



Digital Earth
AFRICA

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TECHNICAL ROADMAP



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Executive Summary

This Technical Roadmap provides guidance to Digital Earth Africa (DE Africa) for selecting and delivering the technical Earth observation components of DE Africa's three-year program establishment plan. The Roadmap identifies technical avenues that the DE Africa program could take over coming years, and (once endorsed) those which are to be pursued during the next developmental 'sprints'. The Roadmap provides an overview of the challenges, opportunities, and downstream impacts of various Earth observation input datasets and output products.

The Technical Roadmap ensures that the technical developments of DE Africa are aligned with and drive to deliver our endorsed vision, viz:

Digital Earth Africa will provide a routine, reliable and operational service, using Earth observations to deliver decision-ready products enabling policy makers, scientists, the private sector and civil society to address social, environmental and economic changes on the continent and develop an ecosystem for innovation across sectors.

And mission:

Digital Earth Africa (DE Africa) will process openly accessible and freely available data to produce decision-ready products. Working closely with the AfriGEO community, DE Africa will be responsive to the information needs, challenges and priorities of the African continent. DE Africa will leverage and build on existing capacity to enable the use of Earth observations to address key challenges across the continent.

Working with regional and global collaborators is fundamental for accomplishing DE Africa's mission, and opportunities for collaboration on varying scales are identified and embedded throughout the Technical Roadmap. More information on the broader context on the strategic framework of this Technical Roadmap is contained in Section 1.

The Technical Roadmap highlights and integrates the user-centric product design required to ensure that technical products remain relevant to the needs of DE Africa's diverse stakeholders.

Flexibility, adaptation and responsiveness are fundamental to success, and the Establishment team has embedded 'Agile' project management into its product development, ensuring that user applicability remains at the core of the work, especially in regard to the Earth observation products and services to be developed. More information on 'Agile' project management and its applicability to DE Africa is contained in Section 2.

As part of DE Africa's responsiveness to user needs and priorities, the Technical Roadmap is a 'living' document: it will be continuously reviewed and updated with guidance from the Technical Advisory Committee (the Committee) and will be a standing item on the Committee meeting agenda. Current Thematic Areas most pertinent across Africa, as identified by the Committee in 2019 and confirmed to remain relevant in 2021, are outlined in Section 7. In no particular order these are: 1) Natural resources including water; 2) Food security; 3) Urban sustainability; 4) Disaster risk reduction; and 5) Marine and coastal environments.

The components in this Technical Roadmap are grouped into **Input Datasets**, the **DE Africa Platform**, and **Services**. Components that are currently being progressed and those that can potentially be developed are both included. Each component is assigned a 'Tier' which considers the technical, logistical, and resourcing difficulty of its development. Specifically:

- ◆ **Input Datasets** are the foundational CEOS Analysis Ready Datasets and ancillary data that can be used to derive output services and accessed directly through the DE Africa Platform. A key strategy for DE Africa is that these will in future be provided ‘ready to use’ by CEOS agencies, however in practice there is considerable expertise and effort required to ensure these data pipelines. They are listed in Section 4.
- ◆ **The DE Africa Platform** includes the software infrastructure and tools that support data visualisation, discovery and analysis and enable users to interface with DE Africa data and services. The components are listed in Section 5.
- ◆ **Services** are the information products derived from Input Datasets. An operational service is continuously updated as required input datasets become available. Services may be updated, based on user feedback, to incorporate new sensors, new algorithms and auxiliary data. Potential services are listed in Section 6 and ordered according to their relevant Thematic Areas.

In the immediate future, this Technical Roadmap should be used by the DE Africa Program Office to guide and prioritise development under DE Africa. To achieve an operational platform that can continuously turn input datasets into reliable output services, the TAC has endorsed following development activities (Section 3):

- ◆ The technical team will continue to progress components that are actively being developed, including fundamental input datasets, infrastructure that enable access and analysis by a range of users and a flagship Water Observations from Space (WOfS) service.
- ◆ Highest priority is given to developing WOfS into an operational service.
- ◆ Food security is chosen to be the priority thematic area to focus on. Continental services that will support this theme include a crop land map, fractional cover and NDVI anomaly. Additional regional prototypes will be developed based on needs of the partners and stakeholders.
- ◆ Potential products listed in this roadmap are used to support user engagement and guide available research capacity. Priority is given to services with identified users in Africa, high impact and potential to scale-up to a continental-wide service.

Future work on the Technical Roadmap involves consultation with the stakeholder community and partner institutions. This consultation will finalise the suitability of the Thematic Areas, and the structure of the Technical Roadmap itself. The stated impacts of the various products and how they are communicated are subject to change, and remain dependent on input from DE Africa’s stakeholders and collaborators.



1. Introduction

1.1 Background

Digital Earth Africa (DE Africa) is an analysis platform for observations of all forms, but particularly those captured from satellites, which have unique potential and pose particular challenges for their full exploitation. DE Africa uses images and information recorded by satellites orbiting our planet to detect physical changes across Africa. DE Africa prepares these petabytes of satellite data, and makes both the data and decision-ready services and products derived from the data, available to governments, civil society, academia and industry for easy use.

The DE Africa Establishment Team has outlined a high level three-year plan (below) to establish DE Africa as an on-going capability within Africa. The Technical Roadmap will deliver the technical components of the program.

<p>Year 1: Setting the foundation</p>	<ul style="list-style-type: none"> ◆ Develop the governance framework, mission and vision ◆ Implement the governance framework ◆ Establish institutional hosting arrangements and DE Africa Office ◆ Recruitment of DE Africa Office staff ◆ Deliver DE Africa Day, web-site & key events ◆ Deliver continental-wide beta water observations from space product ◆ Develop key strategies: Communications and stakeholder engagement, partnerships, and capacity building ◆ Establish key partnerships with in-country enablers and others ◆ Ensure alignment with relevant initiatives, programs and institutions through an Alignment Strategy ◆ Undertake Australian Government Investment Design process ◆ Develop Technical Roadmap ◆ Build the DE Africa data and ODC infrastructure <ul style="list-style-type: none"> ◆ First DE Africa Annual Users Meeting ◆ Implement technical roadmap ◆ Deliver 3 continental-wide products ◆ DE Africa Office operating and fully staffed ◆ Regular training and capacity building program in place ◆ Engage at the country level on uptake of DE Africa products ◆ Increase the ability for African countries to exploit DE Africa services and platforms ◆ Produce a study on the economic value of Earth observation data for Africa ◆ Increase comprehensive stakeholder engagement ◆ Secure co-investment from additional philanthropic/aid agencies
<p>Year 3: A developing ecosystem</p>	<ul style="list-style-type: none"> ◆ Deliver 5 continental-wide products ◆ Deliver case studies on the impact of Earth observation data on decision making in Africa ◆ Demonstrate a developing business case for direct country-level investment based on delivered value

	<ul style="list-style-type: none"> ◆ Demonstrate cases of services and platforms from DE Africa being independently ingested into new, innovative applications ◆ Develop a sustainability plan for the continued operations of DE Africa
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1.2 Purpose and Mandate

During the August 2019 Committee meeting held in Nairobi, Kenya, the Committee agreed to the development of a Technical Roadmap that would articulate what products are to be produced and prioritized under DE Africa.

The Technical Roadmap provides an overview of the potential technological inputs and outputs for DE Africa that can address emerging topics relating to the use of geospatial and Earth observation data, and the pathways to delivering these capabilities and services. The Committee will use the Roadmap to guide the geospatial and Earth observation components to be delivered under DE Africa as outlined in the Governance Framework:

The Committee will provide input on the work programme and will have particular responsibility to guide the development of products [Technical] roadmap, a public-facing document that will lay out the agreed products that DE Africa will develop and produce on an operational basis.

This Technical Roadmap feeds into DE Africa’s three-year plan by providing the framework for the Committee and the Stakeholder Community Group(s) to highlight the potential output for users and stakeholders of DE Africa. The potential outputs included in this Roadmap highlight the potential deliverables of DE Africa that the Governing Board can use to deliver economic, environmental and social benefits to the African people using Earth observation.



2 Roadmap Design and Approach

The components listed in this Technical Roadmap represent a high-level summary of potential activities in which DE Africa may invest or prioritise resources and development effort. In keeping with the 'Agile' Program Management adopted for DE Africa, this document is a guide to achieving the priorities identified by DE Africa, with input from DE Africa's Governing Board, the Technical Advisory Committee, the Stakeholder Community Groups, and other key bodies.

This Technical Roadmap is subject to change as priorities shift in response to government and industry requirements, advances in technology, and relationships with international satellite operators and data providers that support the African Earth observation community. Needs are clarified and defined by the Committee and DE Africa's stakeholders and key users. The Technical Roadmap will be a standing item on the Committee Agenda and will be routinely updated.

2.1 DE Africa Technical Components

This Technical Roadmap outlines the potential Input Datasets, the DE Africa Platform, and Services that will be utilised or produced. Each component can be related to the ODC workflow to ultimately develop Earth observation insights for decision-making (Figure 1). The components are organized into sections:

- ◆ **Input Datasets** are the foundational CEOS Analysis Ready Datasets and ancillary data that can be used to derive output services and accessed directly through the DE Africa Platform. They are listed in Section 4.
- ◆ **The DE Africa Platform** includes infrastructure and tools that support data visualisation, discovery and analysis and enable users to interface with DE Africa data and services. The components are listed in Section 5.
- ◆ **Services** are the information products derived from Input Datasets. An operational service is continuously updated as required input datasets become available. Services may be updated, based on user feedback, to incorporate new sensors, new algorithms and auxiliary data. Potential services are listed in Section 6 and ordered according to their relevant Thematic Areas.

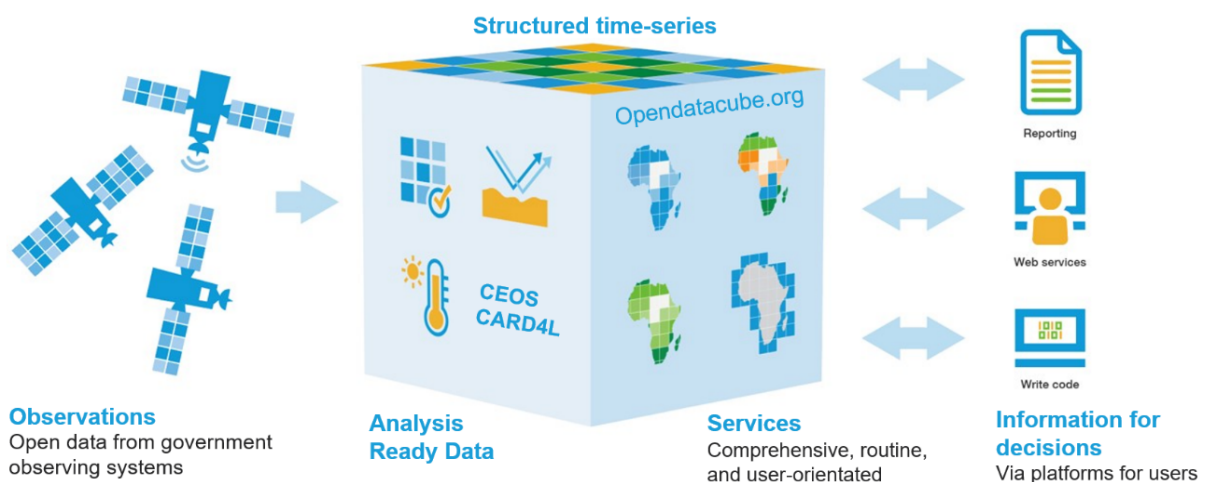


Figure 1: By developing the input Earth observation datasets and delivering platform and services through ODC structured time-series technology, DE Africa is able to produce the Earth observation insights for African users.

Each component has been assigned a ‘**Tier**’ rating. This rating reflects the holistic technical, resourcing, and logistical difficulty in developing the dataset, platform component, or potential service for DE Africa, with Tier 1 the least difficult and Tier 3 the most difficult.

Generally, components classified as Tier 1 indicates that the DE Africa team is already working on the capability, often drawing on the experience of Digital Earth Australia, with the knowledge that a low amount of development work is needed to extend these to DE Africa.

Components classified as Tier 2 and 3 are generally not being currently progressed at the time of writing. Where colour is used in this document, Tier 1 is green, Tier 2 is yellow, and Tier 3 is orange.

Each component has also been assigned a ‘**Status**’ which communicates a greater level of technical and logistical details compared to its Tier. The ‘Status’ classification combines the current activity status (active or not active), the ‘Technical Readiness’ (continental-scale data/workflow; regional-scale demonstrator; or future collaboration opportunity) for a potential product, and the product maturity or relevant progress status for an active product.

The ‘**Technical Readiness**’ considers the required technical considerations specific for developing Earth observation capability, including:

- ◆ The computational scalability of the potential product’s existing codebase, for example, the computational power required for a regional-scale Jupyter Notebook workflow compared to a large-scale continentally applicable codebase.
- ◆ The scientific transferability of the potential product, for example, whether a workflow has been finessed and validated only for a regional environment compared to continent-wide environments.
- ◆ Whether the product, if it exists elsewhere, has been validated.
- ◆ The body of existing work required to support the product development, for example, analogous examples in other ODC initiatives like Digital Earth Australia.

2.2 Agile Project Management

The DE Africa Program takes an Agile, user-centric approach to development that aims to ensure each product that could be developed has a practical, real-world application that will enable positive business change for its users. The product development cycle is illustrated in Figure 2.

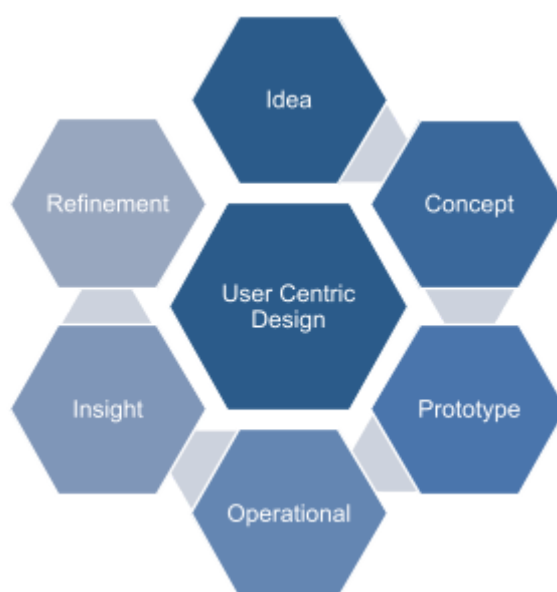


Figure 2: DE Africa product development cycle, based on Agile Project Management.

2.2.1 Idea

A product idea may exist when DE Africa staff and/or stakeholders have an idea of how they might be able to gain further insights from earth observation data. DE Africa staff and stakeholders are constantly engaging with new problem spaces. A product idea usually results from direct engagement with a potential user from outside the program, or from exploratory research.

2.2.2 Concept

A product concept is a refined and tested product idea. This is the point at which at least one potential user has been consulted to work out what the product would look like in order to be useful. The product concept expands on the product idea by clearly identifying an initial product outline and user profile.

2.2.3 Prototype

A prototype represents the first stage a product has materialised based on a concept. A prototype is used to assess technical feasibility of a product, demonstrate its utility to targeted users and to determine whether it should be progressed into an operational product. A prototype product may be iteratively developed into a beta and a provisional product before becoming fully operational.

2.2.4 Operational

An operational product can be a platform component or a service that is developed under DE Africa. Becoming operational is the point at which all systems required to routinely produce the product are up and running. For a platform component, its status should be actively monitored and best efforts are made to maintain its availability and performance. For a service, a fully validated continental-wide product is produced, being updated as required and made available through the DE Africa Platform. Production and update are automated for a dynamic product.

2.2.5 Insight

DE Africa measures its value in terms of the improvements we have enabled in the decisions, policies and programs of others. Insight is the point at which DE Africa's products are embedded into business systems and processes to enable users to gain insights relevant to their activity, and resultantly make more informed business decisions. Often this stage will involve DE Africa staff collaborating directly with organisations and users to help them to embed DE Africa products into their business systems and processes. This is the point at which DE Africa's products generate real value for users, and is the how the program will measure its success.

2.2.6 Refinement

This ongoing phase of the product development cycle involves continuing to work with users to understand how products could be better and to ensure that the positive business changes enabled by the product are maximised, captured and promoted.



2.3 DE Africa Users

Users (or end-users) are the individuals or organisations that ultimately use, or are intended to use, the services and platform produced by the DE Africa program. In the initial stages of product development users may be represented by an archetype or hypothetical 'typical user' until a definitive user is identified. The DE Africa platform and services are designed with a user in mind, guided by the framework of enabling access and use of free and open data. This includes developing different services and platform components that cater to different user capability and user demand, along with diversity in technical capability to interact and use DE Africa's outputs.

Considerations when developing the platform and services include user accessibility and utility to the user. For example, DE Africa has considered the accessibility and utility of an online mapping portal compared to the online Sandbox environment for using and engaging with DE Africa services that accommodates diversity in the level of engagement of end-users in Africa.

2.4 Project Partnerships

DE Africa is collaborating with a range of partners to develop DE Africa's infrastructure and in-continent knowledge. This includes facilities to host DE Africa's EO datasets, and support to improve the quality and utility of DE Africa's EO outputs.

- ◆ DE Africa will be working with Amazon Web Services (AWS) to ensure the best service/cost availability to store, process and interact with DE Africa. AWS is a world-leader for cloud-based computing, and working with AWS improves DE Africa's core infrastructure that enables the scope of DE Africa to reach the entire African continent. This collaboration is in line with the key guiding principles of DE Africa including the interoperability and democratisation of data. Additional partnerships with other cloud service providers are also possible.
- ◆ DE Africa will work with African stakeholders to attain and utilise the calibration and validation data, along with in-situ data, required for improving the quality of satellite data utilised by DE Africa. Without this collaboration, Earth observation insights delivered by DE Africa would be limited by significant uncertainties in the findings and modelling. A data validation strategy is under development.

DE Africa is also working with a range of collaborators to maximise the accessibility of the Earth observation data to stakeholders. More information on DE Africa's strategic approach to project partnerships are detailed in DE Africa's Partnership and Alignment Strategies.

DE Africa is collaborating closely with Esri to maximise the reach of DE Africa's outputs by ensuring compatibility with Esri's Africa Geoportal. This collaboration ensures the user-oriented utility of DE Africa's data, and strengthens the interoperability of data produced by DE Africa to maximise its potential application across the African continent. The intent is to maximize the opportunities for use of DE Africa products and services through additional data portals. Additional partnerships of this type are therefore likely.

For example, the Esri Nearest Water Body Application was developed as a pilot at the 2019 Group on Earth Observations (GEO) Week Summit. This mobile phone application used a waterbody identification service, developed by an external provider for DE Africa, to enable users within Africa to locate nearby water bodies. The Application demonstrated the democratisation of Earth observation data that can readily engage the African people. This initiative highlights the collaboration required to rollout DE Africa's services across the continent.



A major component of DE Africa is to cultivate in-continent capability for the use of ODC technology for Earth observation. This includes potential training and community engagement activities.

- ◆ In alignment with the strategic pathways identified in the Capacity Development Strategy, DE Africa will undertake a number of capacity development and training activities to transfer skills and knowledge to key users and stakeholders across Africa. This activity could take multiple forms and may include training courses, secondments, or "hackathon" like events. Leveraging existing skills and upskilling across users for using Earth observation data is fundamental to building in-continent capacity which is a central outcome of DE Africa's three-year strategy.
- ◆ DE Africa will build relationships with technical users of the Open Data Cube and related technology in order to grow the community around the project. The ODC is currently working on becoming an OSGeo Project to become an authoritative guide to working in the open source geospatial community. The ODC Conference will be supported and Hackathons and other initiatives that help to build capability and strengthen relationships will be organised.

2.5 Guiding International Frameworks

Earth observation is widely recognised as having the potential to contribute to regional and global policy frameworks that contribute to sustainable development (GEO, 2017).¹

Key frameworks that guide DE Africa's development and outputs include the UN 2030 Agenda for Sustainable Development and the associated SDGs, and the African Union's Agenda 2063: *The Africa We Want*. DE Africa also has the potential to contribute to other regional and global policy frameworks including the Paris Agreement under the UN Framework Convention on Climate Change, and the Sendai Framework for Disaster Risk Reduction.

Africa is a rich and diverse continent that faces environmental challenges spanning climate change, environmental degradation, natural resource mismanagement, and food and water security. Many of Africa's developmental challenges identified in the regional and global frameworks can be addressed using DE Africa's Earth observation technology.

2.5.1 Meeting the UN SDGs Using Earth Observation

The UN 2030 Agenda for Sustainable Development articulates the SDGs which outlines a global framework to address social, economic and environmental issues by 2030. With 17 goals, 169 targets and over 230 indicators, achieving the SDGs requires new approaches using data across the global community to achieve national development priorities and sustainable development.

DE Africa's technical programs provides essential evidence that tracks the SDG Indicators over time, and has been recognised in the UN's 2030 Agenda for Sustainable Development for the implementation of solutions to reach specific SDG Targets (see

Figure 3). The applicability of DE Africa lies with increasing uptake of Earth observation in meeting the SDGs, as identified by GEO (GEO, 2017), since:

- ◆ Earth observation provides data from local to global scales: there is an opportunity to provide richer geographic information.
- ◆ Earth observation provides long time series and continuity, providing governments with monitoring capabilities: there is an opportunity to improve the frequency and richness of data.
- ◆ Earth observation enables comparison of geographic information on a global scale: there is an opportunity for standardising and comparing global geographic information.
- ◆ Earth observation provides a diversity of measurements of various geographic indicators: there is an opportunity to measure a range of metrics to build confidence in achieving the SDGs.
- ◆ Earth observation complements traditional statistical methods: there is an opportunity to save money and better validate existing measurements.
- ◆ Earth observation data are free and open, and Earth observation is becoming a more widespread and accessible information source that will be increasingly adopted by the SDGs.

Partnerships Under the SDGs with Earth Observation

¹ See generally, GEO, 'Earth Observations in Support of the 2030 Agenda for Sustainable Development' (Report, GEO, 2017). Available here: https://www.earthobservations.org/documents/publications/201703_geo_eo_for_2030_agenda.pdf (accessed 7 January 2020). See further, Anderson, Katherine, Barbara Ryan, William Sonntag, Argyro Kavvada and Lawrence Friedl, 'Earth Observation in Service of the 2030 Agenda for Sustainable Development' 2017 20(2) *Geo-spatial Information Science*, 77 – 96. Available here: <https://www.tandfonline.com/doi/full/10.1080/10095020.2017.1333230?scroll=top&needAccess=true> (accessed 7 January 2020).

Developing partnerships and collaborative relationships with stakeholders optimises DE Africa's contribution to accomplishing the SDGs, particularly SDG 17 ('Partnerships for the goals') and mandated by GEO in its contribution to the SDGs. The UN has identified that an unprecedented level of cooperation and collaboration is required between civil society and government to achieve the SDGs (Stibbe *et al.* 2018).² Moving away from a siloed interaction of science and society requires the active integration of all stakeholders into the scientific process. This goes to the core of the DE Africa's objectives: to develop long-term, sustainable partnerships centred and developed by the requirements of the African people. DE Africa's partnerships with African stakeholders and international Earth observation platforms is reflective of this 'Partnership Journey' mandated by the UN (see Stibbe *et al.* 2018).

DE Africa's collaborative activity extends the African Earth observations collaboration already spearheaded through the Africa Regional Data Cube (ARDC), GEO and UNECA and coordinated by the Committee and SCG. Collaboration with regional and global data providers has been integrated to DE Africa's activities to ensure the longevity of the free and open data pipeline. Whilst not only ensuring DE Africa's utility and longevity for the future of Africa, embedding collaborative partnerships ensures that DE Africa's products remain user-centric and fit-for-purpose for the diverse of users across the entire African continent.

²Stibbe, Darian, Stuart Reid and Julia Gilbert, 'Maximising the Impact of Partnerships for the SDGs' (Report, The Partnering Initiative and UN Department of Economic and Social Affairs, 2018).

Target Contribute to progress on the Target, not necessarily the Indicator								Goal	Indicator Direct measure or indirect support to the Indicator					
						1.4	1.5	1 No poverty	1.4.2					
					2.3	2.4	2.c	2 Zero hunger	2.4.1					
				3.3	3.4	3.9	3.d	3 Good health and well-being	3.9.1					
								4 Quality education						
							5.a	5 Gender equality	5.a.1					
	6.1	6.3	6.4	6.5	6.6	6.a	6.b	6 Clean water and sanitation	6.3.1	6.3.2	6.4.2	6.5.1	6.6.1	
				7.2	7.3	7.a	7.b	7 Affordable and clean energy	7.1.1					
							8.4	8 Decent work and economic growth						
				9.1	9.4	9.5	9.a	9 Industry, innovation and infrastructure	9.1.1	9.4.1				
					10.6	10.7	10.a	10 Reduced inequalities						
	11.1	11.3	11.4	11.5	11.6	11.7	11.b	11.c	11 Sustainable cities and communities	11.1.1	11.2.1	11.3.1	11.6.2	11.7.1
				12.2	12.4	12.8	12.a	12.b	12 Responsible consumption and production	12.a.1				
				13.1	13.2	13.3	13.b	13 Climate action	13.1.1					
		14.1	14.2	14.3	14.4	14.6	14.7	14.a	14 Life below water	14.3.1	14.4.1	14.5.1		
	15.1	15.2	15.3	15.4	15.5	15.7	15.8	15.9	15 Life on land	15.1.1	15.2.1	15.3.1	15.4.1	15.4.2
							16.8	16 Peace, justice and strong institutions						
17.2	17.3	17.6	17.7	17.8	17.9	17.16	17.17	17.18	17 Partnerships for the goals	17.6.1	17.18.1			

Figure 3: SDG Targets and Indicators, mandated and recognised by the UN for each of the 17 identified SDGs, that can be supported by Earth observation. Figure from EO4SDGs/CEOS.³

2.5.2 Agenda 2063: The Africa We Want

The African Union’s Agenda 2063 provides a strategic blueprint for the future development of the African continent. In implementing Agenda 2063, data that allows policymakers to monitor progress is critical for ensuring the sustainable development outcomes under Agenda 2063. Though data that accurately and reliably monitors these outcomes has historically been expensive, Earth observation data provides opportunities for developing innovative products and services that can support the development imperatives under Agenda 2063 (Kganyago and Mhangara, 2019; Table 1).⁴ DE Africa contributes directly to enabling Earth observations in Africa that works towards the Africa 2063 mandate.

³ See above n 2 (GEO, 2017).

⁴ See generally, Kganyago, Mahlatse and Paidamwoyo Mhangara, ‘The Role of African Emerging Space Agencies in Earth Observation Capacity Building for Facilitating the Implementation and Monitoring of the African Development Agenda: The Case of African Earth Observation Program’ (2019) 8 *International Journal of Geo-Information*, 292 – 314.

Table 1 The African Union's Agenda 2063 First-Ten-Years Implementation Plan goals and priority areas that can be addressed using Earth observation. Adapted from Kganyago and Mhangara (2019).

Agenda 2063 Goal	Agenda 2063 Priority Area	Earth Observation Use
Goal 1: A high standard of living, quality of life, and wellbeing for all citizens	<ul style="list-style-type: none"> ◆ Poverty, inequality, and hunger ◆ Modern and liveable habitats and basic quality services 	<ul style="list-style-type: none"> ◆ Cities and infrastructure mapping
Goal 5: Modern agriculture for increased productivity and production	<ul style="list-style-type: none"> ◆ Agricultural productivity and production 	<ul style="list-style-type: none"> ◆ Agricultural monitoring
Goal 6: Blue/ocean economy for accelerated economic growth	<ul style="list-style-type: none"> ◆ Marine resources and energy ◆ Ports, operations, and marine transport 	<ul style="list-style-type: none"> ◆ Oceanographic observations
Goal 7: Environmentally sustainable and climate resilient economies and communities	<ul style="list-style-type: none"> ◆ Climate resilience and natural disasters preparedness and prevention ◆ Renewable energy ◆ Water security ◆ Sustainable consumption and production ◆ Sustainable natural resource management and biodiversity conservation 	<ul style="list-style-type: none"> ◆ Land cover and use mapping ◆ Biodiversity and ecosystem observations ◆ Hydrological monitoring ◆ Hazards, disasters and environment impact monitoring ◆ Atmospheric and air quality monitoring



3 Current Status and Future Development

This section describes current status of technical development guided by previous Committee decisions and future work endorsed by the TAC. As rest of the document, the text will be updated to reflect new decisions and any change of focus.

3.1 Current Status

As of August 2021, the technical team has made significant progress in all components that underpin the DE Africa capabilities. These include operational input datasets that are fundamental for developing services and insights, infrastructure in Africa that enable access and analysis by users with different technical backgrounds and continental-wide services addressing thematic areas most relevant for Africa.

Focus of technical work has shifted to be improving infrastructure, expanding services and ensuring transition of capability into Africa. Status and planned activities endorsed by the TAC in June 2021 are detailed below.

3.1.1 Input Datasets

Following datasets are now operational and will be maintained:

- ◆ Surface Reflectance and Surface Temperature Landsat Collection 2 (4.2.5)
- ◆ Surface Reflectance Sentinel-2 (4.2.6)
- ◆ Normalized Radar Backscatter Sentinel-1 (4.2.4)
- ◆ Digital Elevation Model SRTM (4.2.1)
- ◆ Normalised Radar Backscatter ALOS/JERS Annual Mosaic (4.2.2 and 4.2.3)

All data are stored in Cape Town, sponsored by the AWS Public Dataset Program. Data pipelines are continuously monitored to ensure the archive is complete and accessible.

As more data providers are moving into the cloud and implementing cloud native technology, more datasets can now be accessed by DE Africa users from outside of our own data store. One such example is the ERA5 gridded climate data (4.3.1). We have implemented code examples in our open source notebooks repository to load and use this dataset.

We will continue to explore additional datasets that are useful and complementary to our current data offerings and build relationships with data providers to ensure sustainable supply of input data.

3.1.2 Platform Components

All platform components listed below and detailed in Section 5.1 are operational in Cape Town. These systems support each other as laid out in Figure 4.

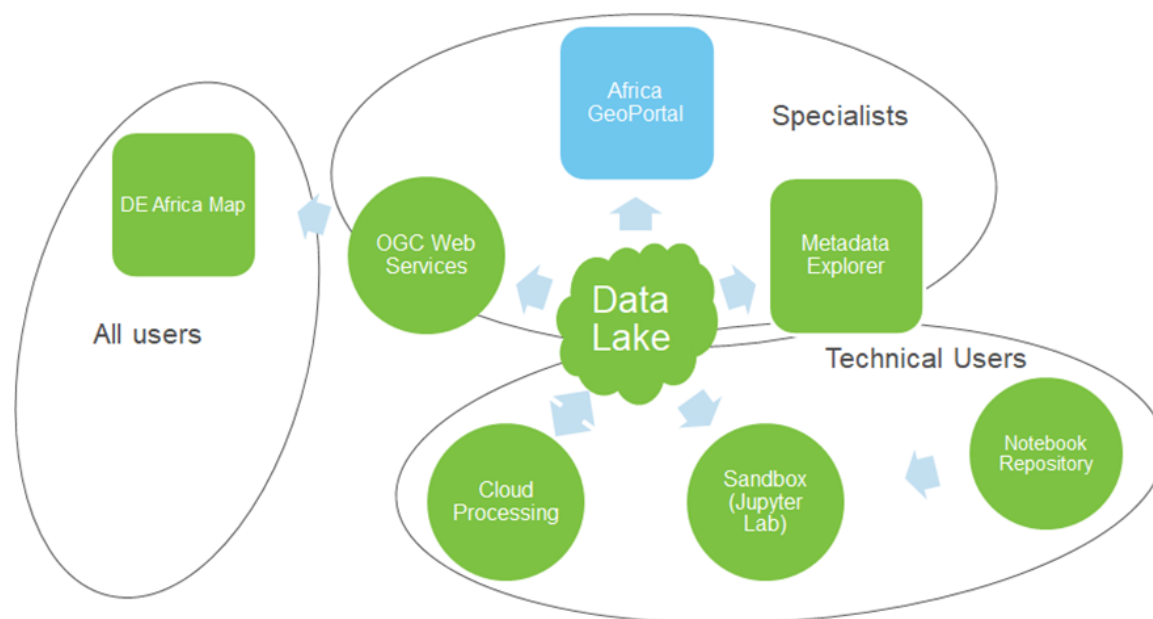


Figure 4: The DE Africa Platform components that are operational in Cape Town. Together they enable access and analysis by users with different technical backgrounds.

In particular, the DE Africa Map portal now supports French and allows visualization of all datasets and products in a number of styles. It is used frequently to engage public and technical users as well as internally for research and development.

The number of registered Sandbox users has been growing steadily and approaching 1000 as of August 2021. The TAC has recognized a need to provide a wider range of computing resources and support that will help both internal and external users with different needs. Various options for tiered access and scaling up have been explored and currently being trialed with IPs.

3.1.3 Services

A continental scale GeoMAD service is now operational, providing at 10 m resolution and for each calendar year:

- ◆ cloud-free representative multi-spectral images - geomedian
- ◆ spectral variability measured in different metrics - median absolute deviations (MADs)

Annual geomedian images enable easy visual and algorithmic interpretation, e.g. understanding urban expansion, at annual intervals. They are useful for characterising permanent landscape features such as woody vegetation. The MADs can be used on their own or together with geomedian to gain insights about the land surface, e.g. for land cover classification and for change detection from year to year. The GeoMAD service will expand to include semiannual products and products based on Landsat that goes back to the 1980s.

The team will continue to develop Water Observations from Space (WOfS, 6.3.1) into an operational service. Beta WOfS has been validated across Africa to produce good results.



Operational service is being developed to be:

- ◆ based on Landsat Collection 2, therefore at 30 m resolution and covers the continent from late 1980s to now,
- ◆ fully validated in Africa,
- ◆ summarised into annual and all-time statistics at 30 m.

While there's currently no plan to implement WOfS on Sentinel-2 (10 m resolution). The classifier has been validated to produce comparable results for Sentinel-2 and therefore can be reliably used at small scale in notebooks.

Food security is identified to be the priority thematic area DE Africa will focus on. A continental-wide crop land map is being developed, with

- ◆ training and validation data collected with partners,
- ◆ a beta product for Eastern Africa available for assessment,
- ◆ models for other regions being built and tested with partners.

3.2 New products and services

Food security remains the priority thematic area, noting products developed for food security will also support applications in other thematic areas.

A **Fractional Cover** service will be developed based on Landsat - photosynthetic vegetation, non-photosynthetic vegetation and bare soil fractions for each 30 m Landsat pixel. This product will support many applications in Food Security, Natural Resource and Disaster Risk Reduction.

The next continental scale product will be a **NDVI anomaly** (as monthly or seasonal product):

- ◆ This is a statistical product that can be generated consistently across the continent. The method is well established and scalable.
- ◆ This product, combined with the crop mask, will be valuable for crop monitoring.
- ◆ The product can also be used for mapping deforestation, vegetation health and drought, therefore relevant for Natural Resource and Disaster Risk Reduction.

Next, we propose to progress a few **regional products**, selected by Implementing Partners (IPs) of specific interest to their stakeholders, that can be scaled up to be operational service in the future.

- ◆ Number of regional products to be worked on is determined by resource availability.
- ◆ For each of these products, the project team will include staff members from at least two IPs and the establishment team. This will ensure capacity building in Africa and regional and cross-institutional collaboration.
- ◆ The project team will develop the project plan and timeline with an user-centric approach.
- ◆ The project will identify feasibility and the best approach to scale up and extend to be operational for other regions in Africa.
- ◆ The project team membership is not exclusive, rather reflects dedicated resources from IPs. The project team will report regularly to the broad DE Africa product development and validation team for consultation and feedback.



One priority regional product from the list below is expected to progress late 2021, to be chosen collectively by the IPs:

- ◆ Crop type mapping of major crops in selected regions
- ◆ Yield estimate (after crop type mapping, for selected major crop types)
- ◆ Land degradation and desertification
- ◆ Irrigated crops extent

We are currently working with the IPs to fast track capacity development activities as soon as possible. These training activities are essential for IPs to fully utilise the capability offered by the DE Africa platform, and develop relevant products of interest to regional partners.

After the proposed activities as noted above, IPs would lead future work (enabled by capacity building program), which may include:

- ◆ Regional products from the list above
- ◆ Extend regional products to other regions where applicable
- ◆ Crop monitoring using crop mask and NDVI anomaly
- ◆ WOfS-based waterbody surface area mapping - as operational in Australia
- ◆ Wetland insight tool based on WOfS and Fractional Cover (can be implemented as a notebook-based tool after Fractional Cover data is available)

4 Input and Analysis Ready Datasets

DE Africa relies on data produced by satellites orbiting the Earth. In order to become a sustainable, operational on-going capability for Africa DE Africa must have routine, timely, reliable and efficient access to these data sources in a form that does not require DE Africa to undertake complex calibration and processing. To achieve this DE Africa will work with data providers and CEOS to ensure a continuous input pipeline of Earth observation data that are analysis ready.

This section presents an overview of the key Earth observation datasets critical for DE Africa's function.

4.1 CEOS Analysis Ready Data for DE Africa

CEOS Analysis Ready Data for Land (CARD4L) are Earth observation data that have been processed to a minimum set of requirements and organised into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and space and with other datasets. In 2019, CEOS produced specifications for land Surface Reflectance, Surface Temperature, and Radar Backscatter intensity.

DE Africa will host CARD4L-compliant datasets. Landsat Collection-2 Surface Reflectance is providing the fundamental starting point for DE Africa and is expected to be the basis for the majority of the information products and services likely to be developed in the Establishment phase of DE Africa. Other crucial data sources are Sentinel-2, which provides more frequent and higher spatial resolution observations from 2015 onwards, and Sentinel-1, a radar mission of particular importance in areas where there is persistent cloud cover.

Ensuring CARD4L-compliance is essential to the Sustainability of DE Africa. DE Africa will work with satellite operators and encourage their efforts to routinely observe Africa, and to operational produce CARD4L-compliant data. This improves the sustainability of the DE Africa Program by removing the burden to produce and maintain bespoke approaches to data processing. It also ensures datasets are processed consistently to a high quality across Africa and are compatible with global datasets. Through efforts coordinated by DE Africa in the longer term, users will be able to work with the global Earth observation community to influence, improve and standardise processing techniques.

DE Africa will steadily increase the breadth and depth of its ARD collections with the addition of data from a range of satellite sensors and, in time, other sources of environmental data such as rainfall, stream gauge radiometric, and surface climate data. For example, Landsat Collection-2 will include CARD4L compliant land Surface Temperature data, and data from the European Sentinel-2 and Sentinel-1 satellites can be processed to be CARD4L Surface Reflectance and Radar Backscatter intensity, respectively.

4.2 Current Activity: Input Datasets

This subsection contains input datasets classified as 'Tier 1'. These datasets are selected because they measure key properties of the Earth surface and enable production and interpretation of other data products. They are compliant to or are being actively progressed to meet the CARD4L standards. Relatively small development effort is required to integrate these datasets into DE Africa.



4.2.1 Digital Elevation Model SRTM

Development Tier	ID	Potential Collaborators	Status
Tier 1	Digital Elevation Model SRTM	TBC	Active: Up-to-date data available through DE Africa

Description: The SRTM (Shuttle Radar Topography Mission) v 3.0 (SRTMGL1) product is obtained from NASA's Land Processes Distributed Active Archive Center and reformatted for use in DE Africa. This is a static dataset.

The Digital Elevation Model SRTM is a model providing topographical information, at 30 metre resolution, derived from data collected by NASA's SRTM in 2000. The Digital Elevation Model has been used as an input dataset for DE Africa.

Impact: This data enables topographic analyses in the DE Africa platform. Topographic information is critical for understanding the land surface characteristics in the height dimension and supports land and natural resource management.

4.2.2 Normalised Radar Backscatter ALOS Annual Mosaic

Development Tier	ID	Potential Collaborators	Status
Tier 1	ALOS Radar Annual Mosaic	AMA; AWS; CEOS; JAXA	Active: Up-to-date data available through DE Africa

Description: The global 25 metre resolution Phased Array-type L-band Synthetic Aperture Radar (PALSAR) and PALSAR-2 mosaic is a free and open dataset generated from images obtained with Japanese L-band Synthetic Aperture Radars (PALSAR and PALSAR-2) on Advanced Land Observing Satellite (ALOS) and Advanced Land Observing Satellite-2 (ALOS-2). Annual mosaics are available for 2007 to 2010 and 2015 onwards. This is the first continental scale Synthetic Aperture Radar (SAR) ARD offered by DE Africa.

The ALOS/ALOS-2 PALSAR/PALSAR-2 mosaics are sourced from JAXA Earth Observation Research Center and reformatted for use in DE Africa. This dataset is updated when a new mosaic or a new version becomes available from JAXA.

Impact: This dataset was offered in ARDC and is therefore required for transition of ARDC capability. SAR data enables monitoring and detecting changes in the tropical regions where cloud-free optical coverage is sparse. It also provides complementary measurement to optical data and can be used to map land cover and changes, including surface water, urban areas, and vegetation.

4.2.3 Normalised Radar Backscatter JERS Annual Mosaic

Development Tier	ID	Potential Collaborators	Status
Tier 1	JERS Radar Annual Mosaic	AMA; AWS; CEOS; JAXA	Active: Up-to-date data available through DE Africa

Description: The continental JERS-1 mosaic for 1996, obtained from the Japanese Earth Resources (JER) satellite, is sourced from JAXA Earth Observation Research Center and reformatted for use in DE Africa. This is a static dataset and will be updated when a new version becomes available from JAXA.

The 25 metre resolution JERS-1 mosaics were generated with the same method as the PALSAR/PALSAR-2 mosaics. In addition to the global mosaic for 1996, partial coverage is offered over tropical regions in Africa from 1994 to 1997 and can be retrieved if required.

Impact: This dataset extends the temporal coverage of L-band SAR data to be over 20 years, hence enabling long term change detection, in particular over forested areas.

4.2.4 Normalised Radar Backscatter Sentinel-1

Development Tier	ID	Potential Collaborators	Status
Tier 1	Sentinel 1	Sinergise; ESA; AWS; e-GEOS; CEOS	Active: Up-to-date data available through DE Africa

Description: This dataset is now operational and is nominally available to users within 1 day from acquisition. The data is available in AWS: <https://registry.opendata.aws/deafrica-sentinel-1/>

ESA's twin Sentinel-1 satellites, launched in 2014 and 2016, currently collect C-band SAR data every 12 days over Africa. Spatial resolution of the Sentinel-1 data is approximately 20m.

The DE Africa team has collaborated with Sinergise to produce CARD4L-compliant Sentinel-1 backscatter. Radiometric Terrain Correction (RTC) has been applied so data acquired with different imaging geometries over the same region can be compared. This is the first continental scale free and open SAR ARD.

Impact: In addition to the usual benefit offered by a SAR sensor, Sentinel-1 provides a high temporal resolution required for time series analysis. This dataset will improve land cover classification and enable characterisation of dynamic systems.

4.2.5 Surface Reflectance and Surface Temperature Landsat Collection 2

Development Tier	ID	Potential Collaborators	Status
Tier 1	Landsat Collection 2	USGS	Active: Up-to-date data available through DE Africa

Description: USGS Collection 2 is now operational and updated daily in the DE Africa platform. The data is available in AWS: <https://registry.opendata.aws/deafrica-landsat/>

This Collection provides multi-spectral land surface reflectance and land surface temperature observations at 30 metre spatial resolution from Landsat 5, 7 and 8. Observations in the Collection commence in the mid-eighties with coverage increasing over time as technical capabilities (instruments, satellites and ground stations) have improved.

USGS Landsat Collection 2 offers improved processing, geometric accuracy, and radiometric calibration compared to previous Collection 1 products. The Level-2 products are endorsed by the Committee on Earth Observation Satellites (CEOS) to be Analysis Ready Data for Land (CARD4L)-compliant.

Impact: This data will provide continental scale coverage, enabling time-deep analysis going back 30 years in some cases (historic coverage is best in northern and southern Africa). It has a wide range of applications in helping to understand and monitor environmental changes.

4.2.6 Surface Reflectance Sentinel-2

Development Tier	ID	Potential Collaborators	Status
Tier 1	Sentinel-2	ESA; AWS; Sinergise; Element 84; CEOS	Active: Up-to-date data available through DE Africa

Description: This dataset is operational and is available nominally within 3 days from acquisition. The data is available in AWS: <https://registry.opendata.aws/deafrica-sentinel-2/>

ESA's twin Sentinel-2 satellites, launched in 2015 and 2017, provide multi-spectral optical observations at a spatial resolution of up to 10 metres. Since early 2018, the pair of satellites have been acquiring images over most of the land surface every five days. This creates a time-deep data resource that can be used to inform a variety of services. Data will usually be added the day after it has been captured by the satellite.

DE Africa is working with Sinergise, who manage the Sentinel-2 JPG2000 data in a collaborative arrangement with the ESA, to process more data that covers the African continent for the year 2017. DE Africa is also working with Element 84 to convert Sinergise's JPG2000 data for Africa to Cloud Optimised GeoTIFFS (COGs) – an open cloud native format that will enable greater accessibility for DE Africa's users.

Impact: This data will provide high spatial and temporal resolution continental scale coverage, enabling characterisation and monitoring of land surface to support management of natural resources.

4.3 Potential Activities: Input and Analysis Ready Datasets

This sub-section contains Tiers 2 and 3 input datasets that have potential and may be sustained under DE Africa, time and resources permitting, but are not currently under development. Numerous opportunities exist for multi-disciplinary datasets to be integrated and utilised by DE Africa, and other unexplored datasets may be added in future iterations of this Technical Roadmap.

'Tier 2' datasets are operationally delivered by a data provider; implementing these datasets in DE Africa would take a minor to moderate amount of developmental work or resourcing. 'Tier 3' datasets are available globally or regionally and could in principle be included in an ODC platform. However, there are significant unknowns involved and/or significant difficulties should be anticipated to including these in Digital Earth Africa as operational datasets.

4.3.1 Climate Gridded Data

Development Tier	ID	Potential Collaborators	Status
Tier 2	Climate Gridded Data	NASA; ECMWF; International climate community	Not active: Continental-scale data

Description: Climate Gridded Data such as rainfall, temperature, and wind are provided by meteorology agencies. For example, the European Centre for Medium-Range Weather Forecasts (ECMWF) provides a global climate reanalysis dataset (the ECMWF Reanalysis 5th Generation, ERA5) at up to 30 kilometre spatial resolution covering the period 1979 to present. Additionally, there are many high-resolution (up to 5 kilometre), multi-sensor, satellite-based rainfall datasets that provide coverage over Africa.

While DE Africa doesn't host any climate data, the ERA5 reanalysis data is available in cloud optimized format in AWS: <https://registry.opendata.aws/ecmwf-era5/>

Impact: Climate is a fundamental driver of environmental processes and change. Access to climate data within an ODC framework will allow the convenient coupling of satellite observations with

important environmental drivers like rainfall and temperature. This DE Africa users to correlate land surface changes with broader scale variations in the climate, potentially allowing for predictions of environmental change. An ODC indexed suite of climate variables will also enable a streamlined calculation of climate metrics like drought indices, which can be useful for exploring the spatio-temporal footprints of drought.

4.3.2 Surface Reflectance and Surface Temperature MODIS

Development Tier	ID	Potential Collaborators	Status
Tier 2	MODIS Satellite Data	NASA	Not active: Continental-scale data

Description: MODIS refers to the Moderate Resolution Imaging Spectroradiometer instrument onboard the two NASA satellite missions, Terra and Aqua. MODIS measures surface reflectance and surface temperature daily at spatial resolutions of up to 250 metres and 1 kilometre, respectively.

Impact: MODIS data enables high temporal resolution monitoring over land and ocean. This data helps understand global dynamics and environmental processes between the land, oceans, and atmosphere. MODIS plays a vital role in validating global, interactive Earth system models for accurately predicting environmental change that can assist policy makers.

4.3.3 Digital Elevation Model ALOS

Development Tier	ID	Potential Collaborators	Status
Tier 2	Digital Elevation Model ALOS	JAXA	Not active: Continental-scale data

Description: The ALOS World 3D – 30 metre (AW3D30) product is provided by JAXA. This global 30 metre resolution Digital Elevation Model is derived from data acquired by ALOS's PRISM panchromatic stereo mapping sensor between 2006 and 2011. It provides more recent information compared to SRTM. There are some identified artefacts in this dataset in some regions, but it is more accurate than SRTM DEM.

Impact: This dataset complements SRTM in providing topographic information.

4.3.4 ALOS Forest/Not Forest Data

Development Tier	ID	Potential Collaborators	Status
Tier 3	ALOS Forest/Not Forest Data	<i>TBC</i>	Not active: Continental-scale data

Description: This 25 metre resolution forest cover classification dataset is provided by JAXA. The dataset is derived from ALOS/ALOS-2 PALSAR/PALSAR-2 L-band SAR data, hence is available for 2007 to 2010 and 2015 onwards.

Impact: Forest cover classification data can be used to assess deforestation and forest degradation and assist with developing ecosystem accounting capabilities.

4.3.5 Near Real Time Satellite Data

Status	ID	Potential Collaborators	Status
Tier 3	Near Real Time Satellite Services	<i>TBC</i>	Not active: Future collaboration opportunity

Description: A provisional version of analysis ready satellite data may be provided faster than data produced via the usual processing method, but with some decrease in accuracy as a pay-off and

significant operational overheads to establish and maintain such a service. Feasibility of this service will depend on capacity of data providers.

Impact: Near Real Time Satellite Services can help decision makers to respond to fast-changing environmental situations, particularly with disaster management.

4.3.6 Surface Reflectance and Surface Temperature Sentinel-3

Development Tier	ID	Potential Collaborators	Status
Tier 3	Sentinel 3	ESA; EUMETSAT	Not active: Continental-scale data

Description: The Sentinel-3 constellation, with two satellites launched in 2016 and 2018 and two more satellites planned, makes use of multiple sensing instruments to monitor the land and ocean. The two most relevant datasets for DE Africa are Surface Reflectance measured by the Ocean and Land Colour Instrument (OLCI) and Surface Temperature measured by the Sea and Land Surface Temperature Radiometer (SLSTR). These two datasets offer measurements at a moderate (300 metres to 1 kilometre) spatial resolution every 1 – 2 days. For more information, visit: <https://sentinel.esa.int/web/sentinel/missions/sentinel-3/overview/mission-summary>

Impact: Sentinel-3 data enables high temporal resolution monitoring over land and ocean. It helps identify environmental changes and supports management of natural resources and agriculture applications.



5 The Digital Earth Africa Platform

The DE Africa program will develop (and support development of) a platform that includes a range of data discovery, visualisation and analysis capabilities that will enable users to utilize Earth Observation data and information services in ways that are meaningful and relevant to the users' needs. DE Africa aims to use industry-standard protocols and formats wherever possible.

Data accessibility and visualisation is of vital importance as the complexity and scale of Earth Observation data can be a barrier to uptake. Data visualisation enables decision makers to see analytics presented visually, simplifying difficult concepts and identifying patterns in the data that might otherwise be overlooked. Interactive visualisation takes the concept further by using technology to drill down into and manipulate the data to enable customisation of scenarios and the analytical outputs for particular purposes.

The core of the DE Africa platform is the **Earth Observation Data Lake**, which includes all datasets that make up the Analysis Ready Data and DE Africa Services. This data will be open for public access to enable expert users to access the data directly. To support discovery of this data, DE Africa will also include a metadata explorer web application.

A suite of standards-based technologies are used to share this spatial data. At the data level, we are storing all raster data as Cloud Optimised GeoTIFFs (COGs). A COG is an agreed community standard that uses a common GeoTIFF with backwards compatible extensions to make reading over a network more efficient. At the service level, DE Africa hosts a range of Open Geospatial Consortium (OGC) Web Services. In addition to existing OGC standards, DE Africa will continue to keep abreast of developments with the new OGC APIs and as they are defined and enter use, we will implement them. The Spatio-Temporal Asset Catalog (STAC) community standard is currently supported and there's ongoing work to update support and make it compatible with work that is being done by others in the community.

To maximize the reach of DE Africa, the team works closely with the Africa GeoPortal to ensure data is accessible and can be analysed by a suite of custom-built applications powered by Esri's ArcGIS online.

To support interactive analysis the DE Africa platform will include a 'Sandbox' environment based on JupyterLab: an environment that provides a user-accessible forum for open source scientific notebook development. This Sandbox will include an ODC environment pre-loaded with all of the Earth observation data in DE Africa, enabling users to immediately start performing interactive analysis on the data without downloading or processing the raw data. The sandbox will have some example notebooks that serve as an interactive tutorial on how to use the ODC, and can be used to run common algorithms over a user chosen location.

After a new algorithm has been developed using the Sandbox it can be run across the entire African continent using DE Africa's cloud native processing jobs. These processing jobs enable scientists to easily scale up their scientific algorithms to continental services.

The DE Africa Platform components outlined in this section enable users to discover, visualise, and analyse Earth observation data with a variety of capabilities, designed to suit users with different expertise and intents. The DE Africa's Platform is also used internally to process and host the data that makes up DE Africa services.



5.1 Current Activity: DE Africa Platform Components

This sub-section contains the capabilities classified as 'Tier 1', which includes capabilities that are being actively developed under DE Africa.

5.1.1 DE Africa Data Lake

Development Tier	ID	Potential Collaborators	Status
Tier 1	Data Lake	AMA, USGS, Sinergise, Element84, AWS, Esri	Active: operational in Cape Town; ongoing development

Description: The Data Lake consists of remote-sensing data stored in open cloud optimised formats such as Cloud Optimised GeoTIFF (COG) with SpatioTemporal Asset Catalog (STAC) metadata. This Data Lake is hosted on Amazon Web Services (AWS) Simple Storage Service (S3) object store.

Impact: DE Africa's Data Lake is the foundation for all products and services. As well as allowing continental scale products to be produced, expert users can directly access these free and open data. The Data Lake also grants users the ability to download DE Africa data or utilise their own choice of tools on the data.

5.1.2 DE Africa Metadata Explorer

Development Tier	ID	Potential Collaborators	Status
Tier 1	Metadata Explorer	NCI	Active: operational; ongoing development

Description: The DE Africa Metadata Explorer is a website that utilises existing ODC infrastructure to inspect metadata for DE Africa services and their underlying datasets. It includes a time-picker and coverage map to help users find datasets.

A dynamic API using STAC 0.6 is available through the Explorer application and there is a current project to update Explorer to support STAC 0.9 with extensions that will make it compatible with work that is being done by others in the community.

Impact: The DE Africa Metadata Explorer enables non-expert users to find specific datasets through time and space as well as query metadata related to each dataset.

5.1.3 Africa GeoPortal

Development Tier	ID	Potential Collaborators	Status
Tier 1	Africa GeoPortal	Esri	Active: Publicly available

Description: The Africa Geoportal, powered by Esri using ArcGIS online, provides users with data, tools and support in visualising, discovering and analysing different aspects of Africa. Access is free to those residing in Africa or working on projects within Africa. Data from DE Africa is made available through the Africa Geoportal and used to support a number of custom-built applications. DE Africa's technical team works in close partnership with Esri to ensure compatibility and effective use of DE Africa products.

Impact: Africa GeoPortal allows users to access Esri's ArcGIS Online service as well as a wealth of free geographic data and imagery and training materials. It provides complimentary technical solutions for a large community of users and extends the reach of the DE Africa program.

5.1.4 Open Geospatial Consortium Web Services

Development Tier	ID	Potential Collaborators	Status
Tier 1	OGC web services	Data61	Active: operational; ongoing development

Description: Ongoing development and support of the OGC web services is being undertaken to deliver DE Africa data through standard Application Program Interfaces (APIs).

The OGC services currently and soon to be implemented are listed in the below table.

Service	Application	Versions supported	Status
Web Map Service (WMS)	Data Visualisation	1.0.0, 1.3.0	Fully implemented
Web Map Tile Service (WMTS)	Data Visualisation	1.0.0	Fully implemented
Web Processing Service (WPS)	Data Analysis	1.0.0	Coming soon
Web Coverage Service (WCS)	Data Delivery	1.0, 2.0 and 2.1	1.0 is fully implemented and 2.0 and 2.1 are coming soon

Impact: This capability delivers freely accessible and interoperable data via services that are compatible with international open standards, enabling users to visualise and analyse data with Geographic Information System (GIS) clients.

5.1.5 DE Africa Map – Web Map Portal

Development Tier	ID	Potential Collaborators	Status
Tier 1	DE Africa Map	Data61	Active: operational; ongoing development

Description: DE Africa Map enables users to visualise and download geospatial datasets in a web browser. It is built on Terria.JS, which is an open source and freely available software. Users can integrate their own data and services with remote-sensing data.

Impact: DE Africa's Web Map Portal enables non-expert users to explore remote-sensing data and derive new insights from the dynamic African landscape.

5.1.6 DE Africa Sandbox – User Computational Platform

Development Tier	ID	Potential Collaborators	Status
Tier 1	Sandbox	AMA, CSIRO, FrontierSI	Active: operational; ongoing development

Description: Ongoing development and support of a cloud-based user computational platform (also known as the DE Africa Sandbox) that operates through a Jupyter Lab environment. The environment includes step-by-step Jupyter notebook tutorials on performing interactive analysis of DE Africa data using Open Data Cube. This environment serves as a training environment supplemented with training material supported by the DE Africa Sandbox Notebooks (detailed below). The DE Africa Sandbox also operates as a hub for innovation to develop new algorithms, datasets, and ad-hoc reports to inform policy making.

Impact: The Sandbox Platform provides users with access to data and analysis tools with no upfront cost, democratising access to remote-sensing data enabling ad-hoc report generation and rapid development of new algorithms.

5.1.7 User Computational Workflows (Notebook repository)

Development Tier	Status	Potential Collaborators	Status
Tier 1	Notebook repository	FrontierSI	Active: operational; ongoing development

Description: A repository of readily available notebooks (workflows and code) will enable users to use, interact, and engage with the DE Africa Sandbox platform. Using these Sandbox Notebooks, users will be able to readily load, process, analyse, and visualise the ARD and other derived data services developed under DE Africa. Users will also be able to scale DE Africa’s Earth observation products to meet their own needs.

However, there is significant work required to transition existing notebooks and pre-packaged coding models to the DE Africa platform, particularly with testing and updating the suitability of these workflows within the multiple diverse climatic regions within Africa. DE Africa is actively working on transitioning existing ODC infrastructure to its own Sandbox platform. Additionally, usability is reliant on the USGS Landsat data release, which may further limit user engagement when utilising the Sandbox Notebooks.

Impact: Developing a repository of readily available Jupyter notebooks (also known as Jupyter Labs) contributes to DE Africa’s commitment to the democratisation of Earth observation data across that is readily available and that can be used by the African population.

5.1.8 Cloud Native Data Processing

Development Tier	ID	Potential Collaborators	Status
Tier 1	Cloud Processing	AWS	Active: operational; ongoing development

Description: Utilising cloud native processing jobs to convert and derive datasets from upstream Analysis Ready Data (ARD) at a continental scale. This capability enables algorithms to be scaled up to run on continental scale datasets.

Impact: Cloud native data processing capabilities, developed for DE Africa, enables the efficient and timely delivery of DE Africa’s services to users.

5.2 Potential Activities: DE Africa Platform Components

This sub-section contains the components classified as ‘Tier 2’, which includes components that are not currently progressed under DE Africa but are potentially operational given direction from the Committee.

5.2.1 Query and Download Interface

Development Tier	ID	Potential Collaborators	Status
Tier 2	Query and Download Interface	jeobrowser	Not active

Description: To enable spatial query and download of DE Africa products through a graphical user interface. One proposed option is to use a similar but upgraded platform as the [Sentinel Australasia Regional Access](#) portal. This platform will support OpenSearch and be aligned with STAC development.

Impact: A graphical user interface provides an intuitive way for the users to search and download DE Africa products.

5.2.2 Virtual Reality Display

Development Tier	ID	Potential Collaborators	Status
Tier 2	Virtual Reality Display	NCI	Not active: A proof-of-concept has been developed

Description: A Virtual Reality Display will be developed to showcase DE Africa products and capabilities at conferences and events. A prototype display showing regional-scale Wetlands Insights Tool data, was developed for the 2019 GEO Week Summit. A virtual reality headset was loaded with pre-processed waterbody extent data for over 40 lakes within Tanzania. An operational display requires purchase and maintenance of hardware and development of contents.

Impact: This tool allows the users to visualise and interact with DE Africa products. It showcases DE Africa capabilities to key stakeholders and encourage greater engagement with a broad community.

5.2.3 Sandbox Computational Scalability

Development Tier	ID	Potential Collaborators	Status
Tier 2	Sandbox Computational Scalability	CSIRO	Active: Internal prototype has been developed, undergoing reliability improvements

Description: To enable the development of algorithms and services that have high computational resource requirements, DE Africa will develop a Dask cluster capability for its Sandbox user platform. Dask is an open source library that enables splitting large processing jobs across a cluster of worker nodes to enable greater computational capabilities.

Impact: Developing DE Africa’s Sandbox computational scalability through Dask enables development of DE Africa’s time-deep, computationally-intensive services. Such services include statistical summaries based on a collection of data over a given time period, including the WOfS annual summary.

6 Thematic Areas and Potential Services

6.1 Overview

6.1.1 Categorisation

This section contains a list of potential services available for development under DE Africa, summarised in Table 2, below. Each service has been categorised according to an identified Thematic Area, though not all services are exclusive to one Thematic Area and may be applied across several Thematic Areas. Each service has also been assigned a 'Tier', a 'Product Maturity' if active and a 'Technical Readiness' if not active.

Thematic Areas: The Thematic Areas were determined with reference to the SDGs, the African Union's Agenda 2063, GEO's priorities, along with broader social, environmental, and economic trends in Africa. The identified Thematic Areas are:

- ◆ Enabling Services
- ◆ Natural Resources
- ◆ Food Security
- ◆ Urban Sustainability
- ◆ Disaster Risk Reduction
- ◆ Coastal and Marine Environments

Technical Readiness: The Technical Readiness of each service, defined in Section 2.1, has been highlighted in Table 2 to illustrate the variations in technical difficulty that may not be captured by the Tier rating.

6.1.2 Product Maturity

For a service being actively progressed, a product maturity level is identified. This status flag reflects the development stage of a service, and can be one of the following:

1. **Prototype:** an internally shared product or workflow, likely in local or regional scale, has been developed for DE Africa and is being progressed into a continental service.
2. **Beta:** an early release product, implemented for African continent but only minimally validated or validated outside Africa, is made available to the public to gather feedback for further improvements.
3. **Provisional:** a continental-wide product has been produced, validated in Africa (though not necessarily to DE Africa validation standards), and made available to the public for operational assessment.
4. **Operational:** a fully validated continental-wide product has been produced, being updated as required and made available through the DE Africa Platform. Production and update are automated for a dynamic product.

An operational service may be further developed for improvement in accuracy and/or temporal and spatial resolution. The changes may involve inclusion of additional input datasets and adoption of new algorithm. All services will be released with incrementing version numbers to track this progression.



6.1.3 Dependencies

Aside from the fundamental dependence on CARD4L and other Earth observation data, several of DE Africa’s services are reliant on or can be supported by the development of other services. **These dependencies are highlighted for each Thematic Area in sections below, and may assist to guide the prioritisation of certain services by the Committee.**

In these diagrams, a service or dataset enables another product if the arrow goes away from the service or dataset. A service or dataset is dependent on another product if the arrow goes towards this service or dataset.

Services are also coloured according to the relevant Tier classification (i.e. Tier 1 is green, Tier 2 is yellow, and Tier 3 services are orange). ARD and relevant datasets are blue. The dependencies have been mapped according to the relevant Thematic Area, along with other relevant services. Services not categorised in the stated Thematic Area have been bolded in the dependency map and the relevant classification stated.

For more information on the dependencies and how this mapping may assist with understanding the technical and logistical difficulty of developing a service, see Appendix A.1.

Table 2 Categorised list of services for DE Africa based on identified Thematic Area.

Thematic Area	Potential Service	Tier	Technical Readiness
Enabling Services	Geomedian Annual Image	1	Continental-scale workflow
	Median Absolute Deviation	1	Continental-scale workflow
	Tasselled Cap	3	Continental-scale workflow
Natural Resources	Water Observations from Space	1	Continental-scale workflow
	Fractional Cover	1	Continental-scale workflow
	Barest Earth	3	Continental-scale workflow
	Illegal Mining Analysis	3	Regional-scale demonstrator
	Land Cover Classification System	3	Regional-scale demonstrator
	Snow Analysis Tools	3	Regional-scale demonstrator
	Water Quality	3	Regional-scale demonstrator
	Wetlands	3	Continental-scale workflow
Food Security	Crop Land Map	1	Under development
	NDVI Anomalies	1	Under development
	Waterbody Mapping	2	Continental-scale workflow
	Desertification and Land Degradation	3	Future collaboration opportunity
	Aquaculture Tools	3	Future collaboration opportunity
	Agriculture Monitoring Tools	3	Future collaboration opportunity
	Irrigated Extent for Crops	3	Continental-scale workflow
Urban Sustainability	Urban Extent and Change	3	Continental-scale workflow
Disaster Risk Reduction	Drought	3	Regional-scale demonstrator

	Fire Scar Mapping	3	Future collaboration opportunity
Marine and Coastal Environments	High and Low Tide Composites	2	Continental-scale workflow
	Intertidal Digital Elevation Model	2	Continental-scale workflow
	Coastal Change Characterisation	2	Regional-scale demonstrator
	Continental Mangrove Mapping	3	Continental-scale workflow

6.2 Enabling Services

Some services are fundamental to enable and significantly augment the application of subsequent Earth observation services for DE Africa and its users. Many applications of Earth observation and the development of insights that may assist policymakers are contingent and dependent on these services.

6.2.1 Potential Activity: Geomedian Annual Image

Development Tier	ID	Potential Collaborators	Status
Tier 1	Annual Geomedian	<i>TBC</i>	Active: operational Sentinel-2 Annual GeoMAD; under development for Landsat collection 2

Description: A geomedian is a composite image generated from a time series of Earth observations. The Annual Geomedian Image is calculated from the surface reflectance values drawn from a calendar year. This provides a median of the physical conditions measured by the earth observations used to create it, and provides a good representation of a typical pixel observation devoid of outliers (e.g. cloud), and exhibits reduced spatial noise.

In contrast to a standard median, a Geomedian Image maintains the relationship between spectral bands. This allows users to conduct further analysis on the composite images as is readily applied to the original satellite images (for example, by allowing the calculation of common band indices like with the normalised difference vegetation index (NDVI)).

A beta product generated from provisional Landsat 8 dataset (2013-2018) has been released.

Impact: Geomedian annual images provide seamless coverage over the whole continent with minimum impact from cloud. It enables easy visual and algorithmic interpretation, e.g. understanding urban expansion, at annual intervals. They are also useful for characterising permanent landscape features such as woody vegetation.

6.2.2 Potential Activity: Median Absolute Deviation

Status	ID	Potential Collaborators	Status
Tier 1	Median Absolute Deviation	<i>TBC</i>	Active: operational Sentinel-2 Annual GeoMAD; under development for Landsat collection 2

Description: The Median Absolute Deviation, applicable to Earth observation, measures variability of observed surface reflectance values within a time period. The product uses three complementary metrics to define spectral variation, and is hence able to distinguish different types of surface changes – for example, land clearing and natural seasonal variation.

The accuracy of the Median Absolute Deviation is dependent on the accuracy of the underlying Earth observation data, and cannot be validated by field data. To improve the outputs of this service, a

sufficiently large data collection is required to calculate a clear median to minimise the effects of poor quality observation data.

Impact: Variability is a key statistical property of a set of observations. Median Absolute Deviation can be used to characterise and measure change in the landscape. This service can be used in machine learning for change detection, land cover mapping, and environmental monitoring. Detecting seasonal variation supplements long-term decision-making by policy makers and industry with short-term, cyclical environmental management considerations.

6.2.3 Potential Activity: Tasseled Cap – Brightness, Greenness, and Wetness Classification

Development Tier	Status	Potential Collaborators	Status
Tier 3	Tasseled Cap	<i>TBC</i>	Not active: Continental-scale workflow

Description: Tasseled Cap is a method of describing the landscape using measurements of brightness, greenness and wetness. Methods and tools for analysing different natural resources using Tasseled Cap are being developed by the Earth observation community and in Digital Earth Australia.

Impact: The Tasseled Cap method was originally developed for the early Landsat satellites to monitor agricultural production, and can be used to analyse natural resources for both government and industry.



6.3 Natural Resources

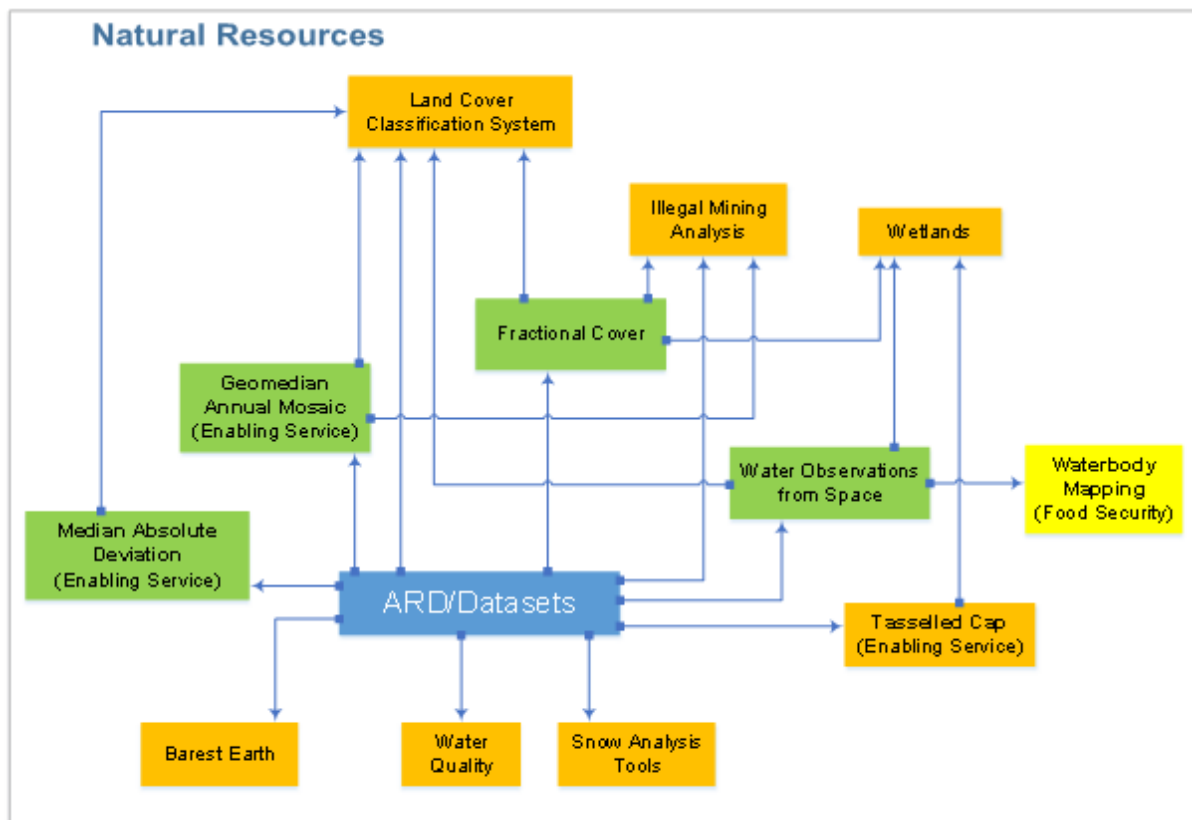
Earth observation has been shown to assist with the sustainable management of natural resources. With increasing demands on Africa's natural resources, Earth observation-informed decision making and management when developing Africa's natural resources underpins the supply of natural resources to the entire continent and to future generations. DE Africa is committed to ensuring the natural resource framework from supporting effective governance of Africa's natural resources and identifying areas where the supply of natural resources is at risk.

Services under 'Natural Resources' contribute to making progress on the African Union's Agenda 2063 Goal 7 (Environmentally sustainable and climate resilient economies and communities).

Relevant SDGs captured under the 'Natural Resources' Thematic Area include:

- ◆ 6: Clean water and sanitation
- ◆ 7: Affordable and clean energy
- ◆ 8: Decent work and economic growth
- ◆ 9: Industry, innovation and infrastructure
- ◆ 12: Responsible consumption and production
- ◆ 15: Life on land (deforestation)

The dependency of services captured under the 'Natural Resources' Thematic Area on general Earth observation datasets, along with other services, is outlined below:



6.3.1 Current Activity: Water Observations from Space

Development Tier	ID	Potential Collaborators	Status
Tier 1	Water Observations from Space	IWMI	Active: beta release based on provisional Landsat 8; under development for Landsat collection 2

Description: Water Observations from Space (WOfS) identifies areas with surface water. This information is made available as individual observations and statistical summaries on varying timescales. When fully operational, individual scene water classifications will be updated automatically when a new upstream product becomes available and nominally within 4 days from acquisition. Annual and all-time summary products will be updated when a complete calendar year of new observations become available.

A beta product generated from provisional Landsat 8 dataset (2013-2018) has been released. Progression into an operational service requires operational Landsat Collection 2 input and validation in Africa to determine its accuracy. There's also ongoing research effort to use complementary Sentinel datasets that may improve its accuracy and spatial and temporal resolution.

Impact: WOfS allows users to understand the location and movement of water present in a landscape. Water information will be made available in near real time and can be used for environmental monitoring, flood mapping, monitoring planned water releases, and management of water resources in highly regulated systems. Summary products can be used to understand long term changes in the landscape and water availability and flooding risk in a historical context. Using Web Services, information derived using WOfS can be visualised to determine the impact of events like floods and droughts.

6.3.2 Potential Activity: Fractional Cover

Development Tier	ID	Potential Collaborators	Status
Tier 1	Fractional Cover	GEOGLAM; GFOI; GMES	Active: prototype based on provisional Landsat 8; under development for Landsat collection 2

Description: Fractional Cover (FC) is derived from Landsat or Sentinel-2 surface reflectance and describes the landscape in terms of coverage by green vegetation, dry vegetation and bare soil. FC service will be available for each individual satellite pass and can be aggregated at different time intervals. Individual date FC for Africa has been generated for Landsat 8 provisional data (2013 – 2018).

The current FC model is built using field data collected in Australia. DE Africa will work with collaborators in Australia and Africa to further develop and validate the model.

Impact: Generally, FC allows users to understand the large scale patterns and trends and inform evidence based decision making and policy on topics including wind and water erosion risk, soil carbon dynamics, land surface process monitoring, land management practices, vegetation studies, fuel load estimation, ecosystem modelling, and rangeland condition.

Using the FC Service on individual dates grants a higher level of granularity to FC data that can be used to determine discrete, relatively fast-changing environmental dynamics. This includes monitoring the effects of implementing policy on certain dates, or monitoring disaster management.

At monthly intervals, FC composites derived from Landsat and Sentinel-2 will have up to a 10 metre resolution. Such a service is anticipated to support tools such as the Rangeland and Pasture

Productivity tool (RAPP) developed by the GEO Global Agricultural Monitoring (GEOGLAM) and in collaboration with CSIRO, the New South Wales Office of Environment and Heritage, and the Australian Department of Agriculture.

Statistical summaries (e.g. percentiles) of FC can be generated for whole-of-archive, or on an annual or seasonal basis. These summaries are designed to make it easier to analyse and interpret FC. For example, the 90th percentile of bare soil for a particular year will identify areas that have experienced a high portion of bare soil during that year. An annual or seasonal FC product can be used to monitor long term landscape changes, such as deforestation and illegal mining.

6.3.3 Potential Activity: Barest Earth

Development Tier	ID	Potential Collaborators	Status
Tier 3	Barest Earth	<i>TBC</i>	Not active: Continental-scale workflow

Description: The Barest Earth service provides a mosaic that presents each pixel at its barest (i.e. least vegetated) recorded state. Areas on the continent are recorded without the effects of seasonal vegetation, cloud cover, and complexities caused by fires and agriculture. Barest Earth is in development for Digital Earth Australia, and may be developed for DE Africa.

Impact: By providing a view of the soil and rock cover, the Barest Earth service may assist mineral exploration, digital soil mapping, soil health assessments, land degradation monitoring, and environmental management.

6.3.4 Potential Activity: Illegal Mining Analysis

Development Tier	ID	Potential Collaborators	Status
Tier 3	Illegal Mining Analysis	<i>TBC</i>	Not active: Regional-scale demonstrator

Description: Illegal mining activities can be identified by performing change detection on optical surface reflectance and normalised radar backscatter data. Tools for detecting and monitoring such activities can also be built on other services that provide land cover information.

ARDC developed an Illegal Mining Analysis service through a Jupyter Notebook workflow. Whilst this workflow could be made available within the DE Africa Sandbox environment, this depends on the availability of SAR Datasets. Illegal Mining Analysis services therefore require collaboration before becoming a mature standalone service under DE Africa.

Impact: Monitoring illegal mining activity in Africa to develop targeted initiatives across government and industry that reduce illegal mining strengthens countries' economies. These initiatives can also contribute to ensuring national security by securing the commodities pipeline. Along with ensuring the sustainable resourcing of commodities for countries' development, reduced illegal mining assists to reduce human trafficking and slavery.

6.3.5 Potential Activity: Land Cover Classification System

Development Tier	ID	Potential Collaborators	Status
Tier 3	Land Cover Classification System	<i>TBC</i>	Not active: Regional-scale demonstrator

Description: A new national land cover service is currently being developed based on the UN Food and Agriculture Organization (FAO)'s Land Cover Classification System (LCCS) by Digital Earth Australia and international collaborators; LCCS may be applied to DE Africa. LCCS will primarily be based on Landsat data augmented with data from other satellites such as Sentinel-1 and Sentinel-2.

Impact: LCCS allows the observation of land cover dynamics (including changes to vegetation, soils, exposed rocks, water bodies, and anthropogenic features). These dynamics can be used to inform policy makers and industry seeking to understand changes to the environment.

6.3.6 Potential Activity: Snow Analysis Tools

Development Tier	ID	Potential Collaborators	Status
Tier 3	Snow Analysis Tools	Swiss Data Cube	Not active: Regional-scale demonstrator

Description: A Snow Detection method was developed and implemented in the Swiss Data Cube. It uses time-series Landsat surface reflectance data to map snow cover extent and evolution over time. The method can be adapted to work in DE Africa. See further:

<https://www.swissdatacube.org/index.php/tag/snow/>

Impact: Snow Analysis Tools monitor changes to snow extents that allow policymakers to determine the impacts of climate and environmental changes to snow-covered areas. In Africa, this includes areas of high elevation (for example, Mount Kilimanjaro in Tanzania) and mountains ranges (for example, the Atlas Mountains in Morocco).

6.3.7 Potential Activity: Water Quality

Development Tier	Status	Potential Collaborators	Status
Tier 3	Water Quality	<i>TBC</i>	Not active: Regional-scale demonstrator

Description: Select water quality indicators can be derived from satellite data based on optical properties of the water. These methods are currently under development for Digital Earth Australia and require an involved field validation campaign. Though Water Quality may be developed for DE Africa, the field validation component adds significantly to the logistical difficulty of developing this service.

Impact: Monitoring water quality has direct applications for the improved identification of water quality reporting directly referenced by the SDGs. For example, monitoring water quality using Earth observation enables improved identification of harmful algal blooms.

6.3.8 Potential Activity: Wetlands

Development Tier	ID	Potential Collaborators	Status
Tier 3	Wetlands	<i>TBC</i>	Not active: Continental-scale workflow

Description: This web service-based tool can provide vegetation and inundation information on wetlands through time. This product uses WOfS (for open water), Tasselled Cap indices (for wet vegetation) and FC (for vegetation) datasets. The Wetlands Insight tool is currently available for selected Ramsar wetlands in Australia, and may be developed for DE Africa.

Impact: By monitoring changes in the wetness and vegetation of identified wetlands across Africa, ecosystem health and the effectiveness of wetland management can be identified. Along from supporting biodiversity, wetlands assist to ensure the availability of clean water and sanitation for humans that contribute directly to monitoring the SDGs.

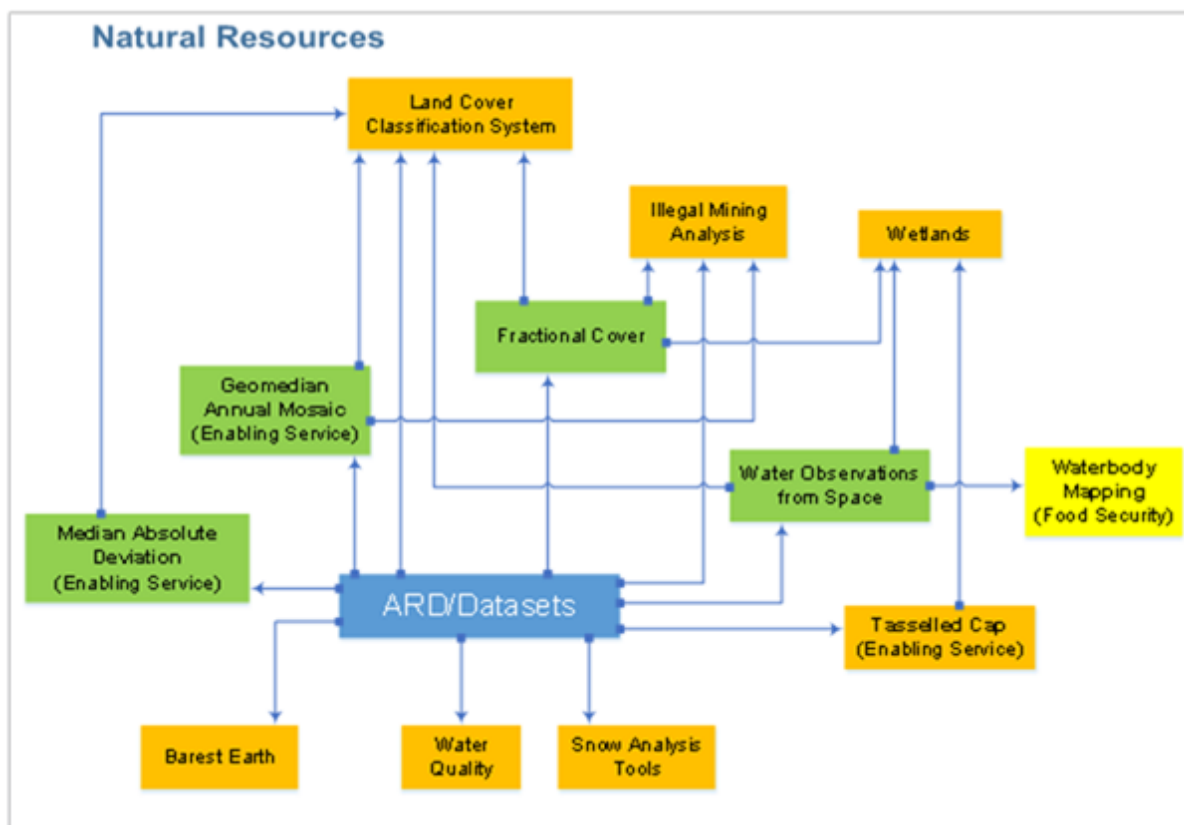
6.4 Food Security

Ensuring food security across the African continent is fundamental in supporting Africa's growing population. Through GEOGLAM, Earth observation has been successfully applied to strengthened agricultural decision-making by policy makers and businesses in Africa. DE Africa's services support and extend these initiatives to the full breadth of issues that may impact food security. The increased capacity for ensuring future food security enabled by Earth observation has far-reaching effects on Africa's population and the sustainable development of the African continent.

Services under 'Food Security' contribute to making progress on the African Union's Agenda 2063 Goal 5 (Modern agriculture for increased productivity and production). Relevant SDGs captured by the services under 'Food Security' include:

- ◆ 2: Zero hunger
- ◆ 3: Good health and well-being
- ◆ 6: Clean water and sanitation
- ◆ 9: Industry, innovation and infrastructure
- ◆ 12: Responsible consumption and production
- ◆ 15: Life on land

The dependency of services captured under the 'Food Security' Thematic Area on general Earth observation datasets, along with other services, is outlined below:



6.4.1 Current Activity: Crop Land Map

Development Tier	ID	Potential Collaborators	Status
Tier 1	Crop Land Map	GEOGLAM;RCMRD; AGRHYMET;AFRIGIST; OSS;GPSDD;ICPAC;	Active: beta for Eastern Africa and other regions under development

Description: A crop land map identifies areas that have been cropped in a given year. A consistent up-to-date crop land mask for the continent (at Landsat/Sentinel-2 spatial resolution) is noted as a gap in Agriculture monitoring tools operated by e.g. GEOGLAM crop monitor. Specifications of this product will be defined in consultation with collaborators.

As an annual product, this service will be updated when a complete calendar year of new observations become available.

Impact: A crop land map/mask is critical for crop monitoring and crop modelling. A continental-wide consistent product will support regional and local crop monitoring services and is expected to be used by ministries and state departments of Agriculture in the countries, international organizations, academia and private sector.

6.4.2 Current Activity: NDVI Anomalies

Development Tier	ID	Potential Collaborators	Status
Tier 1	NDVI Anomalies	GEOGLAM;RCMRD; AGRHYMET;AFRIGIST; OSS;GPSDD;ICPAC;	Active: concept design

Description: An NDVI anomaly is the difference between the average NDVI for a particular month of a given year and the average NDVI for the same month over a specified number of years. It is used to characterize vegetation status and is an indicator of vegetation health and drought. NDVI anomalies measured at 10 to 30 metre spatial resolution will enable monitoring of crop conditions at paddock scale.

As a monthly product will be updated when a complete month of new observations become available.

Impact: NDVI anomalies will support regional and local crop monitoring services.

6.4.3 Potential Activity: Waterbody Mapping

Development Tier	ID	Potential Collaborators	Status
Tier 2	Waterbody Mapping	<i>TBC</i>	Not active: Continental-scale workflow

Description: Waterbody Mapping is a web based mapping tool that maps permanent waterbodies based on WOfS summary data. The surface area of waterbodies, identified from WOfS, is monitored to identify changes to the waterbody extent. Waterbody Mapping may be developed for DE Africa.

Impact: Water availability is a critical factor that drives agricultural decision-making and financial outcomes for primary producers. This service has also been applied to assist with aerial firefighting support by identifying the nearest waterbody to a fire front in Australia. Through mapping the locations of permanent waterbodies, ongoing satellite imagery collection can provide a time history of the surface water extent within each waterbody, which is critical for adaptive decision-making about how to manage scarce water supplies.

6.4.4 Potential Activity: Desertification and Land Degradation

Development Tier	ID	Potential Collaborators	Status
Tier 3	Desertification and Land Degradation	OSS	Not active: Future collaboration opportunity

Description: Analysing the degradation of fertile land is of interest to Africa. Proper tools and methods are yet to be defined but may build on existing and developmental services such as FC, Agricultural Mapping and Woody Vegetation Cover.

Impact: Desertification and land degradation is a major issue for agriculture in Africa. Monitoring desertification of previously productive agricultural areas assists to develop programs and policy that ameliorate the effects of desertification and land degradation, and assist landowners and farmers to identify best-practice techniques that ensure a sustainable use of land.

6.4.5 Potential Activity: Agriculture Monitoring Tools

Development Tier	ID	Potential Collaborators	Status
Tier 3	Agriculture	GEOGLAM	Not active: Future collaboration opportunity

Description: Tools and methods built on waterbodies and agricultural data provides insight into the dynamics between water availability and productivity. Methods for this are not currently under development for Digital Earth Australia, though may be developed for DE Africa.

In developing Agricultural Tools, DE Africa may collaborate with GEOGLAM to ensure the utility and uptake of these services to existing African agricultural and food security initiatives.

Impact: Monitoring agriculture links social, environmental, and economic factors that underpin several SDGs. As a driver for quality of life from small communities through to entire countries' populations, monitoring water availability and productivity to measure agricultural production is an invaluable tool for policy makers and private industry in Africa.

6.4.6 Potential Activity: Aquaculture Tools

Development Tier	ID	Potential Collaborators	Status
Tier 3	Aquaculture	<i>TBC</i>	Not active: Future collaboration opportunity

Description: Earth observation tools and methods exist for the analysis for aquaculture production. Methods for this are not currently under development for Digital Earth Australia, though may be developed for DE Africa.

Impact: Numerous communities in Africa rely on aquatic ecosystems, which underpin community health and growth. Monitoring aquaculture references several SDGs, and provides a valuable tool for policy makers and private industry targeting areas reliant on aquaculture in Africa.

6.4.7 Potential Activity: Irrigated Extent for Crops

Development Tier	ID	Potential Collaborators	Status
Tier 3	Irrigated Extent for Crops	<i>TBC</i>	Not active: Continental-scale workflow

Description: This tool maps irrigated cropping areas. Various methods are currently under development for Digital Earth Australia, and may be adapted for DE Africa. At the moment, this mapping has only been done in semi-arid to arid conditions, and may have limited applicability across the African continent.

Impact: Understanding irrigator responses to changes in water availability and irrigator responses to seasonal changes is also critical for building strategies to support effective management of water and land resources.

6.5 Urban Sustainability

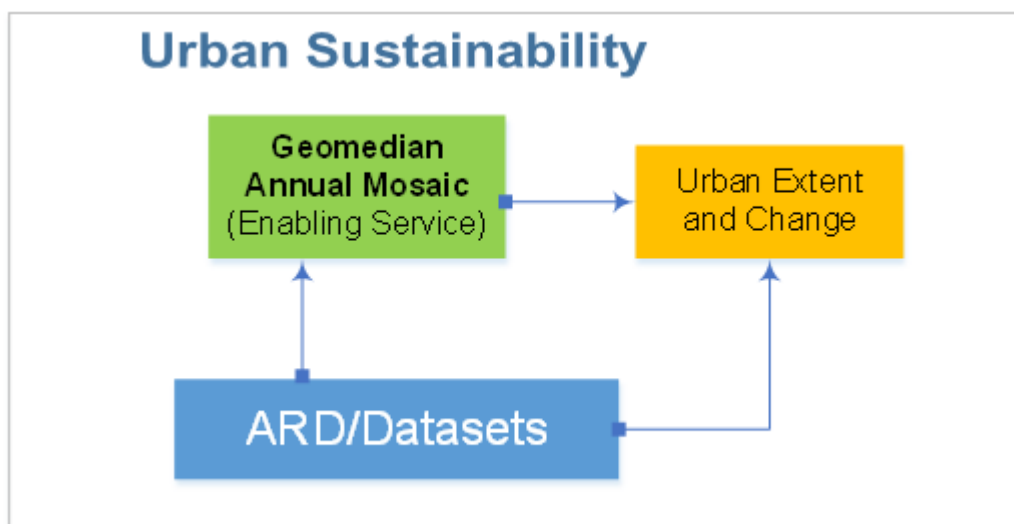
Current rates of expansion of human infrastructure and urban growth are unprecedented in human history. Across Africa, the scale and rate of this urban growth has meant that governments have struggled to effectively govern or monitor human activities. Additionally, in emerging economies, the urban population is expected to double between 2000 and 2030 and adding two billion more people to the global population (GEO, 2017). In Africa, this presents an immense challenge for governments to provide the governance and natural resources that can support this population and increased human activity. GEO has shown Earth observation to be an effective tool in providing information that can assist African governments to manage and support rapid urban expansion.

DE Africa's services work to establish Earth observation as a powerful tool to provide information on urban settlements on a continental scale. DE Africa's services can provide information on urban growth and development, and also provide information that can lead to the effective governance of the relationship between humans and land consumption.

Services under the 'Urban Sustainability' Thematic Area contribute to making progress on the African Union's Agenda 2063 Goal 1 (A high standard of living, quality of life, and wellbeing for all citizens). Relevant SDGs captured by the services under 'Urban Sustainability' Thematic Area include:

- ◆ 1: No poverty
- ◆ 3: Good health and well-being
- ◆ 11: Sustainable cities and communities
- ◆ 12: Responsible consumption and production
- ◆ 15: Life on land
- ◆ 17: Partnerships for the goals

The dependency of services captured under the 'Urban Sustainability' Thematic Area on general Earth observation datasets, along with other services, is outlined below:



6.5.1 Potential Activity: Urban Extent and Change

Development Tier	ID	Potential Collaborators	Status
Tier 3	Urban Extent and Change	<i>TBC</i>	Not active: Continental-scale workflow

Description: A service may be developed to map the expansion of urban area over time. Case studies have been conducted under the ARDC, and a method is being developed for Digital Earth Australia; this service may be adapted for DE Africa.

Impact: Unregulated urban growth hampers the development of smart, safe and sustainable cities in Africa. The Urban Extent and Change Tool enables an oversight of urban activity that can inform future urban planning to ensure the growth of sustainable cities and communities.

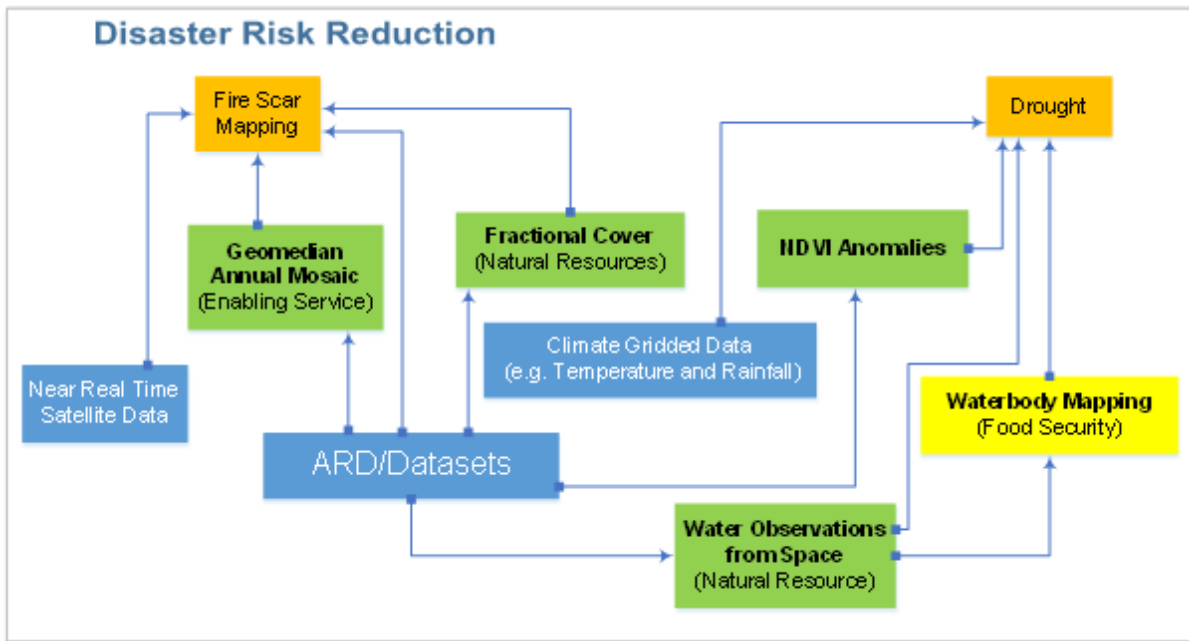
6.6 Disaster Risk Reduction

Countries across Africa span numerous different environments that each is impacted by a unique set of natural disasters. Populations and infrastructure are often exposed to the surrounding environment, making them particularly vulnerable to sudden changes in environmental conditions that cause disasters. Earth observation has proven effective in increasing the capacity of governments and communities to strengthen disaster risk reduction.

Services under the ‘Disaster Risk Reduction’ Thematic Area contribute to making progress on the African Union’s Agenda 2063 Goal 7 (Environmentally sustainable and climate resilient economies and communities). DE Africa’s services also contribute to global sustainable development frameworks for disaster risk reduction, including the UN’s Sendai Framework for Disaster Risk Reduction. Relevant SDGs captured by the services under the ‘Disaster Risk Reduction’ Thematic Area are include.

- ◆ 3: Good health and well-being
- ◆ 11: Sustainable cities and communities

The dependency of services captured under the ‘Disaster Risk Reduction’ Thematic Area on general Earth observation datasets, along with other services, is outlined below:



6.6.1 Potential Activity: Drought

Development Tier	ID	Potential Collaborators	Status
Tier 3	Drought	<i>TBC</i>	Not active: Regional-scale demonstrator

Description: Drought information calculated or modelled based on in-situ country measurements or weather satellites may be used with satellite data to provide estimations of the spatial and temporal distribution of drought intensity. The Standardised Precipitation-Evapotranspiration Index (SPEI) metric was implemented as a pilot project within Cambodia in an ODC environment. Such a service may be developed for DE Africa.

Impact: Drought is a major issue for numerous countries and communities across Africa. Earth observation information has already been proven through existing GEO initiatives to be a successful method that can prepare communities for preparing for and ameliorating the far-reaching social, economic, and environmental effects of drought.

6.6.2 Potential Activity: Fire Scar Mapping

Development Tier	Status	Potential Collaborators	Status
Tier 3	Fire Scar Mapping	<i>TBC</i>	Not active: Future collaboration opportunity

Description: Fire scar and burn severity can be mapped from time-series multispectral analysis. An automated change detection algorithm is being implemented in Digital Earth Australia to map annual burnt extents with Landsat, and may be developed for DE Africa. The method is specifically developed to improve mapping in the forested environments in southern Australia, and is applicable to certain environments in Africa.

Impact: Aside from understanding the impact of fires on the African landscape, fire scar mapping assists with identifying areas that are at risk of being affected by future fires and can contribute to disaster management planning.

6.7 Marine and Coastal Environments

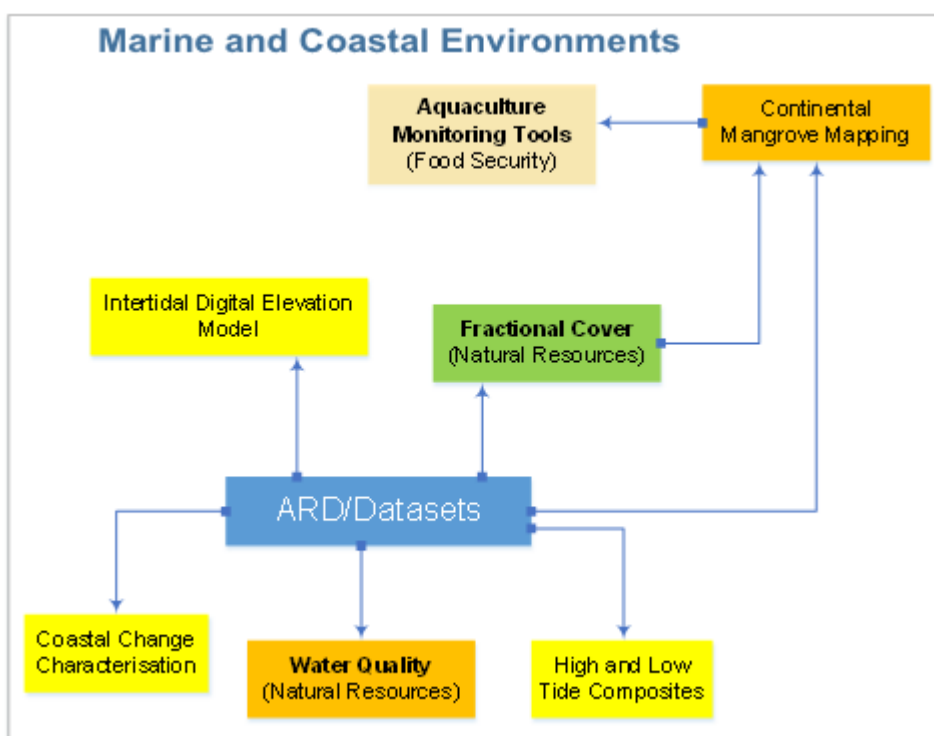
Marine and coastal environments support some of the most biodiverse regions in the world. Marine ecosystems provide breeding and nursery areas of a significant number of species that also contribute to the African economy through rich fishing areas. Additionally, marine and coastal ecosystems play an important role in securing freshwater sources for populations across Africa that otherwise often have limited access to reliable freshwater. Finally, marine and coastal environments provide an additional element of protection against natural disasters for vulnerable populations. Targeting Earth observation on marine and coastal environments through DE Africa therefore contributes to improved decision-making by policy makers and businesses that has implications on ecosystem and population health.

Services under the 'Marine and Coastal Environments' Thematic Area contribute to making progress on the African Union's Agenda 2063 Goal 6 (Blue/ocean economy for accelerated economic growth), along with Goal 7 (Environmentally sustainable and climate resilient economies and communities). Relevant SDGs captured by the services include:

- ◆ 6: Clean water and sanitation
- ◆ 13: Climate action
- ◆ 14: Life below water
- ◆ 15: Life on land

Under this Thematic Area, DE Africa may undertake collaborative activity with the National Oceanic and Atmospheric Administration (NOAA) to generate tools relating to marine and coastal environments, including surface water mapping, natural resources, and disaster management.

The dependency of services captured under the 'Marine and Coastal Environments' Thematic Area on general Earth observation datasets, along with other services, is outlined below:



6.7.1 Potential Activity: High and Low Tide Composites

Development Tier	ID	Potential Collaborators	Status
Tier 2	High and Low Tide Composites	NOAA <i>et al.</i> (<i>TBC</i>)	Not active: Continental-scale workflow

Description: The High and Low Tide Composites service allows user to analyse inter-tidal zones, which are difficult regions to characterise due to the dynamic nature of the tide. High and Low Tide Composites uses two surface reflectance composite mosaics. The two mosaics allow cloud free and noise reduced visualisation of shallow water and intertidal coastal regions, as observed at high and low tide respectively. This is a nationally available service for Digital Earth Australia, and may be developed for DE Africa.

Impact: Intertidal zones form critical habitats for a wide range of organisms from birds to fish and sea grass. Identifying the coastline at high and low tide can also be used to characterise coastal changes that can be used to mitigate the impacts of erosion for coastal communities. Monitoring tidal maxima can also identify at-risk communities for natural disasters.



6.7.2 Potential Activity: Intertidal Digital Elevation Model

Development Tier	ID	Potential Collaborators	Status
Tier 2	Intertidal Digital Elevation Model	NOAA <i>et al.</i> (<i>TBC</i>)	Not active: Continental-scale workflow

Description: The Intertidal Digital Elevation Model is a dataset, using thousands of satellite images of the coastline taken at different height conditions, that maps the three-dimensional structure of the intertidal zone. The height conditions are described by mapping the location of the land-sea boundary (the waterline) across a range of known tides (for example, low and high tides). A continental-scale workflow has been developed to produce the National Intertidal Digital Elevation Model (NIDEM) for Digital Earth Australia, and may be adapted for DE Africa.

Impact: Monitoring changes to the three-dimensional structure of the intertidal zone can be used to monitor the impacts of anthropogenic aquatic activity on ecosystems. Three-dimensional information can also inform accessibility to inland areas for coastal communities. Intertidal zones are faced with increasing threats from coastal erosion, land reclamation (for example, port construction), and sea level rise. Accurate elevation data describing the height and shape of the coastline can help predict when and where these threats will have the greatest impact.

6.7.3 Potential Activity: Coastal Change Characterisation

Development Tier	ID	Potential Collaborators	Status
Tier 2	Coastal Change Characterisation	NOAA <i>et al.</i> (<i>TBC</i>)	Not active: Regional-scale demonstrator

Description: The Coastal Change Characterisation service builds on the tidally tagged composites used to generate the Intertidal Digital Elevation Model service. Areas of change can be analysed in the context of the coastal compartments and ‘smartline’ coastal geomorphological classifications. This service may be developed for DE Africa.

Impact: The Coastal Change Characterisation service can be used to help identify coastline types where Earth observation techniques can be used to understand coastal stability and coastal erosion risk, and demonstrate how Earth observation techniques can provide insight into rates of coastal erosion for some coastline types. Characterising coastal change and measuring impacts of coastal erosion at a continental scale helps inform policies on mitigating the impacts of erosion.

6.7.4 Potential Activity: Continental Mangrove Mapping

Development Tier	ID	Potential Collaborators	Status
Tier 3	Continental Mangrove Mapping	NOAA <i>et al.</i> (<i>TBC</i>)	Not active: Continental-scale workflow

Description: This project may be developed under DE Africa to create a map showing continental-scale mangrove extent, density, and change using dense time-series of data. The mangrove canopy is classed into certain percentiles using the Fractional Cover service.

Impact: Mangroves are integral for supporting biodiverse coastal ecosystems; measuring the human and natural impacts on mangrove health over time can assist in informing policies for conservation, and can be used to help understand how mangroves respond to disturbance events such as severe tropical cyclones. Mangrove Monitoring can also assist to supporting aquaculture and population health, since mangroves ecosystems often underpin the health of coastal communities and the aquaculture supply chain.

Appendix A Services

B.1 Service Dependency Matrices

Based on the dependency maps developed for this Technical Roadmap (see generally Section 6), the dependencies between services and datasets were calculated as follows:

- If the service or dataset enables another product (i.e. arrow goes away from the service or dataset), the service or dataset was assigned a value of +1.
- If a service or dataset is dependent on another product (i.e. arrow goes towards this service or dataset), the service or dataset was assigned a value of -1.

The net dependencies were calculated, summarised below in Table 3. **The higher the ‘Dependence’ sum, the more the product enables other services. The lower the sum, the more dependent the product on others for its development.** Table 3 also considers the datasets and/or services already been progressed under DE Africa.

Table 3 Dependencies for Active/Not active Datasets or Services.

Activity	Dependence	Product	Thematic Area
Active	21	ARD/Datasets (General)	Foundational Data
Active	7	Fractional Cover	Natural Resources
Active	5	Water Observations from Space	Natural Resources
Active	4	Geomedian Annual Image	Enabling Service
Not Active	3	Waterbody Mapping	Food Security
Not Active	2	Climate Gridded Data	Foundational Data
Not Active	1	Near Real Time Satellite Data	Foundational Data
Active	1	Median Absolute Deviation	Enabling Service
Not Active	1	Tasselled Cap	Enabling Service
Not Active	1	Water Quality	Natural Resources
Active	1	NDVI Anomalies	Food Security
Active	0	Crop Land Map	Food Security
Not Active	0	Barest Earth	Natural Resources
Not Active	0	Snow Analysis Tools	Natural Resources
Not Active	0	Irrigated Extent for Crops	Food Security
Not Active	0	Coastal Change Characterisation	Marine and Coastal Environments
Not Active	0	Continental Mangrove Mapping	Marine and Coastal Environments

Not Active	0	High and Low Tide Composites	Marine and Coastal Environments
Not Active	0	Intertidal Digital Elevation Model	Marine and Coastal Environments
Not Active	-1	Desertification and Land Degradation	Food Security
Not Active	-1	Urban Extent and Change	Urban Sustainability
Not Active	-2	Illegal Mining Analysis	Natural Resources
Not Active	-2	Wetlands	Natural Resources
Not Active	-3	Drought	Disaster Risk Reduction
Not Active	-3	Land Cover Classification System	Natural Resources
Not Active	-3	Agriculture Tools	Food Security
Not Active	-3	Aquaculture Tools	Food Security
Not Active	-3	Fire Scar Mapping	Disaster Risk Reduction



B.1 Changelog

Revision Date	Change Location	Change Description
September 2019	All	Version 0.1: Initial Draft version of document (Tom Butler)
October 2019	All	Version 0.2: Restructured document (Erin Telfer)
October 2019	All	Version 0.3: First attempt at populating text (Matthew Teh and Erin Telfer)
January 2020	All	Version 0.4: Restructuring and populating document for initial review (Matthew Teh, Fang Yuan and Chad Burton)
February 2020	All	Version 0.5: Draft for review of the Technical Advisory Committee (Fang Yuan)
February 2020	All	Version 0.6: Streamlining of content / messaging (Adam Lewis)
April 2020	All	Version 0.7: Changes based on TAC feedback, including: <ol style="list-style-type: none"> 1 Updated Executive Summary and Current Status and Recommendations sections to reflect endorsed current activities. 2 For all active input datasets and services, added expected update frequency. 3 Changed Gridded Climate Data and MODIS to be Tier 2 input datasets. 4 Updated text around supporting spatial data standards and added details of supported STAC and OGC versions in relevant sections. 5 Added Africa GeoPortal as an active Platform component. 6 Updated thematic areas to be “Disaster Risk Reduction” and “Urban Sustainability” instead of “Disaster Management” and “Human Infrastructure”. 7 Added Crop Land Map and NDVI Anomalies as active (tier 1) and potential (tier 3) services. Updated related tables and figures.
April 2020	Version number	Version 1.0 for public distribution
August 2021	All	Version 1.1: Changes based on June 2021 TAC endorsed work plan, including: <ol style="list-style-type: none"> 1 Updated Executive Summary 2 Updated chapter 3 to “Current Status and Future Development” based on endorsed work plan 3 Updated chapter 4, 5, 6 and Appendix A to reflect current status of datasets, platform components and services.
September 2021	All	Version 1.2: Added power user trial in chapter 3; fixed a few typos.

Glossary

Term	Definition
ACIAR	Australian Centre for International Agricultural Research
ALOS	Advanced Land Observing Satellite
AMA	Analytical Mechanics Associates (United States)
APIs	Application Program Interfaces
ARD	Analysis Ready Data
ARDC	African Regional Data Cube
AWS	Amazon Web Services: Cloud computing infrastructure provided by Amazon (United States).
AW3D30	The ALOS World 3D – 30 metre product, developed by JAXA
CARD4L	CEOS Analysis Ready Data for Land
CEOS	Committee on Earth Observations Satellites
COG	Cloud Optimised GeoTIFF: Data file format.
CSIR	Council for Scientific and Industrial Research (South Africa)
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DE Africa	Digital Earth Africa
ECMWF	European Centre for Medium-Range Weather Forecasts
EO	Earth observation
ERA5	ECMWF Reanalysis 5 th Generation dataset
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAO	Food and Agriculture Organization of the United Nations
FC	Fractional Cover
GEO	Group on Earth Observations
GEOGLAM	Group on Earth Observations Global Agricultural Monitoring Initiative
GFOI	Group on Earth Observation's Global Forest Operations Initiative
GIS	Geospatial Information System
GMES	Global Monitoring for Environment and Security
GPSDD	Global Partnership for Sustainable Development Data
JAXA	Japan Aerospace Exploration Agency
JER	Japanese Earth Resources satellite
LCCS	Land Cover Classification System
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration (United States)
NCI	National Computational Infrastructure (Australia)
NDVI	Normalised difference vegetation index
NIDEM	National Intertidal Digital Elevation Model Product
NOAA	National Oceanic and Atmospheric Administration (United States)
ODC	Open Data Cube
OGC	Open Geospatial Consortium
OLCI	Ocean and Land Colour Instrument
OSCAR	Observing Systems Capability Analysis and Review Tool

PALSAR	Phased Array-type L-band Synthetic Aperture Radar, an instrument operational on JAXA's ALOS.
RAPP	Rangeland and Pasture Productivity tool. Developed by GEOGLAM in collaboration with CSIRO, the New South Wales Office of Environment and Heritage, and the Australian Department of Agriculture
S3	Simple Storage Service: Cloud object store used in AWS.
SAR	Synthetic Aperture Radar
SCG	Stakeholder Community Group
SDGs	Sustainable Development Goals
SLSTR	Sea and Land Surface Temperature Radiometer
SPEI	Standardised Precipitation-Evapotranspiration Index
SRTM	NASA's Shuttle Radar Topography Mission
STAC	SpatioTemporal Asset Catalogue
The Committee	DE Africa's Technical Advisory Committee
UNECA	United Nations Economic Commission for Africa
USGS	United States Geological Survey
WCS	Web Coverage Service
WEF	World Economic Forum
WMS	Web Map Service
WMTS	Web Map Tile Service
WOfS	Water Observations from Space
WPS	Web Processing Service