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Developing capacity for impactful use of Earth Observation data: Lessons from the AfriCultuReS project

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A B S T R A C T

An increasing number of products and services based on satellite Earth Observation (EO) data are being developed for use by decision-makers in African agricultural contexts, providing information such as weather and climate forecasts, crop yields and water availability. Capacity development to support impactful use of EO data is a key component of many EO-for-development initiatives, but there is little consensus over where or how capacity should be developed. Our goal in this piece is to provide a critical perspective on the capacity development required to support the creation of more impactful EO data services. Drawing on a capacity needs assessment carried out as part of the AfriCultuReS project (a major EO-for-development initiative), we identify proximate factors which inhibit the success of EO data services such as flawed communication strategies, low relevance in African agricultural contexts, duplication of existing products, and lack of financial sustainability. We link these proximate challenges to deeper issues such as unequal access to funding and resources, fragmentation in the EO field, and relational asymmetries of power, all of which combine to exclude important forms of knowledge from decision-making. Based on this needs assessment, we argue that capacity

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development requires broader systems-based approaches which develop the capacities of all actors (including those in the Global North) to respect different forms of knowledge, use and participate in co-design approaches, and recognise and challenge the asymmetries of power which currently limit the involvement of certain groups in processes of EO data service design.

1. Introduction

Decision-support tools drawing on satellite Earth Observation (EO) data have increased rapidly in number in recent years. Many such tools are being targeted at stakeholders in African food and agricultural systems, with examples ranging from large-scale famine early warning systems to weather and crop management advice for individual farmers. While a substantial number of EO data service initiatives are being led entirely within African countries, many others involve partnerships or consortia comprising both organisations from African countries and from countries in the Global North.

Decision-makers in many African agricultural contexts must contend with limitations in the availability and quality of large-scale data (Jerven, 2013). EO data services are intended to fill these gaps, facilitating 'better' decisions which lead to achievement of sustainable development objectives such as greater food security (Anderson et al., 2017; Espey, 2019). The literature on weather and climate services in African countries indicates that such information services can result in positive impacts on agricultural incomes and yields at local scales (see review by Nkiaka et al., 2019). But while many success stories can be found in the grey literature, there is less rigorous, peer-reviewed evidence for larger-scale impacts on sustainable development indicators in African agricultural contexts (Tall et al., 2018; Vaughan et al., 2019).

This limited documented impact is likely attributable in part to there being so few post-hoc assessments of EO data service initiatives (Msangi et al., 2006; Tall et al., 2018). But, despite recent rapid growth in the geospatial sectors of many African countries, it is also still often argued that there is not sufficient capacity in these countries to access, analyse or use EO data effectively. This is why capacity development is viewed as an essential component in many EO-for-development initiatives, such as the global efforts of the Group on Earth Observations (GEO; Anderson et al., 2017).

This apparently simple claim is, however, much more problematic than it might first appear. Capacity development is a contested idea, and one with no single common interpretation. The term has been criticised as a 'buzzword', used by diverse actors to advance differing agendas (Eade, 2007). The academic literature on capacity development is surprisingly sparse given the ubiquity of the term and there is little critical evaluation of what effective capacity development looks like (where such critical evaluations exist, they often find little evidence of sustained capacity development impacts; Ubels et al., 2010; Hewitson, 2015). A similar lack of clarity is evident in capacity development for information services incorporating EO data. In a survey of researchers and practitioners working on weather and climate services, for example, Vaughan et al. (2016) found that 'while 30% of respondents prioritised case studies to establish good practice with respect to capacity development … there is no consensus regarding how to advance capacity building for climate services.'

The goal of this paper is to provide a critical reflection on capacity development needs in EO-for-development, based on our experiences in the first two years of the AfriCultuReS project. We draw on a capacity needs assessment carried out in user workshops, and on what we have learned about capacity development through being part of this project – both in terms of what has worked well and less well. These experiences lead us to argue for capacity development approaches involving multidimensional learning across geographies, disciplines and worldviews, and which equip EO-for-development practitioners to recognise and challenge asymmetries of power.

2. Capacity development: definitions and critiques

The concepts of capacity building and capacity development have been part of the international development mainstream since the early 1990s, arising from recognition that 'technical assistance' approaches often failed to produce lasting impacts (Wubneh, 2003; Craig, 2007). Some early practitioners of capacity development adopted a narrow approach focused on solving human resource problems in particular institutions (Cohen, 1993). But the concept has since evolved to place greater emphasis on empowerment and self-determination. This is exemplified in the definition adopted by the United Nations Development Program (UNDP), who define capacity development as 'the process through which individuals, organisations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time' (Wignaraja, 2009).

The language associated with this understanding of capacity development echoes that of the capabilities approach first proposed by Sen (1999), who argued that the goal of development should be that people have greater freedom to achieve the lives they have reason to value (Sen, 1999). Within this school of thought, 'empowerment' has been conceptualised as describing the extent to which people are able to make *effective* choices; firstly, whether they are able to choose a goal, and secondly, whether they are able to translate their choice into the achievement of that goal (Alsop and Heinsohn, 2005; Kleine, 2011). The extent to which people can make choices and then realise those choices depends both on individual agency (the capacity of an actor to visualise different options and make a choice) and the opportunity structure within which the actor operates (which includes factors such as policy and legal frameworks and formal and informal institutions; Alsop and Heinsohn, 2005; Kleine, 2011). Viewed through the lens of the capabilities approach, the goal of capacity development to empower entails developing capacities which enable members of a particular population to choose and realise their own goals – returning to the UNDP definition, 'to set and achieve their own development objectives over time.' It is this understanding of capacity development as a process of empowerment which must consider both agency and opportunity structure which

informs this paper.

Many authors still favour the term 'capacity building' as opposed to capacity development or strengthening. But the idea of 'building' capacity has been criticised as 'conceptually paternalistic' (Mugisha, 2015), potentially implying a vacuum of capacity which can only be addressed with input from outsiders. This is particularly misleading given the depth of work on EO data services already occurring in African countries (Woldai, 2020). To avoid risking this association, we use the terms 'capacity development' or 'capacity strengthening' except when directly quoting authors who use other terminology.

One critique of capacity development is particularly relevant in the context of EO data services designed for African agricultural contexts. This is that the need for capacity development is expected of usually countries and people in the Global South, particularly when capacity development is carried out as part of initiatives involving North-South collaborations. This is rather unfortunately illustrated by Target 9 of Sustainable Development Goal 17 'Partnership for the Goals' (emphasis added):

> 'Enhance international support for implementing effective and targeted capacity building in **developing countries** to support national plants to implement all the sustainable development goals, including through North-South, South-South and triangular co-operation.'

This is highly problematic. The SDGs are meant to be global goals. They apply to all nations and are a response to universal deficiencies. As we shall see below, there are obvious ways in which capacity within wealthier countries could be substantially improved.

This critique reflects a broader tension in capacity development work, which is that capacity development as currently practiced often privileges particular groups and particular kinds of knowledge. Capacity development efforts, however well-intended, often result in information flowing only one way, from those with greater to those with less power over project decision-making (Bockstael, 2017). This means, for example, that capacity development approaches are more likely to be defined in the Global North for roll-out in the Global South (leading some authors to characterise capacity development as a form of coloniality; Adriansen and Madsen, 2019) and are more likely to be perceived to involve transfers of information from those with more technical scientific knowledge to those with less.

As we will show in this paper, such one-way knowledge transfer approaches are poorly equipped to solve the societal challenges targeted by EO data services, an argument also made by Tedmanson (2012) when reflecting more broadly on capacity development work. To illustrate this, we reflect on our recent work as part of the AfriCultuReS project.

3. The AfriCultuReS project

AfriCultuReS ('Enhancing food security in **Afri**can agri**Cultu**ral systems with the support of **Re**mote **S**ensing'; www.africultures.eu) is a major international collaboration funded as part of the European Union Horizon 2020 program (European Commission, 2014). The project is carried out by a consortium of eight African and nine European partner organisations, with African partners located in Tunisia, Ghana, Niger, Kenya, Ethiopia, Rwanda, Mozambique and South Africa. The consortium includes both private sector organisations and research and academic institutions.

The project goal is to make high quality data available to agriculture sector stakeholders in eight African countries via an online platform which combines satellite EO data with climate and crop modelling. The platform will support a range of EO-based products bundled into seven services (Crop, Climate, Land, Livestock, Weather, Water, Drought), increasing the access of decision-makers to short-term early warning, longer-term agricultural forecasts, yield data and land use/land cover map. Full details of all products can be found in Alexandridis et al. (2020). The ultimate hope is that enhanced data provision will support decision-making which increases crop and livestock yields and reduces yield variability, so contributing to improved food security in the eight African focus countries.

Capacity development is a key component of the AfriCultuReS work program. To improve our understanding of capacity development needs, we convened a series of one-day workshops between September and November 2019 in seven of the eight AfriCultuReS countries (omitting only Niger). The primary goal of these workshops was user engagement and to shape project direction. However, we believe workshop outcomes will be of much wider interest to researcher and practitioners in EO-for-Development, particularly given the paucity of academic writing focused specifically on capacity development in the EO-for-Development context (with notable exceptions such as Shukla et al., 2021).

Workshops involved between 15 and 35 participants, invited by in-country AfriCultuReS partners because they belonged to organisations perceived as potential users of AfriCultuReS products or with substantial EO-for-development expertise. The majority of workshop participants were therefore from government departments and other public sector organisations relevant to agriculture and environmental management, and from research institutions. A smaller number of attendees represented farmers' associations, non-governmental or intergovernmental organisations, or small-to-medium enterprises specialising in geospatial applications. Participants received per diems and/or reimbursement for travel and accommodation expenses depending on the norms of the country in which the workshop was being held.

While precise workshop structure varied over the series (as we learned from and improved on previous workshops), all workshops included broadly the same themes: (i) a discussion of the proposed AfriCultuReS product portfolio and the extent to which this met the needs of potential users in each country; (ii) an interactive demonstration of a prototype of the AfriCultuReS web platform; (iii) a capacity needs assessment exercise. For the capacity needs assessment, workshop participants were split into groups of four to seven people and asked to fill out a table listing barriers to the success of EO data services and the strategies which could be used to address them.

Data derived from these workshops included the tables of capacity development needs and strategies, along with notes on and recordings of participant feedback on all three of the workshop topics mentioned above. For six of the workshops, these were compiled

by the lead author after each workshop and used to produce a summary report, drawing out core themes from workshop discussions. This summary report was shared with representatives of the relevant in-country AfriCultuReS partner organisation and any other workshop attendees from the AfriCultuReS consortium, to try and ensure as accurate as possible a representation of workshop content. The exception was the workshop in Mozambique, for which we worked from the raw workshop data. In this paper, we draw on materials from all seven of the workshops to map out the barriers to success of EO data services highlighted by participants, recognising that these discussions have relevance beyond our specific project and in the wider EO-for-development space.

We note three caveats before discussing workshop findings. First, we recognise that any one project can only provide a partial perspective, particularly given our dependence on workshops. Workshops have well-documented issues in terms of accessibility and ours were no exception; the majority of workshop participants were from organisations based in the capital cities in which workshops were held, and already had a degree of existing interest in EO data services. For this reason, we do not depend on workshop outcomes alone, but triangulate these findings with published literature. In particular, we refer to literature from the parallel field of Information and Communication Technology for Development (ICT4D).

Second, while we talk about capacity development needs to support impactful use of EO data 'in African countries', we recognise that there will be huge variation both within and between African countries. Our workshop findings highlight important issues; but we acknowledge that they are broad-brush and that there is huge potential for more detailed evaluations of capacity needs focused at smaller scales.

Third, we frame our argument from a particular perspective on the objectives of capacity development for EO data services. As discussed above, we see the aim of capacity development as being to address the barriers which currently prevent people from choosing and achieving their goals. But we recognise that those working on EO data services often have other motivations which may not be easily compatible with this vision of capacity-development-as-empowerment, such as the profit motive of private sector organisations and the publication and promotion motives of many academic actors. We consider the additional challenges arising from these conflicting motivations later in this piece.

4. Workshop outcomes

Based on the discussions in the seven AfriCultuReS workshops, we propose a 'theory of stasis' (Fig. 1) summarising the reasons given by workshop participants that products drawing upon EO data may fail to achieve lasting impacts. We split these factors into: (i) proximate causes of failure, which are the immediate and more easily observable reasons why EO data services may not have sustained impacts; and (ii) ultimate causes, which are the more profound issues suggested to lead to these observable issues. We also map some of the pathways between these proximate and ultimate causes. We now address proximate and ultimate barriers in turn.
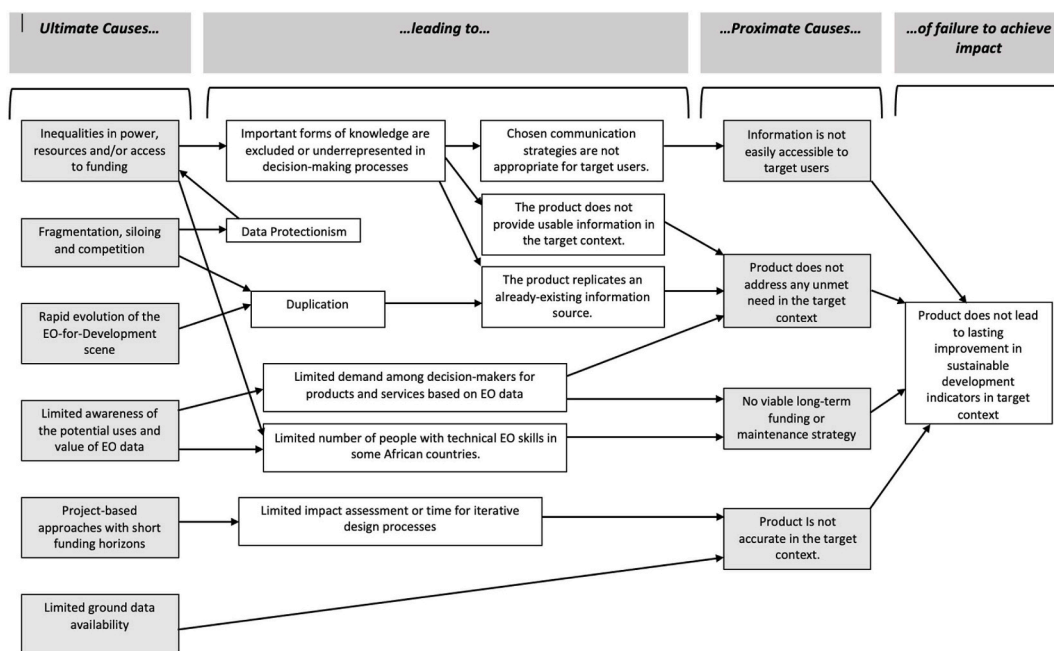

Fig. 1. A theory of stasis for EO-for-Development products in African countries. This figure summarises barriers to impact for EO-for-development projects and proposed connections between them, based on discussions in seven user workshops held as part of the AfriCultuReS project between September and November 2019.

4.1. Proximate factors

A first proximate challenge identified by workshop participants was communicating EO-derived information to target decision-makers, which is particularly complex is cases where the key decision-makers are smallholder farmers. A project output like an on-line platform was perceived as useful for a GIS-competent user with a reliable internet connection and a smartphone or computer, but this would exclude many of those living in rural African contexts. Participants stressed the importance of working with existing, trusted networks, such as community radio stations, which disseminate information in locally appropriate languages, and which are still effective in contexts of low literacy. Participants also stressed the importance of understanding and working with existing in-person knowledge exchange networks, such as traditional leadership and agricultural extension systems.

A second proximate explanation for why EO data services might not produce sustained positive impacts is that the service does not meet an unmet need within the focus context. In some cases, this may be because target decision-makers lack the resources needed to act on the information provided. In others, it may be because a product already exists which delivers the same service. The problem of duplication was identified by participants in six of the seven AfriCultuReS workshops. Participants in Kenya, Tunisia, South Africa, Rwanda, Ghana and Ethiopia all referred to the increasingly crowded nature of the EO data service field in their respective countries, with a growing number of initiatives aiming to provide similar services and targeting similar sets of decision-makers.

A third proximate explanation for why EO data services fail to produce long-term impacts is that they lack a viable long-term funding model. The question of 'who can pay' and 'who will pay' recurred frequently in workshops, with many participants having witnessed previous promising projects that collapsed when funds ran out. Such questions often arose in tandem with questions around ownership, with willingness to fund linked to sense of ownership and level of involvement in product design.

The final proximate reason given for lack of impact from previous EO data service initiatives is that products may not be accurate in the target contexts, reducing their value to potential users. In part this can reflect the relatively coarse resolution of many remote sensing products which does not capture well the fragmented nature of land use on the ground. Participants in Ethiopia, Rwanda and Mozambique discussed how many EO data services are not equipped to cope with highly fragmented smallholder farming landscapes. A similar problem is that single units of land may contain multiple crops. Participants in Mozambique pointed out that appropriate models have not been developed to provide the information required by the many smallholder farmers practicing intercropping.

4.2. Underlying factors

These four proximate factors derive from deeper issues shaping the outcomes of EO data services initiatives. The first such issue is that of who is involved in project decision-making processes. This is reflected in the fact that the solutions proposed by workshop participants for all the proximate problems described above focused on building collaborations and partnerships with in-country stakeholders who have different kinds of expertise, including potential product users.

The networks of people who create, disseminate and use EO data are structured by continuing inequalities. Gender inequalities were particularly noticeable in the AfriCultuReS workshop series. In one of the workshops, for example, only three women were in attendance in comparison to more than twenty men (reflecting wider gender disparities in EO research), and the role of the facilitator became to make sure that these women's perspectives were heard. This involved speaking directly to female participants during small group discussions, rather than assuming that female participants would necessarily be confident to speak during plenary sessions.

Gender inequalities were, however, just one among a number of axes of inequality and power discussed or observed during the workshops. Other examples included the inequalities arising from differences in ease of access to funding or data, levels of privileged technical knowledge, or confidence sharing ideas in the main workshop language (English, French or Portuguese, depending on location). The interactions between all of these factors shaped both who contributed most to conversations in these specific workshops, and who was perceived as having the greatest influence over decision-making in EO data service initiatives. The consequence of these continuing inequalities is that certain important kinds of knowledge (such as those of the potential product users) are less likely to be represented in decision-making processes.

The duplication of effort which concerned workshop participants appears to arise both from breaks in communication in the networks of actors involved in producing and using EO data services, and from the fact that the current structure of the EO-for-development scene incentivises competition over collaboration. Participants in Ethiopia, Kenya and Ghana all discussed how EO-for-development initiatives are silo-ed rather than networked. They also pointed out that data has value in commercialised environments, whether monetary or through the competitive advantage exclusive access to that data bestows, and this means that many organisations will be willing to share data only if there is a convincing value proposition for the advantages of data sharing. The potential for duplications and wasted energies is compounded by the rapid pace of change in the EO-for-development scene; participants in Kenya and Tunisia, both countries with well-established geospatial sectors, discussed the difficulties of keeping skills and products up to date in a rapidly changing landscape.

An additional barrier identified by participants in multiple workshops was lack of recognition of the potential values and uses of EO data among key decision-makers. This resulted in lack of demand for and uptake of EO data services, and also made it more challenging to run training initiatives (both because of a shortage of qualified trainers, and also because of lack of buy-in at management level in both public and private sector organisations). The final underlying causes identified were the short-term nature of many initiatives, leaving insufficient time for adaptive learning, and the limited availability of ground data to evaluate the accuracy of EO data products in African rural contexts.

5. Discussion

The four proximate barriers to impact we identify here are supported by the literature on climate services. Previous studies have highlighted issues with communicating information in appropriate formats (Nkiaka et al., 2019; Hansen et al., 2019), providing information which potential users cannot act upon because they lack the necessary resources (Ingram et al., 2002; Roudier et al., 2016; Jew et al., 2020), duplication of effort (Carr et al., 2020) and lack of models for long-term financial sustainability (Brasseur and Gallardo, 2016). There have also been calls to address this issue through stronger partnerships and co-design approaches which make space for diverse forms of knowledge (Kristjanson et al., 2009; Makate, 2019; Vincent et al., 2018; Vogel et al., 2019). And yet, it still seems that remote sensing data are often poorly integrated with other forms of knowledge (Cord et al., 2017; Findlater et al., 2021).

These are longstanding and well-recognised issues in the wider field of ICT4D. Their persistence emphasises the fact that they derive from deep-seated structural inequalities and differences that have been fostered for decades. This raises further questions with regards to the scope of capacity development. Should the objective be to develop the capacities needed for people to understand the tools created by a specific project? To what extent can it take on the larger-scale structural issues which make it harder for ICT4D initiatives to succeed?

The empowerment-focused UNDP capacity development definition framing this paper would suggest the need for a structural approach. So too would the work by Alsop and Heinsohn (2005) and Kleine (2011), both of which emphasise the importance of the 'opportunity structure' in which individuals operate. Taking a broader structural or systems-wide perspective on capacity development means broadening the scope of capacity development activities, to include those with high technical knowledge and partners based in the global north. In particular, this means developing the capacity needed to recognise and challenge asymmetries of power. As Vincent et al. (2020) and Daly and Dilling (2019) argue, any effort at co-design without attention to power is likely to perpetuate an unjust status quo.

This recalls Ziervogel et al.'s (2016) argument for 'transformative capacity', defined as 'the capacity of individuals and organisations to be able to transform themselves in a deliberate, conscious way.' In some cases, underrepresented groups can build capacity to challenge power asymmetries by organising in physical or virtual space. A good example is online networks of female EO experts, such as Ladies of Landsat and Women in Geospatial. But the onus is also on those who currently have power to know when to step back and make space. This may involve larger-scale events, such as the recent Group on Earth Observation Indigenous Hackathon, or smaller-scale interactions ensuring that less powerful voices are heard in project design. All of these approaches require first that the individuals involved recognise capacity to be lacking. Many countries are seeing an increase in data science training programmes and in the number of students enrolled in those programmes as part of a wider push towards 'digital transformation'. But these programmes often emphasise technical aspects and have a very cursory engagement with data science ethics (Oliver and McNeil, 2021). Our argument is that reflexivity and a degree of critical social science should be seen as an essential component of any applied data science training.

The idea that everyone can be both teacher and learner in EO-for-development is reinforced by our own experiences in the first two years of the AfriCultuReS project. The project consortium is formed of strong partnerships between African and European partner organisations, and learning from each other over the course of the project has been a privilege. But the core consortium does not include many anticipated end-users of AfriCultuReS products. In the original project design, in-person engagements with users were also scheduled for later in the project schedule. While we recognised this as an issue early in the project lifespan and sought to shift closer to a co-design model, a complete change in approach was impossible, particularly within the time and resource constraints of a four-year project. As Findlater et al. (2021) point out, the success of climate and other EO data services is all about relationships; and equitable, meaningful relationships take time to build and a different, often under-valued set of skills.

The approach to capacity development we propose here would be one of continuous reflexivity and learning, but we recognise that this does not necessarily integrate neatly with the project-based nature of much EO-for-development work. However, there are pragmatic steps which can be taken within projects such as AfriCultuReS as part of this collective learning process. At the project design stage, EO-for-development can learn from established best practice in parallel disciplines, using resources such as the (Principles for Digital Development,) (https://digitalprinciples.org) or the Ethical Standards in ICT4D (Dearden and Kleine, 2019). Capacity development activities can be designed to reach across different disciplinary boundaries, such as by publishing reflexive pieces in traditionally natural science journals (Vincent et al., 2020 in *Nature Climate Change* is a good example). Projects can ensure that in-country partners are project leads or co-leads – including partners who are not from technical EO backgrounds. And projects can aim to broker connections and support existing EO-for-development activities occurring in-country, to avoid competing with and undermining locally-led programmes. In all cases, funding organisations have a powerful role to play, given their power to shape who is represented in project leadership and whether is sufficient time to build meaningful and equitable relationships.

Thus far we have framed our argument in terms of the capacity development needed if EO data services are to improve the wellbeing of poorer and marginalised peoples – the stated goal of most EO-for-development initiatives. But here, we return to the challenge of conflicting motivations mentioned earlier. Those who could drive rapid transformative change are often those who also benefit most from the status quo. It is easy to talk about building the capacity of 'the poor' in African countries. It is much harder for those involved in the development of EO data services to reflect critically on their own actions and positionality, acknowledge that meaningful societal change may require personal or organisational sacrifices, and then continue to prioritise the pursuit of meaningful change over all other competing motivations.

6. Conclusions

The objective of this piece was to outline some of the barriers reducing the impacts of EO data service initiatives and the capacity development required to address these barriers. Approaches which are already commonly included in capacity development toolkits, such as technical training programs and development of open data resources, are addressing some important capacity gaps. But we argue that a *transformative* capacity development approach would need to go further, beyond unidirectional knowledge transfer approaches to systems-based approaches which also include people and organisations with high technical knowledge and in Global North as well as Global South. This would develop the capacities required to engage in meaningful and equitable co-design processes for EO data services, and to challenge the relational dynamics of power which currently exclude certain groups from using EO data.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

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