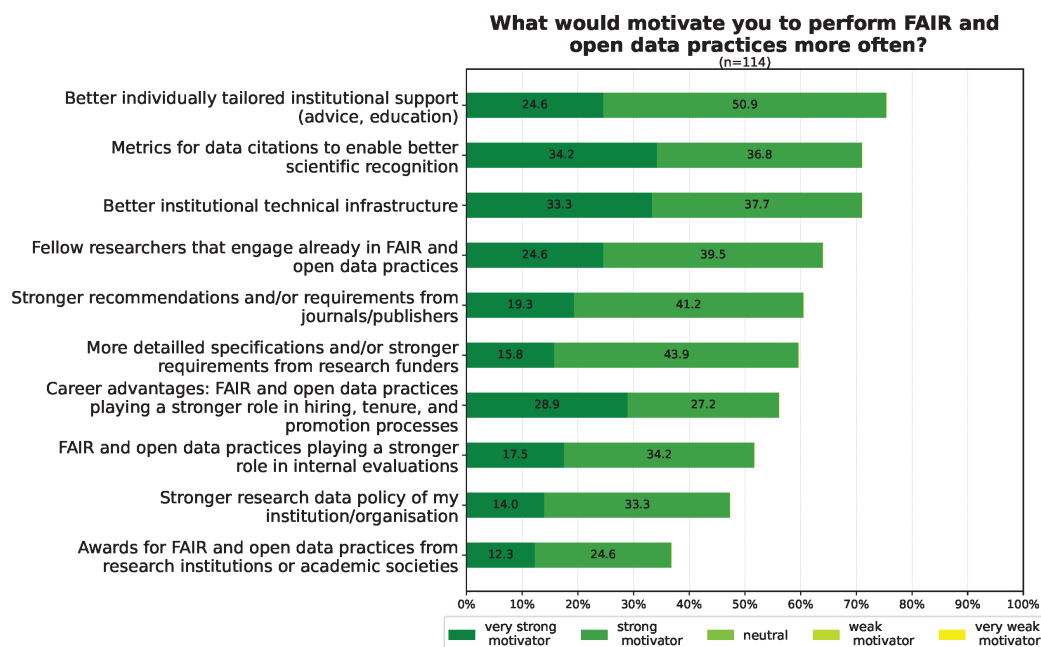


Figure 1: Bar chart of answers to the question “What would motivate you to perform FAIR and open data practices more often?”. Only answers “always” and “often”, ordered according to cumulative percentage.

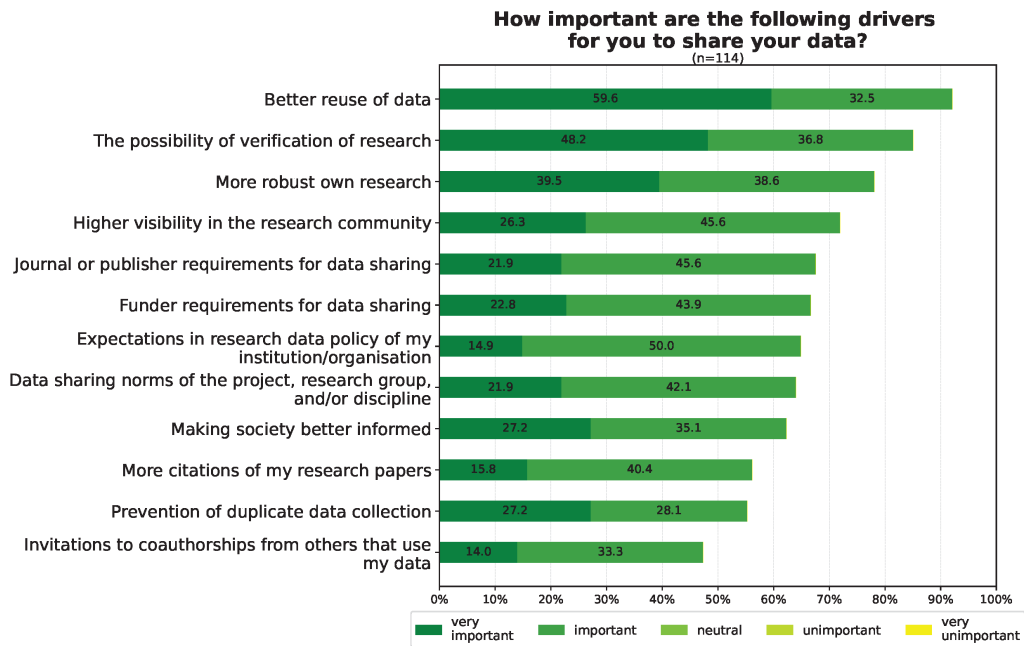


Figure 2: Fig. 2: Bar chart of answers to the question “How important are the following drivers for you to share your data?”.

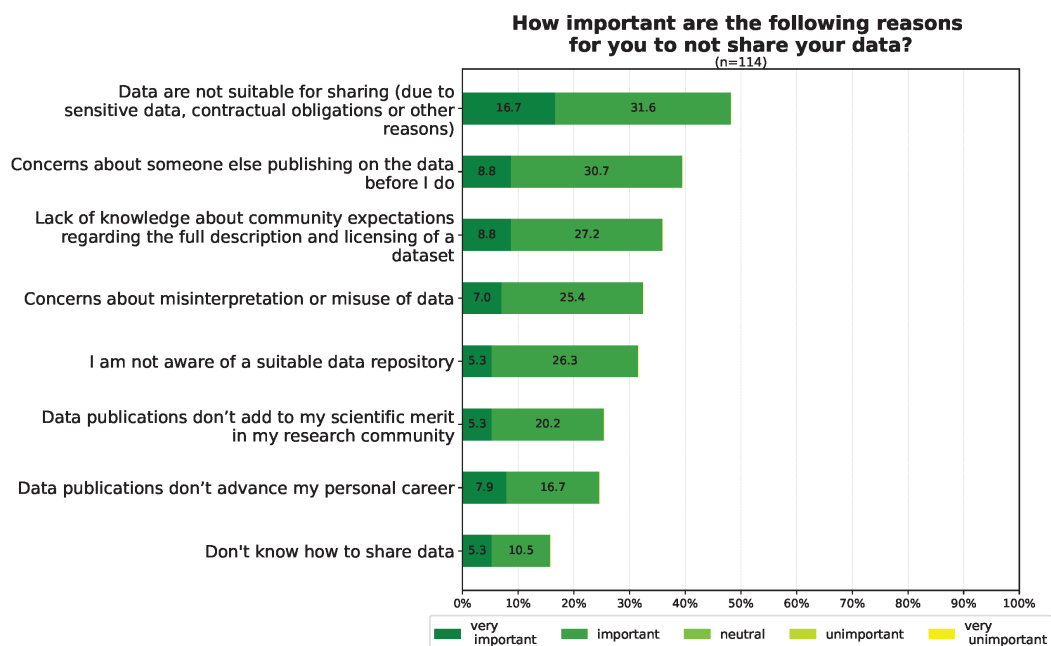


Figure 3: Fig. 3: Bar chart of answers to the question “How important are the following reasons for you to not share your data?”. Only answers “very important” and “important”, ordered according to percentage of answers.

3 Discussion

Data sharing is an important component of FAIR and open data practices and thus, motivators and barriers for both do often overlap. Motivators and barriers are therefore summarized and discussed together for each topic.

3.1 Better science

The three most important drivers for data sharing (“better reuse of data”, “the possibility of verification of research”, and “more robust own research”; Fig. 2) may be summarised under the term ‘better science’. These drivers emphasise that researchers are intrinsically motivated and primarily share data in order to advance science, consistent with a study by Chawinga and Zinn (2019). Additionally, nearly all survey participants claimed publishing of open data to be important in their community to advance research, in line with the notion that the expansion of FAIR and open data practices for research as a whole is “very important” or “important” for 96% of the participants in this survey (Hübner, 2024).

Although there is obviously general agreement on the positive effects of FAIR and open data practices, there are many barriers in everyday research (see below) that prevent data sharing and other FAIR and open practices from becoming a matter of course. It is therefore important that all stakeholders involved in research data management take a close look at these barriers and work to improve conditions for researchers and communicate these improvements to the research community.

3.2 Need for education and better infrastructure

Better advice and education from institutions ranks highest as motivator for performing more FAIR and open data practices (75 %, Fig. 1). This may reflect uncertainty of researchers regarding the specific requirements and expectations of research institutions and funders, as well as a lack in data management literacy. A barrier to the practice of data sharing is the lack of knowledge about community expectations regarding the full description and licensing of a dataset, with 38 % citing this as a major obstacle (Fig 3). Other barriers, such as not knowing where to publish data (32 %) and not knowing how to share data (16 %, Fig 3), rank lower in importance.

This suggests that basic knowledge about data publication is present in the research community, but that there are still uncertainties and gaps in knowledge about specific aspects that should be identified and addressed. Research institutions could provide clear and concise guidelines and standards for FAIR and open data practices, as well as provide training and support for researchers to understand and implement these practices effectively.

Researchers are also calling for improved technical infrastructure to support the implementation of these practices (71 %, Fig .1). There are already many different infrastructures in place that support researchers in FAIR and open research data management practices, but these services are scattered and heterogeneous, often underfunded with personnel, and only a few of them have a long-term perspective (Bernard et al., 2021). These shortcomings may be the major reason why better infrastructure is still perceived as a strong motivator for FAIR and open data practices by researchers.

3.3 Data citation metrics

Data citation metrics are a highly motivating factor for 71 % of survey respondents to adopt FAIR and open data practices (Fig. 1). However, the development of suitable metrics is a grand challenge, as current metrics often rely on simplistic counts that fail to capture the quality and impact of research data.

Determining the quality of research data sets is a complex task, and any metrics developed must ideally encompass a range of quality criteria (zu Castell et al., 2024). Additionally, it is also essential to consider the potential risks associated with quantitative metrics (Helmer et al., 2020).

For only 56 % of the survey participants, receiving more citations to their research papers is a motivator for data sharing (Fig. 2). The relatively low ranking of this motivator by survey participants may be due to a lack of confidence in the effectiveness of data publications to increase citations of related journal articles, despite the positive correlation between articles that include statements linking to data in a repository and higher citation impact (Colavizza et al., 2020).

3.4 Role models

Colleagues as role models are important incentives, as the indicator “Fellow researchers that engage already in FAIR & open data practice” is ranking high (64 %, Fig .1). This may inform institutions to develop programs that make researchers that engage in FAIR and open data practice more visible, e.g. by the introduction of data champions.¹ Additionally, institutions could feature research data publications of a research department on a departmental website in order to improve visibility of data publications.²

¹Examples of Data Champion networks at the universities of Bielefeld, Hannover, and Cambridge are available online (accessed 5 April 2025): <https://www.uni-bielefeld.de/ub/digital/forschungsdaten/data-champions/data-champions-netzwerk/>, <https://www.fdm.uni-hannover.de/de/data-champions>, <https://www.data.cam.ac.uk/intro-data-champions>.

²<https://www.geo.fu-berlin.de/forschung/forschungsdaten/Forschungsdaten-des-Fachbereichs/index.html> (accessed 05 April 2025)

3.5 Requirements from publishers, funders, institutions and disciplinary norms

Stronger recommendations and/or requirements from journals/publishers for FAIR and open data practices are important incentives for 60 % of the participants (Fig. 1), and about 67 % when asked specifically about recommendations and/or requirements to publish data (Fig. 2). Publishers and journals have begun to encourage, and even require, data sharing in recent years, and academic communities have increasingly adopted data availability statements (DAS) in research articles (Jiao et al., 2024). However, the effectiveness of DAS is sometimes low (Gabelica et al., 2022) and journal data policies can be more comprehensive and effective, also in the Earth Sciences (Christian et al., 2020; Enabling FAIR Data Community, 2018; Hrynaskiewicz et al., 2020; Hübner, 2020; Roche, 2016).

Stronger and/or more detailed funder requirements for FAIR and open data practices are important incentives for 60 % of the participants (Fig. 1) and for about 67 % when asked specifically about recommendations and/or requirements to publish data (Fig. 2). However, many research funders already have strong requirements for FAIR and open data practices, including data sharing, in place.³

One possible explanation for this survey result is that researchers may consider funder requirements as sufficiently strong and any tightening of the regulations would not be perceived as motivation, but as coercion. Alternatively, researchers may feel that the current requirements are not being monitored and/or enforced consistently or effectively and are therefore perceived as relatively unimportant.

Institutional provisions play a slightly less important role as incentive for data publishing and are an even lower motivator for FAIR and open data practices in general (Figs. 1 and 2). This may be due to that institutional research data policies may not be well-known by researchers, or they are usually not consistently enforced or monitored. Potential action for NFDI4Earth may be to raise awareness about improved institutional research data policies, including promoting available resources (Arbeitskreis Open Science der Helmholtz-Gemeinschaft, 2019; Hiemenz & Kuberek, 2018; Llebot & Castillo, 2023).

For survey participants, disciplinary data sharing norms play a less important role as incentives for data sharing (Fig. 2). However, strong disciplinary norms do exist (COPDESS, 2014; Enabling FAIR Data Community, 2018; NFDI4Earth Consortium, 2024), and it may be a task ahead especially for NFDI4Earth and partners to foster uptake of the messages conveyed with these statements. Eventually, these norms are

³Guideline 13, DFG's "Guidelines for Safeguarding Good Scientific Practice" codex (<https://doi.org/10.5281/zenodo.6472827>); "In Horizon Europe, research data should be made open access by default and licensed under the latest version of CC BY (attribution required) or CC 0 (public domain), or equivalent. However, it is recognized that data should be 'as open as possible, as closed as necessary' ..." <https://www.openaire.eu/how-to-comply-with-horizon-europe-mandate-for-rdm> (accessed 05 April 2025)

very valuable to inform funders, publishers and institutions to formulate their policies and transform the norms into concrete, and possibly obligatory, instructions.

3.6 Career advantages

Only 56 % of the participants consider career advantages as an important motivator for FAIR and open data practices (Fig. 1). Compared to other motivators in the survey, it ranks in the middle to lower range. Answers about career-related indicators in the “data sharing” (see Fig. 2) support the fact that researchers do consider career advantages a rather weak incentive. Closely related to the career advantages, FAIR and open data practices playing a stronger role in internal evaluations ranks low compared to other incentives addressed in this section.

The absence of current mechanisms in research institutions to structurally acknowledge FAIR & open data practices in career-related procedures (Pontika et al., 2022) may in part explain the survey result: researchers simply have no personal experience that such practices play any role for career advancement or research assessment and institutional hiring, tenure, and promotion processes.

Various declarations and guidelines have been put forward to promote more responsible and transparent evaluation and assessment methods (DORA Steering Committee, 2012; Hicks et al., 2015; Wilsdon et al., 2015). Especially CoARA⁴ has been recently strongly promoted, and as of June 2025, 12 of the NFDI4Earth members have already directly or as part of a group signed the CoARA declaration. This initiative has the strong potential to influence values, attitudes, and habits of researchers in the long run, driving the cultural change towards more FAIR and open data practices.

3.7 Awards

Only 37 % of the participants think that awards for FAIR & open data practices are important incentives. Research institutions, NFDI consortia and academic societies may take this result as a hint to design awards very carefully and not to overrate this instrument.

3.8 Data are not suitable for sharing

The most important barrier to data sharing is the “data are not suitable for sharing” (Fig. 3), which comes as a surprise. Research data from the Earth Sciences are usually easier to share than data from e.g. the social sciences, where personal data is often present. The sub-discipline of human geography is an exception where qualitative research methods are often applied and where sharing faces conceptual and

⁴<https://coara.eu/> (accessed 05 April 2025)

ethical challenges (Lamb et al., 2024). However, it is worth noting that researchers from human geography did not take part in this survey.

Spatial data in the Earth, environmental and agricultural sciences and some solid Earth data may be difficult to share openly because they may contain sensitive data (Hartmann, 2019) or due to ethical reasons related to natural and anthropogenic hazards and risk communication (Cocco et al., 2025). But these exceptions only are of concern to some sub-areas of the Earth System Sciences.

Business interests can lead to contractual obligations that may hinder data sharing. This applies mainly to projects with industry collaborations. However, although Earth System Sciences research includes applied science as well as basic research, Earth System Sciences is a discipline that is not exceptionally strong in industrial cooperation, like e.g. Engineering Sciences (Kotiranta et al., 2020).

As the importance of this barrier cannot be convincingly explained by the frequent occurrence of sensitive data or particularly frequent industrial cooperation in the Earth System Sciences compared to other disciplines, it can be assumed that other reasons contribute to the participants' perception that data are not suitable of sharing, including the other issues addressed with this question in the current survey.

3.9 Fear of being scooped

Scooping is the second most important reason to not share data (40 %, Fig. 3). It's essential to acknowledge and recognize this fear, rather than dismissing it as an irrational concern: by acknowledging the fear of being scooped, it may be addressed in a more constructive way (Pasquetto et al., 2024).

Although the fear of being scooped is a prevalent barrier, the risk of being scooped by someone else is relatively low in reality, especially for researchers who have invested time and effort in collecting data and developing code: as Gomes et al. (2022) note, those who have invested in their research are often best equipped to build upon and analyze their own work. Appropriate credit for data, curation, and publication in trustworthy repositories, as well as carefully chosen access embargoes may be instruments to counteract the fear of being scooped and to be more confident in sharing their data.

3.10 Misuse of data

Misuse of research data is related to scooping in that it is a fear that can create obstacles to the open sharing and reuse of data (Fig. 3). The term "misuse" can encompass a wide range of behaviors, including unintentional errors, unauthorized reuse, and intentional manipulation (Pasquetto et al., 2024). The lack of contextual information about a dataset and its meaning is often cited as a common source of data misuse

(excluding cases of intentional misuse). To address this major issue, curating and documenting data is a key intervention to prevent inappropriate and unwanted uses of open research data (Wilkinson et al., 2016). This is because documentation provides essential context and meaning to a dataset, enabling users to understand its limitations, biases, and potential applications.

4 Conclusions

This survey may serve the ESS community as an opportunity to rethink about how to strengthen the motivators for FAIR & open data practices in general and, in particular, for data publication that are important for the participants of this survey. At the same time, barriers of high importance to survey participants may be assessed in order to identify targeted future actions to phase out disincentivizing environments and structures. It is important to foster existing and new strategic partnerships with potential allies like academic societies, the FID GEO⁵, or the NFDI4Earth, for joint targeted projects to improve the adoption of FAIR and open data practices.

Developments of data citation metrics and other metrics for the recognition of FAIR and open data practices are, at the national and international level, still in their infancy. NFDI4Earth supports the cultural change towards more FAIR and open data practices and more variable research evaluation with its services, with the NFDI4Earth FAIRness and Openness Commitment, and with its work with academic societies. Such activities accompany and support the implementation of initiatives like CoARA which tackle these issues at a broader scale and in a wider context.

Answers about career-related indicators in the “data sharing” sections of this survey support the fact that researchers do consider career advantages as a rather weak motivator for FAIR and open data practices. This may simply reflect the current reality: to date, FAIR and open data practices do play only minor or, mostly, no roles in the hiring, tenure or promotion processes. Again, CoARA is a major player addressing these issues and should be supported strongly by NFDI4Earth members willing not to accept closed data practices anymore. It will be essential to recognize the value of data production and make it a key indicator of scientific performance. Only when researchers are rewarded for their data-related activities will they be motivated to invest time and resources into producing high-quality data sets (Pascu & Burgelman, 2022).

It is notable that the three most important drivers for data publication in this survey can be summarized in the perception that data sharing improves science as a whole. This indicates that data sharing is a highly valued practice in principle. Together with the fact that, in praxis, data sharing is not yet the default for many researchers today, the ESS community may concentrate on community norms which are supported by training, education, infrastructure, and recognition and which eventually may turn into

⁵Fachinformationsdienst Geowissenschaften, <https://www.fidgeo.de> (accessed 05 April 2025)

new or stronger data sharing policies once the community has broadly accepted such norms. Especially researchers acting as leaders and decision-makers in their roles as e.g. deans or reviewers, can have a special impact here.

When looking at the barriers for data sharing, supporting training and education activities is apparently the most effective way to counteract these barriers. This is especially true in the light of the fact that the technical infrastructure to share data in the Earth System Sciences is already present today. Additionally, appropriate credit for data publication should be implemented by NFDI4Earth member institutions in the course of a re-assessment of research evaluations.

The most important reason for not sharing data is the consideration of survey participants that the data are not suitable for sharing. The high importance of this barrier cannot be explained easily and may stem from a mixture of reasons, including unfamiliarity with data publishing and its benefits, fears of being scooped and a general notion that “my data” must not be shared with others.

NFDI4Earth member institutions should take advantage of NFDI4Earth-developed instruments in order to provide better assistance and infrastructure to its researchers: educational resources and training opportunities as well as the OneStop4All and the User Support Network can be used by institutions to improve local research support. In this way, the core outputs of NFDI4Earth may develop in the future into valuable and well-received support instruments for researchers, organisations and institutions. Last but not least, effective communication of these instruments within the research community will be crucial to ensure that researchers know that they exist, how to use them and how to benefit from them.

The present survey adds to the corpus of existing studies on the adoption of FAIR and open data practices by targeting specifically the German ESS research community. The survey participants' responses provide a detailed picture of the researchers' attitudes. However, the results are largely consistent with those of other studies that examined different disciplines or were discipline-agnostic. No distinctive features specific to the geosciences could be identified.

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