Australian Government

Australian Centre for International Agricultural Research

Final report

Project full title	Information for Agriculture, Food and Water Security – Digital Earth Africa
project ID	WAC/2021/164
date published	14/02/2024
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final report number	FR2024-003
ISBN	978-1-922983-84-8
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

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2 Executive summary

The Information for Agriculture, Food and Water Security (IAFWS) project delivered consultations in six African countries on the use of Earth Observation to meet information needs arising in the agriculture and food security domain. Initial consultations, deep-dive workshops, and policy dialogues for dissemination of findings took place in Botswana, Ethiopia, Kenya, Rwanda, South Africa, and Uganda. The national workshops engaged approximately 377 participants (200 in national consultative workshops and 177 in dissemination workshops) from nearly 150 different international, regional, national and sub-national organisations representing academia, government, parastatal, non-government organisations, civil society, UN agencies, private sector and farmer organizations. 32% of participants were female and 68% were male, with some countries, such as Uganda, having a 50:50 split and others, such as Ethiopia, having <10% female participation.

Participants were asked to list their needs in relation to use of EO data, record the strengths, weaknesses, opportunities, and threats of the Digital Earth Africa platform, and list potential product development ideas. Users also received hands-on training on how to access and use Digital Earth Africa products and services.

The stakeholder consultations revealed the following key pathways to impact:

1. Connecting with smallholder farmers by recognising them as agents of food security, and engaging with them through a broader network of stakeholders.
2. Enhancing the technical capacity of users through training, and incorporating the needs of end users as part of product co-design processes.
3. Developing and disseminating user-friendly knowledge and research products for public consumption and usage to address real world problems

Technical and capacity development activities ideated in the workshops were listed against three 'tiers' representing the relative effort required for implementation. Tier 1 corresponds to the least additional requirement of resources, Tier 2 to country-specific adaptation of existing workflows and joint capacity building, and Tier 3 would require considerable additional resources, such as through multi-agency, multi-year projects.

Technical opportunities identified were as follows:

- Tier 1
    - Spatial information on soil fertility and characteristics
- Tier 2
    - Crop-type mapping
    - Irrigated area mapping
    - Climate and crop production dashboards
- Tier 3
    - Early warning systems - pests and diseases
    - Early warning systems - crop production

Capacity development products and services opportunities were:

- Tier 1
    - Short training video series
    - Soil information training material
- Tier 2
    - Link with software developers and other service providers to enable app development and other interfaces
- Tier 3
    - Continental agriculture and food-security specific capacity development initiative

These opportunities were outlined in a Roadmap, alongside potential partners and strategies to connect to smallholder farmers. Development of both technical and capacity development products and services should take place through a series of dialogues with identified users, smallholder farmers and their representatives, and intermediaries such as extension agencies and the private sector. The Roadmap will be revisited and treated as a dynamic document based on ongoing in-country engagement activities across the African continent.

3 Background

It is widely recognised that there is unfulfilled potential to apply Earth Observation (EO) technology and techniques to agricultural and water management challenges across the African continent. Despite an increasing abundance of data sources and access platforms, barriers to utilisation remain. These barriers can be broadly separated into inadequacies on the data supply side, and capacity gaps on the user side. Both these aspects of underutilisation have been explored in the academic literature on EO in Africa.

In a review of the AfriCultuReS project, Pritchard et al. (2022) recognised the growing number of satellite-derived products and services being designed for decision makers in African agriculture. However, they identify that EO in African agriculture is characterised by underutilisation, unfulfilled potential, and unaddressed capacity gaps. They attribute some of these failings to duplication of existing products and sometimes parallel initiatives, and fragmentation in the EO community. This reveals some challenges with the implementation of EO in African Agriculture.

Speranza et al. (2022) identified that most EO users in Africa are either governmental organisations or researchers, with very few other users beyond these sectors. Additionally, they purport that dissemination of EO skills and knowledge have been primarily delivered by government officers and researchers, though recognise a growing opportunity for the private sector to deploy EO products and services.

The available free and open EO data is necessary but not sufficient for use in the agricultural sector. Kganyago & Mhangara (2019) canvassed numerous data sources and access/analysis platforms available to African users and reported two global initiatives that included Google Earth Engine (GEE) and the Sentinel Analysis Platform (SNAP). They use the South African National Space Agency (SANSA), Digital Earth Africa's host organisation, as an example of an organisation coordinating EO activities in South Africa. It is also important to note the existence of continent-wide initiatives such as Digital Earth Africa, and GMES & Africa since 2019. This characterisation of SANSA as an agency of knowledge dissemination is consistent with the observation made by Speranza et al. (2022) that extension and adoption has generally been driven by government departments.

The literature on the current status of EO for agriculture and natural resources in Africa reveals a common emphasis on the need for capacity building in various forms, in addition to context-specific challenges with data supply and presentation (Kganyago & Mhangara, 2019; Pritchard et al., 2022; Speranza et al., 2022). This suggests that future investment should aim to optimise and improve existing data products and services to meet needs in the African context, but focus more deeply on capacity building through several entry points beyond the government and research sectors.

4 Objectives

The Information for Agriculture, Food and Water Security (IAFWS) Project aimed to:

● Support consultations with African agricultural and water management agencies to understand the needs, opportunities and gaps for using EO - based services to sustainably increase agricultural productivity through improved water use, and;

● Develop a Roadmap for DE Africa to deliver services tailored to these needs to improve productivity and build resilience. This Roadmap identifies pathways to connect with smallholder farmers via intermediaries, such as national governments and non-government agencies. These pathways are classified according to the complexity of technical developments needed and the depth of the discussions required to implement them with impact.

5 Methodology

The project was implemented under six components with specific approaches:

1. Development of detailed project plan including a stakeholder mapping, project timeline and a communication plan
2. Development of country-specific materials (presentations and demonstrations of Digital Earth Africa platforms (maps and sandbox) identified in the project plan to support stakeholder engagement: Materials focused mostly on water resources and crop or vegetation and were adjusted to fit within the local context.
3. Established information needs and priorities for agricultural and water management agencies during stakeholder consultation workshops in Uganda and Botswana in November 2022, Kenya and Rwanda in December 2022, Ethiopia in January 2023 and South Africa in February 2023. Through these initial workshops,the stakeholder list was updated, ongoing EO for food security initiatives were profiled, end user needs and expectations were documented, and potential areas of collaboration were identified.
4. Built technical capacity of end users in the use of the DE Africa platform based on the needs and priorities identified during initial consultation workshops. This was done through deep-dive training sessions for participants from agricultural and water management agencies in Ethiopia in January 2023, in Uganda, South Africa and Kenya in February 2023 and in Rwanda and Botswana in March 2023. The hands-on training ranged from simple explorations of crop and water dynamics via DE Africa maps to advanced statistical analyses through the sandbox.
5. Development of a roadmap (this document) for meeting the EO data needs and addressing the challenges faced by users in the agricultural sector. Outputs from the initial consultative workshops and the deep-dive training sessions were used to develop a policy brief with clear policy directions to support the institutionalization of the use of EO data by both state and non-state actors in each country. The policy briefs were aimed to inspire consistent and timely integration of EO at each stage of the planning process for agricultural and food security projects. To ensure uptake of the recommendations from this (IAFWS) project, policy dialogues were organized in Rwanda in May 2023 and in Uganda, Botswana, Ethiopia and Kenya in June 2023.
6. Dissemination of the IAFWS project results. This was achieved through many avenues, including use of already popular and trusted platforms such as institutional websites, social media pages (mainly twitter, facebook, WhatsApp and LinkedIn). The messages were published in various forms including newspaper (print and online) articles, blogs, TV interviews, Radio messages, event flyers, posters, banners and infographics. These messages help to increase awareness of use of EO data in the agricultural sector with the aim of improving food security and climate adaptation.

The countries proposed for the preliminary meetings and later deep-dives include: (i) Uganda, (ii) Kenya, (iii) Rwanda, (iv) Ethiopia, (v) South Africa, and (vi) Botswana. The justification for selecting these countries was largely based on the existence of relevant stakeholders and the potential of these actors to consume/utilize DE Africa products and services. Specifically, the countries were selected based on the following reasons:

1. Existence of large number of stakeholders (Kenya, Uganda, Rwanda, Botswana, Ethiopia, South Africa);
2. High interest to deploy EO data and information for development actions (Kenya, Uganda, Rwanda, Botswana, Ethiopia, South Africa);
3. Existence of large arid and semi-arid areas that could potentially benefit from deployment of EO data and tools for drought mitigation (Ethiopia, Kenya, Uganda and Botswana);

4. Well-developed ICT sectors that could potentially support enhanced utilization of the EO products and services (Kenya, Rwanda and South Africa);
5. High potential for irrigation to increase crop production through irrigated agriculture (Rwanda, Kenya, Uganda, Ethiopia, Botswana and South Africa).
6. Presence of DE Africa offices in the country (Kenya, Rwanda, South Africa)
7. Existence of partner organizations critical for realization of DE Africa's agenda (Ethiopia, South Africa, Uganda)

Figure 1: Participants engaged in focus group discussions at the initial consultation in Botswana.

Figure 2: Participants at the Rwanda initial consultation.

6 Achievements against activities and outputs/milestones

Objective 1: To support consultations with African agricultural and water management agencies to understand the needs, opportunities and gaps for using EO - based services to sustainably increase agricultural productivity through improved water use.

no.	activity	outputs/ milestones	completion date	comments
1.1	Initial consultations	Botswana 6th & 7th November 2022 Ethiopia 17th - 18th January 2023 Kenya 8th December 2022 Rwanda 6th December 2022 South Africa 14th-15th February 2023 Uganda 30th November 2022	15th February 2023	The consultations engaged around 200 people from approximately 145 different organisations. 68% of attendees were male and 32% female. An overview of Digital Earth Africa and ASARECA was given before an introduction to Earth Observation products and services available. Participants then formed focus groups to conduct a strengths, weaknesses, opportunities, and threats analysis of the application of Earth Observation methods to agriculture, food and water security through Digital Earth Africa. The results of these participant-led analyses were documented.
1.2	Deep-dive consultations	Botswana 2nd & 3rd March 2023 Ethiopia 19th January 2023 Kenya 27th & 28th February 2023 Rwanda 2nd & 3rd March 2023 South Africa 16th February Uganda 23rd February 2023	3rd March 2023	The deep-dive consultations involved a more detailed overview of the Digital Earth Africa platform and hands-on training in how to use the platform to investigate crop health, phenology, vegetation anomalies and water extent. This gave participants a greater appreciation of the strengths and limitations of the platform and enabled them to give informed requests for technical product development which were documented as primary data for formulating the roadmap.

1.3	Dissemination workshops - policy dialogues	May and June 2023	30th June 2023	The policy dialogues were attended by 177 participants (29 in Botswana, 34 in Ethiopia, 55 in Kenya, 36 in Rwanda, 25 in South Africa and 50 in Uganda). Key issues that emerged from the policy dialogues included: (i) several institutions are using EO data, products and services for ecological modelling and forecasting pest outbreaks. (ii) There is a need to partner with telecom companies to be able to reach and get feedback from millions of farmers. (iii) Since some smallholder farmers who need EO information are illiterate or don't have access to smartphones, a network of extension service providers or digital connectors are required to increase uptake of e-services. (iv) Most of the agricultural data at National Agricultural Research Institutes (NARIs), MoA, Meteorology departments and universities are not accessible to the private sector or any other development partners. (v) Use cases are needed to demonstrate to farmers how EO data can support decision-making and increase farm productivity or resilience. (vi) There is a need for ASARECA and CCARDESA to support their stakeholders in digitizing agricultural data collection and cloud storage. This may involve committing to make agricultural data FAIR (Findable, Accessible, Interoperable, and Reusable) and constitute stakeholders within the EO data value chain into a platform to avoid duplication. (vii) ASARECA to support its member NARIs in drafting a data governance framework and establishing one-stop hubs for all agricultural research data within a country. (viii) ASARECA and CCARDESA to consider partnership and linking their Knowledge Management (KM) hubs with non-agricultural institutions such as National Space Agencies, UN agencies and Government MDAs that already have Geodata portals, data cubes, EO Knowledge hubs and access to high-resolution satellite imagery. (ix) ASARECA and Kenya National Bureau of statistics to jointly develop standardized data (administrative and survey) collection and publication/sharing protocols and increase data literacy among both state and non-state actors at county level.

				(x) ASARECA to champion use of data/evidence in decision-making especially during policy formulation and implementation.

PC = partner country, A = Australia

Objective 2: To develop a Roadmap for DE Africa to deliver services tailored to these needs to improve productivity and build resilience. This Roadmap seeks to classify pathways to connect with smallholder farmers based on the complexity of applications and of the discussions required to implement them.

no.	activity	outputs/ milestones	completion date	comments
2.1	Roadmap development	Roadmap drafted	16/06/2023	Drafting of the roadmap began as the final deep-dive consultations were completed. The proposed structure of the roadmap was shared and feedback sought in the following forums: 1. Digital Earth Africa global team visit to Pretoria, March 2023. 2. Digital Earth Africa science team visit to Australia, April 2023. 3. Weekly meetings between ASARECA and Digital Earth Africa. This meant that the structure and content of the roadmap was developed collaboratively, with an internal draft produced in late May. Ongoing reviews and additions were made in late May and throughout June. This final report draws on elements of the drafted roadmap.

PC = partner country, A = Australia

7 Key results and discussion

The strengths, weaknesses, opportunities and threats nominated by participants at each of the initial consultations are summarised in Table 1. The opportunities to pursue capacity building is particularly notable as it overcomes one of the nominated weaknesses; lack of awareness about the Digital Earth Africa program. The opportunities to develop more relevant and accessible products and services for African agriculture were further elucidated during the deep-dive consultations.

Table 1: Summary of responses to the strengths, weaknesses, opportunities, and threats analysis conducted by participants at the six consultations.

Strengths	Weaknesses
● Tailored to the African continent ● Open and free data	● Limited awareness; not well known ● Resolution (spatial and temporal) is perceived as low for some applications
Opportunities	**Threats**
● Conduct further capacity building and user engagement activities ● Develop products and services with more relevance to smallholder farmers	● Financial sustainability ● Competition from similar service providers

Workshop participants were asked to list strategies to connect with smallholder farmers. Common themes were:

- Develop accessible user interfaces that farmers can engage with
- Engage with farmers through networks, especially via extension officers and agencies
- Identify and work with 'champion' farmers

Participants at the project consultations strongly emphasised that smallholder farmers are part of a broader network of actors and that farmers themselves may not necessarily be end-users, though it is important they are the intended beneficiaries. Co-design processes should recognise the centrality of smallholder farmers as part of a broader network of actors and service providers. These ideas led to the development of Figure 3, a conceptual diagram showing how Digital Earth Africa could play a role by working among networks to deliver services of varying complexity; ranging from data visualisation to decision processes and policy implementation.
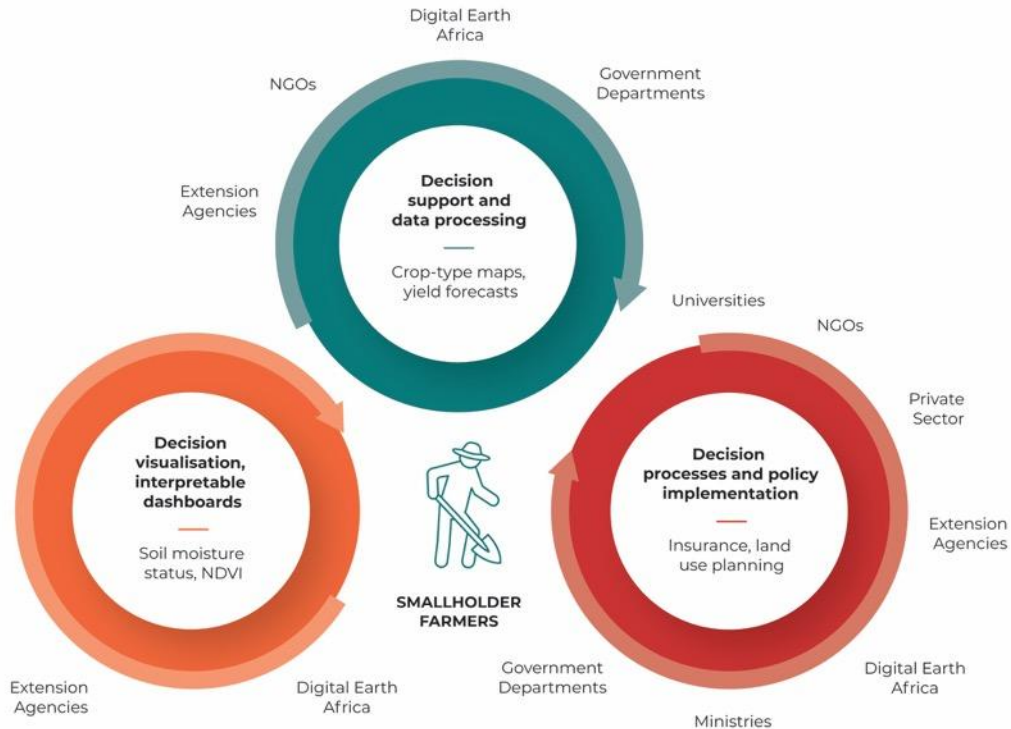
Figure 3: Conceptual diagram illustrating pathways to impacting smallholder farmers via simple data visualisation, decision support and data processing, and decision processes and policy implementation. Circular arrows represent an ongoing co-design dialogue with the stakeholders listed.

The focus on utilising the networks displayed in Figure 3 meant that **connecting with smallholder farmers** was the primary finding of the consultations and the initial section of the roadmap. **Capacity building and training** was the second theme that appeared in several consultations. The importance of training as part of co-design dialogue is reflected in the circular arrows in Figure 3 and Figure 4. The consultation team noticed that participants gave more informed and thus more valuable suggestions and feedback on how they could integrate Earth Observation into decision making and interactions with smallholder farmers. Training would be integrated into any product design and dissemination activity with Digital Earth Africa's existing capacity development resources. However, additional opportunities were identified during the consultation process:

- Short training video series
- Expand IAFWS to more countries
- Design soil information training material

The third key theme to emerge from the consultation was the design of **relevant and accessible Earth Observation products and services**. These were suggested by participants across several countries and categorised in Table 2. The identification of demand for such products and services is only the initial step of a much more comprehensive co-design process outlined in Figure 4, which would identify decision points that a product/service informs.

Table 2: Summary of product development suggestions made during consultations in six African countries.

Soil	Crops	Climate, Weather & Water
- Land suitability - Fertility - Land use and development planning	- Yield forecast - Crop-type mapping - Pests and diseases - Irrigated area mapping - Market information - Weed detection	- Rainfall - Temperature - Forecasts and outlooks - Early warning systems, incl. for floods
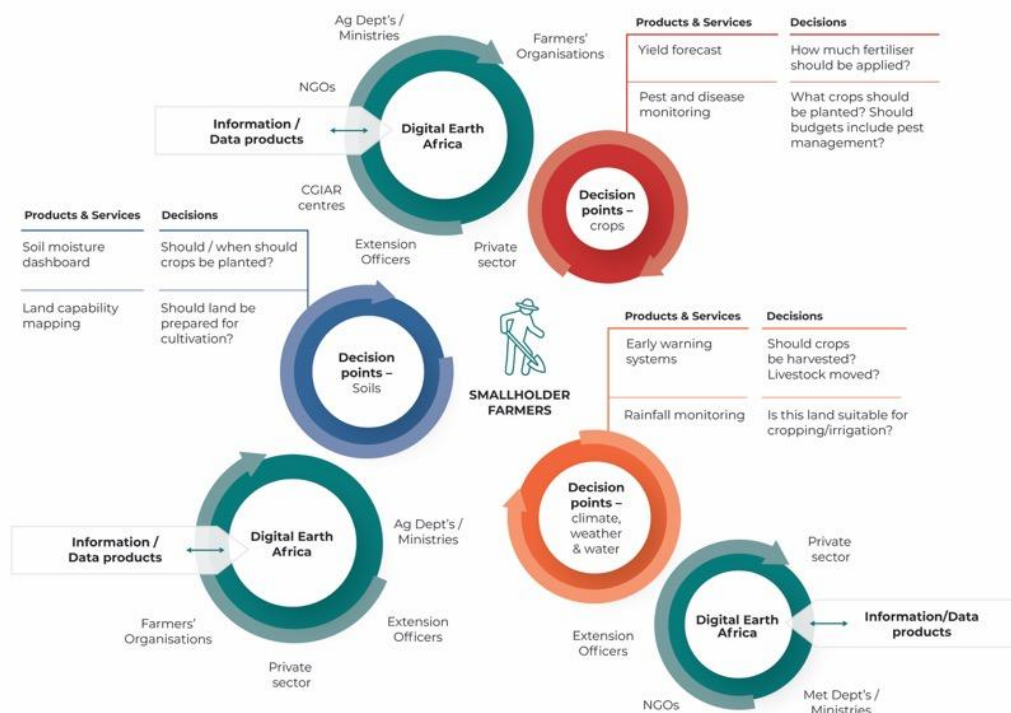
Figure 4: Conceptual illustration of how smallholder farmers can engage with Digital Earth Africa through decision points in various thematic aspects of agriculture. Circular arrows represent circular dialogue processes while grey bi-directional arrows represent information/data flow and feedback. Examples of decision points and related products and services (to be further scoped in dialogues) are given in tables with border colours corresponding to thematic areas.

A major part of further consultation is ensuring that services and products will be accessible to desired users. To achieve this, two elements of their design need to be considered:

1. The network via which the product or service is to be adopted, such as through state (extension agencies, Ministries of Agriculture) or non-state (NGOs, private agronomists) actors.
2. The interface used to access the product or service, such as an interactive Dashboard, a static map, or an analysis environment.

Networks can be developed by seeking advice from a range of relevant actors in the first instance, which will vary by country and region. For example, private sector actors formed

a large portion of participants in South Africa and Kenya and consultation feedback from South Africa especially noted the importance of the private sector. Contrastingly, state actors, such as the Rwanda Agriculture and Animal Resources Development Board (RAB), were widely referred to in Rwanda. Broad initial engagement will identify a select set of actors able to play a bridging role between DE Africa and smallholder farmers.

Decisions on interfaces must be made in consultation with bridging intermediaries and users. Their capacity in EO analytics, the level of time invested in receiving information from the interface, and the volume/detail of information required to inform a decision must be considered during consultation. For example, a static crop-type map may be sufficient in some instances, while a dynamic interface showing the latest agroclimatic measures for a farm area selected by a user may be necessary in other circumstances.

Having identified pathways to impact via connecting with smallholder farmers, capacity development, and developing accessible products and services; specific activities to progress these paths were listed. Technical and capacity development activities were listed against three 'tiers' representing the relative effort required for implementation. Tier 1 corresponds to the least additional requirement of resources, Tier 2 to country-specific adaptation of existing workflows and joint capacity building, and Tier 3 would require considerable additional resources, such as through multi-agency, multi-year projects. Potential partner and supporter organisations were also listed alongside each possible activity.

Technical opportunities identified were as follows:

- Tier 1
    - Spatial information on soil fertility and characteristics
- Tier 2
    - Crop-type mapping
    - Irrigated area mapping
    - Climate & crop production dashboards
- Tier 3
    - Early warning systems - pests & diseases
   - Early warning systems - crop production

Capacity development products and services opportunities were:

- Tier 1
    - Short training video series
    - Soil information training material
- Tier 2
    - Link with software developers and other service providers to enable app development and other interfaces
- Tier 3
    - Continental agriculture & food security specific capacity development initiative

The pathway to achieving some of the opportunities identified in this Roadmap can be conceptualised as a series of sequential dialogues. Figure 5 illustrates this by showing a sequence of steps that can be followed when pursuing an identified opportunity. This diagram can be used as a planning tool and a checklist to ensure necessary consultation and dialogue occurs in product development, and that opportunities for user engagement and feedback are not missed.

The dialogue processes described in Figure 5 begin with identifying relevant user groups. A 'decision point' or information need is then identified before an initial use case is

implemented. Feedback on the product or service is then sought as part of a training process. The product or service is then revised based on feedback and scaled beyond the use case. Finally, the product or service is presented to the broader community with feedback sought and revisions made as necessary.
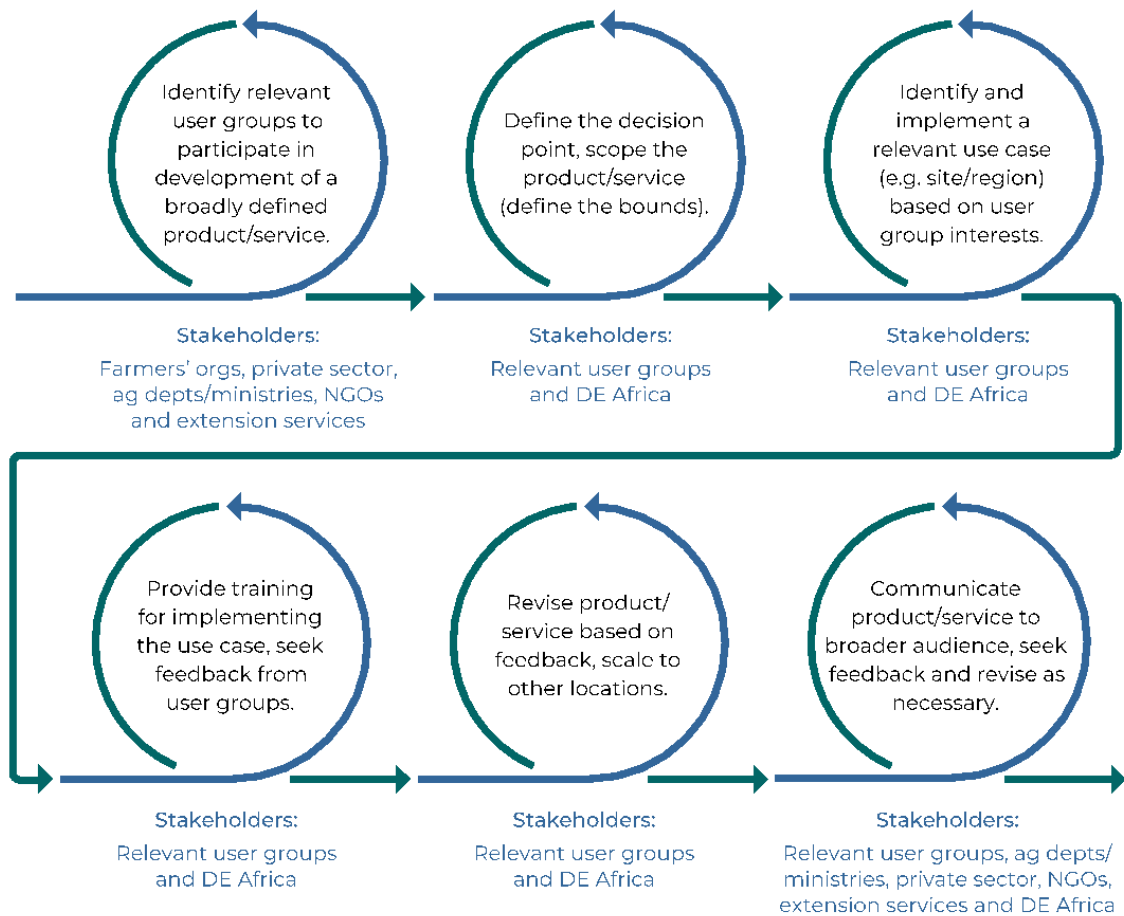
Figure 5: Sequential steps of circular dialogue which Digital Earth Africa will undertake when pursuing opportunities to provide information for agriculture, food, and water security.

8 Impacts

8.1 Scientific impacts – now and in 5 years

As this project was a consultative needs assessment, there have been no direct scientific outcomes. However, based on identified needs there are likely to be applied scientific developments related to the opportunities identified in the Roadmap. Examples include improved crop/ irrigated land mapping techniques for the African continent, or novel forecasting and early warning systems for crop production and pest impacts.

8.2 Capacity impacts – now and in 5 years

This project has directly improved the capacity of approximately 200 people from approximately 145 different organisations who attended the initial and deep-dive consultations. Attendees received training in how to access, analyse, and interpret Earth Observation data and apply it to their own situation. Feedback was sought on the usefulness and accessibility of the Earth Observation data and tools available.

In five years, this feedback will have informed a capacity building process for a much larger number and diverse group of users. Capacity development over the forthcoming five years will include suggestions made during consultations, such as short training videos and training tailored to certain groups, such as extension agents and app developers.

8.3 Community impacts – now and in 5 years

The project has leveraged and strengthened the network of researchers and value chain actors interested in EO in eastern and central Africa. There new relationships and networks that have formed between DE Africa, government departments, NGOs, and the private sector, resulting from the group fora held in six countries.

In five years, it is envisaged that this strengthened and expanded network will have produced novel capacity building material and delivered user-defined project outcomes in the agricultural and NRM sector. The network of EO users will also continue to expand over the coming five years, resulting in a larger, stronger, and more dynamic community in Africa.

It is also envisaged that smallholder farmers will benefit from the enhanced capacity of the network that services them. Embedding EO into African agricultural research, development, and extension communities will mean that the benefits of this technology will feed into services provided to smallholder farmers.

8.4 Communication and dissemination activities

Results of the consultations and items of the Roadmap were disseminated in policy dialogues/dissemination workshops conducted in all six countries and attended by 177 participants. A policy brief was prepared for each country and made available online and further publicised on social media channels.

Further, dissemination of project results is planned at GEO Week, Cape Town on 6th November 2023 and at the Australian Embassy, Kenya, alongside ACIAR and DE Africa colleagues in November 2023.

9 Conclusions and recommendations

9.1 Conclusions

Consultations in Botswana, Ethiopia, Kenya, Rwanda, Uganda, and South Africa revealed that Earth Observation can meet information needs in agriculture and food programs by connecting with smallholder farmers via networks, building capacity of a range of users, and developing accessible products and services. Development of both technical and capacity development products and services should take place through a series of dialogues with identified users, smallholder farmers and their representatives, and intermediaries such as extension agencies and the private sector.

9.2 Recommendations

The following recommendations arose from consultations and the development of the Roadmap:

1. DE Africa to enact a clear communication strategy that targets the agriculture and NRM sectors, focusing on DE Africa as a free and open service specifically designed for the African continent.

2. The project model of consultation and in-country engagement be expanded to other African nations, especially member states of ASARECA and CCARDESA. This would occur after a review of the consultation structure.
3. Digital Earth Africa to approach partners listed in the Roadmap for potential pursuit of identified opportunities.
4. Once partners are identified, opportunities are to be pursued following a process of circular dialogues during which capacity development activities and user feedback enhance product and service offerings.
5. The Roadmap be revisited and treated as a dynamic document based on ongoing in-country engagement activities across the African continent.

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10.2 List of publications produced by project

Digital Earth Africa, Information for Agriculture, Food and Water Security- A Roadmap for meeting the Earth Observation data needs of end users in Africa (2023), *in preparation*

Okonya JS, Warinda E, Ilakut B, Debele T, Tesfaye G, Kabiri S, Tadege A, Wogderes A, Tuyishimire J, Mubea K & Wellington, M (2023). Harnessing Satellite Technology for Climate Resilience and Increased Agricultural Productivity in Kenya (2023), ASARECA Policy Brief June 2023, http://dx.doi.org/10.13140/RG.2.2.31437.82404

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