DELIVERABLE 2

EO AFRICA R&D Facility

Community Report

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EO AFRICA R&D Facility – Community Report

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Abbreviations and Acronyms

AARSE	African Association of Remote Sensing of the Environment
ACPC	African Climate Policy Centre
AFRIGIST	African Regional Institute for Geospatial Information Science and Technology
AGRHYMET	Agriculture, Hydrology, Meteorology (research center; Niamey, Niger)
AMCOMET	African Ministerial Conference on Meteorology
AMCOW	African Ministers' Council on Water
ARC	African Research Challenges
AU	African Union
AWS	Amazon Web Services
CILSS	Permanent Interstate Committee for Drought Control in the Sahel
CP	Consortium Partner
CR	Community Report
CREWS	Climate Risk and Early Warning Systems
D0,...	Deliverable 0,...
DEA	Digital Earth Africa
DIAS	Data and Information Access Service
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FP	Facility Portal
FR	Final Review
GEE	Google Earth Engine
GMES & Africa	Global Monitoring for Environment and Security and Africa
ICT	Information and Communication Technology
ITC	Faculty of Geo-Information Science and Earth Observation of the University of Twente
JRC	Joint Research Centre
KO	Kick-Off Meeting
NASA-SERVIR	A joint development initiative of National Aeronautics and Space Administration (NASA) and United States Agency for International Development (USAID)
PAU	Pan-African University
RC	Research Call
RCMRD	Regional Center for Mapping of Recourses for Development
RR	Readiness Review (in combination with D5 (D5-RR): Research Result)
SANSA	South African National Space Agency
SoW	Statement of Work
TCBF	TIGER Capacity Building Facility
TUW	Technical University of Vienna
UN	United Nations
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environmental Programme
UNOOSA	United Nations Office for Outer Space Affairs

UN-SPIDER	UN Platform for Space-based Information for Disaster Management and Emergency Response
UNU-INRA	United Nations University – Institute for Natural Resources in Africa
USAID-AGRA	USAID – Alliance for Green Revolution Africa
UT	University of Twente
VITO	Flemish Institute of Technology
WESR	World Environment Situation Room
WHYCOS	World Hydrological Cycle Observation System
WMO	World Meteorological Organisation

Table of Contents

1 Executive Summary

The present Community Report (CR) aims at drawing a baseline about the *EO research community* of Africa by identifying the key players (innovation clusters and networks), describing their structure, how they work and their funding structures. The EO AFRICA R&D Facility utilises the findings of the present report for the definition of its programme in general and the Capacity Building Plan (D6), in particular. The analysis stands on three main pillars: experiences of the consortium members, a literature review and a user need survey extended with interviews.

The concept of capacity development (CD) through research was evolving during the consecutive phases of the TIGER Capacity Building Facility (TCBF). ITC coordinated this series of projects; VITO and TUW were also involved in several actions.

Several forms of CD actions took place in TCBF, among others:

- distance education courses for supporting research projects,
- a series of post-graduate and PhD level research projects in the Alcantara programme, and
- support of joint publications of European and African researchers.

The main conclusions show the importance of the involvement of African partners (knowledge hubs) in the CD actions. The feedback from the participants showed that the F2F CB actions were the most appreciated ones. The joint research projects for a European and an African partner were successful modalities for CD through research. An active and successful network was developed under TIGER, but this was lately dormant.

The literature review started from a recent publication: Woldai (2020), which provides a thorough review of the African EO community and defines the trends in all segments of it. Using this publication as the origin, the most important references of it, as well as those new articles, which refer to it, were traced.

An internet-based questionnaire was developed to get an insight into the African EO community, understand their views on research challenges and CD needs. More than three hundred respondents reacted, but 253 complete forms were submitted from 38 countries. Regarding the community, the following conclusions were made:

- Most of the African EO community can be successfully approached in English, but for equal opportunities, French should also be used in the actions of the Facility.
- The respondents represent well the African EO community involved in research.
- African universities play a dominant role in educating the EO experts in Africa, although the contribution of the European institutions is still considerable.
- There are existing cooperations between the African and European academia, but further opportunities exist.
- The African EO community shows interest and demand for the activities of the Facility.

The literature- and internet-based review of the regional knowledge centres, initiatives and programmes led to the following conclusions:

- The most successful international networks are based on existing institutions and well-connected individuals. As a result, the networks and initiatives are interwoven with each other.

- The knowledge centres play an important role in both generating and disseminating EO-based technologies. There is a risk of having insufficient financial resources, especially for those institutions, which are dependent dominantly on a single donor, e.g., government funding (like universities).
- The reviewed initiatives and networks focus on the delivery of EO-based products, and their CD activities focus on the dissemination and application of the data. In this light, the niche of the EO AFRICA R&D Facility, i.e., capacity development through and for research, is unique and fills a gap.
- The EO AFRICA R&D Facility needs to utilize the existing connections to African institutions of the Consortium Partners (e.g., the TIGER network) AND has to be open to collaborating with emerging and established initiatives, especially the GMES & Africa.

All African national space programmes provide legislations and strategies for the particular countries and have international linkages via inter-governmental networks and institutions, like RCMRD, AGRHYMET or OSS. The programmes support the development of the space industry and, via that, the whole economy. However, there is a gap both in human resources and institutional capacities for optimally utilising the potential that national programmes provide. These gaps are also identified as a significant drawback for the development of national economies. In this respect, the following conclusions can be made about the Facility's tasks:

- Direct support of individual national space programmes is beyond the main objective of the Facility, but collaboration with national institutions is beneficial. This is possible with proactive national institutions on a bilateral basis.
- The establishment of such collaborations should be triggered in an open and transparent approach. The best way to reach out to all national space programmes for the EO AFRICA R&D Facility is to work strongly together with regional centres established and supported by African governments.

The private EO sector has been getting on a stronger leg in the last decade in Africa. Cooperation with profit-oriented actors is possible where mutual interests exist, but strictly on a non-profit-oriented basis. Overall. the various CD activities will eventually also support the downstream commercial sector, and this shall be seen as a positive result. The Facility needs to support the development of the sector with the specific niche: capacity development with and through research:

- The private sector is more active now than it was in the time of the TIGER Capacity Building Facility.
- Informing selected actors of the private sector can increase the visibility of the Facility. The private sector is free to engage in collaborative efforts with African R&D entities. Therefore, the EO AFRICA R&D Facility's research calls will benefit the CD of the whole value chain reaching, eventually also the commercial downstream sector. This will indirectly also support the African EO marketplace. The EO AFRICA R&D Facility will not support directly private commercial entities.

2 Introduction

The present Community Report (CR) aims at drawing a baseline about the EO research community of Africa by identifying the key players (innovation clusters and networks), describing their structure, how they work and their funding structures. The EO AFRICA R&D Facility utilises the findings for the definition of its programme in general and the Capacity Building Plan (D6), in particular.

The analysis stands on three main pillars:

1. experiences of the consortium members, with a focus on the TIGER Capacity Building Facility (TCBF),
2. a literature review and the analysis of the websites of relevant organisations.
3. a user need survey and related personal interviews organised by the EO AFRICA R&D Facility.

The first two pillars are based on existing and widely published data, so in the following, to avoid redundancy, *Sub-sections 2.1 and 2.2* only summarise the relevant findings. The User Need Survey provided a new EO AFRICA R&D Facility-specific insight into the African EO community; therefore, that is discussed in detail in *Chapter 3*.

2.1 TIGER Capacity Building Facility

ESA launched the TIGER Initiative to support the water sector of Africa in using Earth observation data (Achache, Aschbacher, & Briggs, 2004; TIGER Steering Committee, 2005). The concept of capacity development (CD) through research was evolving during the consecutive phases of the TIGER Capacity Building Facility (TCBF). ITC, the prime of the present EO AFRICA R&D Facility, coordinated this series of projects, and two of the Consortium Partners (VITO and TUW) were also involved in several actions. Several forms of CD actions were tested in TCBF, the first programme where distance education courses were used for supporting research projects in a structured set of combined actions. A separate but related action was a series of post-graduate and PhD level research projects in the Alcantara programme. It involved one year of focused research by young African researchers supervised by European universities, including ITC. Two of the supervised researchers defended their PhD theses on the topic of their TIGER-Alcantara research. A special issue of the Remote Sensing journal (Benjamin Koetz, Vekerdy, Menenti, et al., 2015) gives a good overview of the most important scientific achievements of the TCBF. Several further publications summarise the lessons learned during TCBF, both from the CD and the networking points of view (Vekerdy, Su, van Lieshout, et al., 2009; Vekerdy, Su, Menenti, et al., 2010; B Koetz, Fernandez, & Pallazo, 2012; Vekerdy, Su, Mannaerts, et al., 2012). Characteristic conclusions are the following:

- The involvement of partner knowledge hubs (TIGER Regional Centres at AGRHYMET, RCMRD, OSS and SANSA) increased the efficiency of the capacity development actions.
- The program of TCBF included several CB action types (among others, distance learning, individual supervision, F2F short courses). According to the feedback from the participants, F2F courses were the most appreciated form of capacity building actions.
- Financing joint research projects carried out in cooperation between African and European partners was a successful modality for capacity development through research.

- The TIGER network, developed during the active years of the TIGER Initiative, could attract several hundreds of individuals and institutions all over Africa.This network was dormant in the last two years, but some parts of it are still present in cyberspace, like www.tiger-net.org. and there is an ongoing action to re-activate the network and channel it into the new EO AFRICA initiative.

2.2 Literature review

A good starting point in the recent scientific literature is Woldai (2020). This publication provides a thorough review of the African EO community and defines the trends in all segments of it. Using this publication as the origin, the most important referred and referring articles were reviewed.

Web sites of the companies and organisations formed another rich information source. The most important ones are listed in *Chapter 7*.

Unfortunately, not all information is available freely, especially the ones related to the private sector. It was beyond the financial opportunities of our project to purchase some sources of information, e.g., the annual industry report by Space in Africa.

2.3 User Need Survey

In the framework of the present project, information was collected from a broad segment of the African EO community to identify research challenges specific to the African context in the application fields of water scarcity and food security. Furthermore, the survey aimed at getting an insight into the EO community of the continent and drawing a baseline for the CD actions. Due to its importance, *Chapter 3* describes the survey in detail.

For a deeper insight, in addition to the survey, interviews were done with selected reputed actors of the EO community. Their opinion is considered and included in the interpretation of the statistical results below.

3 Detailed Description of the User Need Survey

The here-presented statistical analysis represents the state of the survey on 31 July 2021. Only the fully completed questionnaires are included in the results below.

The collection of the answers is continued even beyond this date for offering more chances for the new members of the EO AFRICA community to express their views. The responses will be re-analysed before each significant community-related action of the Facility.

3.1 Survey methodology

The survey could be filled up anonymously, but if the respondent wanted to join the EO AFRICA Community, then he/she could provide some personal data. These data are handled by ESA and our Consortium according to the GDPR, as indicated in the questionnaire.

The questionnaire of the survey targeted six topics:

- Background: Information about the respondent to identify his/her scientific experience and professional position.
- African research topics: These questions aim at defining the existing EO-related research topics and the scientific challenges in Africa.
- Human and institutional EO capacity in Africa: These questions are asked to establish the human capacity baseline for the Facility.
- EO and auxiliary data: Questions about which data is used recently and what other data types are required.
- Information technology: Questions about the recently used and the required ICT infrastructure and tools.
- Final suggestions and expression of interest: An opportunity for the respondent to contribute to the EO AFRICA R&D Facility with ideas and join the community.

An English and a French questionnaire were sent out to the target audience. *Appendix 1* presents the complete text of the English version.

It is difficult to assess how many potential respondents got the invitation to participate because several channels were used, including social media. The most important ones were:

- ITC alumni network (Eng.) (about 6000 members)
- AARSE network (Eng. & Fr.) (about 2800 members)
- Social media (Eng. & Fr.)
- Contacts and networks of the Consortium Partners (Eng. or Fr.)

It can be safely stated that the invitation was sent out to a targeted audience of several thousands. A large part of the audience got the invitation in both languages, although not simultaneously. For example, the AARSE network first got the English version and then a week later the French one, so many of those who wanted to answer have already filled the English version. Only a fraction (<5%) of the targeted audience filled the questionnaires; still, a significant number of responses were collected for the analysis (*Table 1*). The bias in the number of responses per language does not reflect the actual distribution of the demand. Two facts can be the reasons for it:

1. Many of the Francophone Respondents had already filled the English version when they got the invitation for the French one.

2. Many Francophone EO experts use English in their professional activities, e.g., because they studied in English-speaking institutions (e.g., ITC).

Table 1 Overall statistics about the survey languages

Language	Nr. of responses	Complete answers	Completion rate (%)	Typical time spent (min)
English	299	239	80	28
French	16	14	88	30
Total	*313*	*253*	*81*	*29*

For getting a deeper insight, interviews were done with some selected experts about the same topics as of the survey. These interviews got a particular weight in our conclusions.

3.2 Responding community

The Respondents are spread over Africa with a particular pattern (*Figure 1* and *Figure 2*). The country of origin could be identified only when the respondent provided personal data voluntarily (225 answers). Considering the countries' official languages, the answers do not show such an extreme bias towards English, as was experienced in the languages of the survey responses; compare *Table 1.* and *Figure 3.*

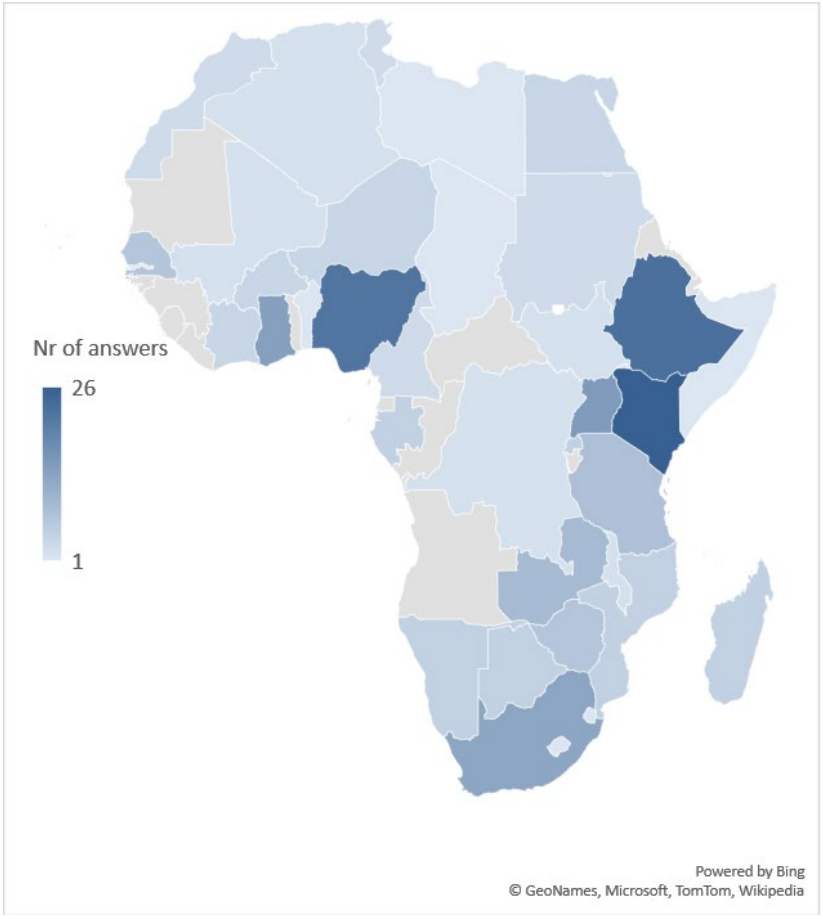

Figure 1 Geographic distribution of the number of the non-anonymous, completed questionnaires (n = 225)

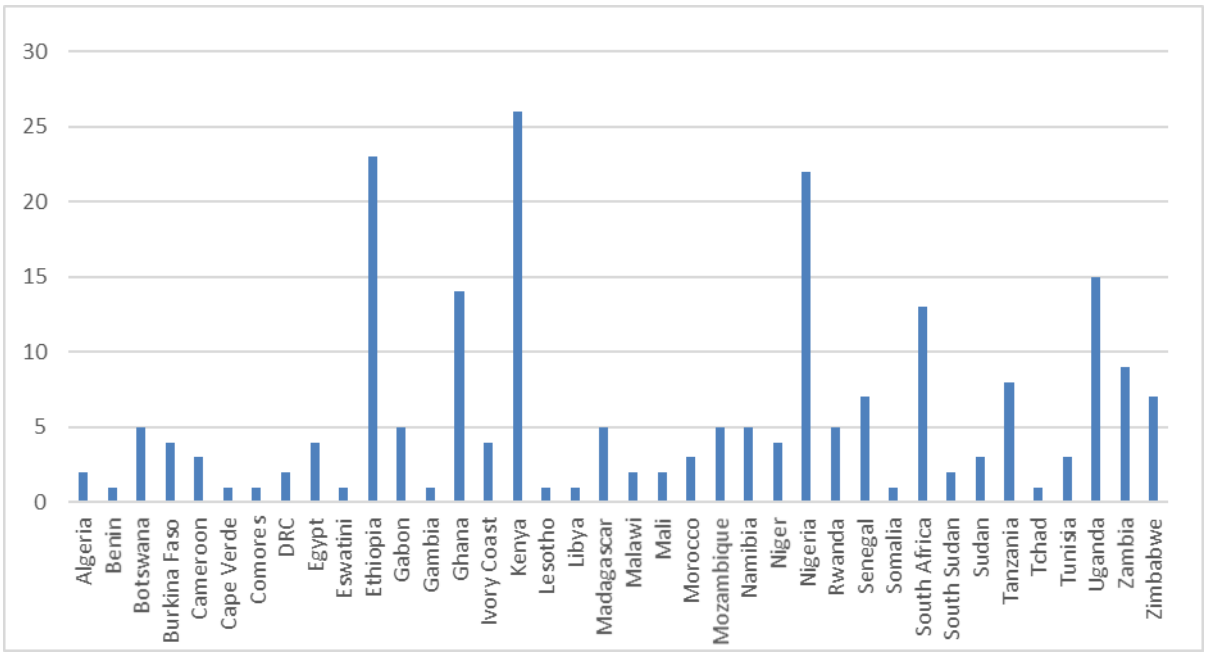

Figure 2 List of countries from where non-anonymous answers were received (n = 225)

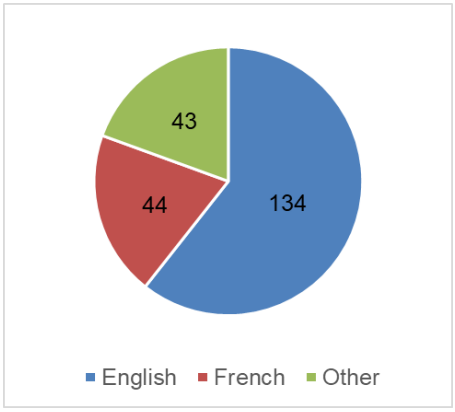

Figure 3 Distribution of the responses by the official languages of the countries (n = 221)

The category "Other" in *Figure 3* covers a number of different languages (predominantly Arabic, but also Swahili, Portuguese, etc.). However, it is beyond the possibility of the present analysis to reveal precisely the reasons for the English bias.

It is concluded that most of the EO community can be successfully approached in English, but for the sake of broadening the opportunities, offering CD material and events in French can be an asset of the Facility. Each CD action must be analysed in the planning phase to decide whether the use of the French language is required.

3.3 Analysis methods

As *Table 1* shows, about 20 % of the respondents did not complete the survey entirely. Assuming that the experts who paid their time for expressing their opinion gave the most reliable and representative answers, the unfinished responses were excluded from the analysis, so 253 questionnaires formed the basis of the statistics. In the overall analysis, the English and French sets of answers were merged. Still, where it is meaningful, a distinction is made in the discussion below between the responses received from English-speaking and Francophone/other countries.

Descriptive statistics was applied to the dataset, and the results were visualised by graphs. For presenting word-by-word citations of the answers, the typos were corrected.

3.4 Analysis of the answers to community-related questions

The objective of the Questions 1–5 was to get information about the background of the Respondent. The questions were merely aiming at collecting information to determine the answers' representativity of the African EO scenery.

The other groups of the questions dealt with the existing and required state of the following topics in Africa:

- Q6–9: Characteristic African EO research topics
- Q10–13: Human and institutional capacity
- Q14–19: EO and auxiliary data
- Q20–28: Information technology

In the following, the questions related to the focus of the present report: the EO community, are discussed (Q1–5 and Q12).

3.4.1 Question 1 about the type and location of the respondent's professional work

The question asked about the origin of the Respondent and the location where he/she works. (*Appendix 1* on *Page 34)*. *Figure 4* summarises the answers.

The figure demonstrates that most of the Respondents are native Africans who work in Africa, i.e., they are deeply rooted in the African EO community. *Table 2* proves that those who did not identify themselves as part of the pre-defined groups of the question are also closely related to the African EO community. In some cases, the specifications demonstrate a slight misinterpretation of the question.

It is also evident that only a few non-African experts completed the survey, but all of them work on African topics, so they have a good insight into the African EO challenges.

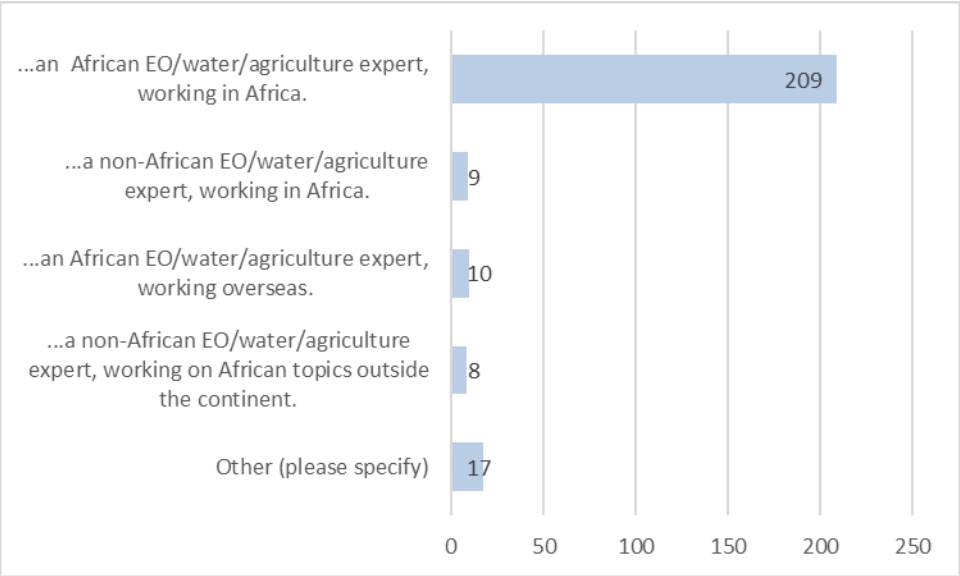

Figure 4 Answers to Question 1 (sample size 253)

Table 2 Specifications in the "Other" category of Question 1

African searcher in Remote Sensing
African working in Africa on geospatial nature of conflict and security
African, geologist, geospatial analyst
an African Eo land use planner
an African expert on urban and regional development
A PhD African EO/Meteorology/Climate Sciences
data analysis and Environmental management
EO Defense
EO Land expert
Geomatic Engineer
I am an African/ IA expert
Lecturer in GIS and Remote Sensing
National Geospatial Development Agency (ADE, IP)
Photogrammetry
Physical geographer and geoinformation
Retired EO user/expert
Software Developer (geospatial)

3.4.2 Question 2 about the Respondent's highest degree/certificate in EO or geo-information

The question asks about the highest degree/certificate of the Respondent (*Appendix 1* on *Page 34*). *Figure 5* summarises the answers. The figure gives an interesting cross-section of the Respondents' scientific background. Most of the actors (86%) who reacted to our questionnaire have a scientific background (MSc or PhD) – understandably, since this field needs sophisticated knowledge, which can be easiest gained by formal education.

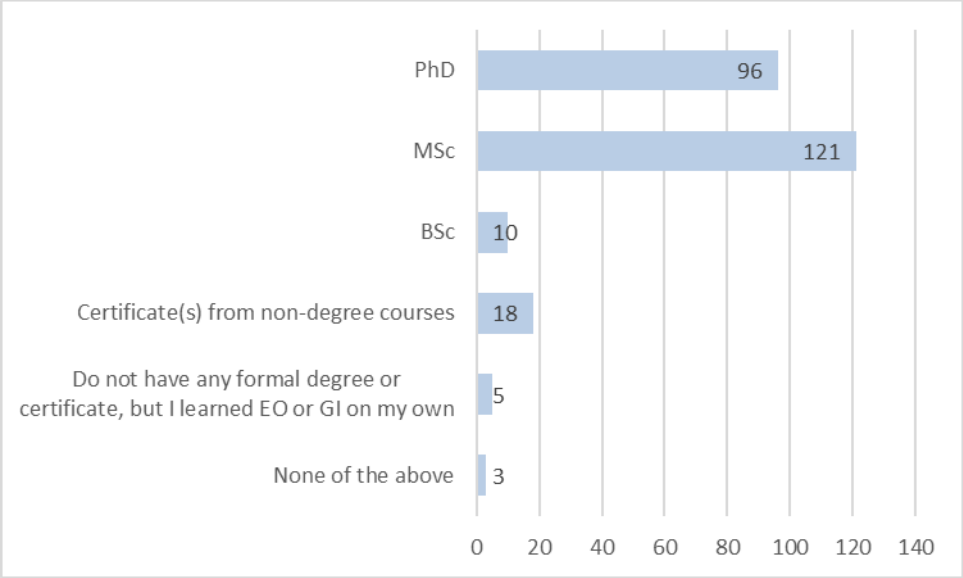

Figure 5 Answers to Question 2 (sample size 253)

All the other categories sum up to 14%. Among them, there are more Respondents who got their EO training in non-degree courses than in formal BSc education. This fact raises some questions, which cannot be directly answered from the survey data:

- Do the BSc curricula at the universities address EO sufficiently (or at all)?
- Is our survey representative for all segments of the African EO community?

Furthermore, the survey result also points out the importance of the short courses in capacity development.

3.4.3 Question 3 about how the Respondent is involved in EO

The question asks about which aspect of EO the Respondent is dealing with (*Appendix 1* on *Page 34*). *Figure 6* and *Table 3* summarise the answers.

In answering this question, it was possible to choose multiple categories. About half of the respondents (47%) identified themselves with only one category, but the other half indicated more, showing that many Africans have multiple (and multidisciplinary) tasks/jobs. 22% indicated three or more involvement types.

Most of the Respondents identified themselves (among others) as experts involved in the management of an application field using EO-based information. This demonstrates that EO data is getting used in the daily practice of different application disciplines in Africa. Research-related work categories are in the second and third places, but together these categories represent 52% of the cases.

About 10% of the Respondents identified themselves with EO technology/ICT-related work showing that this industry is still fragile and underrepresented in the continent.

In about 2.5% of the cases did the Respondents indicate "Other" aspects of EO. Most of the list of the specifications (*Table 3*) refers to some specific application fields, and the others refer to positions of the Respondent.

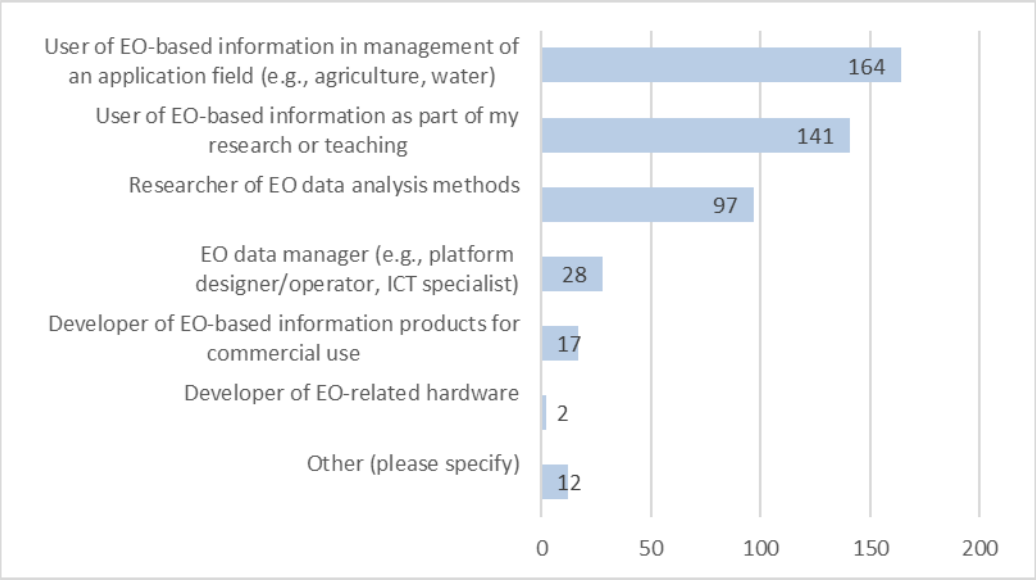

Figure 6 Answers to Question 3 (sample size 254 – multiple choices were possible, 461 choices were made)

Table 3 Specifications in the "Other" category of Question 3

An EO data enthusiast, working with EO data for multiple personal projects as part of my learning objectives
Developer of EO-based information products for Government organisations
Director of a private enterprise that operates an EO industry - strategic planning, reselling; management and application, developing products and services for commercial use and providing open-source library and online book, journals and other resources
EO based in Natural Resources Management (Forest & Wildlife)
Hydrogeologists and environmental geologists
I am a humanitarian worker and have not used the product
Lecturer in GIS and Remote Sensing Technical University of Kenya
Photogrammetry
Research Wascal program/Climate change.
User of EO data as part of my work
User of EO data in research and applications in the field of natural hazards, INCLUDING THE RISKS ASSOCIATED WITH WATER (LANDSLIDES, FLOODS, EROSION)
Utilize geology, GIS & engineering data to regulate oil industry

3.4.4 Question 4 about where the Respondent studied EO

The question asks about the origin of the Respondent's EO knowledge (*Appendix 1* on *Page 34*). *Figure 7* and *Table 4* summarise the answers.

Only the answers of the African Respondents were analysed.

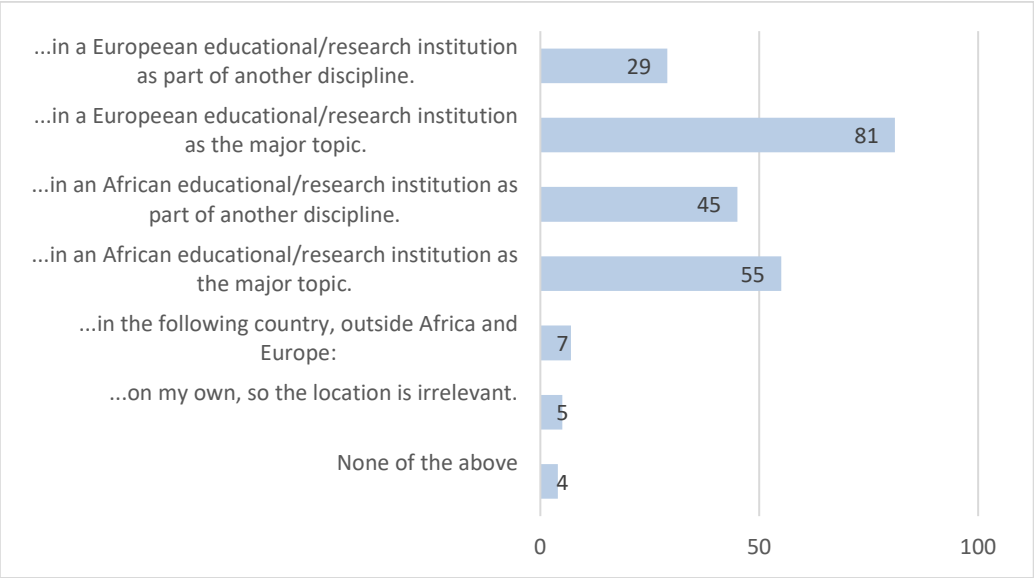

Figure 7 Answers to Question 4 (Sample size: 226)

Table 4 Mentioned countries of EO study outside Europe and Africa

Country of study	Nr. of mentioning
Australia	1
Malaysia	1
Canada	2
USA	3

About half of the Respondents studied outside of Africa, most of them in Europe. This fact is most probably due to the study/fellowship programmes of the European countries[1] and the historical relationships dating back to colonial times. Other countries have minor or just emerging such programmes (e.g., China), but their effects are not yet significant on the African EO community.

The other half of the respondents studied EO in Africa, demonstrating that the role of the African universities is essential in training the new generations of EO experts. It cannot be proved by these statistics, but the experience of the Consortium Partners (CPs) suggests that there were proportionally much fewer African-trained EO experts twenty years ago. The survey result (showing that about half of the Respondents were trained in Africa) demonstrates an emerging strength of the higher educational institutions in EO on the continent.

[1] Alumni from ITC have a special role in the EO community of Africa, since more than six thousand specialists were trained on Earth observation and geo-information sciences at this institution at post-graduate diploma, MSc and PhD levels in the last seven decades. The questionnaire did not contain special questions about this background, but ITC's alumni network was strongly involved in the survey.

3.4.5 Question 5 about the work experience of the Respondents

The question asks about which sector of the society the Respondent works in and the level of experience (*Appendix 1* on *Page 34*). *Figure 8* and *Figure 9* summarise the answers.

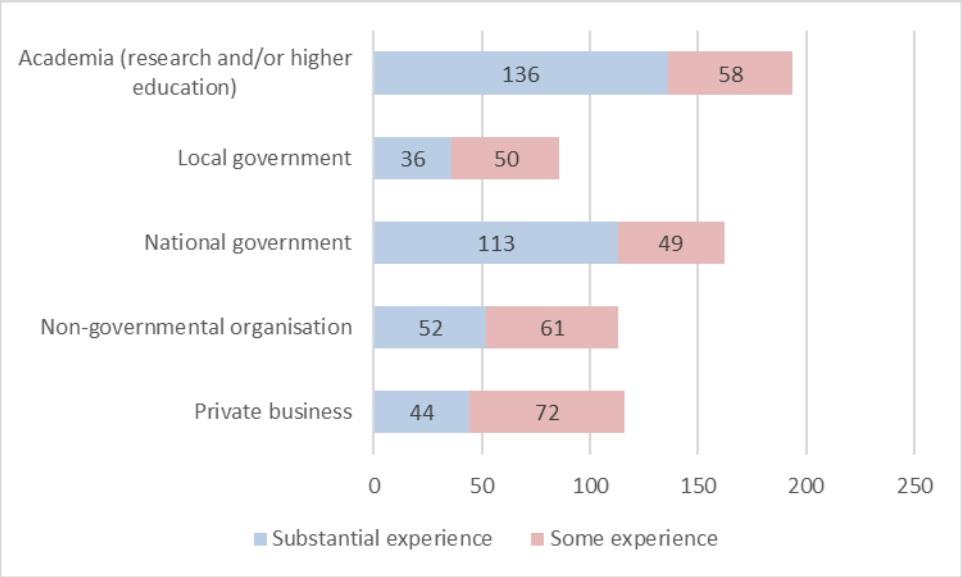

Figure 8 Answers to Question 5 (Sample size: 254 – multiple choices were possible)

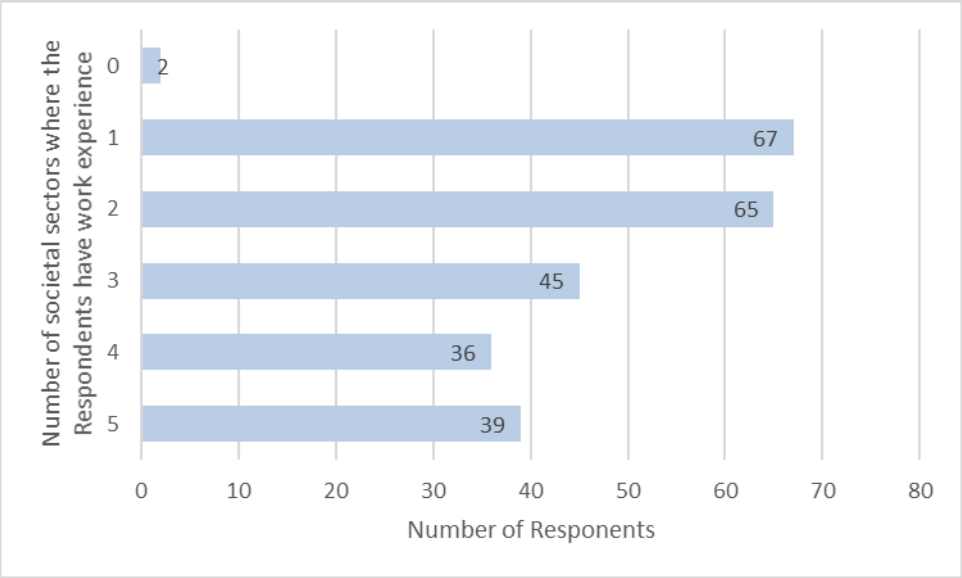

Figure 9 Number of Respondents with work experience in different numbers of societal sectors (Sample size 254)

Most of the Respondents have at least some work experience in academia and in governmental sectors at different levels. It is interesting to note that 73% of them indicated two or more different sector[2]s, proving, on the one hand, deep insight of the individuals into different aspects

[2] Having experience in 4-5 sectors does not necessarily mean actual involvement in all of them at the same time. More likely, this demonstrates the mobility and flexibility of the respondent over a longer carrier.

of Earth observation, on the other hand, a dynamic societal environment, where the use of this technology evolves intensively.

Table 5 shows the figures from another view angle. It demonstrates, for example, that although 116 Respondents have work experience in the private sector, there is only one Respondent (1%) who never worked in any other sector, while this figure is the highest in Academia (18%). Even this latter figure is relatively low, proving that most of the Respondents of the Facility's main target group have a much broader experience than only one societal field.

Table 5 Number of Respondents by societal sectors

Societal sectors where the Respondent has work experience	Number of Respondents			
	Two or more sectors	One sector	Two or more sectors	One sector
Private business	115	1	99%	1%
Non-governmental organisation	107	6	95%	5%
National government	138	24	85%	15%
Local government	84	2	98%	2%
Academia (research and/or higher education)	160	34	82%	18%

3.4.6 Question 12 about the Respondent's level of involvement in African-European scientific/technical cooperation

The question asks whether the Respondent, as an African specialist, has technical/scientific cooperation with European partners in the field of EO / Agriculture / Water (*Appendix 1* on *Page 38*). *Figure 10* summarises the answers.

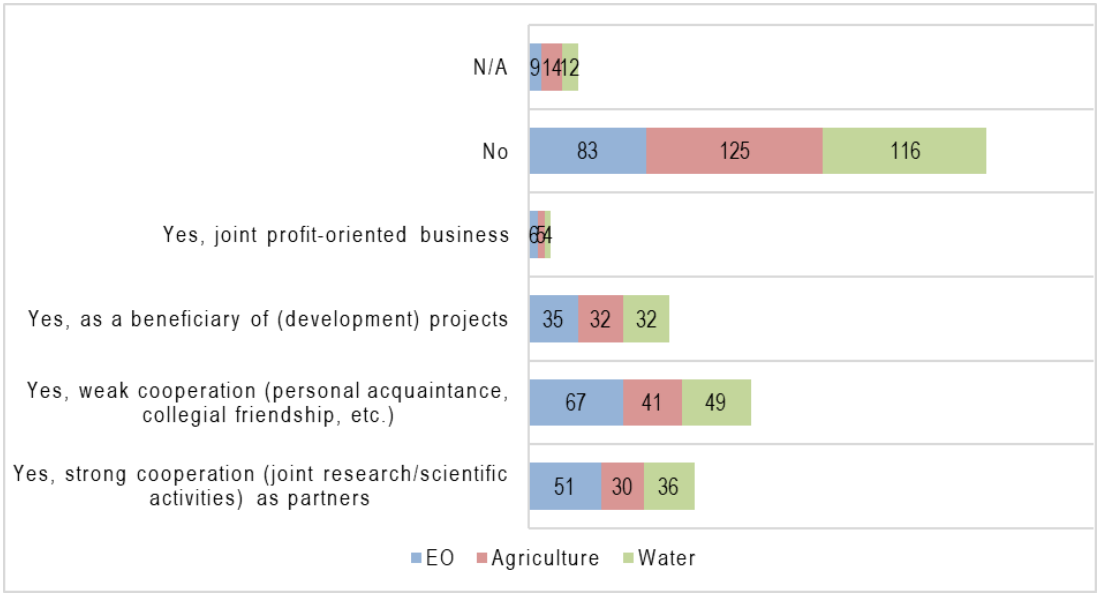

Figure 10 The level of involvement of the Respondent in African-European cooperation (n=251)

In most of the covered scientific fields, about half of the Respondents have no or weak involvement in African-European cooperation, and only 15-20% is involved in solid cooperation with European partners. There is ample room for improving this aspect, especially that more

than 50% of the Respondents have experience (and maybe contacts) with European partners from their studies (*Figure 7*).

3.5 Conclusions of the User Need Survey related to the EO community

The survey fulfilled its main objective and provided a good insight into the EO community of Africa. More than 250 questionnaires were complete and provided a representative insight into the African EO community.

Another aspect of the survey is also to be mentioned: it served as an outreach of the Facility to the African EO community and drew the attention of the experts to our upcoming activities.

The most important community-related conclusions of the User Need Survey are:

- *The Respondents represent the target group of the EO AFRICA R&D Facility, i.e. the African EO community involved in research and higher education (Q1 & Q2) with a substantial experience in a broad scale of stakeholder segments of the society (Q3 & Q5).*
- *African universities play a dominant role in defining the African EO capacity, although the contribution of the European higher educational institutions is more influential than any of the other countries owning advanced space technologies (Q4).*
- *There are existing links in Africa with European academia, but there are still unexploited potentials and possibilities (Q12)*
- *The high number of respondents and their answers prove an interest and demand for the activities of the EO AFRICA R&D Facility.*

4 Regional Centres, Initiatives and Programmes

This chapter provides an overview of the African institutes for higher education and the regional knowledge centres having Earth Observation as one of their core activities. A further intention is to cover other international main initiatives, projects and hubs. Many developments (not only at regional/continental scale) take place in Africa, so it is unavoidable that some 'actions' avoided our attention, so they are not included in this overview.

Woldai (2020) gives a comprehensive overview of prominent organisations. Woldai counted '90 institutions (universities/colleges/African and United Nations regional training centres) in 28 countries', 'over 53 national space agencies' and 'around 17 scientific National Associations or Societies'. More and more universities are taking up EO related topics in their curriculum and research.

The websites of the institutions provided the basic information for the present review. *Chapter 7* includes the referred sources and links.

Last but not least, an essential source of information is the African Association of Remote Sensing of the Environment (AARSE, *Table 7* in *Section 7.3*). It is an umbrella organisation with 2000+ members (individuals and organisations), with a good oversight of the initiatives, programs, projects, products and services in Earth observation and geo-information technology.

4.1 UN- and AU-initiated training centres and universities

The UN established several institutes in Africa to promote the use of EO. Below the most important ones are described.

UNOOSA[3] has established two African regional centres for space science and technology education: CRASTE-LF in Morocco and ARCSSTE-E in Nigeria (*Section 7.2*). These institutes have a regional basis, deliver several short duration training events, and through linkages with national universities, have a formal/accredited degree education. Furthermore, UNOOSA teams up with other organisations[4] in delivering webinars and MOOCs via the internet.

UNECA[5] established the African Regional Institute for Geospatial Science and Technology (AFRIGIST, *Section 7.2*) – formally known as RECTAS – in 1972, and the Regional Centre for Mapping of Resources for Development (RCMRD) in 1975, that 'trains highly skilled manpower in geospatial information science and technology, and its applications'.

AFRIGIST is located within the campus of Obafemi Awolowo University, Ile-Ife, Nigeria. Trainees are mainly coming from West Africa.

RCMRD (*Section 7.2*) was established in Nairobi. It has 20 contracting members in East and Southern Africa, with a mission to 'strengthen the member States and our stakeholders' capacity through Generation, Application and Dissemination of Geo-information and Applied Technologies for sustainable development. RCMRD runs large projects with linkages to NASA–SERVIR, GMES & Africa and the USAID–AGRA program focusing on agriculture

[3] https://www.unoosa.org/

[4] https://www.unoosa.org/oosa/en/ourwork/psa/schedule/2021/2021eotraining.html

[5] https://www.uneca.org/

development and investments. RCMRD also has strong ties with the Digital Earth Africa (DEA) initiative.

The United Nations University established an office in Ghana (UNU-INRA, *Section 7.2*) focusing on research in natural resources. UNU-INRA plays an active role in enhancing the ability of African universities and research institutions to contribute to finding solutions to Africa's developmental problems through workshops and research support. The field of EO can be part of the research activity but is not a requirement.

In 1974 the Interstate Committee for Drought Control in the Sahel[6] (CILSS) established AGRHYMET Regional Centre (*Section 7.2*) in Niamey, Niger. Its main objectives: 'are the contribution to achieving food security and increased agricultural production in the CILSS member States and the improvement natural resources management in the Sahelian region'. AGRHYMET was a partner for ESA in the Tiger Capacity Building Facility. AGRHYMET is currently running a large project related to Capacity building and operationalization of the Regional Climate Center (RCC) for the Sahel and West Africa sponsored by, among others, the EU. AGRHYMET is releasing climate-related weather analysis on a regular basis. They offer a wide range of short training courses (max. 2 weeks) on agriculture and water-related topics, such as a course with the title: 'Use of satellite data for Integrated Water Resources Management (IWRM)'. AGRHYMET delegates a member to the Technical Advisory Committee of the DEA initiative.

Woldai (2020) provides a comprehensive list of the academic institutions offering EO related degree programs. Ninety institutions provide EO-related education around the continent in 28 African countries. Many universities mentioned in that list were involved in the TCBF and/or have informal links to the University of Twente through its alumni network.

However, Woldai (2020) points out that educational institutions are hampered by a lack of capacity for direct involvement in EO activities, outdated curricula and technologies. This statement is also supported by Nakalembe (2020), underlining that governments need to invest in and build stronger partnerships with local universities for training new graduates to fill the human resource gaps in utilising EO products.

An important human capacity development initiative of the AU is the Pan African University (PAU, *Section 7.2*) Network, encompassing 5 large universities (in Kenya, Cameroun, Nigeria, Algeria and South Africa). The PAU network node of Algeria hosts the water and energy and also climate change education and research portfolio and the PAU node in South Africa for the space sciences at the Cape Peninsula University of Technology, amongst others. The Institute for Space Sciences is not fully established yet.

4.2 Initiatives and programmes

4.2.1 Climate-related centres and programmes

For several decades, attention has been given to climate monitoring and forecasting operations and research across Africa, as these have a direct impact on water scarcity and food security. The Intergovernmental Panel on Climate Change[7] (IPCC) Assessment Reports (IPCC, 2021) integrate the findings of the IPCC on the state of global climate change and the analysis of

[6] http://www.cilss.int/
[7] http://www.ipcc.ch/

past and future trends. Climate model predictions show a variable picture of impacts across the African continent, reaffirmed with greater confidence in the recently published Sixth Assessment Report. In Africa, it is predicted that flood hazards are likely to rise, particularly in the tropical parts of Africa, whilst Southern Africa is expected to be increasingly affected by wildfires and droughts. By regions, West, Southern, and East Africa are expected to experience higher heat waves and can be further reviewed using the ICCP Interactive Atlas[8]. The Water and Climate Agenda of the African Union (AU) is set for a large part by the AMCOW[9] and AMCOMET[10] mechanisms. Several UN-related organisations work in coordination with the AU on climate issues. A number of these organisations and programmes are mentioned below.

UNECA–ACPC, African Climate Policy Centre (*Section 7.3*) is a direct pan-African connection to the global IPCC activities, located in Addis Ababa (Ethiopia). ACPC is a hub for demand-led knowledge generation on climate change in Africa. It is an African centre addressing the need for greatly improved climate information for Africa and strengthening the use of such information for decisions related to climate impacts across Africa. UNECA is also hosting an intra-ACP Programme implemented through the ClimDev Africa Special Fund[11] (CDSF).

The African Centre for Climatological Applications Development (ACMAD, *Section 7.3*), based in Niamey (Niger), is the weather and climate centre with African continental competence. Two regional Climate centres closely related to ACMAD and WMO are the ICPAC (Nairobi) and the SADC-CSC (Gaborone), see *Section 7.3*.

WMO has put in place the World Hydrological Cycle Observing System[12] (WHYCOS) to improve basic observation activities, strengthening international cooperation and promoting the free exchange of data in the field of hydrology. Most larger river basins in Africa are a WHYCOS component. The National Meteorological and Hydrological Services cooperate closely with the WMO regions and provide synoptic station data continuously (usually on a 6-hourly basis) to the WMO-GTS[13]. Another more recent WMO initiative is the Climate Risk and Early Warning Systems[14] (CREWS), with the objective to ensure the availability of essential information and services needed by governments, economic sectors and citizens through increased access to early weather warnings and risk information. The Global Climate Observing System[15] (GCOS) observations remain crucial for monitoring, understanding and predicting the variations and changes of the climate system.

To facilitate and standardise access to data, the European Commission has funded the deployment of five cloud-based platforms. They provide centralised access to Copernicus data and information, as well as to processing tools. These platforms are known as the DIAS, or Data and Information Access Services[16]. In line with these initiatives, UNDP announced a 'Renewed Strategic Offer In Africa'[17] to create platforms for big data companies to work with African ministries in social development sectors to propose smart solutions in the areas of

[8] https://interactive-atlas.ipcc.ch/
[9] https://amcow-online.org/
[10] https://amcomet.wmo.int/
[11] https://ndcpartnership.org/funding-and-initiatives-navigator/clim-dev-special-fund-cdsf
[12] https://hydrohub.wmo.int/en/world-hydrological-cycle-observing-system-whycos
[13] https://www.wmo.int/pages/prog/www/TEM/GTS
[14] https://public.wmo.int/en/climate-risk-and-early-warning-systems-crews
[15] https://gcos.wmo.int/en/home
[16] https://www.copernicus.eu/en/access-data/dias
[17] https://www.africa.undp.org/

health / food security. The World Environment Situation Room[18] (WESR) is the future United Nations Environment Programme (UNEP) online data and knowledge platform. It will enable users to visualize, interrogate, access, link and download data, information and knowledge products regarding the world environment situation in near real-time.

Another AU initiative of climate adaptation is the "Great Green Wall Initiative". It is a pan-African programme launched in 2007 to reverse land degradation and desertification in the Sahel and Sahara, boost food security and support local communities to adapt to climate change.

4.2.2 Large continental EO initiatives

Besides ESA, there are other space agencies that are involved in capacity building and applied research for and in Africa. The most prominent ones are GMES & Africa, NASA SERVIR, Digital Earth Africa and China's Belt and Road, in which the applied use of Earth Observation is at the centre of the project activities.

GMES & Africa programme (*Section 7.3*) supported by EUMETSAT and JRC is implemented by thirteen consortia of institutions that represent the Eastern, Western, Northern, Southern and Central regions of the African continent. The new GMES & Africa 2 Program, also managed by the African Union Commission, aims to cover the entire supply chain for services on water & natural resources (e.g. land use, wetlands, land, forest resources, etc.) and marine & coastal areas (e.g. coastal area monitoring, ship traffic and pollution monitoring, etc.). The action supports African organisations, policy-makers and practitioners, to make more effective use of Earth observation data to develop relevant operational information services to support the sustainable management of natural resources and tackling climate change. In this framework, an operational EO processing tool was developed by JRC, called eStation (Lavaysse, Roudier, Venkatachalam, et al., 2021).

Policies, strategies and frameworks in Africa where GMES & Africa contributes are described in the Science, Technology and Innovation Strategy for Africa (African Union Commission, 2014), the Africa's Space Policy (African Union Commission, 2013), the Africa's Space Strategy (African Union, 2019), the Africa's Integrated Maritime Strategy – 2050 (African Union Commission, 2012), the Africa Blue Economy Strategy (African Union IBAR, 2019), the Africa Regional Strategy for Disaster Risk Reduction (African Union Commission, 2004), the Integrated African Strategy on Meteorology (WMO & AU, 2012) and the Africa Water Vision 2025 (ECA, AU, & AfDB, 2003). Currently, about 250 different satellite images, land, ocean and atmosphere products are operationally (near real-time) disseminated using the EUMETCast Africa Service, including those produced by the various Satellite Application Facilities and other third parties.

NASA SERVIR (*Section 7.3*) has hubs in West Africa (AGRHYMET) with a focus on four thematic areas: agriculture and food security; water resources and hydroclimatic disasters; weather and climate; and land cover, land use change and ecosystems. The research is focussing on geospatial decision support to allow stakeholders to make informed decisions. The Eastern and Southern Africa hub is led by RCMRD and is focussing on hydrologic estimation in the region, delivering data to aid flood forecasting, flood relief, and post-event flood mapping. NASA SERVIR is providing inputs related to EO Services for decision making, Capacity building and enhanced coordination and collaboration (USAID & NASA, 2020).

[18] https://wesr.unep.org/

Digital Earth Africa (*Section 7.3*) is an Australian initiative financed by the Australian government and Helmsley Charitable Trust (AUD 24 million for 2019-2022) and offers an operational data infrastructure to unlock historical and current satellite data (Lewis, Agrawal, & Ramage, 2019). The translation from data to decision-ready products is the focus. Water resources and food security are two themes that are looked at. CSIRO[19] (Australia) developed the data cube and a cloud-based platform using the Jupyter Lab environment for data analysis and algorithm development capability. An online training programme has been developed to autonomously learn how to access the data cube and use the analysis tools. GEO's Capacity Development Working Group[20] is assisting DE Africa as they scale up training and build capacity across Africa. The Technical Advisory Boards consists of many key players of the African EO community coming from among others: SANSA, RCMRD, UNECA and AGRHYMET.

China is also active in the EO sector in Africa. It launched in 2016 an "International science programme for the sustainable development of the Belt and Road Region using big Earth data". It is a long-term effort (10 years) sponsored by the Chinese government to support progress towards the SDGs targets using EO Science Technology, including Big Earth Data. Both EO infrastructure and personal skills are addressed in the B&R initiative. Environment, water resources and food security are some of the themes which are financed through international cooperation programmes and projects. Working groups, among others, on Agriculture and Food Security and Water Resources are established. The Institute of Remote Sensing and Digital Earth[21] in Beijing, China (RADI) plays a central role in the initiative, where also a large part of the capacity building in the form of MSc and PhD programs take place. In Africa, local workshops are being organized, and many African students study EO-related disciplines lately at various Chinese universities.

4.3 Networks

Table 7 in *Section 7.3* includes more details about the networks discussed in the following.

The African Association of Remote Sensing of the Environment (AARSE) is an Africa-wide network organization with over 2000 members. The primary aim of AARSE is to increase the awareness of African governments and their institutions, the private sector and the society at large, about the empowering and enhancing benefits of developing, applying and utilizing products and services of Earth Observation Systems and Geo-information Technology[22]. AARSE is organizing a bi-yearly conference which draws a lot of continent-wide attention.

AfriGEO (*Section 7.3*) is an initiative in the GEO framework to enable countries and organisations to get access to bi- and multilateral EO initiatives across Africa. It aims at creating synergies to avoid duplications of activities, coordinates stakeholders, and links the African EO community and GEO/GEOSS (GEO Executive Committee, 2012). AfriGEO has members from 30 countries all over the continent.

[19] https://www.csiro.au/
[20] https://earthobservations.org/cb.php
[21] http://english.radi.cas.cn/
[22] https://africanremotesensing.org/about/governance/

The UN Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) is a programme operated by the UN Office for Outer Space Affairs with two regional offices in Africa (Nigeria and Kenya). It seeks to make critical satellite data available to disaster management agencies around the world. Agencies can access maps and space-based information free of charge through mechanisms set up by the global space community, including the International Charter: Space and Major Disasters and the Copernicus Emergency Management Service. UN-SPIDER also provides advice on space technologies that can be used to monitor different types of natural hazards, on products developed by the space community for disaster management applications, links to satellite imagery sites, and information on software packages to process such imagery.

4.4 Conclusions on the EO knowledge centres, initiatives and networks in Africa

There are numerous international activities in Earth observation over the continent. On the one hand, many of them are initiated and formally executed at the inter-governmental level and financed by third parties, like the UN, ESA, NASA. Many of these activities have a limited lifetime. On the other hand, partly as a result of these inter-governmental activities, there is an informal technical/scientific EO community (community of practice) developing in Africa, which carries on the results of the previous projects.

The most important conclusions are:

- *International networks and initiatives are active in the continent. The most successful ones are based on existing institutions and well-connected individuals. As a result, the networks and initiatives are interwoven with each other. This structure reduces the risk of unnecessary competition, but also reduces the transparency of the processes. Anyway, there are more advantages than disadvantages of this practice, especially for the African stakeholders.*
- *The knowledge centres play an important role in both generating and disseminating EO-based technologies. There is a risk of having insufficient financial resources, especially for those institutions, which are dependent dominantly on a single donor, e.g, government funding (universities).*
- *The reviewed initiatives and networks focus on the delivery of EO-based products, and their CD activities focus on the dissemination and application of the data. In this light, the niche of the EO AFRICA R&D Facility, i.e., capacity development through and for research, is unique and fills a gap.*
- *The EO AFRICA R&D Facility needs to utilize the existing connections to African institutions of the Consortium Partners (e.g., the TIGER network), and has to be open for collaborating with emerging and established initiatives, especially the GMES & Africa.*

5 National Space Programmes

Giving a systematic history of the continent's space activities is beyond the scope of the present report, so in the following, a selection of the prominent actors is provided (their URLs are included in *Table 6* in *Section 7.2*).

5.1 Development trends

From the second half of the last century, more and more nations developed space ambitions. For example, Kenya, with the cooperation of Italy, established a satellite launching base in the 1960s in Malindi. In the same period, a satellite tracking station was established in Hartebeesthoek, South Africa, with the support of NASA. Nowadays, ten receiving and tracking stations are active in six countries (Woldai, 2020).

The first steps were made with support from overseas countries, but gradually, independent governmental institutions were established, e.g., the National Space Secretariate in 2009, later the Kenya Space Agency (KSA) grew out of it, or the South African National Space Agency (SANSA), or the National Space Research and Development Agency of Nigeria (NASRDA). The TIGER Capacity Building Facility collaborated with, among others, them throughout the initiative's lifetime.

For the second decade of our century, national institutions coordinate the space programme of the countries all around the continent. Eleven countries launched more than 30 satellites, and another ten satellites are in preparation for being launched in the coming four years (Space in Africa, 2021a). It is proof for the emerging continental industry that nine of the satellites were designed and assembled in Africa (Space Generation Advisory Council, 2021). All space activities will directly contribute, among others, to increasing the availability of big EO data with the opportunity of directly utilising it for the social and economic benefits of the countries.

All national space programmes provide legislations and strategies for the particular countries and have international linkages via inter-governmental networks and institutions, like RCMRD, AGRHYMET or OSS.

5.2 Conclusions and opportunities for the Facility

The TIGER experience showed that there is a gap both in human resources and institutional capacities for optimally utilising the potential that national programmes provide. These gaps are also identified as a significant drawback for the development of national economies, as it is also underlined in Africa's space strategy (African Union, 2019). Further reviewed sources also support this statement (e.g., Nakalembe, 2020; Woldai, 2020)

The most important conclusions are:

- *Direct support of individual national space programmes is beyond the main objective of the Facility, but collaboration with national institutions is beneficial. This is possible with proactive national institutions on bilateral basis.*
- *The best way to reach out to all national space programmes for the EO AFRICA R&D Facility is to work strongly together with regional centres established and supported by African governments.*

6 Private Sector

Africa's space industry is booming (Adebola & Adebola, 2021). The total space budget of the continent for 2021 is USD 548.6 million (Space in Africa, 2021a), with an attractive increase in the last few years. This data represents all sectors of the space industry, Earth observation included. The space race is a multi-polar competition in Africa (Fabricius, 2021), with several actors around the continent.

6.1 Development trends

A substantial segment of the private sector is focusing on the utilisation of remote sensing data. The first survey of the private EO sector in Africa was conducted in 2016 (AARSE & EARSC, 2016; Woldai & Zeil-Fahlbusch, 2019), based on a questionnaire filled by 78 companies from 21 countries. The results show that the EO private sector is really "young" on the continent since only a few companies were founded before 2000, and gradual growth of the number of new EO companies occurred in the new millennium.

In 2019, there were about 130 private companies active on the continent, making annual profits between a few ten-thousand and five million USD (Woldai, 2020). A review of the findings was presented on the Third African Stakeholders Dialogue (LocateIT Ltd., 2019).

Although African nations launch satellites, the use of African satellite data by the private sector does not show such an optimistic picture. Concluding from a questionnaire-based survey Woldai, (2020) states that "*African satellite data currently does not play a substantial role in the private business*" (page 121) since most of the companies work with EO data provided by non-African sources.

Without the possibility and necessity of a deep analysis of the private sector, hereby, an example of a private company is presented, which is involved in regularly reviewing the African EO community.

One of the emerging private companies is *Space in Africa*, a Nigerian private enterprise, which developed an information hub about the activities of the African space sector. The company grew up in three years to be an important actor in the space-related African information arena. For subscribers, they annually publish a comprehensive report[23] with actual statistics and analysis. The latest report (Space in Africa, 2021b) lists 81 space application projects across the continent, including EO applications in disaster monitoring, security, agriculture, land use and management, forest management, among others.

Also, the "Big Five": Google, Apple, Microsoft, Amazon and Facebook are affecting the ways monitoring data, observations, etc., will be stored, used and disseminated, e.g., using AWS and GEE. Massive efforts concerning food security and water scarcity, quality, epidemiology, sanitation, health, etc., exist across Africa and initiatives undertaken by international foundations such as the Bill & Melinda Gates Foundation (BMG) play an ever-increasing role in many parts of society.

[23] https://spaceinafrica.com/reports/

6.2 Conclusions and opportunities for the Facility

Cooperation with profit-oriented actors is possible where mutual interests exist, but strictly on a non-profit-oriented basis. Overall. the various CD activities will eventually also support the downstream commercial sector, and this shall be seen as a positive result. The Facility needs to support the development of the sector with the specific niche: capacity development with and through research.

The most important conclusions are:

- The private sector is more active now than it was in the time of the TIGER Capacity Building Facility. .
- Informing selected actors of the private sector can increase the visibility of the Facility. The private sector is free to engage collaborative efforts with African R&D entities. Therefore, the EO AFRICA R&D Facility's research calls will benefit the CD of the whole value chain reaching, eventually also the commercial downstream sector. This will indirectly also support the African EO marketplace. The EO AFRICA R&D Facility will not support directly private commercial entities.

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7.2 Referred key institutions

The list in *Table 6* provides a highlight of the key institutions relevant for the EO AFRICA R&D Facility. For a more comprehensive list, please turn to, e.g., Space in Africa (2021b)

Table 6 Key EO institutions in Africa

Institution (URL)	Profile, activity *	Geographic scope
UNU-INRA United Nations University – Institute for Natural Resources in Africa Ghana (https://inra.unu.edu/)	UNU-INRA's activities centre on four core areas: research, capacity development, policy advice, and knowledge sharing and transfer.	Operating units in five countries: Cameroon, Ivory Coast, Namibia, Senegal and Zambia
AFRIGIST African Regional Institute for Geospatial Information Science and Technology Nigeria (https://afrigist.org/)	Offers various training packages in a range of subject areas in geospatial science and application of its various techniques and also offers blended (customized) learning opportunities.	West Africa
AGRHYMET Regional Center Niger (www.agrhymet.ne)	Contribution to achieving food security and increased agricultural production in the CILSS member States and the improvement of natural resources management in the Sahelian region.	The Sahel and West Africa
ARCSSTE-E African Regional Centre for Space Science and Technology – English Nigeria (https://arcsstee.org.ng/home/)	The mission is to build a high-quality capacity and critical mass of indigenous Space Scientists/ Educators in English speaking African countries for the development and application of Space Science & Technology for Sustainable National & Regional Development.	Anglophone Africa
CRASTE-LF *Centre Régional Africain des Sciences et Technologies de l'Espace en Langue Française* / African Regional Centre for Space Science and Technology in French Language Morocco (https://crastelf.org.ma/)	The mission of the Center is to organize regional training courses, seminars, workshops, conferences and technical meetings of experts in order to improve the technical skills of specialists, teachers, administrators and decision-makers and to keep them informed. progress made in the application of space technology.	Francophone Africa
PAU Pan African University Five locations (https://pau-au.africa/)	The PAU is a flagship institution of the African Union and operates under the Department of Human Resources, Sciences and Technology.	Africa
EgSA Egyptian Space Agency (https://egsa.gov.eg/)	The Egyptian Space Agency is an Egyptian public economic authority established in August 2019, with a legal personality and affiliated with the President of the Arab Republic of Egypt. Established by Law No. 3 of 2018, which aims to create, transfer space technology development, localization and own self-capabilities to build & launch satellites from Egyptian territory. In 2019,	Egypt

Institution (URL)	Profile, activity *	Geographic scope
	Egyptian President Abdel Fattah Al-Sisi announced the appointment of Dr Mohamed ElKoosy as the CEO of the Egyptian Space Agency.	
AGEOS Gabonese Space Agency (http://ageos.ga/)	Contributes to the implementation of government policy in terms of collecting, analyzing and making available data from spatial observation of the national territory for the sustainable management of the land and maritime environment, natural resources , land use, regional planning, as well as research and innovation.	Gabon
KSA Kenyan Space Agency (https://ksa.go.ke/)	KSA is mandated to promote, coordinate and regulate space-related activities in the country. This is achieved through the promotion of research and innovations in space science, technology and respective applications. It also spurs Kenya's competitiveness and positioning in playing a critical role in the regional and global space agenda.	Kenya
NASDRA National Space Research and Development Agency Nigeria (https://nasrda.gov.ng/)	The main thrust of the Agency's activities is geared towards making space science and technology application an integral part of the overall strategies for sustainable national development.	Nigeria
RCMRD Regional Centre for Mapping of Resources for Development Kenya (www.rcmrd.org)	Intergovernmental institution To strengthen the member States and the stakeholders' capacity through generation, application and dissemination of geo-information and allied technologies for sustainable development. RCMRD was a Regional Centre of TIGER CBF.	20 contracting member states + 4 non-contracting member states in East and South Africa
OSS Sahara and Sahel Observatory *Observatoire du Sahara et du Sahel* Tunisia (http://www.oss-online.org/en)	An organization with an international scope & an African vocation. It operates in the arid, semi-arid, sub-humid & dry areas of the Sahara-Sahel region. OSS mission is based essentially on knowledge transfer, capacity building & awareness-raising. OSS was a Regional Centre of TIGER CBF.	26 African countries, 7 non-African countries, 13 governmental & 3 non-governmental organizations
SANSA South African National Space Agency (https://www.sansa.org.za/)	SANSA was created to promote the use of space and strengthen cooperation in space-related activities while fostering research in space science, advancing scientific engineering through developing human capital, and supporting industrial development in space technologies. SANSA was a Regional Centre of TIGER CBF.	South Africa

* As defined on the corresponding websites.

7.3 Referred projects, initiatives and networks

The list in Table 7 provides a highlight of the projects, initiatives and networks relevant for the EO AFRICA R&D Facility. For a more comprehensive list, please turn to, e.g., Space in Africa (2021b)

Table 7 Projects, initiatives and networks

Programme, Project, Initiative (URL)	Profile, activity	Members, participants
AARSE African Association of Remote Sensing of the Environment (https://africanremotesensing.org/)	Association to increase the awareness of African governments and their institutions, the private sector and the society at large, about the empowering and enhancing benefits of developing, applying and utilizing responsibly the products and services of Earth Observation Systems and Geo-information Technology.	Individuals, institutions all over Africa
ACMAD African Centre for Meteorological Applications Development Niger (http://www.acmad.net)	The Weather and Climate Centre with African continental competence. It was created in 1987 by the Conference of Ministers of the United Nations Economic Commission for Africa (UNECA) and the World Meteorological Organisation (WMO). ACMAD has been operational in Niamey since 1992. ACMAD is composed of 53 Member States, the 53 countries of the continent. To ensure its mission, ACMAD functions primarily with meteorologists detached by its Members States.	Africa
AfriGEO African Group on Earth Observations (https://www.earthobservations.org/afrigeo.php#)	Intergovernmental and interinstitutional organisation for coordinating EO within the GEO framework. This coordination initiative has been recognized as essential to enhancing Africa's capacity for producing, managing and using Earth observations, thus also enabling the Region's participation in, and contribution to, the Global Earth Observation System of Systems (GEOSS).	Individuals, institutions all over Africa in about 30 countries.
DEA Digital Earth Africa https://www.digitalearthafrica.org/	DE Africa is a project developing an African data cube. It processes openly accessible and freely available data to produce decision-ready products.	Africa
EUMETCast Africa service (https://navigator.eumetsat.int/)	African data service through the Earth Observation Portal of the EUMETSAT	Africa
GGW Great Green Wall Initiative (http://www.greatgreenwallinitiative.org/)	The Great Green Wall is an African-led initiative that aims to grow an 8000 km new green "wall" across the entire width of the continent to transform the lives of millions living on the frontline of climate change. The UN Convention to Combat Desertification is a key partner in the initiative.	Sahel
GMES & Africa (http://gmes.africa-union.org/ and https://au.int/en/GMESAfrica)	30 million Euro joint programme of the European Commission and the African Union Commission to adapt and use the Copernicus Programme data and services in the African context.	Africa
ICPAC IGAD Climate Prediction and Applications Centre Kenya (https://www.icpac.net/)	A Climate Center accredited by the World Meteorological Organization provides Climate Services to 11 East African Countries. Our services aim at creating resilience in a region deeply affected by climate change and extreme weather.	East Africa
NASA SERVIR - Eastern and Southern Africa www.servir.rcmrd.org	A joint initiative of the National Aeronautics and Space Administration (NASA) and the United States Agency for International Development (USAID) works in partnership with leading regional organizations to help developing countries use the information provided by Earth-observing satellites and geospatial technologies for managing climate risks and land use.	RCMRD member states – East and Southern Africa
NASA SERVIR West Africa www.servir.cilss.int/en/	idem	West Africa
SADC–CSC Southern African Development Community–Climate Services Centre Botswana	Provides operational, regional services for monitoring and predicting extremes in climate conditions. The Centre develops and disseminates meteorological, environmental and hydro-meteorological products.	SADC countries (16), Southern Africa

Programme, Project, Initiative (URL)	Profile, activity	Members, participants
(http://www.icpac.net/ and http://www.sadc.int/sadc-secretariat/services-centres/climate-services-centre/)		
SASSCAL https://www.sasscal.org/	To strengthen the regional capacity to generate and use scientific knowledge products and services for decision making on climate change and adaptive land management through research management, human capital development and services brokerage.To conduct research in adaptation to climate change and sustainable land management to provide products, services and information for decision-making to contribute to the creation of a knowledge-based society through academic and non-academic capacity development programmes	Southern Africa
UNECA–ACPC UNECA African Climate Policy Centre Ethiopia (https://www.uneca.org/acpc)	The overall goal is to contribute to poverty reduction through successful mitigation and adaptation to climate change in Africa and to improve the capacity of African countries to participate effectively in multilateral climate negotiations.	Africa
WASCAL https://wascal.org/	a large-scale research-focused Climate Service Centre designed to help tackle this challenge and thereby enhance the resilience of human and environmental systems to climate change and increased variability. It does so by strengthening the research infrastructure and capacity in West Africa related to climate change and by pooling the expertise of ten West African countries and Germany.	West Africa

Appendix 1 The User Need Survey Questions (English version)

EO AFRICA R&D Facility - User need survey

Background

EO AFRICA R&D Facility

In 2020, the European Space Agency (ESA) launched the EO AFRICA (African Framework for Research, Innovation, Communities and Applications) Initiative to build an African-European research and development (R&D) partnership to facilitate the sustainable adoption of Earth Observation and related space technology in Africa. The initiative is driven by African research challenges and user needs and follows a long-term vision (>10 years) for Africa's emergent digital era.

The EO AFRICA R&D Facility is the backbone of the Initiative, with the overarching goal of fostering an African-European R&D collaboration to enable an active research community and creative innovation processes for the continuous development of EO capabilities in Africa.

Our consortium implements the EO AFRICA R&D Facility. One of the principal objectives is to identify and respond to EO research challenges specific to the African environment in the application fields of water scarcity and food security.

The present questionnaire aims at collecting information from a broad segment of the EO scientific arena and the stakeholders of the satellite-based data collection and processing technology.

Based on the outcomes of this survey, we shall implement the Facility by:
- Issuing and supporting research calls for European-African collaborative research projects to facilitate an African – European exchange in research and knowhow.
- Establishing a digital Innovation Laboratory in the cloud for EO application development
*** to foster an open-source EO development community and**
*** to build partnership programmes with African innovation hubs**
- Setting up an English-French bi-lingual EO AFRICA Space Academy (in cooperation with African knowledge centres) to offer EO training courses
- Developing a Digital Space Campus for Africa offering online EO learning/training as part of the EO AFRICA Space Academy

By answering the following survey, you can shape the EO AFRICA R&D Facility to the special African needs and potentials. We appreciate your contribution.

The survey is anonymous! Nevertheless, you may provide some personal information on the last page if you want to be part of the EO AFRICA community. As a member, you will get the possibility to be involved in our actions and training events.

Filling the survey will take about 20 minutes.

Thank you for your contribution!

EO AFRICA R&D Facility Team

For more information about the Facility, please turn to https://www.itc.nl/news/2021/3/985999/eo-africa-rd-facility-kick-off#a-strong-base

1. I am...

- ( ) ...an African EO/water/agriculture expert, working in Africa.
- ( ) ...a non-African EO/water/agriculture expert, working in Africa.
- ( ) ...an African EO/water/agriculture expert, working overseas.
- ( ) ...a non-African EO/water/agriculture expert, working on African topics outside the continent.
- ( ) Other (please specify)

2. My highest degree/certificate in Earth Observation or Geo-Information

- ( ) PhD
- ( ) MSc
- ( ) BSc
- ( ) Certificate(s) from non-degree courses
- ( ) Do not have any formal degree or certificate, but I learned EO or GI on my own
- ( ) None of the above

3. I belong to the following group(s):

- [ ] User of EO-based information in management of an application field (e.g., agriculture, water, etc.)
- [ ] User of EO-based information as part of my research or teaching
- [ ] EO data manager (e.g., platform designer/operator, ICT specialist)
- [ ] Developer of EO-based information products for commercial use
- [ ] Researcher of EO data analysis methods
- [ ] Developer of EO-related hardware
- [ ] Other (please specify)

4. I studied Earth Observation...

- ...in an African educational/research institution as the major topic.
- ...in an African educational/research institution as part of another discipline.
- ...in a Europeean educational/research institution as the major topic.
- ...in a Europeean educational/research institution as part of another discipline.
- ...on my own, so the location is irrelevant.
- ...in the following country, outside Africa and Europe:
- None of the above

5. I have work experience in the following sectors:

	No work experience	Some work experience	Substantial work experience
Private business			
Non-governmental organisation			
National government			
Local government			
Academia (research and/or higher education)			

Other substantial experience (please specify)

EO AFRICA R&D Facility - User need survey

African research topics

By the following questions, we would like to get your opinion about the most important Africa-related research topics in the fields of EO technology as well as its water- and agriculture-related applications.

6. Identify the **three most important** water-related challenges in your region/country, in which EO could contribute to the solution.

- [ ] Mapping water bodies and floods
- [ ] Quantifying soil moisture
- [ ] Quantifying evaporation
- [ ] Defining groundwater level/volume of big basins
- [ ] Mapping rainfall distribution
- [ ] Defining river discharge
- [ ] Identifying droughts
- [ ] Hydrological forecast (droughts, floods, etc.)
- [ ] Other (please specify)

7. Identify the **three most important** agriculture (food security) related challenges in your region/country, in which EO could contribute to the solution.

- [ ] Identifying/mapping cropping areas
- [ ] Identifying/mapping crop types
- [ ] Crop yield forecast
- [ ] Identifying/mapping crop stress/drought/failure
- [ ] Supporting precision farming
- [ ] Monitoring crop development
- [ ] Mapping deforestation
- [ ] Rangeland mapping
- [ ] Land suitability assessment
- [ ] Other (please specify)

8. Rank the following EO technology/capacity challenges according to their importance for solving the challenges identified in the previous two questions:

Lack of EO data with sufficiently high spatial resolution

Lack of EO data with sufficiently high temporal resolution

Lack of proper data processing algorithms

Lack of human capacity to process the EO data properly

Lack of institutional capacity to utilize EO-based information

Lack of computational capacity (SW/HW) to process data

Lack of proper internet connection

9. Identify the **three most important** EO technology-related challenges in your region/country.

- [ ] Low computation capacity of personal computers
- [ ] Low data storage capacity of personal computers
- [ ] Low computation capacity at institutional level
- [ ] Low data storage capacity at the institutions
- [ ] No access to the internet
- [ ] Low-speed connection to the internet
- [ ] Other (please specify)

EO AFRICA R&D Facility - User need survey

Human and institutional EO capacity in Africa

10. The EO AFRICA R&D Facility plans to develop online training courses of 40 hours study length. Indicate how important are the following topics for Africa!

	not needed	limited importance	medium importance	very high importance
Introduction of satellite EO (optical and SAR, focus on Sentinel missions),	○	○	○	○
Cloud computing for EO	○	○	○	○
EO for agricultural monitoring – biomass production	○	○	○	○
EO for crop health and diseases detection	○	○	○	○
EO for agricultural insurances	○	○	○	○
EO for wetland/water bodies dynamics	○	○	○	○
EO for irrigation management	○	○	○	○
EO for flood mapping and disaster management	○	○	○	○
EO for coastal management	○	○	○	○
Time series analyses	○	○	○	○
Use of EO big data	○	○	○	○

Other (please specify)

11. Which are the **three most important** training course types to deliver in the EO AFRICA R&D Facility and at which scientific level (you can indicate more levels for each selected course type)?

	Basic scientific level	Medium scientific level	High scientific level
Distance courses on EO application topics	☐	☐	☐
Distance courses on EO technology topics	☐	☐	☐
Face to face courses on EO application topics	☐	☐	☐
Face to face courses on EO technology topics	☐	☐	☐
Webinars on EO application topics	☐	☐	☐
Webinars on EO technology topics	☐	☐	☐
Massive Open Online Courses (MOOCs) on EO application topics	☐	☐	☐
Massive Open Online Courses (MOOCs) on EO technology courses	☐	☐	☐

12. The EO AFRICA R&D Facility aims at strengthening the scientific cooperation between African and European partners. For giving an insight into the existing level of cooperations between the two continents, please answer the following questions:

	No	Yes, weak cooperation (personal acquaintance, collegial friendship, etc.)	Yes, as a beneficiary of (development) projects	Yes, strong cooperation (joint research/scientific activities) as partners	Yes, joint profit-oriented business	N/A
As an African specialist, do you have technical/scientific cooperation with European partners in the field of EO?	○	○	○	○	○	○
As an African specialist, do you have technical/scientific cooperation with European partners in the field of agriculture?	○	○	○	○	○	○
As an African specialist, do you have technical/scientific cooperation with European partners in the field of water?	○	○	○	○	○	○

13. If you are affiliated to a higher educational institute, are you interested in implementing the educational material of the EO AFRICA R&D Facility in your curriculum?

- I am not affiliated to a higher educational institute.
- Yes
- No

EO AFRICA R&D Facility - User need survey

EO and auxiliary data

In this page, we ask you to reveal which data you use in your work and what other data you would need.

14. Which of the following best describes the extent of your interest/projects/studies? (Select as many as needed!)

- [ ] Local (e.g. city level)
- [ ] Regional (e.g. multiple cities or regions)
- [ ] National
- [ ] Multi-national (e.g. several countries)
- [ ] Continental
- [ ] Global

15. I use EO data streams from the European Copernicus programme

Never a lot

16. In addition to EO data, which of the following data types are you interested in?

- [ ] Geospatial data updated periodically (e.g. in-situ sensor network data updated weekly or daily)
- [ ] Geospatial data updated near-real time (e.g. in-situ sensor network data updated every 15 minutes or shorter)
- [ ] Crowdsourced geospatial data (e.g. citizen science data)
- [ ] Data that needs to be geolocated (e.g. news feeds, social media)
- [ ] Other (please specify)

17. Which optical (VIS, NIR, SWIR, TIR) sensors do/did you use in your EO work related to Africa? (If you skip this question, we assume that you do not use any optical satellite data in your work.)

	Never	A few times	Frequently
Medium spatial resolution (250-1000 m, e.g., MODIS, NOAA AVHRR, MERIS, Sentinel-3/OLCI or others)	○	○	○
High spatial resolution (5-100 m, e.g., Landsat 1-8 / MSS, TM, ETM & OLI; Sentinel-2; IRS / LISS or others)	○	○	○
Very high spatial resolution (0.5-5 m, e.g., SPOT / NAOMI, Quickbird, RapidEye / REIS or others)	○	○	○

Other frequently used (please specify)

18. Which microwave sensors do/did you use in your EO work related to Africa? (If you skip this question, we assume that you do not use any microwave satellite data in your work.)

	Never	A few times	Frequently
Passive Microwave Radiometer (e.g., Aqua / AMSR-E, SMAP, or others)	○	○	○
C-band SAR (e.g., Envisat / ASAR, Sentinel-1, Radarsat / SAR-C, or others)	○	○	○
L-band SAR (e.g., ALOS / PALSAR, JERS / SAR, or others)	○	○	○

Other frequently used (please specify)

19. Indicate the **three most important** data types that you would like to use in the near future and you did not have the chance to use them frequently yet?

- [ ] Very high spatial resolution (0.5-5 m) optical images
- [ ] Hyperspectral satellite images
- [ ] Multispectral optical images with 5-100 m spatial resolution
- [ ] SAR images
- [ ] Passive microwave images
- [ ] Vegetation and other indices derived from satellite data at various spatial resolutions
- [ ] Geophysical and biophysical parameters (e.g., soil moisture, precipitation, leaf area index) derived from satellite data at various spatial resolutions
- [ ] Other (please specify)

EO AFRICA R&D Facility - User need survey

Information technology

20. What is your primary EO data computing device? (Select one!)

- ○ Desktop computer
- ○ Laptop computer
- ○ institutional server or remote desktop
- ○ Cloud-based platform

21. Where is your EO data primarily stored? (Select as many as needed!)

- ☐ Locally, on the computer (e.g. HDD)
- ☐ On an external storage, connected to the computer (e.g. External HDD)
- ☐ Remotely, on an institutional server (i.e. server located at your institutes premises)
- ☐ Remotely, in the cloud

22. If you use EO data stored remotely, how do you process it? (Select as many as needed!)

- ☐ Manually retrieve and process it locally.
- ☐ Automatically retrieve (e.g. by analysis software) and process it locally.
- ☐ Process remotely (e.g. by using remote desktop connection or interactive notebooks).
- ☐ I do not store data remotely.

23. Please indicate your experience with the following technologies:

	No experience	Past experience	Active user	Planning to use
Desktop GIS/EO applications (e.g. QGIS)	○	○	○	○
Geospatial databases (e.g. PostGIS)	○	○	○	○
Interactive notebooks (e.g. JupyterLab)	○	○	○	○
Machine learning frameworks (e.g. TensorFlow, Keras, PyTorch)	○	○	○	○
Distributed computing frameworks (e.g. Dask, Apache Spark)	○	○	○	○
Geospatial cloud computing platforms (e.g. Google Earth Engine)	○	○	○	○

24. Please indicate your experience with the following practices:

	No experience	Past experience	Active user	Planning to use
Data sharing (e.g. Zenodo, Dataverse)	○	○	○	○
Code sharing (e.g. Github, Gitlab)	○	○	○	○
Open science	○	○	○	○

25. Which of the following services are necessary for supporting your EO-related work?

- ☐ Cloud computing infrastructure (e.g. virtual machines)
- ☐ Special computing units (e.g. GPU, TPU)
- ☐ Data storage (i.e. to store big data sets)
- ☐ Shared workspace (i.e. shared storage accessible by the project team)
- ☐ Database server (e.g. PostgreSQL, MariaDB)
- ☐ Map server (e.g. Geoserver, Mapserver)
- ☐ File sharing (e.g. NextCloud)
- ☐ Code sharing (e.g. GitLab)

26. Please indicate your level with the following programming languages:

	No experience	Beginner user	Intermediate user	Advanced user
Python				
R				
Java				
Other				

Please specify the "Other" language

27. What is your typical internet connection?

	WiFi (10-50 Mb)	ADSL (<25 Mb)	10 Mb Ethernet	100 Mb Ethernet	1 Gb Ethernet	N/A
Work						
Home						

28. Please rank the importance of the following ICT practices in your daily workflows:

Being able to continue to work outside the office (e.g. from home or field) with similar analysis capabilities.

Being able to process large datasets without the need to download them first.

Being able to access large-scale computing infrastructure to perform analysis quickly.

Being able to follow interactive online training courses without interruption.

Being able to follow live video streams without interruption.

Being able to access streaming training materials (e.g. videos) also offline (e.g. download and watch later)

EO AFRICA R&D Facility - User need survey

Final suggestions and expression of interest

29. Do you have any further suggestion about how to make the EO AFRICA R&D Facility a success?

30. Please provide your contact information, if you would like to be informed about, or involved in the EO AFRICA R&D Facility's actions.

These data will be handled according to the General Data Protection Regulations. It will be stored by the EO AFRICA R&D Facility and will be destroyed automatically at the end of its activity or any time on your request (z.vekerdy@utwente.nl). It will be used only in relation to the EO AFRICA R&D Facility's networking activities. It will not be given to any third party.

Name	
Institution (company) / position	
Country	
Email Address	
Phone Number	

Appendix 2 List of All Deliverables of the EO AFRICA R&D Facility

For an overview, *Table 8* list all deliverables of the EO AFRICA R&D Facility.

Table 8 Deliverables of the EO AFRICA R&D Facility Project

Document Identifier	***Due*/Delivery Date**	**Deliverable**
D0-PMP	16.04.2021.	Project Management Plan
D1-ARC	*KO+3 (v1) (31.05.2021.)* *KO+11 (v2) (31.01.2022.)*	African Research Challenges
D2-CR	*KO+3 (31.05.2021.)*	Community Report
D3-RC	*KO+11 (v1) (31.01.2022.)* *KO+23 (v2) (31.01.2023.)*	Research Calls documentation
D4-IL	*KO+6 (v1) (31.08.2021.)* *KO+11 (v2) (31.01.2022.)* *codebase KO+36 (28.02.2024)*	EO Africa Innovation Lab
D5-RR	*KO+24 (v1) (28.02.2023.)* *KO+36 (v2) (28.02.2024.)*	Research Results
D6-CDP	*KO+3 (31.08.2021.)*	Capacity Development Plan
D7-TM	*KO+11 (31.01.2022.)*	Training Modules
D8-CDR	*KO+18 (v1) (31.08.2022.)* *KO+35 (v2) (31.01.2024.)*	Capacity Development Report
D9-FP	*KO+2 (01.05.2021.)*	EO Africa Facility Portal
D10-PP	*KO+30 (31.08.2023.)*	Promotional Package
D11-RM	*KO+35 (31.01.2024.)*	Roadmap
D12-HP	*KO+36 (28.02.2024.)*	Handover Package
D13-FR	*KO+36 (28.02.2024.)*	Final Report