Panaglobo Consulting
on behalf of
Digital Earth Africa

Analysis ready data

A smart way to use Earth observation for Africa’s rising nations

INSIGHT REPORT

MAY 2022

Content

Cover image, Lake Chad. This Landsat This Landsat-8 image from 4 July 2014 shows Lake Chad in West Africa's Sahel region – a transition zone between the Sahara Desert to the north and savannahs and woodlands to the south.

This report was developed by Panaglobo Consulting on behalf of Digital Earth Africa

Executive summary

Earth observation gives us new perspectives which we can translate into knowledge and wisdom for the good of humanity and the planet

Namib Desert. The Copernicus Sentinel-2 mission takes us over part of the Namib Desert in western Namibia. At 55 million years old, Namib is considered the oldest desert on Earth.

The number of satellites surrounding the planet is constantly increasing, and so is the immensity of available data. Is everyone able to profit equally from this progress? Are the wealthier nations ensuring that technologically less advanced countries have a share in what we call big data? This study shines a spotlight on the potential of Earth observation data that is ready for use to serve the common good - and in this case specifically by Africa's rising nations. The system in focus will allow those who are willing to use it to gain increased insight into the magic of space data analysis to address the fundamental challenges we face as humanity and as a planet.

Fundamental needs such as food and clean air and water have not been met in many parts of the world and now climate change is bringing new challenges to the forefront and increasingly threatening fragile environments. Appropriate countermeasures are necessary.
Earth observation (EO) can be one of the most valuable assets to tackle these challenges, often felt most acutely by the vulnerable and most precious life forms and environments. Satellite images can tell stories and monitoring time sequences show changes in realities on earth and water. The resulting insights can be the key to finding new solutions to build a more resilient environment, adapting to change and living in a safer world.

- ❖ With food security as one of the most urgent issues, **agricultural** development and technological progress in this area can potentially profit from DE Africa's infrastructure by $2.6 billion. Efficient use of scarce water resources and the adoption of precision farming methods can increase yield and build resilience in times of climate change.

- ❖ Using Africa's vast **forests** for carbon sequestration is another source of benefit (up to $2 billion). We also take a look at the impact on the environment of forest fires and the potential optimisation of the timber market.

Digital Earth (DE) Africa presents itself as a non-Commercial, innovative EO data infrastructure to enhance Africa's socioeconomic development.
It allows for undiscriminated use of free satellite data and its analysis in the form of pre-processed information, called analysis ready data (ARD). The associated technological progress will allow for more informed strategic decision making by authorities, commercial entities and individuals.

This study addresses four key sectors mentioned in the African Union's development goals.
It attempts to quantify the impact that ARD could have on the continent by shining a light on four key socioeconomic sectors

- ❖ **Mining** is an important branch of industry in Africa where we see $680 million potential benefit from DE Africa's technology. Additional benefits like health, work conditions and fair regulations are not quantified but are not less important.

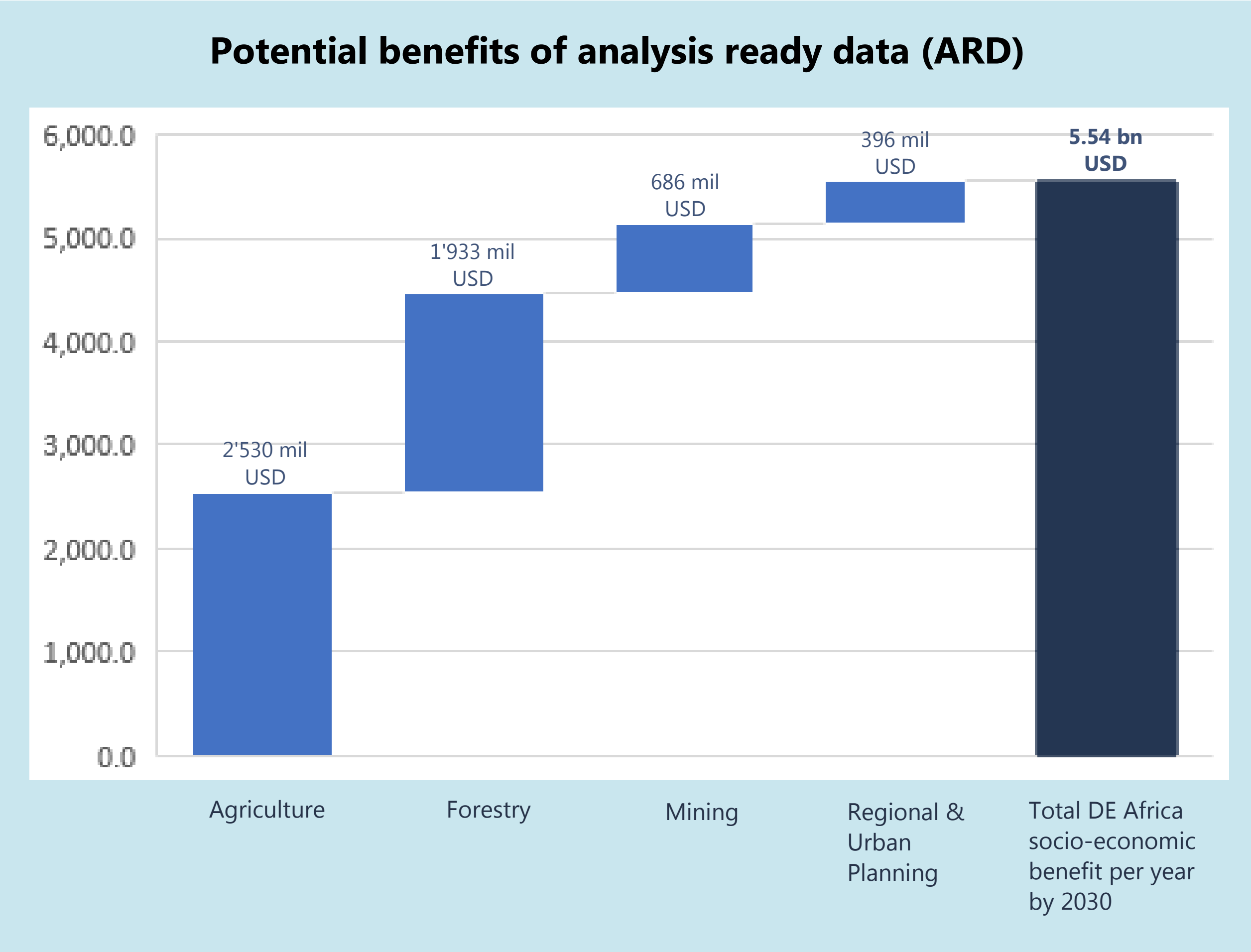
- ❖ Improvements in **land registration** and **urban planning** can profit greatly from EO. Africa's cities are growing faster than cities anywhere else in the world and controlled urbanisation is essential to guarantee safety for the population and the environment.

Agriculture

Forestry

Mining

Regional & Urban Planning



Source: Team Analysis

Introduction

How analysis ready data opens new doors for Africa's Earth observation community

The Okavango River. An area covering northern Namibia and southern Angola is pictured in this Kompsat-2 image. Running across the image, the Okavango River forms the border between Namibia to the south and Angola to the north. Circular agricultural plots up to about 600 m in diameter.

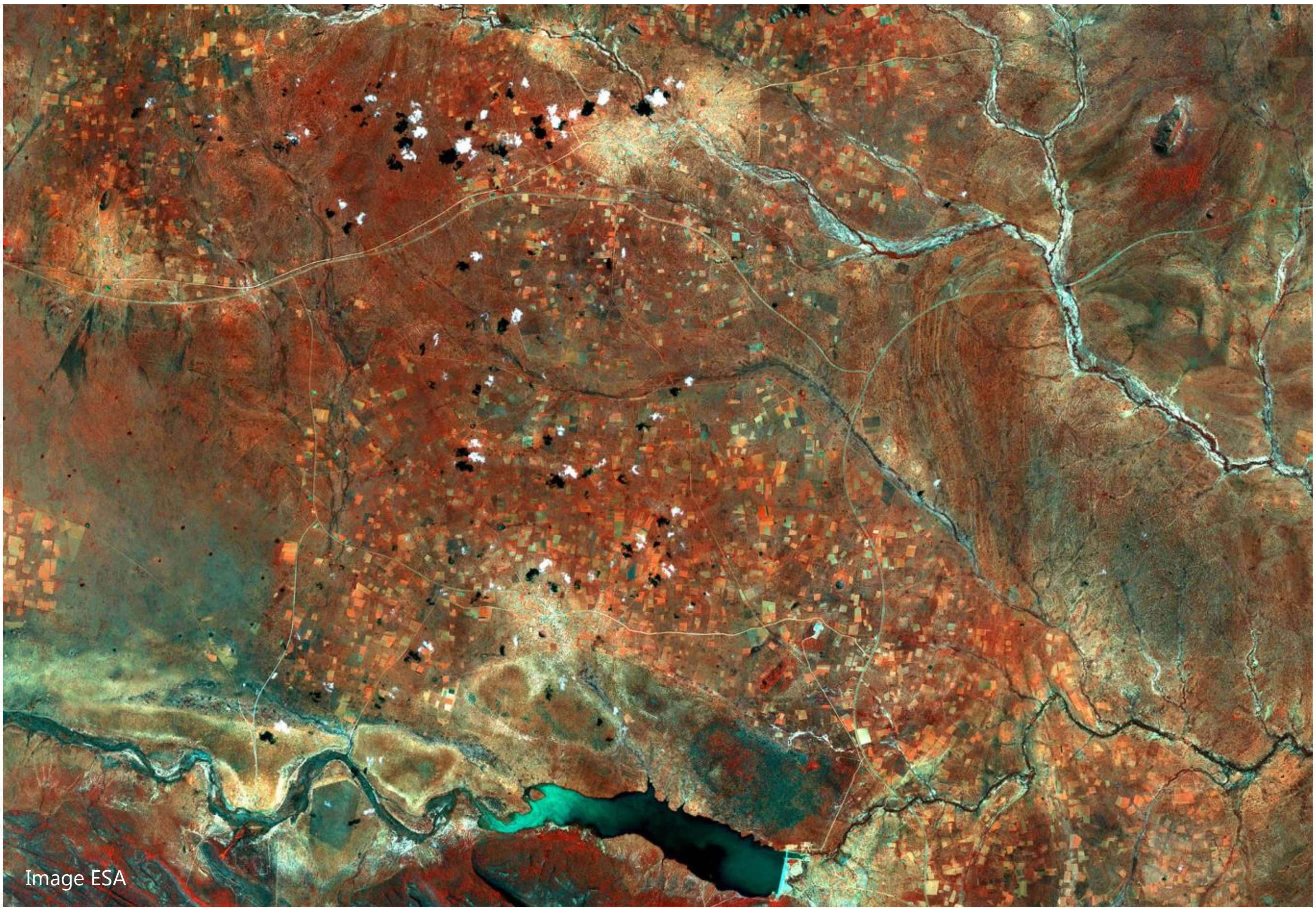
Views from space have led to countless advances in understanding Earth and the systems that affect our daily life. Modern Earth observation satellite missions provide innovative opportunities to address our information needs by delivering dedicated insights into the status and dynamics of the land and water surface – from global to local scale, from remote rural settings to urban areas, and from today back to the past and into the future.

Despite the increasing accessibility of satellite data, translating it into usable information still requires substantial skills and resources. Before data is ready for analysis, satellite images must be ortho-rectified and cleaned from atmospheric attenuation and radiation irregularities. Analysis ready data (ARD) offers an efficient and time-saving approach to unlock the immense amount of information contained in such data collections. The idea of pre-processed, standardised stacks of imagery, together with adequate analytical tools and algorithms that allow access even to novice users is considered as a game-changer in Earth observation technology.

The mission of DE Africa is to help Africa tackle some of its most urgent challenges, such as food security, water supply and climate change. Analysis ready data can play a major part in providing African-based solutions to these challenges. DE Africa's platform allows for scalable handling of continental multi-sensor datasets. These can be used directly for monitoring patterns both in space and time.

By providing 100 per cent free, open and ready-to-use products, DE Africa offers the tools for solutions increasingly needed by decision makers - from the individual farmer to the regional planner to national policy makers. The ease of access to this infrastructure opens the territory to a non-expert community. That in turn serves the growing demand for global transparency by governments, international and non-government organisations, businesses, news media, and individuals.

This data infrastructure approach offers full access to multiple sensor data collections in combination with cloud processing, analytics and visualisation capabilities to address specific topics anywhere in Africa. DE Africa, which uses the Open Data Cube (ODC), is especially designed for extensive time scans and in-depth investigations of today's demanding challenges in sustainable resource management.



Central District, Botswana, showing the Lotsane River. Sentinel-2A false-colour image 22 March 2016.

Digital Earth Africa

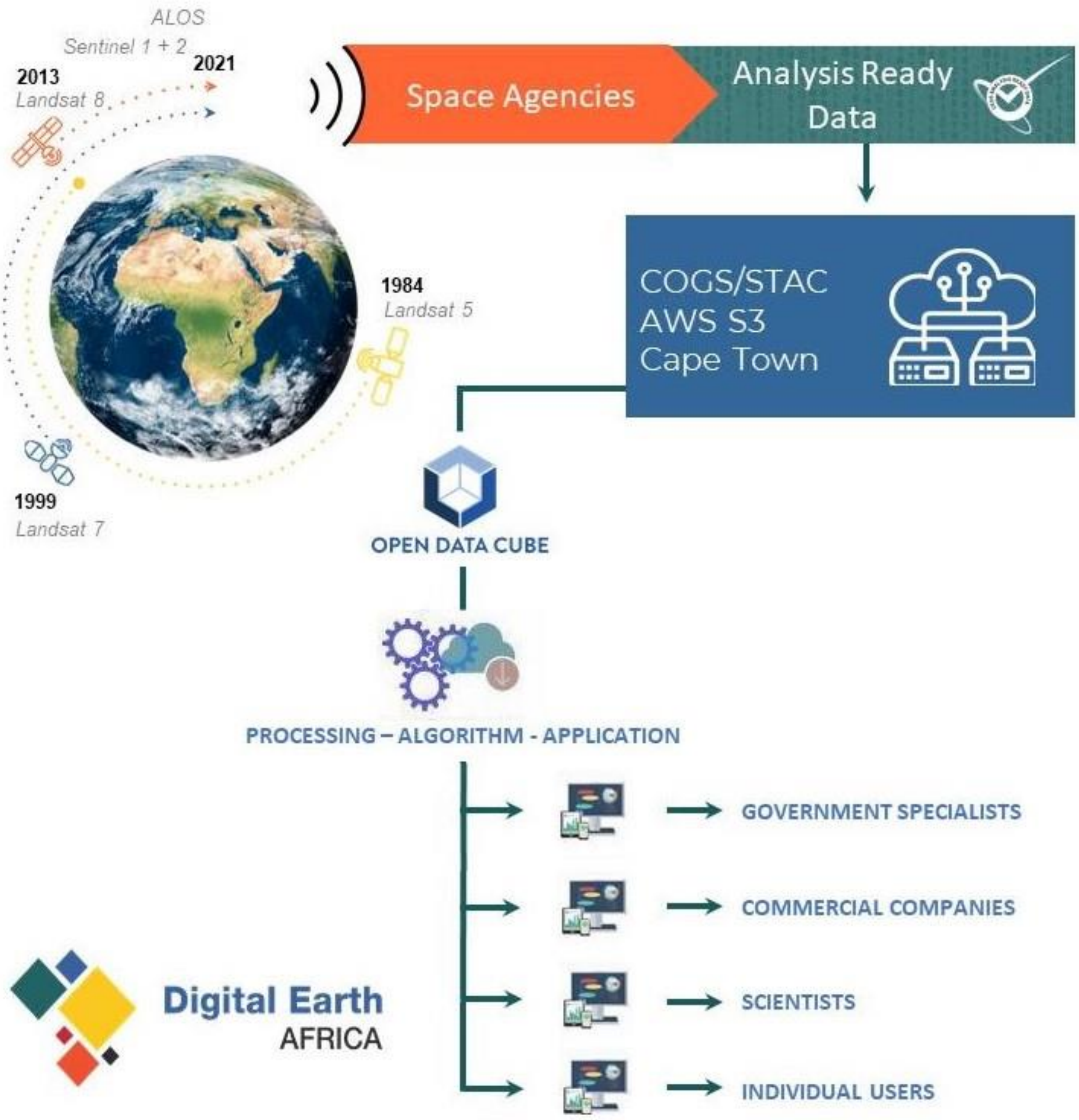


Figure 1: Architecture of Digital Earth Africa (Source: Digital Earth Africa)

The DE Africa platform acts as a business enabler and encourages start-up companies and small to medium-sized enterprises in Africa to use remote sensing for their services without having to invest in large capital or technical expertise in cloud computing. It provides opportunities for economic growth, wellbeing, and the achievement of a sustainable future.

The platform and technical road map are governed and directed by the African community and through the Group on Earth observations (AfriGEO). Established work groups and task teams drive the development in accordance with Africa's current and future needs.

Earth observation potential for Africa

A freely accessible satellite data archive for Africa - supporting its development goals

The successful realisation of the African Union's Agenda 2063 will be key to the continent's economic development, social prosperity, political stability, environmental protection, and regional integration in future. Agenda 2063 encapsulates not only Africa's aspirations for the future but also identifies five priority areas, referred to as the High 5s: 1) Light up & power Africa, 2) Feed Africa, 3) Industrialize Africa, 4) Integrate Africa, 5) Improve the quality of life for the people of Africa. These 5 critical priorities in Agenda 2063 are central to the Ten Year Implementation Plan as well as intrinsically linked to the UN Sustainable Development Goals (SDG) to mitigate and adapt to the changing climate, and build capacity in Africa for a resilient continent.

Earth observation (EO) products and services are best suited to measure and monitor indicators on sustainable development in Africa in relation to the SDGs and Agenda 2063 as shown in Figure 2.

AU Agenda 2063 targets and indicators that can be supported by EO

Target Not necessarily the indicator	Agenda 2063	Goals African Union Development Agency Agenda 2063 / The Africa we want	Areas supported by EO
• Poverty, inequality and hunger • Modern and livable habitats and basic quality services		1. A high standard of living, quality of life and well being for all	1. Agricultural monitoring 2. Cities & infrastructure mapping 3. Population distribution
		2. Well educated citizens and skills revolution underpinned by science, technology and innovation	
		3. Healthy and well-nourished citizens	
		4. Transformed economies and job creation	
• Agricultural productivity and production		5. Modern agriculture for increased productivity and production	1. Agricultural monitoring 2. Infrastructure monitoring
• Marine resources and energy • Ports operations and marine transport		6. Blue/ocean economy for accelerated economic growth	1. Oceanic observation
• Climate resilience and natural disasters preparedness and prevention • Renewable energy • Water security • Sustainable consumption and production patterns • Sustainable natural resource management and Biodiversity conservation		7. Environmentally sustainable and climate resilient economies and communities	1. Land cover & use mapping 2. Biodiversity & ecosystem observation 3. Hydrological & air quality monitoring 4. Hazards, disaster & environmental impact monitoring 5. Atmospheric and weather pattern monitoring

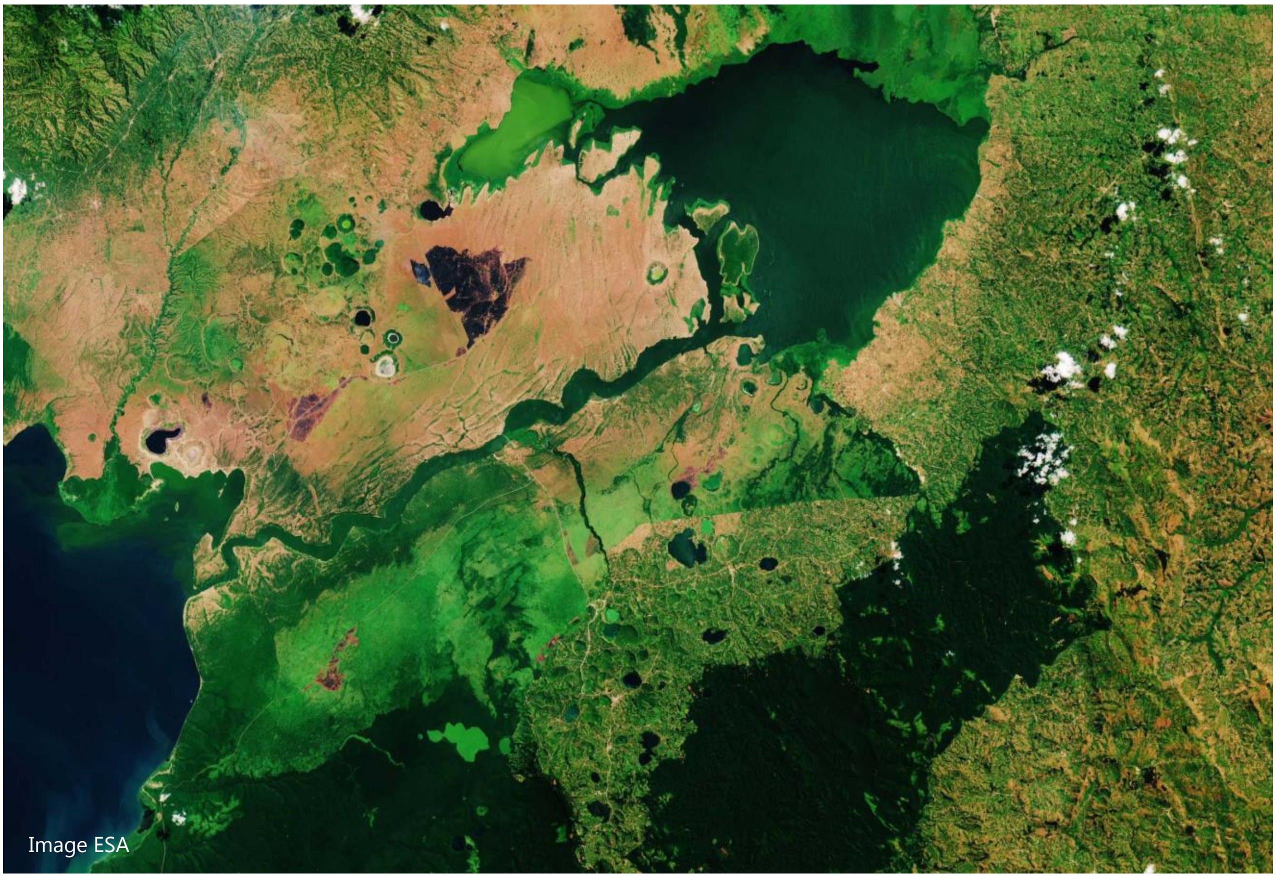
Figure 2: African Union 2036 targets and indicators that can be supported by EO [1]

Africa’s development challenges met by Earth observation and big data

Accurate, consistent and unbiased data will help address Africa’s development challenges. Experts in food security, environmental and development planning and forest management have pledged to unlock the power of Earth observation (EO) to support the implementation of African policies such as Agenda 2063 and the African Space Policy and Strategy.[2]

The need to make best use of space assets for monitoring and implementing national-to-continental sustainable development policies in Africa is ubiquitous. Earth observation satellites have the capability to frequently collect data about the Earth’s natural resources, the climate and human impact on them. They cover large areas in sufficient detail and can overcome the limitations of cumbersome traditional surveys. The uptake and integration of data analytics practices and analysis ready EO data into evidence-based decision making is the next step. From this perspective, DE Africa, with its continent-wide data infrastructure, is a valuable asset that Africa can rely upon.

Many countries already follow the analysis ready data (ARD) concept and, using the Open Data Cube (ODC), have started to integrate this leading-edge technology into their national policy and information systems. These include Australia, Mexico, Brazil, Switzerland and Vietnam, among others. Digital Earth Africa currently has active use cases in various countries in Africa and is working closely with organisations across Senegal, Ghana, Tunisia, Niger, Nigeria, Kenya and Tanzania to name a few. It is continuously developing in scale, sustainability, and functionality to support all African countries through a fully operational continent-wide EO service.



Lake George, Uganda. This Copernicus Sentinel-2 image takes us over Lake George, in western Uganda. In 1988, Lake George was designated as Uganda's first Ramsar site, given its importance as a centre for biological diversity.

The Open Data Cube (ODC) concept

The Open Data Cube (ODC) is a core technology to apply analysis ready data (ARD) and is embedded in DE Africa. The ODC is the engine for accessing, managing, and analysing large quantities of analysis ready EO data. It provides the technical foundation for several international, regional, and national scale data architecture solutions - DE Africa being the largest of them.

The ODC's goal is to foster the community to develop, sustain, and grow the breadth and depth of applications in support of global priority agendas, such as those found in the United Nations Sustainable Development Goals (SDG) and the Paris and Sendai Agreements. The ODC has an active global user community focusing on expanding and further developing these data, products and services to increase the value and impact of global satellite data. The community is seeking to provide reliable, ongoing access across all of Africa, allowing users to use and contribute to Jupyter Notebooks, share algorithms, and provide mutual support in resolving issues.

A network of partner organisations is already established to ensure smooth uptake, and capacity development at the country level.

Analysis ready data (ARD) within DE Africa is easily available on the cloud and users can simply add and index their own processed data.

Importantly, ARD simplifies all use of EO data, regardless of specific platforms such as the ODC and DE Africa.

Strong and reliable Earth observation access for a rising Africa

Africa is the world's second largest and second-most populous continent after Asia. At about 30.3 million km^2 including adjacent islands, it covers 6 per cent of Earth's total surface area and 20 per cent of its land area. With 1.3 billion people as of 2018, Africa also accounts for the planet's fastest growing population. Amid unforeseen challenges like COVID-19, the schedule for reaching the continent's development goals is at risk. At this point it is even more critical to support Africa on its path to climate change resilience, food security and sustainable management of natural resources with the world's largest ODC. Increased access to information about land and water is indispensable for decision makers, scientists, the farming community and urban planners, among others.

Digital Earth Africa's aim is to provide decision-ready information without the need to invest in expensive hardware, software, and specialist pre-processing of satellite data. This liberation of EO data will support the continent in establishing required strategies, managing its forests, building sustainable cities, and competing in global markets on an equal level.

Potential benefit for key sectors

This report's attention is directed at four key sectors:

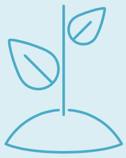
- Agriculture
- Forestry
- Mining
- Regional and Urban Planning.

It examines how these can benefit from ARD and therefore DE Africa's ODC.
The four sectors have been selected for two reasons:

1. They are important for socioeconomic development in Africa
2. Earth observation has the potential for substantial impact and benefit in each of these sectors.

For each sector we discuss 3 to 4 applications that can benefit from operational use of ARD. The following table shows how these four sectors relate to the Sustainable Development Goals (SDGs).

Benefit for Agriculture



- Production and yield
- Supply chain efficiency
- Agriculture insurance

Benefit for Forestry

- Carbon market
- Timber industry
- Ecosystems and biodiversity

Benefit for Mining

- Exploration
- Preparation and extraction
- Mine closure and aftercare

Benefit for Regional and Urban Planning

- Settlements
- Infrastructure
- Vulnerability

Image: Panaglobo

Applied model and quantifying the impact of analysis ready data

To quantify and monetise the potential impact of DE Africa's analysis ready data (ARD), this study defines a framework using up-to-date economic indicators to assess the potential ARD benefits across each of the four sectors:

- Agriculture
- Forestry
- Mining
- Regional and Urban Planning

We have reviewed literature related to EObenefit analysis and extracted data and information as they apply to the examined sectors.

In general, the benefit calculation consists of:

1. A baseline in USD per year, e.g. total yield in Africa
2. A portion of EO benefit in percent, e.g. 10 percent yield increase due to enhanced input management
3. A share attributed to the benefit of ARD (e.g., 50 per cent).

The benefit is therefore an estimate of the benefit of ARD to Africa.

Benefit = Baseline x Portion of Earth observation benefit x analysis ready data share

We differentiated three types of baseline data from which we monetised the potential impact of ARD based on the available information.

1. In some cases baseline information was available, for example in the form of agricultural yield data, or loss of forests in hectares per year.
2. In other cases, the information available was less precise, such as infrastructure budgets for the entire continent, which are themselves based on assumptions.
3. In the third scenario, the potential benefits depend on future policy developments and alignment with international agreements, for instance the countries' willingness to reduce deforestation.

Data used to model the baseline numbers are the latest available. The resulting benefits are calculated on an annual basis. The numbers are not meant to be hard facts, but rather modelled estimates that depend on different factors such as governmental willingness to adjust policy and legal frameworks, etc. The calculated benefits for improvements in agricultural yield and timber productivity will take about a decade to come to full fruition and are therefore projections to the year 2030.

Significant effort was invested into expert consultations in relevant fields. In nearly all cases, specialists' judgement was applied to evaluate EO impact on each of the areas discussed. In some areas we had to deal with a certain degree of uncertainty and, as such, the study includes a number of caveats to ensure the results are not misinterpreted. In other areas we were not able to quantify any benefits of ARD. This includes climate change resilience, desertification, and the protection of forest populations, to name a few.

Benefit analysis is a popular tool in decision making, because it presents a measurable outcome that can be compared with alternatives. But to obtain this picture and assign a certainty to it, one must accept assumptions that are not always realistic. It has been mentioned in literature that the impacts on environmental projects are particularly complex and therefore difficult to quantify. However, we have taken care to be conservative using appropriate data based on country or continent-specific data.

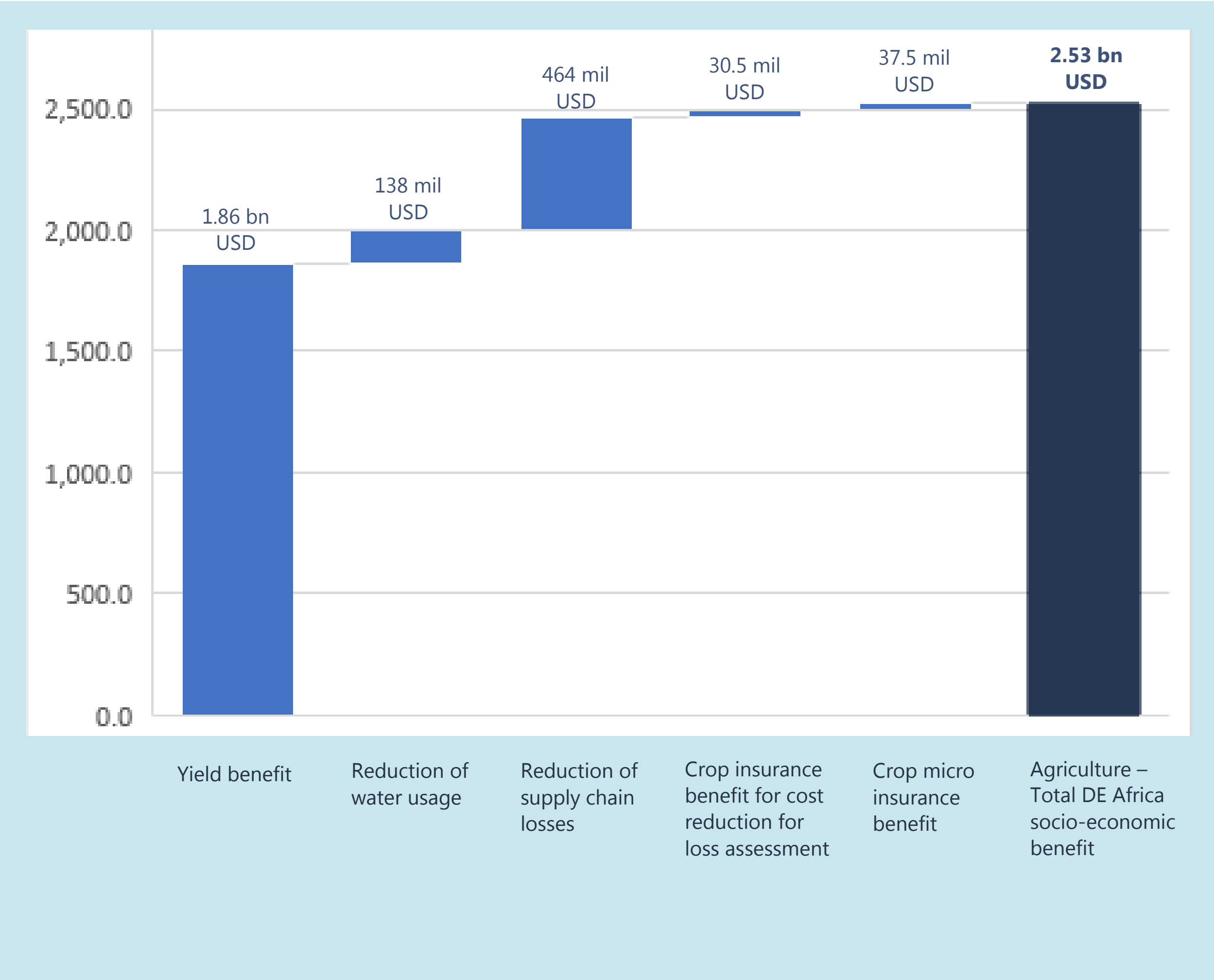
From this perspective the study produces insight into EO applications and offers insight into the thematics of each of the selected sectors.

Agriculture

Subsectors:

- Improving yield
- Crop insurance
- Supply chain efficiency

Analysis ready data benefits



Source: Team Analysis

Improving yield

Earth observation to boost food security and increase agricultural yield

Increasing crop yield

Sub-Saharan African (SSA) countries have not yet benefited from their huge agricultural potential and still experience high prevalence of undernourishment. As a result, countries import more agricultural products than they export. More than 60 per cent of the population of SSA are smallholder farmers, and about 23 per cent of SSA's gross domestic product GDP comes from agriculture.[3] Yet Africa's full agricultural potential remains untapped.

A fast growing population compounded by the effects of climate change represents challenges to Africa's farming industry. Threats like weather hazards, loss of soil fertility, water scarcity, post-harvest losses and limited market access need to be addressed.

In light of these concerns, sustainable and more efficient farming practices are gaining traction, demanding the use of digital technology to increase productivity and yield. The UK Space Agency has forecast that satellite solutions for agriculture will be almost seven times more cost effective in the long term than non-space alternatives for improving crop yields.[4] The combination of analysis ready satellite data, ground measurements and near-real-time weather data can be used to develop notifications and informed recommendations, which farmers may receive through mobile phone apps, call centers, websites, or personal advice from extension officers.

Precision farming leads to improved farming decisions and field practices resulting in increased crop yield, even while reducing production costs. Data from satellites can be used to monitor crops and detect variabilities within or between fields. Vegetation indices provide critical data regarding the variations in crop coverage, crop vigor and health, soil moisture or the presence of disease and infestation. These insights support the precise, demand-specific treatment of plants and help farmers to adapt sowing time and seeding depth to specific soil conditions in a cost efficient and sustainable manner while minimising any negative environmental impact.

Adoption of these precision farming technologies in smallholder farming systems in SSA can substantially improve overall efficiency of input use, i.e., increase yields with best use of available input recourses. This especially applies to the use of fertiliser and its scarce availability, but is also applicable to crop protection, weed control, and other treatments.[5]

The study quantifies the potential impact of ARD on agriculture yield on the African continent by taking $309 billion/year as the annual agriculture gross production value for the year 2020.[6] By modelling the increasing positive impact of ARD and other factors to the year 2030 we expect a gross production value of $363 billion. According to various studies EO can contribute to yield improvement by

5 to 20 per cent. We used a conservative impact of 6

per cent.[7] This calculation presupposes that large farms (20 per cent in Africa) will increase their production by up to 6 per cent by 2030 and smallholder farmers (80 per cent in Africa) will increase their production by 3 per cent in the same time period. Our benefit calculation takes the $363 billion as a baseline and so expresses expected annual benefit for 2030.

The Earth observation impact of 3.6 per cent was calculated using the proportional average impact factors of smallholder farms (3 per cent) and large farms (6 per cent) in our formula.

Yield improvements through EO presupposes in most cases investments such

as the installation of irrigation systems or the purchase of inputs. Our economic model takes the varying investment power of individual nations into account by applying a 80 per cent investment power factor to the strongest country (Tunisia) and lower relating factors to all the other nations. The investment power is calculated from the median household income of each country and results in our formula with an average investment power factor of 28.4 per cent for the continent. The resulting $1.86 billion annual benefit of ARD is 50 per cent of the EO benefit. As a comparison, Rwanda’s agriculture GDP is about $2.5 billion.

1.86

bn USD

Yield improvement benefit based on precision agriculture using analysis ready data

Constant improvements in agricultural practices based on big data (ARD) can potentially lead to 1.86 bn USD annual benefits by 2030

Water saving through smarter irrigation practices

While water is essential for plant growth, it is scarce in many parts of Africa. Resourceful and controlled application of crop irrigation is therefore imperative for African farmers. Farmers can optimise irrigation rates and soil fertility using EO based soil moisture estimates. This often results in dramatic water savings. Africa’s annual water withdrawal for agriculture has a value of $9.2 billion. With supporting smart technology and modernised irrigation systems, water usage can be reduced by up to 35 per cent, according to a case study by Frank van Steenbergen and Petra Schmitter.[8]

In our formula a conservative 30 per cent of potential water saving factor was taken with a 10 per cent portion of EO benefit and 50 per cent ARD share. The resulting $138 million benefit is the equivalent of the annual income of 200,000 SSA farmers.

138

mil USD

Benefit from water savings through improved irrigation practices

We have estimated a benefit of $138 million per year by using DE Africa's analysis ready data from space in combination with original measurements of soil moisture for water use reduction

DE Africa's cloud-based ODC can be of great benefit to Africa's agriculture sector. The web-based platform offers free and open analysis ready data with regular continent-wide coverage by satellites like Landsat and Sentinel-1 and 2. The platform is easy to use, allowing the broader agricultural community to tap into this rich data source.


Image ESA

CASE STUDY

More crop per drop

The Food and Agriculture Organisation of the United Nations online platform WaPOR provides free access to satellite-based data for monitoring and reporting on agriculture water productivity over Africa and the Middle East. The agricultural water productivity is an indicator for the quantity of output in relation to the quantity of water consumed to produce the output. The goal is to assist countries in these regions in developing their capacity to monitor and improve crop yields through improved management of water and to help to understand the spatial variability of water and crop-related variables.

In a two-year field program in Koga, Ethiopia, the International Water Management Institute used its expertise in novel technologies to identify ways to improve crop yields through improved management of water and soil nutrients. In total 602 farmers (about 6 per cent of the target farmers in the entire Koga scheme) were reached and provided with training and innovative tools that allowed them to enhance on-farm irrigation management decisions. The tools allowed them to “look beyond the soil” and assessed whether the land should be irrigated or had been irrigated too much.

Within one or two seasons of becoming comfortable with the tools farmers reduced their field irrigation supplies. According to key farmers, they typically extended the irrigation cycle from the local storage reservoirs from 8 to 11 days, or 9 to 12-13 days – effectively a water use reduction of 35 per cent. With reduced water applications the wheat crop yield went up by 10 to 20 per cent according to farmers’ estimates. The gain in terms of water productivity was a spectacular 35-40 per cent. The farmers noted that improved water management resulted in a faster rotation among water users in the same group and resulted in a decline in water related conflicts. The saved water was used to extend the area under cultivation within the blocks, but also to reduce water deliveries from main scheme operations to fill night storages.

Additional research showed that soil nutrient loss was reduced. All in all, a spectacular increase in water productivity was achieved through joint learning and farmer-led action resulting in a large group of farmers advocating for better water management.

Source: More crop per drop: Farmer-learning and the promise of improved water use in agriculture
Using remote sensing in support of solutions to reduce agricultural water productivity gaps

From this point of view, ARD offers highly valuable information not only to field farmers but also to moving pastoralists. Finding an adequate waterhole with enough water and vegetation to meet their livestock’s needs is not only essential, but also challenging since locations tend to vary more widely with increasing fluctuation in climate patterns. The information received from scouts investigating an area is costly, slow and risky. Analysis ready data is an innovative, smart and accurate alternative offering location and status on water and vegetation cover in real time, transmitted via SMS text messages.

CASE STUDY

Garbal and Afriscout Service

On average, pastoralists are losing over a third of their herd every year. In addition, pastoralists can spend hundreds of dollars on scouting to find pasture and substantially more on supplemental feed when pasture can't be found. With approximately 270 million pastoralists across the continent of Africa, this represents substantial expenditures and lost resources which also has effects on the health and well-being of families and communities that rely on pastoralism for their livelihood.

The Garbal service in Mali and Burkina Faso, and Afriscout service in Kenya, Ethiopia and Tanzania, use satellite imagery such as Sentinel-2, Meteosat, Proba-V and ground information on pasture quality and livestock concentration to offer users real time information on the nearest pasture and water sources. Both services help pastoralists make decisions about their movements, minimising risks and losses. They reduce the pressure on the environment by avoiding overgrazing, allowing degraded areas to recover and decreasing the likelihood of conflicts between pastoralist communities.

So far, Afriscout has mapped over 538,000 square miles of communal grazing lands in Kenya, Ethiopia, and Tanzania where there are currently more than 11,000 registered users. In 2019, 350 new users registered each month and shared information with at least seven other families. In Mali and Burkina Faso, pastoralists can access Garbal's advisory service through Unstructured Supplementary Service Data (USSD) text messages or targeted calls to service centres. Since its launch in November 2017, Garbal service has received 197,578 USSD requests in Mali and 93,679 calls in Mali and Burkina Faso. Pastoralists who used Garbal service reported an additional $475 in income from milk production per herd per year in Burkina Faso. In Mali, Garbal users increased their milk production by an average of 9.6 per cent and reduced their losses by $191 compared to non-users.

Aggregate results show:

- Over 80 per cent of users claim that migration decisions were significantly impacted since using the maps.
- Over 50 per cent of users stated that the maps are now their most important resource for migration decisions, which include where and when to move herds along with how many animals to move.
- Nearly 100 per cent of users found the maps to be accurate or very accurate.
- Over 75 per cent of users found using the maps saved time, reduced scouting, reduced livestock deaths, and improved livestock conditions.

Source: *Garbal: a satellite information service for pastoralist farmers in northern Mali*
AfriScout: The Shepherd's Eye in the Sky
GARBAL: An open GIS for livestock herders in Mali and Burkina Faso

Supply chain efficiency

A closer look at Africa's food supply chain

In many African regions the supply chain for food products is fragmented and involves multiple layers of intermediaries. This raises retail prices and makes large scale distribution networks more challenging. Africa's estimated 33 million smallholder farmers have less than optimal access to fair and trusted markets and they lack information about yield forecasts, prices and market demand. Moreover, they often struggle with logistical bottlenecks for essential materials such as seed and fertiliser.

The distances from remote rural farming areas to commercial hubs can be far greater than in other parts of the world and roads and railways may close for days after severe weather events.

This hurdle eats into farmers' profit margins, and at the same time results in the loss of large amounts of food urgently needed to counter hunger and malnutrition. Estimates of post-harvest losses in Africa range from between 30 to 50 per cent.[9]

The implementation of ARD for the agricultural supply chain in Africa has the potential to improve the overall situation. Information on what is growing where, how much, and when, provided at a cross-regional scale, helps to match supply and demand. Accurate crop maps, crop acreage, yield forecasts and harvest schedules improve post-harvest logistics such as adequate transport and sufficient storage infrastructure.


Image Unsplash.com

CASE STUDY

Crop Monitor for Early Warning in Uganda

The Crop Monitor for Early Warning (CM4EW) is an international initiative that provides monthly transparent, multi-source, consensus assessments of the crop growing conditions, status, and agro-climatic conditions. It serves to reduce uncertainty and strengthen decision support by providing actionable information to national, regional and international agencies concerned with food security, through timely consensus assessment of crop conditions published within the monthly CM4EW bulletin. The program was developed in response to pressing needs for enhanced early warning of crop shortfalls and for better coordination across the various agencies responsible for crop assessments in regions most at risk to food insecurity.

Each month 14 partners from the global food security response community come together with their own monitoring and observations to address discrepancies and create a consensus report. Partners include the international food security community (World Food Program, UN-FAO, Famine Early Warning System Network, etc.), and several national food security ministries.

In 2015 Group on Earth Observations Global Agricultural Monitoring (GEOGLAM) started to work with the Ugandan Office of the Prime Minister (OPM) to develop an EO based crop monitoring system for the country. The crop monitor process informed the development of the Disaster Risk Financing Program and in 2017, the system was able to provide early warning of a likely crop failure due to drought 3 months sooner than previous years when assessments were largely ground-based.

Using satellite data, the OPM triggered the Disaster Risk Financing fund to scale up labor intensive public works projects to compensate for yield losses in affected regions starting in 2017. The timely analysis enabled proactive response and quick payouts before the full effects of the drought were felt.

An evaluation of the Disaster Risk Financing fund indicated that the Government of Uganda realised a saving of $2.7 million (51 per cent) against an overall emergency fund of $5.3 million in the year 2017. The program has supported 66,075 households (approx. 300,000 people). Uganda was able to run the EO based assessment locally, which increased the credibility and ownership of the results. Earth observation based monitoring is now an operational part of the Ugandan National Early Warning Bulletin.

"In the past we always reacted to crop failure, spending billions of shillings to provide food aid in the region. 2017 was the first time we acted proactively because we had clear evidence from satellite data very early in the season". Martin Owor, Commissioner Office of the Prime Minister (OPM)

Source: (Catherine Nakalembe, GEOGLAM/NASA-Harvest, and Ian Jarvis, GEOGLAM Secretariat).

Satellite data analytics and ARD as provided by DE Africa will enable monitoring of crop growth and yield parameters. In the event of of crop failures, governments can take timely action on global markets to compensate for shortfalls and initiate financial support for farmers as shown in the Ugandan Crop Monitor for Early Warning (CM4EW) case study. All African countries can implement early warning systems for crop failure since DE Africa allows implementation of such proven methods across the continent. Knowledge about demand, yield supply, market volatility, price developments and input costs enable players to better calculate financial risks and profit from market transparency.

We estimated that 10 per cent of current post harvest losses in Africa can be saved and the contribution from EO would be another 10 per cent. The benefit from ARD being half of this would amount to $464 million which could flow back into the farmers' income channel. This money could be used to buy fertiliser and as a result increase yield. $464 million could buy approximately 228 tons of nitrogen.

464

mil USD

Supply chain improvement potential of using analysis ready data by DE Africa

Information on crop acreage, expected yield, harvest schedule improves post-harvest logistics and reduces food losses. Benefits could be as high as $464 mil per year.

Here, the compelling case for the DE Africa ODC becomes most apparent. Through its scalability from a single field to regional, national or continent-wide view, the demands of the entire supply chain can be made visible.

Crop insurance

Earth observation – an enabler for Africa's agriculture insurance industry

Crop insurance

Crop losses due to extreme droughts or other severe weather events are a common phenomenon in African countries. In most cases, the farmer shoulders the risk of crop losses. Insurance penetration for African smallholder farmers currently accounts for less than 3 per cent.[10] The reasons why farmers hesitate to use insurance to mitigate risk can be seen on following graph:

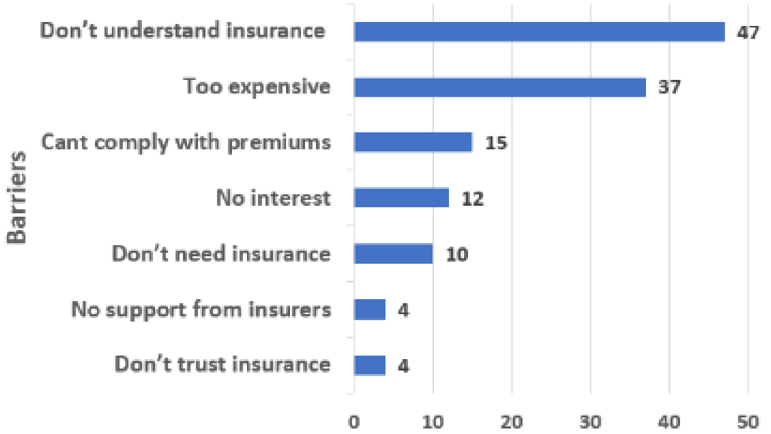


Figure 3: The main barriers for crop insurance. [11]

As the impact of climate change increases, the implementation of sustainable risk systems will be important for future agricultural development. Insurance support in the form of claim payments enables impoverished farmers to remain on their land, retain their livestock and continue investing in the next season's planting.

Faced with high administrative costs, insufficient statistical data, knowledge gaps, information asymmetries, operational issues and the heterogenic structure of farm sizes, it is challenging for insurance companies to offer compelling products. Agriculture in Africa is risky, therefore premium rates are inevitably high and often unaffordable within the cost and return margins available to farmers.

Understanding the nature of the risks, their frequency and severity, and their impact on families and communities is fundamental in tailoring suitable insurance products. Earth observation data that makes it possible to look back more than 30 years and analyse crops, field productivity, weather patterns and their impact on crop yield, as well as the current farming practices in use is essential for a sound risk assessment.

Openly available satellite data provided by DE Africa's system can be used to localise and identify insured fields remotely and therefore save substantial costs for administration, travel and fraud. In addition, remote sensing has become an indispensable tool for assessing insurance claims by offering a means to accurately measure acreage and determine the severity of affected crops, providing unbiased information on the extent of the damage.

Costs for loss adjustments are estimated to be 4 per cent of paid premiums.[12] Penetration of indemnity-based insurance in Africa is low and considered to range between 0.01 and 0.7 per cent.[13] In our benefit analysis for the year 2030 we conservatively projected the premiums to be 0.6 per cent of the agriculture gross production value. Assuming 70 per cent reduction of loss adjustment costs through more efficient processing with EO and a 50 per cent ARD share could save the industry $30.5 million per year in 2030.[14] This sum would pay the annual salary of 10,700 loss adjusters in Uganda as a comparison.

30.5
mil USD

Agriculture insurance – analysis ready data benefit from reduced loss adjustment costs

Earth observation data is used for claim loss assessment. This saves time and travel costs for assessors

Index based microinsurance models

In the recent past, indemnity-based insurance models have been increasingly replaced by innovative, technology-based models like index insurance. This type of insurance service is based on predetermined indexes, such as rainfall levels or drought. Payouts for claims resulting from weather and catastrophic events are then made to affected farmers. Mobile data providers, agro-industry, and insurance or financial service providers often cooperate to provide these insurance products. This ensures ease of communication through smart phones, a relationship to customers via the local agro-industry, and expertise in product design from insurance companies or financial institutions.

Insurance payouts are calculated on the basis of an empirical relationship between a proxy index and expected yield loss. Remote sensing data is the only efficient approach to achieve widespread geographical coverage and therefore provides the basis for calculations that allow the use of this type of insurance.

Companies often offer index-based insurance in cooperation with governments or development organisations. These provide the legal framework and define the insurance as part of a national agricultural policy to co-finance the risk premium and administrative costs and carry liability for catastrophic losses.

	Set-up costs	Operational costs	Claim settlement speed	Risk of moral hazard and adverse selection	Basis risk	Actuarial difficulty
Indemnity based	Medium	High	High	High	Low	Low
Area yield index	Low	Medium	High	Low	Low	Low
EO benefit	High	High	Medium	High	High	High

Figure 4: Characteristics of indemnity-based insurance, yield index-based insurance and Earth observation benefits. [15]

These tech-based insurance models, called microinsurances or hybrid insurances, are gaining traction because of their ease of use and the additional services they offer like weather data, seeding date proposal etc. This study assumes that premiums for this type of insurance will reach $500 million by 2030. The assumption is based on the number of customers this sector expects to have by 2030 (10 million customers) and the fact that this type of insurance is often subsidised by governments, which in return gain an instrument for agriculture policy steering.

Since this insurance model is still in its growth phase, estimates of EO benefits are scarce, from literature as well as from experts. But it is clear that without EO, this type of insurance would not be possible, because it is too costly to evaluate large agricultural areas ‘manually’. The study therefore rates the EO benefit at 15 per cent of insurance premiums, of which half can be attributed to ARD. This results in an ARD benefit of $37.5 million for the micro-insurance model.

37.5
mil USD

Crop insurance – analysis ready data benefit for crop micro-insurance

Smart-phone based microinsurance models are gaining traction with smallholder farmers in Africa. They are heavily based on Earth observation data

Digital Earth Africa’s ARD with its long-term time-series archive of historical datasets can be used to calculate the correlation of yield estimates with weather data and crop health to conclude correlation ratios. In contrast to a traditional remote sensing approach, the datasets of DE Africa are readily stored and organised for immediate analysis without time-consuming, laborious and often costly processing. In summary, ARD and the ability to process big data volumes efficiently in the cloud makes the system a true enabler for holistically modelled index-insurance products, even in remote locations of Africa with a majority of smallholder farmers.

CASE STUDY

Crop Mapping Kenya

NASA Harvest has partnered with the Kenyan Ministry of Agriculture to map agricultural practices on a national level. Satellite Earth observations (EO) provide frequent and timely data that is vital to monitoring complex and highly variable agricultural systems. This large volume of data can give insights into crop type, crop condition, and potential crop yield for a multitude of regions that have diverse socio-economic levels, cultural practices, and climates.

The key to enacting successful agricultural policy is putting this valuable information into the hands of critical stakeholders across governments (at all levels), international aid organisations, market analysts, agricultural insurance agencies, and organisations throughout the supply chain in a meaningful way. The team develops medium spatial resolution maps of both national cropland area and crop type using the GEO implementation of Sen2Agri-AWS throughout several countries including Mali, Kenya and Sudan with the help of in-country NASA Harvest partners.

The resulting maps aim to provide stakeholders with information on the spatial extent of local cropland area, historical crop types, and in-season crop type maps to help inform crop condition assessments and planted area estimates.

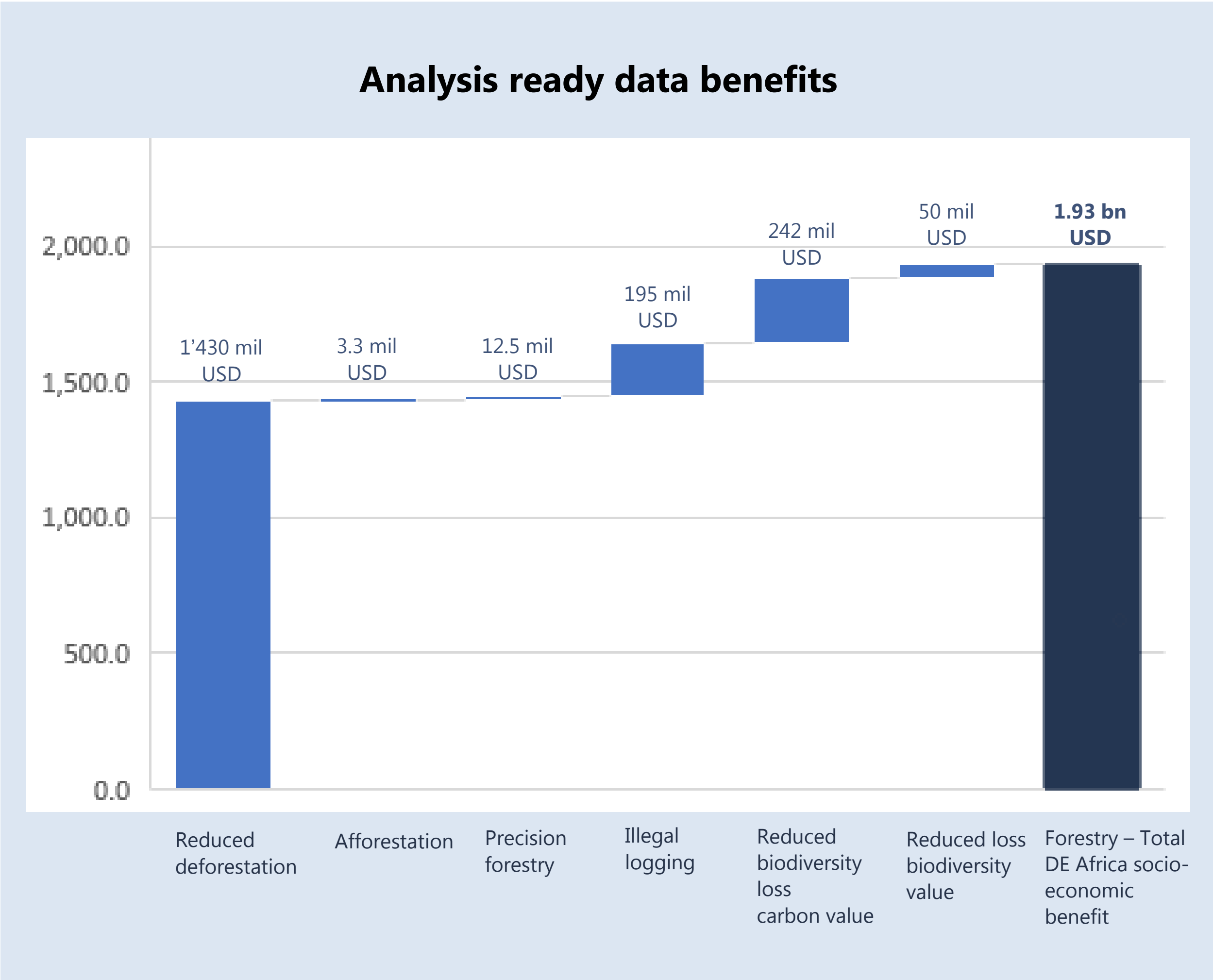
While methodologies to optimise supply chains by reducing losses and improving efficiency of logistics would have immense benefits, meeting this challenge requires the coordination of several actors and datasets. Robust methods of identifying spatiotemporal patterns in crop distributions from EO data are necessary to ensure that downstream analyses of crops and agricultural sustainability variables correctly capture agricultural landscapes. This allows for rapid identification of changes in crop development, helping governments improve planning of food assistance during droughts, flooding, and other food security crises.

Source: GEO-Amazon Awards Grants to NASA Harvest Partners
https://africanews.space/geo-amazon-awards-grants-to-nasa-harvest-partners

Forestry

Subsectors:

- Carbon market
- Timber market
- Ecosystem and biodiversity



Source: Team Analysis

Deforestation

Reducing deforestation – carbon market - forest management

Reduced deforestation

Forests are vital for Africa's welfare and important for water regulation and soil protection. More than 70 per cent of Africa's population depends on forest for wood, fiber production, generating income and jobs, meeting needs for food and medicinal plants and supporting ecosystem services. Woodlands and forests supply approximately 60 per cent of all energy.[16] The continent is home to 18 per cent of the world's remaining rainforests, covering over 3.6 million square kilometers of land mass; the Congo Basin is one of the world's largest tropical rainforests with over 8000 plant species. Last but not least, there is increasing recognition of the importance of forests in combatting climate change. Forests sequester carbon dioxide from the atmosphere, store the carbon in plants and soils, and release the oxygen. Therefore, they play a significant role in achieving net zero emissions by 2050, a key ambition in the Sustainable Development Scenario.

As populations increase, deforestation and forest degradation pose the biggest threats to forests, not only in Africa. Almost 20 per cent of Africa's forests and woodlands are classified as degraded,[17] mostly as a result of activities such as agricultural development, illegal logging, mining and infrastructure projects. The net rate of forest loss has accelerated in each of the past three decades, culminating in 3.9 million hectare annual loss from 2010 to 2020.[18]

Through the United Nations Framework Convention on Climate Change (UNFCCC), the global community has agreed on a framework to reward countries for reducing deforestation. This offers significant potential for forest-rich African countries that participate in the carbon market. Governments in those countries are ready to act.

Learning about forest conditions on a wide scale and in detail and quantifying phenomena such as forest degradation have only become feasible through satellite remote sensing. Radar satellites that can "see" through clouds are especially well-equipped to reveal changes in tropical rainforest canopy that previously remained undetected. Forest monitoring using satellite images has reached the point where these datasets now directly inform international policy agreements. In support of the Paris Agreement on Climate Change, governments use the technology to track and report on forest cover, the associated carbon stock and emissions of carbon dioxide into the atmosphere caused by cutting down trees and other types of land-use changes - because this information is required to establish incentive mechanisms aimed at reducing climate change.

A robust, transparent and unbiased system like the one provided by DE Africa offers tremendous opportunities for mapping and monitoring carbon stock changes over time. Analysis based on frequent and regularly acquired imagery enables decision makers to track and respond in time. It also reveals the extent and efficacy of action taken to mitigate greenhouse gas emissions. In summary, ARD from DE Africa facilitates the entire process of monitoring, reporting and verification (MRV) required to participate in the global carbon market. Furthermore, DE Africa could also play a supportive role in implementing the new policies suggested by the World Bank to accelerate the current MRV process. According to the World Bank a centralised cloud service with decentralised multipurpose platforms and data bases would serve to collate an unprecedented volume of centrally or locally located remote sensing and in-situ data. The decentralised multipurpose platforms could be customised by users according to their needs. Hence, the system would enable the use of enhanced MRV methodologies at multiple scales and take account of different local circumstances and uses.[19]

We have estimated that with ARD support and accompanying action, deforestation in African countries could be reduced by 6 per cent per year, or by 236,000 ha – the equivalent of 330,000 soccer fields. The total financial gain from the carbon market, at a price of $15 per tCO2e, could amount to $1.43 billion.

1,430
mil USD

Potential analysis ready data impact (benefit) on reduced deforestation

Based on PWC studies on the Global Monitoring for Environment and Security program (GMES) a 5 – 20 per cent reduction of deforestation through Earth observation can be achieved. We calculated with a conservative 12 per cent Earth observation benefit with 50 per cent of that attributable to analysis ready data.

Afforestation and reforestation

Afforestation, the planting of trees on land that was not previously forest, reforestation, in which forests are replanted on land that had been forest in the past, and forest restoration, which involves planting new trees to improve the health of a degraded forest, are part of the Paris Agreement. Newly planted forests are an important approach to mitigate global warming. Their complex interactions with the climate system can shift regional low-level jets, enhancing precipitation and enhancing moisture penetration. This results in enhanced evapotranspiration, surface cooling and the modification of the latitudinal temperature gradient. It is estimated that the carbon sequestration potential of large-scale afforestation could overwhelm geophysical warming effects over time.

In line with this, various large-scale efforts in planting trees have emerged in Africa, including the sub-Saharan Great Green Wall.

Afforestation projects need careful planning and longtime attention to guarantee success. Young trees are prone to being overgrown by other plants and vulnerable to threats from the environment and animals. Constant monitoring of afforested areas effectively supports the survival of trees until they reach a robust live stage. Satellite information decreases the cost of data collection, while increasing their accuracy. Most importantly, it enables quick response and analysis of problems even in remote areas. Analysis ready data with its historical data archive can be of extreme importance for the selection of afforestation sites.

Tree planting Uganda

The ARD benefit for afforestation in Africa in this study focuses on forest plantations only because they allow for a more or less constant surface measurement. There are active reforestation projects taking place, but their scope is difficult to quantify because of their scattered and unique nature.

Financial compensation can also be obtained for carbon dioxide (CO_2) sequestration, the increased uptake of carbon in terrestrial reservoirs (trees) by removing $CO_2$from the atmosphere. Better insights into specific local growing conditions provided by ARD can help to increase the success rates of afforestation and reforestation projects. Our calculation projects a benefit of $3.3 million from the use of ARD to support afforestation programs in Africa. (Baseline afforestation number is 19,000 ha/year and only reflects Africa's tree plantations). [20] We are estimating a greenhouse gas (GHG) sequestration of 2,270 tCO_2e/100years per hectare of new grown forest from seedling to fully grown trees and then take the average per year = 22.7 tCO_2e. Earth observation benefit for afforestation projects is estimated with 10 per cent and ARD is 50 percent of that. The value of tCO2e is calculated with $15.

3.3
mil USD

Supporting afforestation programs – potential analysis ready data benefit

Our calculation of ARD benefits is based on Africa's afforestation efforts of 194,000 ha per year. The results express the value of CO_2e sequestrated by the afforested area.

Forest management

In a more holistic approach to ensure forest activities are in sync with social, environmental and economic demands, the shift to sustainable forest management is necessary. Nowadays, forest management plans aim to offer more than simply a way to manage timber cutting. Good forest management engages all forest stakeholders in the early stages of planning.

It takes into account issues affecting wildlife and it creates refuges for plant and animal biodiversity. Sustainable forest management also requires estimates for harvest volumes and earnings from forest produce, as well as systems for allocating and monitoring new logging concessions. It harmonises the legislative frameworks for forest policies while incorporating the rights and interests of Indigenous communities. In essence, it allows the local population and the private sector to take on more significant roles and responsibilities in the management of forest resources and yields a greater appreciation of this important natural asset. There have been repeated political demands for sustainable management and development of the forest sector as a key to socioeconomic development and environmental protection; among them, the Sustainable Forest Management Framework for Africa (2020-2030) in active participation with African Union Member States. Currently management plans exist for less than 25 per cent of forests in Africa.[21]

All the above-mentioned issues require a profound and regular assessment of forest resources. Monitoring forest areas is therefore crucial and EO is a cost-effective solution providing comprehensive, accurate, repeatable and timely status information for vast areas that are often difficult to access. Earth observation has a long history in forest management but is relatively sparsely used in Africa. Digital Earth Africa's GeoMAD (Geomedian and triple Median Absolute Deviation) service can be of particular significance when monitoring areas with heavy cloud cover such as tropical rain forests. It uses annual cloud-free mosaics to create unique statistics and bring all the data into an analysis. Applied to long-term series of images, it allows for visualisation and analysis of changes across the African landscape.

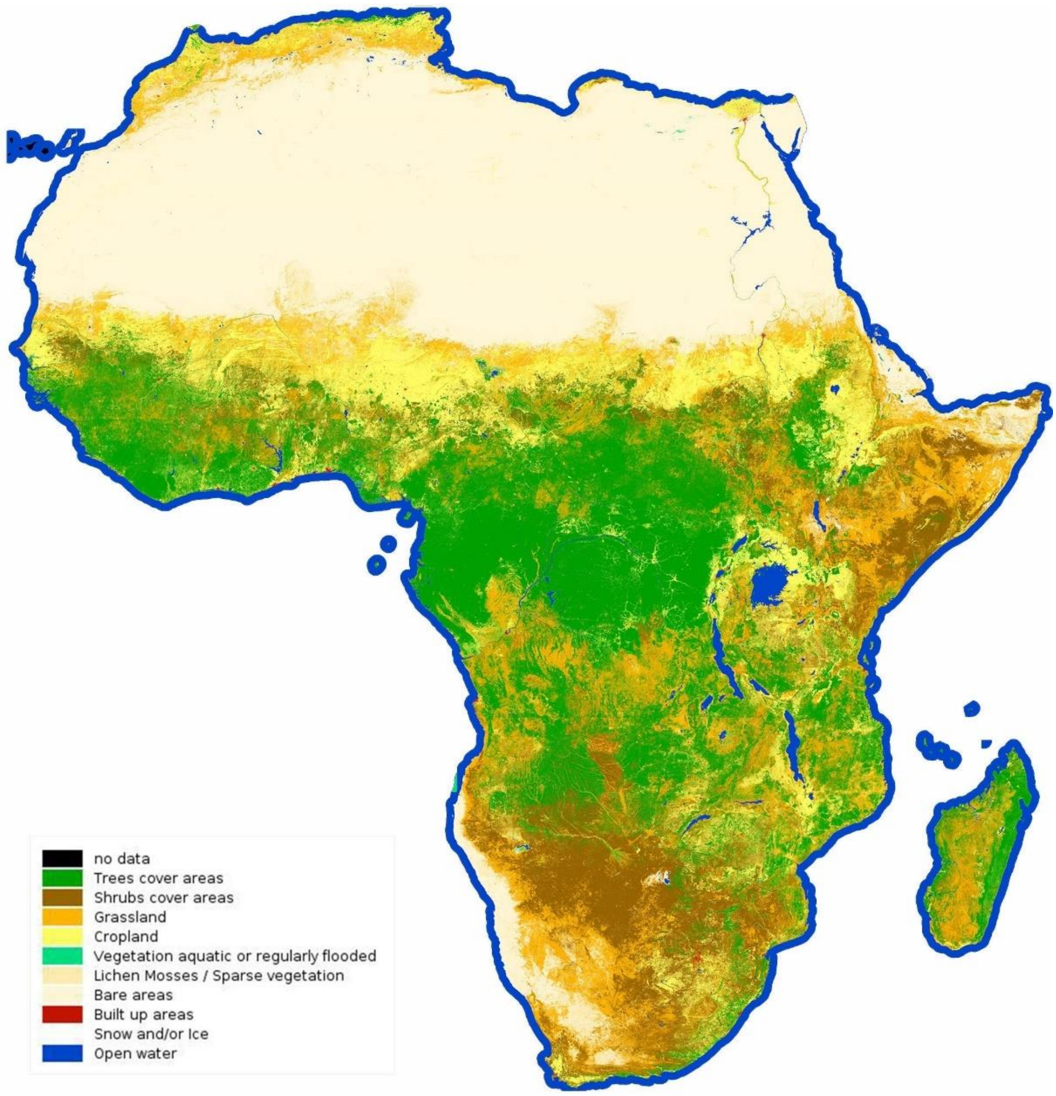


Image ESA

CASE STUDY

Mozambique Carbon program

Mozambique is one the few sub-Saharan countries with a significant portion of natural forest covering about 43per cent of its territory (34 million hectares). However, deforestation and forest degradation have been increasing in recent years, due to several direct drivers of deforestation including small-scale agriculture, charcoal production, timber exploitation and illegal logging.

At the begin of February 2019 Mozambique signed an Emission Reductions Payment Agreement with the Carbon Fund of the Forest Carbon Partnership Facility (FCPF), a global partnership housed at the World Bank. The program provides results-based payments for emission reductions, with the goal of reducing 10 million tons of carbon emissions by 2024. Mozambique's Zambézia Integrated Landscape Management Program has since then been seeking to promote forest conservation and reduce deforestation and forest degradation, while at the same time improve the lives of rural populations in nine districts of the Province of Zambézia.

It is the responsibility of the monitoring, reporting, veritification (MRV) unit under the National Sustainable Development Fund (FNDS) to generate all information related to emissions from deforestation on national, province and district level. The unit led by Aristides Muhate is a team of young qualified geospatial experts which started its work in 2016. Since then, substantial efforts have been undertaken in terms of personnel resources to develop standardised processes for measuring, monitoring and reporting of emissions and removals occurring within the monitoring period. The satellite and monitoring system mainly uses Sentinel-2 data to specifically determine the number of hectares of deforestation within a given geographic area. Based on the satellite imagery and the developed methodologies the MRV unit was also able to generate annual historical deforestation maps for all provinces for the years 2017, 2018 and 2019. This detailed information revealed for the first time the alarming level of deforestation occurring in the country. It helped decision makers to better understand land use changes, dynamics and hot spot areas to develop effective mitigation strategies.

In August 2020 Mozambique was able to submit an official monitoring report confirming the reduction of carbon emissions. Results were then verified by an independent third-party organisation in 2021. On October 15 2021 Mozambique officially received approximately 6.4 million USD for its efforts in tackling deforestation and forest degradation. The Forest Carbon Partnership Facility (FCPF) rewarded Mozambique for reducing 1.28 million tons of carbon emissions since 2019. The payment is the first of four under the country's Emission Reductions Payment Agreement with the FCPF that could unlock up to $50 million for reducing up to 10 million tons of CO_2 emissions in Mozambique's Zambézia Province by the end of 2024.

Source: Aristides Muhate, MRV Unit, National Sustainable Development Fund, Ministry of Agriculture and Rural Development, Mozambique https://fnds.gov.mz/mrv/

Timber market

Earth observation as a supporting tool to regulate and protect the timber market

Timber market

Because of growing concern about the increasing rate of deforestation, Africa's timber market is currently going through a phase of change. While hardwood exports play a significant role in the economies of tropical countries in terms of volume and earnings, some countries are starting to regulate exports. Domestic markets are equally important - sometimes even more so. The difference is that national production and trade are largely informal and unaccounted for. The most forest-rich countries, such as Democratic Republic of Congo, Nigeria, Cameroon and Mozambique, have imposed restrictions on roundwood exports to protect dwindling forest reserves.

For the domestic market, timber plays an indispensable role as the dominant energy source for sub-Saharan Africa, on which about 93 per cent of rural households and 58 per cent of urban households rely.[22]

To serve the high domestic biomass consumption, sustainable forest management and a regulated timber market are essential. The illicit timber trade is a major risk factor which can be mitigated with the use of modern technologies like remote sensing. Digital Earth Africa's ARD technology facilitates the monitoring of vast forest areas, particularly with its time-series capability, which uncovers changes in forest cover likely to have been caused by illegal logging. We assume illicit timber trade currently accounted for $13 billion and can potentially be reduced by 30 per cent.[23] The estimated share of EO in reducing the illegal activities is 10 per cent, of which 50 per cent is assigned to ARD and results in a total of $195 million of benefits.

195
mil USD

Reduced illegal logging – potential analysis ready data benefit

The illicit timber trade is difficult to quantify. Estimates for Africa put it at around USD 13 bn per year. Examples from Amazonia have shown that the illegal trade can be decimated by 60 per cent through use of remote sensing technologies. We assume a 3 per cent benefit from analysis ready data.

Another high-risk factor for the timber inventory is forest fires, which mostly stem from inadequate farming practices. Forest fire mapping on the basis of satellite imagery is a useful practice to recognise high-risk areas. Examples have shown that targeted information campaigns in risk areas can raise awareness in the farm community, resulting in a reduced incidence of forest fires.

According to the Food and Agriculture Organisation of the United Nations, pests and diseases affected 0.3 per cent of the total forest area in 80 reporting countries.[24] Remote sensing data can uncover affected areas and targeted measures can be initiated. Studies show that remote sensing can achieve a detection accuracy of 80 to 95 per cent for pest and disease outbreaks over very large areas of forest.[25] Without the information from space, pests and diseases are likely to be detected at a late stage and therefore represent a threat to forests and the timber production.

Precision forestry

The widely acknowledged importance of natural forests for mitigating climate change means timber, poles and wood fuel will have to increasingly come from other sources. Forest plantations will prove essential in meeting current and future needs. These can take the form of either intensively managed commercial plantations or widespread planting by small farmers.[26]

Precision forestry in Scandinavian countries, among others, has proven to be a sustainable and profitable solution that takes environmental protection measures and climate change mitigation goals into account. Of the estimated 3.8 million hectares of commercial plantations in Africa, the most successful ventures have generally been those where the private sector has been encouraged.


Image Unsplash.com

To attract further investment, good and fair governance with policies that recognise the land rights of people and communities is important, especially for the long-term business of tree planting.[27]

Earth observation technology can improve plantation management significantly.

Site-specific management such as fertilisation and drainage to improve the cost-effectiveness of interventions are often based on data from soil sensors. Studies in South Africa show that soil preparation and fertilisation targeted to specific sites can improve forest yield by between 10 and 50 per cent.

12.5

mil USD

Yield improvement through precision forestry – potential analysis ready data benefit

Precision forestry as practiced in plantations has great growth potential in Africa. Our calculations assume growth from 3.8 mil ha currently to 8 mil ha by 2030 and 5 per cent yield improvement through Earth observation.

Forest health has become an increasingly important concept for plantation forestry. Various damaging agents that are expected to become more widespread with global warming need the quick attention of forest managers. Insects, disease outbreaks, alien species invasion - if not properly monitored - could have devastating effects on the commercial forestry sector. Forest protection strategies typically depend on timely detection. Remote sensing has gained wide acceptance and plays a growing role in this.

The freely accessible DE Africa platform with its built-in analysis capabilities has the potential to significantly improve plantation yield, with benefits such as higher forest productivity, lower operational costs, and improved planning effectiveness.

While the quickest gains can typically be made through better planning and cost reduction, the largest potential driver of long-term value creation is through improved tree growth. By applying a range of precision tools and approaches and improving correlation through increased data collection and better data analysis, companies can make better overall decisions.

Forest ecosystems biodiversity

The conservation of forests and their biodiversity must be one of the main focus points

Biodiversity conservation

Biodiversity is more than simply the collection of plants and animals on earth; it is about local ecosystems and promoting healthy conditions for organisms to thrive. In the context of climate change, biodiversity and its conservation has attracted renewed attention and is now regarded as a common concern of mankind. For Africa, conservation efforts will not only support biodiversity, but will also contribute to poverty alleviation and socioeconomic development.

Image ESA

Biodiversity invigorates the tourism industry, a sector that accounted for about 7 per cent of Africa's gross domestic product (GDP) in 2019, capacity building, establishing participatory contributing $169 billion to its economy.[28] Substantial work has been undertaken by African countries to protect their natural assets such as forest management processes, enforcing conservation regulations like anti-poaching measures and establishing protection areas. However, given the scale of the challenges, efforts need to be intensified to reverse the current trends of biodiversity loss.[29]

Wildlife protection

Forests are important habitats providing shelter for animals, plants and humans. However, they are often misused as hunting grounds. Poaching and illegal trafficking of animals is still considered one of the leading drivers of biodiversity loss. It is an environmental crime that rips species from their habitat and endangers the future survival of both wildlife and ecosystems. As an example, thousands of gorillas, considered a delicacy in central Africa, are poached from rain forests every year. In 2021, the African forest elephant was classified as "critically endangered" by the International Union for the Conservation of Nature (IUCN). Over the last 31 years its population has fallen by 86 per cent, mostly as a result of intensified poaching for its coveted pink-tinted ivory. It will take several decades for the original population size to recover because of its slow reproductive rates.[30]

Around 30% of Earth's land surface is covered by forest. It is estimated that this precious forest is home to around 80% of biodiversity on land. The Biomass mission will measure forest biomass, height and disturbance to address gaps in our knowledge of the carbon cycle.

Forest fires

Forest fires - natural or man-made, controlled or uncontrolled - have a profound impact on biodiversity and the forest ecosystem. Traditional techniques such as slash-and-burn for shifting cultivation are still common practice in Africa. Farmers cut down some of the vegetation and set fire to the rest to clear the land for growing crops. It has the advantage of killing pests and diseases while providing nutrients for future crops and rangelands. However, this technique is controversial as it can lead to deforestation, soil erosion, and loss of animal life.

Loss of forest also impacts the water cycle, of which forests are an integral part. Forests store water in the soil, filter water, supply clean water and recharge the ground water table, whereas agricultural lands have more overland flows that lead to erosion.

Indigenous population

Indigenous people successfully demonstrate how effectively they control the use of natural resources through worship, traditional knowledge and moral constraints. Observing and tracking ecosystems is a vital part of their stewardship of the land and their efforts to foster coexistence between humans and wildlife. Collaborating with Indigenous communities helps to conserve biodiversity as well as supporting Indigenous rights to land, sustainable resource use and well-being. A better understanding of biodiversity status, trends and challenges will increase our awareness and respect for nature.

Satellites can be our eyes in the sky for this. They can image remote areas that are inaccessible for geographic or political reasons. It is a non-invasive technology capable of tracking moving species across broad geographic territories and borders. In addition, frequent and regular monitoring with satellites enables users to detect disturbances, such as forest fires, as they happen. Forest rangers can immediately react and start counteractive measures. A platform like DE Africa with its free and open data policy brings additional advantages in examining how biodiversity is being affected. The existence of several decades of satellite data make it possible to provide transparent and uniform parameters and to quantify changes in habitats over many years. Monitoring land cover change within protected areas or parks can reveal hotspots that should be investigated based on suggestions of human activity and patterns of movement within and around the park. Offering access to comparable information in various parts of the continent, DE Africa could stimulate a lively, steady and transparent exchange of data and experience. This in turn helps to develop a local conservation strategy combined with local action in support of biodiversity.

According to FAO about 8 million ha of African forests are affected by forest fires per year. SERVIR and NASA estimate that up to 20 per cent of forest fire impacts could be reduced by improved fire management supported by EO data.[31] Our formula envisages a potential for forest fire reduction of 10 per cent assuming an impact from EO of 10 per cent. The benefit of ARD is again the 50 per cent share of this.

We find the loss of biodiversity because of forest fires must be expressed as loss in biodiversity value and as monetizable loss in carbon sequestration power.

There are various approaches in literature to value biodiversity. We took a value expressed by the Boston Consulting Group with $1,250/ha as factor for our formula.[32] We consequently got $50 million as an ARD benefit for reduced forest fire impact shown as biodiversity value.

50

mil USD

Reduced loss of biodiversity through forest fires – potential analysis ready data benefit

(based on Biodiversity value)

Hot spot areas of forest fires can be identified on satellite images. Loss of forest fire can be reduced with improved administrative attention and regulation. Analysis ready data savings up to $50 mil.

Reduced forest fires also implicate an increased carbon sequestration power and can directly lead to compensation of $6,060 per ha (see deforestation formula). We used the same approach as for reduced forest fire -biodiversity value- taking a 10 per cent reduction potential and assuming an impact from EO of 10 per cent. With 50 per cent assigned to ARD the gain in carbon compensation would yield into $242 million.

242

mil USD

Reduced loss of biodiversity through forest fires - potential analysis ready data benefit

(based on carbon value)

Information campaigns in Africa have shown encouraging results in fighting forest fire losses. Potential carbon value of forest fire losses equals $242 mil.

CASE STUDY

New Earth observation technology benefits African Parks' anti-poaching efforts in Garamba National Park

African Parks, a conservation NGO which manages national parks and protected areas across Africa, faces unique challenges in Garamba National Park, which it has managed in partnership with Democratic Republic of Congo's Institut Congolais pour la Conservation de la Nature (ICCN) since 2005. Stemming primarily from four different sources, an escalation in poaching increasingly threatens the park's extraordinary wildlife. Of particular concern is poaching for elephant ivory, which has dramatically reduced populations in recent years.

In 2015, the potential role of satellite Earth observation to contribute valuable anti-poaching information led African Parks to collaborate with the European Space Agency in the EO4Wildlife project. The objective was to evaluate how new satellite technology including data from Sentinel-1 and 2 could contribute to African Parks monitoring of the park and planning and implementation of anti-poaching efforts within its vast area.

Technical consultants from Hatfield Consultants, Airbus, and Pink Matter Solutions worked with African Parks to provide up-to-date baseline land cover and habitat maps, savannah fire detection and fire scar mapping, and ongoing change detection services. These helped to provide valuable information for planning the deployment of ranger patrols and to contribute as a force multiplier. Monitoring of fires and land cover change within the park revealed areas that should be investigated based on suggestions of human activity and patterns of movement within and around the park.

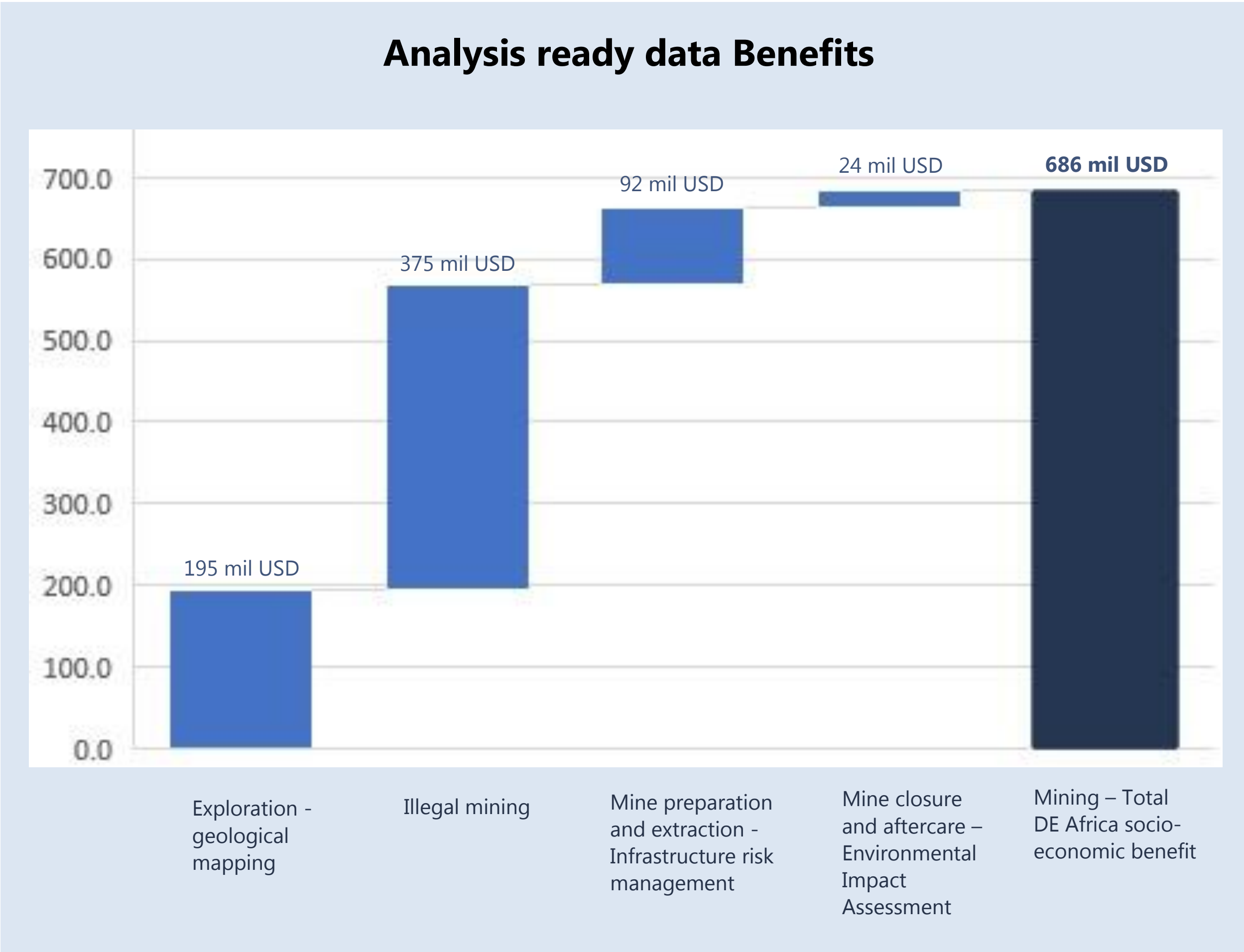
Significant efforts by African Parks have resulted in greatly increased levels of aerial surveillance, the strengthening and re-equipping of the ranger force, development of necessary park infrastructure and a strategic emphasis on ranger mobility, rapid deployment capability and use of intelligence information. For the first time in many years elephant poaching has significantly decreased to 2 carcasses in 2018 and 8 carcasses in 2019. The current status of the elephant population remains unclear but low in recent years (1,200 in 2017). The population of critically endangered Kordofan giraffe is growing but remains critically low (62 individuals). Further strengthening of management measures in the next years will be important, including the designation of a formal buffer zone, implementation of management plans, as well as the continued addressing of potential threats from outside the site.

Source: New Earth Observation Technology benefits African Parks' Anti-poaching efforts in Garamba National Park

Mining

Subsectors:

- Exploration
- Mine preparation and extraction
- Illegal mining
- Mine closure and rehabilitation



Source: Team Analysis

Mineral exploration

Exploring Africa's geological resources with satellite data

Exploration of natural resources

Africa hosts about 30 per cent of the world's total mineral reserves. The dominant eight commodities in sub-Saharan Africa are gold, copper, iron, limestone, uranium, diamond, bauxite and petroleum, which account for 405 mines and occupy 85 per cent of the 3,055 km^2 total mine-areal extent. The mining and quarrying of 60 different types of minerals accounts for around 20 per cent of Africa's economic activity.

Still, expenditure on exploration activity in Africa has remained below \$5 per km^2 relative to an average of \$65 per km^2 in Canada, Australia and Latin America. The main reasons for an underdeveloped mining sector are a lack of investment power, technology and a skilled work force, in addition to political instability in certain regions.

However, the industry sector is striving to modernise and aims to fulfil sustainable development goals. Modernisation is also focused on areas such as risk management, health and safety, environmental performance, stakeholder engagement and ethical business practices.

The first stage in the life cycle of a new mine is geological mapping together with mineral exploration, followed by mine-site design and planning, construction, production and mine closure and aftercare.

In the last two decades, significant effort has been undertaken in Africa to understand the geology, the current tectonic setup, the distribution of natural resources and the associated natural hazards. However, many regions in Africa still lack geoscientific observations and are geologically unexplored.[33]

The purpose of exploration is to collect various information on a certain area to project the mineral composition. Earth observation has considerable potential to maximise efficiency in this phase of the mining life cycle as an indispensable tool for geological mapping, especially in regions with limited infrastructure and harsh environmental conditions.

Earth surface materials can be detected by analysing the reflectance of the surface, most suitable in many narrow contiguous spectral bands across the electromagnetic spectrum - so called hyperspectral imaging. Data derived from satellites such as landforms, structural features, soils, vegetation types, drainage patterns and gravitational fields add valuable information to the whole picture of geological investigation.[34]

With its analytical capability DE Africa can offer all the required analyses in one system to investigate an area of geological interest. The system allows mining and exploration companies to carry out very efficient screening of surface geology in a relatively short time. It helps to identify anomalies in the geological structure such as fault fractures and rifts that may be indicative of mineral deposition.

The Open Data Cube (ODC) data fusion functionality can be exploited by combining radar and multispectral imagery. Results from such an image fusion accommodate the radar-based detection of sub-surface structures while enhancing the interpretation of linear structures based on multispectral analysis.
The main benefit however is the transparency of information provided by the DE Africa platform. Relevant information, analyses and results can be openly shared with all stakeholders involved - the local communities, mining authorities and decision makers, and the surveying and mining industry.

The annual African mineral mining exploration budget is estimated with a total of $1.3 billion.[35] As a comparison, about a third of Cape Verde's GDP. As suggested by experts we applied a 30 per cent cost factor for EO benefit calculation, of which 50 per cent is awarded to ARD. The total benefit from ARD would therefore amount to $195 million per year.

195

mil USD

Geological exploration & mapping – potential analysis ready data benefit

In 2018 exploration budgets for non-ferrous metals in Africa totaled around $1.3 bn USD. From a 30 per cent benefit from Earth observation, we calculated a 50 per cent benefit for DE Africa's analysis ready data – resulting in $195 mil USD.

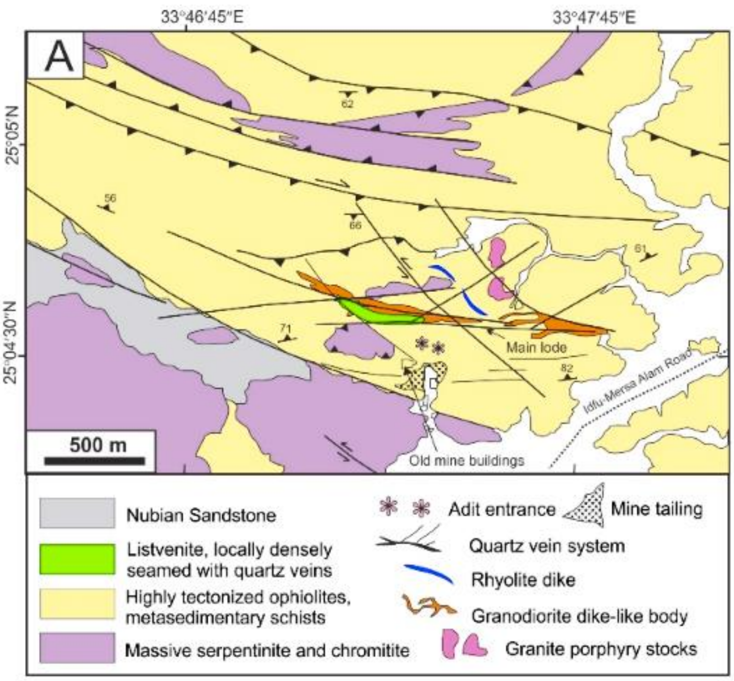


Figure 4. Detailed geological map of selected gold occurrences/deposits in the Barrmaiya (Egypt deposit area). The Barramiya gold deposit is expressed in auriferous quartz and quartz–carbonate veins.[36]

The map (Figure 4) is based on remote sensing data. It is used for mineral exploration purposes. In this case gold exploration in Egypt. (See also case study on the next page).

CASE STUDY

Earth observation for mineral exploration in Egypt

Remote sensing satellite imagery has a high capability of providing a synoptic view of geological structures, alteration zones and lithological units in metallogenic provinces. Typically, application of multi-sensor satellite imagery can be considered as a cost-efficient exploration strategy for prospecting orogenic gold mineralization in transpression and transtension zones, which are located in harsh regions around the world.

Synthetic Aperture Radar (SAR) is an active microwave remote sensing sensor that transmits and detects radiation with wavelengths between 2.0 and 100 cm. Longer wavelengths (L-band) can enhance the depth of penetration of radar signals through the Earth's surface and therefore provide valuable information for structural geology mapping related to orogenic gold mineralisation. The C-band and L-band SAR data, i.e., the Sentinel-1 and Phased Array type L-band Synthetic Aperture Radar (PALSAR) data, have successfully promoted mapping of structural lineaments that are associated with hydrothermal gold mineralisation in tropical, arid, and semi-arid environments.

The Central Eastern Desert of Egypt is built up mainly of tectonized ophiolites, metasedimentary rock successions, granitoid intrusions, and subordinate volcanic rocks and molasse sediments. Gold–quartz veins cutting mainly through the metavolcanic–metasedimentary rock successions or in small granitic intrusions were intensely mined out and produced gold during ancient times.

Sentinel-1, PALSAR, ASTER, and Sentinel-2 data are analysed to decode the distribution of geological structures and hydrothermal alteration zones associated with gold–quartz veins in Barramiya–Mueilha. This contribution comes in response to the present-day surge in gold exploration in the Eastern Desert of Egypt and other parts of the Nubian Shield (i.e., Sudan, Arabia, Eritrea, and Ethiopia).

The main objectives of this project are to:

- map the major lineaments, curvilinear structures, and intersections in the area using Sentinel-1 and PALSAR datasets to identify the alteration zones and lithological units
- integrate field, structural analysis, and multi-sensor satellite imagery for an ample understanding of the setting and structural controls of gold occurrences
- inaugurate a cost-effective multi-sensor satellite imagery approach for orogenic gold in transpression and transtension zones in the Egyptian Eastern Desert and analogous areas.

Source: Orogenic Gold in Transpression and Transtension Zones: Field and Remote Sensing Studies of the Barramiya – Mueilha Sector, Egypt, Basem Zoheir, Mohamed Abd El-Wahed, Amin Beiranvand Pour, Amr Abdelnasser

Mine preparation & extraction

Satellite data is a commonly used information source in modern mining

Permitting and preparation

Mining in Africa faces challenges such as inadequate access to capital and insufficient productivity, a lack of skilled labor, poor infrastructure, reputational risk, social responsibility, commodity prices and currency fluctuations and widespread fraud and corruption.[37]

To improve issues in the mining sector the African Union and the Economic Commission for Africa came up with a vision aiming to standardise Africa's mineral policy. The vision includes valuing environmental resources, promoting local developments, encouraging regional cooperation and harmonisation. All these goals ask for reporting transparency for all involved stakeholders. Remote sensing is the only efficient method to measure conditions on the ground and contributes to an improved and more accurate reporting system which supports the standardisation of the mining sector in Africa.

In general, before a mine can go into operation, a number of licenses and permits must be obtained. Baseline assessments of the environment, the extent of planned ground shifting and the impact on the population and air quality, etc. in the area need to be addressed. A site layout design must be submitted. The mine can only start operating after all the necessary permits have been awarded.

The chances of receiving a mining license to operate a new site could be considerably increased with better geo-information, if advanced techniques, such as EO as part of 'Digital Effectiveness' are applied. Earth observation or ARD are typically used to establish all needed baseline assessment maps for mine permits: land cover classification, elevation, water quality, vegetation cover, air quality, infrastructure and population density in the region. With a freely accessible data source in the form of DE Africa's ODC, everybody involved will benefit from simplified access to the required information.

Infrastructure monitoring and planning

An operating mine undergoes many phases of change and planning these changes is essential to keep operation smooth and efficient. A complete understanding of the site and its access points is required. Regular satellite imagery providing an overview of the current situation can be used as a planning base for roads, dams, buildings and stockpile placement, energy supply and emergency routes.

Poor mining practices in the past have created a bad reputation for the sector in some developing countries. There is significant pressure on governments and their agencies to ensure that regulations for environment, health and safety are adhered to and that a mine is monitored and controlled throughout the cycle.

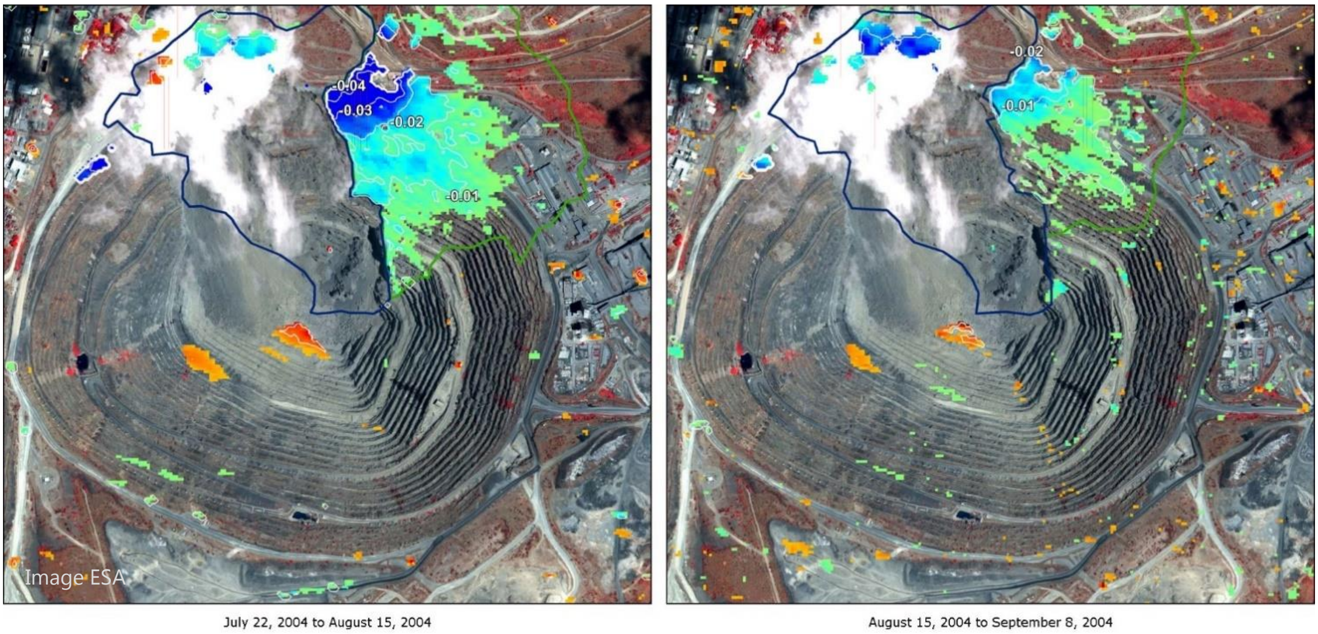


Figure 5: 2 months of pit movement - monitoring of ground subsidence occurring around Rio Tinto's Palabora mine in South Africa using Interferometric Synthetic Aperture Radar.

Infrastructure represents as much as 80 per cent of a mine's cost, so it should be a key consideration in the optimisation process. Earth observation helps to plan more accurately and more efficiently, saving both time and costs. The EO applications most often used for infrastructure planning and monitoring in the mining sector concern roads, stockpiles, buildings, water catchments, dams and settlements. Safety and pollution (ground, water and air) can also be monitored with the help of satellite information.

The volume of stockpiles in mines can be estimated with approx. 10 – 20 per cent accuracy. For detecting bulk volume changes greater than 50 m^3, low resolution synthetic aperture radar imagery (5 x 20 m) of the Sentinel-1 constellation is sufficient.

In the context of mitigating risks in mines, EO can be of immense support. According to experts the 408 largest commercially operated mines in Africa spend an average of $1.5 million per year on infrastructure risk management. The potential benefit from EO for infrastructure risk mitigation including the monitoring of industrial infrastructure, slope stability, surface motion over time, etc. is estimated at 30 per cent. Fifty per cent of the EO benefit was attributed to the impact of ARD which yielded into a total of $92 million savings.

92
mil USD

Improving Mining Infrastructure Risk Management – potential analysis ready data benefit

On the basis of 408 large commercially operated mines in Africa and their risk management budgets we calculated an analysis ready data benefit of $92 mil.

Interferometric Synthetic Aperture Radar (InSAR) is a technique for mapping ground deformation using radar images of the Earth's surface that are collected from orbiting satellites. This type of measurement allows users to monitor the stability of tailing dams, roads, bridges and the surrounding structures reliably and cost-effectively. The accuracy of such measurements is in the millimeter range.

Its ability to detect the smallest surface movements, which can be an indicator of underground stabilities, makes EO indispensable for security. Digital Earth Africa's analysis ready data including the Sentinel-1 data allows for a quick response in case of an emergency because pre-processed data means enormous time savings in a situation where a timely response is critical.

Tailings dam monitoring

Water catchments are a frequent feature of mining sites. Monitoring surface height, water quality and the condition of a dam, if in place, is necessary for safety.

Water quality issues are detectable with satellite information, too. In the Republic of Congo, for instance, where an estimated 15.9kg of mercury is released annually, gold mining is the "main cause of water, fish and public health problems" according to the local authorities.[38] The detection of such contaminations with the support of ARD can lead to adequate actions and reduce the danger for the affected population and environment.

Illegal mining

Earth observation in support of transparency in the mining sector

Artisanal mining

In many resource-rich developing countries, artisanal and small-scale mining (ASM) is an important source of revenue for people living in rural regions. It is largely informal and often illegal, and is associated with low health, safety and environmental standards. Nevertheless, it is a major source of mineral resources production in the world. It accounts for 20 per cent of the global supply of gold, 80 per cent of the sapphire supply, 25 per cent of the diamond supply and 25 per cent of tin extraction. It also provides essential minerals used in ubiquitous electronic products such as phones or laptops.

In sub-Saharan Africa, almost 10 million people in 23 countries are directly engaged in ASM - 2 million in the Democratic Republic of the Congo and between 1 and 1.5 million each in Sudan, Ghana and Tanzania. Sadly, a large percentage are children. Artisanal and small-scale mining typically takes place in inaccessible locations with a general lack of government support.[39]

A study of accidents and injuries in Ghana found that fatality rates are 90 times higher than in large-scale mines.[40] Artisanal miners sometimes enter abandoned shafts, travelling as far as 4km underground, where they live for several days at a time, risking their lives for almost negligible earnings. In addition, environmental issues such as improper handling of waste and heavy metals, contamination of water bodies, abandoned excavated pits and a lack of reclamation are common in areas where such mining is carried out.

Mining of gems, gold and sapphires at Ilakaka Ihosy District, Ihorombe Region, Madagascar

Governance and control, either from the mining industry or regulative authorities, are absent. A better overview and greater transparency about ASM is essential for the development of effective policies and reform. This knowledge needs to form the basis of national policy and institutional improvements to achieve change on the ground, but also to raise awareness at the international level. Reforms including increased local participation in decision making, education and training, adoption of improved technology, strengthening regulatory institutions, the enforcement of legislation and regulation, and the provision of technical support could help improve socioeconomic and environmental performance in ASM

Southeast Namibia and the western edge of the Kalahari Desert. Copernicus Sentinel-2 mission.

Illegal mining and trade

A system like DE Africa offers actionable insights on illegal mining activities outside mining concessions. Analysis based on Sentinel-1 and Sentinel-2 data allows the user to localise ASM sites, estimate their size and shape and go back in time and find out when activities started.

For on-the-ground regulation, real-time information about mine activities can help streamline the deployment of limited resources. For policy makers this data can help direct future policy and clarify whether past interventions were useful. On a global level, this kind of international cooperation facilitated through DE Africa can accelerate progress on UN Sustainable Development Goals.

Illegal mining and the illicit trafficking of precious metals constitute a multi-billion-dollar transnational criminal industry which results in the loss of taxes, revenue, capital expenditure, exports, foreign exchange earnings and procurement generated by legal mining.

The African Development Bank estimated Africa’s losses because of illegal mining and illicit trade of minerals at $15 billion, more than the continents annual diamond export value ($12.8 billion in 2018).[41] If EO could reduce illegal mining through the detection of mining sites and reduce illicit trade activities by 5 per cent and ARD be to make up 50 per cent of that, $375 million could potentially be saved.

375

mil USD

Regulate illegal mining & trade – potential analysis ready data benefit

According to the African Development Bank, $15 bn is annually lost through the illegal mineral trade. Analysis ready data could potentially reduce this loss by $375 mil.

$375 million savings would pay the annual salary of more than 200,000 mine workers in some African countries.[42]

CASE STUDY

Ghana, illicit mining

In recent times, the Ghanaian Government has been working in collaboration with the Ghana National Artisanal and Small-Scale Miners Association to coordinate scientific testing of mercury-free alternatives to traditional gold panning.

The success of these initiatives depends on access to real-time information on mining operations. In close collaboration with the national government, SERVIR-Amazonia and SERVIR-West Africa are using Earth observation and geospatial technologies to provide actionable insights on illegal gold mining activities to support forest conservation. Information on the location of illegal mining activities outside mining concessions and in proximity to target areas is provided to the government.

They developed a remote sensing methodology to identify and quantify the extent of illicit mining activities in the high forest zone of Ghana, where these activities are rampant. The analysis, based on Sentinel-1 and Sentinel-2 data, creates annual composite maps of illicit mining area footprints. These maps are used for monitoring degraded mined sites and for planning land restoration activities.

Source: Reducing illegal gold mining in the tropical forests of Ghana and Peru: A forthcoming collaboration across the Atlantic

CASE STUDY

ASMSpotter – detecting artisanal and small-scale gold mining (ASGM)

Artisanal and small-scale gold mining (ASGM) is associated with low environmental and work safety standards. It has an estimated market value of $14bn. ASGM sites are

- located in more than 80 developing countries
- affecting the lives of 10 to 20 million miners and their families
- responsible for large amounts of deforestation
- accounting for 10 per cent of global gold production.

Obtaining timely data on the location and extent of Artisanal and small-scale mining (ASM) in their respective region of interest is important for governmental agencies, NGOs and researchers. It would enable them to enforce concession rights and labor legislation or to research migration patterns. As this requires vast areas to be monitored, satellite imagery is best suitable for the task.

ASMSpotter is a tool developed by the company Dida which uses AI algorithms to analyse satellite images from the Copernicus satellite Sentinel-2 and from Planet, a commercial satellite data provider. It automatically identifies ASM sites - to 80-90 per cent accuracy- and can help to monitor change over time using time-lapse series. The software helps public authorities and industry (large-scale mines, buyers, etc.) to effectively and continuously identify and monitor ASM over large geographic regions by the application of Machine Learning and Computer Vision algorithms to satellite imagery.

For the kickstart activity, ASMSpotter relied mainly on high-resolution multispectral images provided by Planet at a resolution of approximately 3m per pixel and daily revisit. Dida is currently working on achieving the same performance on the open-access, but lower-resolution data from the Sentinel-2 satellites. In terms of applicability, the segmentation masks computed on the basis of Sentinel-2 images resolve ASM sites similarly well compared to those using PlanetScope, although they reduce the running costs of ASMSpotter by a margin.

Source: Artisanal and Small Mine Detection
https://www.levinsources.com/knowledge-centre/insights/asmspotter-microsoft-ai-for-earth-prize

Mine closure & aftercare

Rehabilitation of closed and abandoned mines

Rehabilitation

Mining is an inherently invasive process which requires large quantities of energy and water, often in remote and arid areas, and generates a large amount of potentially hazardous waste. Each stage of the mining process has the potential to inflict environmental damage to a varying extent. The environmental and health impacts of mining on surrounding communities have been a major source of concern for governments, the general public and stakeholder organisations. The spotlight on the sector has increased pressure to minimise the damage of mining operations including land cover change, waste rock and tailing disposal, dust and noise, and water contamination, water use and re-use. New technologies currently being tested seek to reduce the mining footprint and use required resources more efficiently.


Image Unsplash.com

Revegetation is a critical step in mine site rehabilitation.

The mining industry must demonstrate that the area of the mining site has been rehabilitated and returned to an agreed endpoint after the mine's closure. A baseline assessment shows the site before mine operation started and is the goal to reach after rehabilitation. Optical satellite imagery allows for baseline assessment and for continuous monitoring of the rehabilitation steps and the consequent evolution of the revegetation around and on the mining site.

Waste and pollution

Waste treatment and disposal phases during a mine closure are other potential monitoring applications for EO. The assessment of water quality is vital not only during mining operation but also during aftercare. Spatial and temporal rehabilitation information can be provided through satellite imagery.

Rainwater erosion and surface runoff in mining areas lead to pollutant diffusion and consequently to groundwater pollution which can put human life at risk. The risks and paths of pollutant diffusion caused by surface runoff can be monitored and simulated through satellite data. Once the circle of pollution in groundwater is understood, counteractions can be applied.

Specifically, the use of mercury by artisanal gold miners has led to serious air and water pollution in African countries such as DR of Congo, Ghana, Kenya, Mozambique, Sudan, Tanzania, and Zimbabwe. One or two grams of metallic mercury are released into the environment for every gram of gold produced using the amalgamation process.[43]

Air pollution is another important aspect of mining activity. Gas concentrations such as NO_2 and SO_2 are indicators of the overall pollution of a mining area. Their spatial distribution and temporal trends can be monitored by the Copernicus satellite Sentinel-5 and Aura satellite from NASA.

It is complex to estimate the benefit of ARD on the environmental impact of mining in Africa. We calculated the annual total foreign investments in the mining sector at $48 billion. Foreign investment accounts for the bulk of investment in Africa's mining sector. Investments in environmental mining issues constitute between 1.5 and 6 per cent depending on world regions.[44] Taking a conservative approach, we calculated environmental investments with 2 per cent of total investments of mine operations and end up with $960 million. Assuming environmental damage can be reduced by smart planning before the start of a mining operations or monitoring of site rehabilitation a 5per cent EO cost-benefit is estimated, of which 50 per cent can be attributed to ARD benefit.[45] This results in a total of $24 million benefit.

24
mil USD

Mine Closure & Aftercare – potential analysis ready data benefit

From the modeled environmental budgets of mining companies, we applied a cost-benefit factor for Earth observation of 5 per cent of which half is assigned to analysis ready data and yields into $24 mil USD benefit for mine rehabilitation.

According to The Nature Conservancy it costs approximately $1.50 to plant a tree.[46] The $24 million benefit for mine rehabilitation from ARD could theoretically allow for the reforestation of 16 million trees per year in Africa. This corresponds to 144 km^2 or one and a half times the size of the city of Barcelona in Spain.

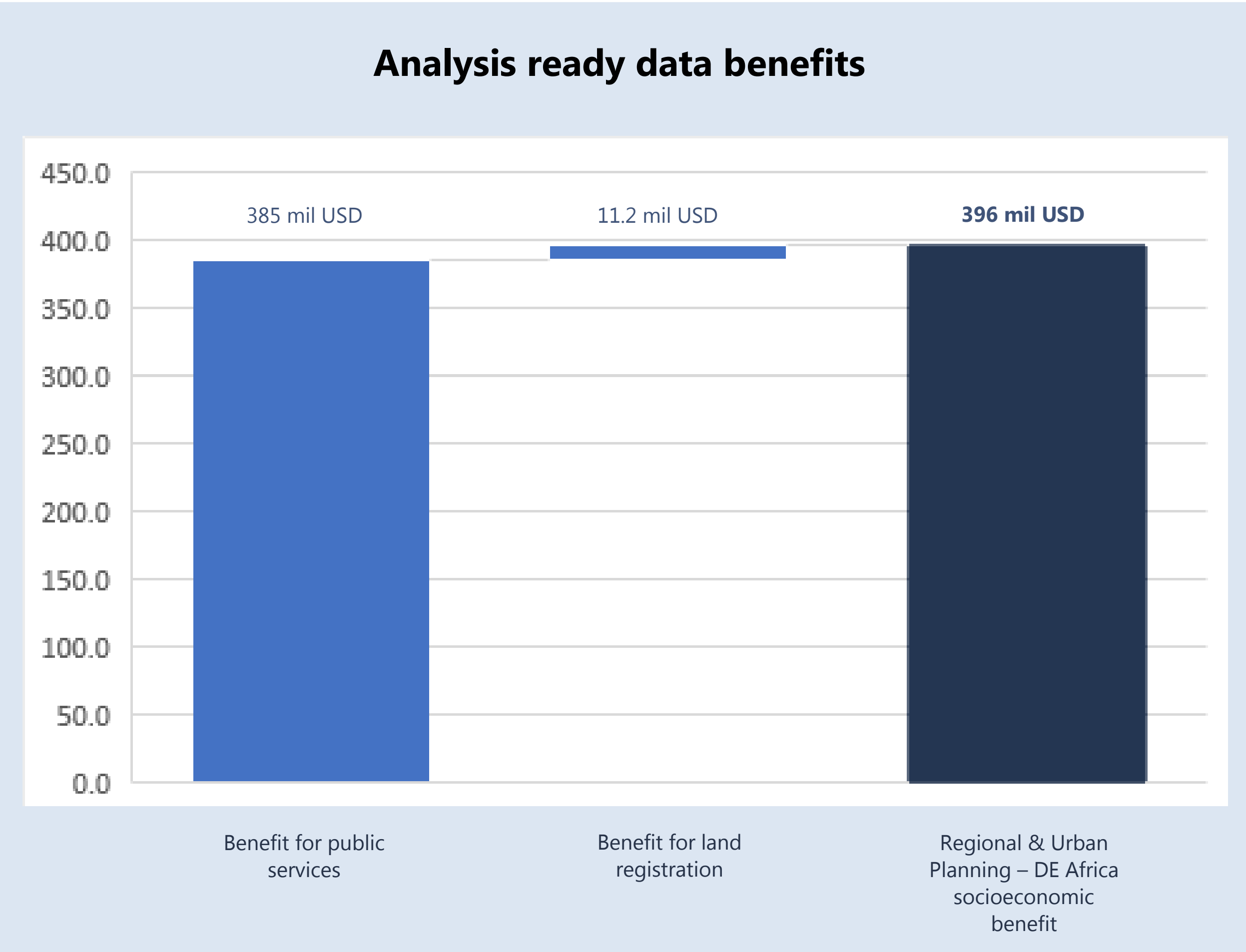
From a governance perspective, there is also room to improve how mining companies exit an operation in respect to their reporting obligations. In many African jurisdictions the laws governing mine rehabilitation and closure are poorly implemented. Sound planning and management of mining activities from the start can avoid high rehabilitation costs, thereby preserving public and private capital.

Digital Earth Africa's ODC with its ARD concept facilitates the ecological monitoring of mining areas during operation and helps to monitor the progress of rehabilitation to ensure that closed mines are transformed back to the site's original state.

Regional & urban planning

Subsectors:

- Benefit for land registration
- Benefit for infrastructure planning and public services



Source: Team Analysis

Land registration & settlements

Earth observation as an unbiased tool for use in drawing land borders and identifying the extent of settlements

Land registration

The African Centre for Economic Transformation (ACET) estimates that in sub-Saharan Africa, 90 - 95 per cent of land falls under a customary tenure system, with largely communal and unregistered ownership.[47] Cadastral inefficiencies restrict GDP growth by an estimated 1.3 per cent each year according to McKinsey studies.[48]

Investing in secure tenure and land administration is beneficial for a nation. Reforms to land rights and land use regulations can significantly reduce land costs – these are responsible for up to 80 per cent of housing costs in developing cities. ACET estimates that e.g., in Uganda land disputes represent about half of the total caseload, leading to an estimated 5 -11 per cent loss in agricultural production in the country.

Secure tenure and accurate up-to-date land records enable the imposition of value-based property taxes, which can contribute significantly to local government revenues and services. This source of revenue is commonly under-utilised in low income countries, accounting for 0.6 per cent of GDP versus 2.2 per cent for industrialised countries.[49]

The use of medium to high resolution imagery results in increased and efficient data throughput for land registration projects, area prioritisation for ground survey, and efficient maintenance of cadastral maps in digital format. Even drone images for highest possible resolution can be uploaded to the platform and used on DE Africa's system for analysis that requires higher resolution imagery.

Using participatory land registration and community mapping approaches, EO imagery helps to reassert Indigenous people's rights, advance local claims to land titles, build community awareness, support legal claims over natural resources and resolve conflicts already during the mapping process.

To calculate the potential ARD benefit for Land registration in Africa we take the World Bank estimate of $450 million for land registration investments as baseline.[50] We rated the EO benefit at 5 per cent and the ARD benefit at 50 per cent of this. This is a conservative approach which results in a benefit of $11.2 million per year. In comparison, if value-based property taxes in Africa were to increase by 0.1 per cent because of stricter land registration applications, more than $2 billion in government revenues could be collected.

11.2

mil USD

Land Registration – potential analysis ready data benefit

The World Bank estimates 450 mil USD annual investment for land registration for Africa. We calculated a 5 per cent benefit from Earth observation, 50 per cent of which would come from analysis ready data.

Settlements

Africa's population is growing rapidly and so is the flow to urban centers. In many developing countries, municipal records are often unable to keep pace with the high rate of urbanisation and informal urban development. Urban density is a measure to characterise spatial urban pattern and the structure of cities.

Nairobi, Kenya.

A critical requirement in urban planning is an understanding of urban extent and density conditions to identify priorities for investment. Earth observation has proven useful for population studies and for estimating population size between censuses.

Earth observation provides information for urban planning by mapping land classes, urban extent, built up area, and measuring population density. It is a powerful tool for governments, policy makers, researchers and urban planners to obtain a better understanding of the drivers, dynamics and impact of urbanisation.

NASA reports that progress in urban mapping based on remote sensing is contributing to the creation of more accurate and detailed maps of cities, enabling an unprecedented understanding of the dynamics of urban growth and sprawl.[51]

Regular acquisition of images and ARD applications have great value for tracking these changes. Current EO applications for urban planning are dominated by Asian (36 per cent), North American (33 per cent), and European countries (29 per cent) with few applications in Africa (2 per cent), where it is probably needed the most, given the rapid rates of urbanisation.[52]

It is worth noting that urban planning is the biggest income creator for Africa's growing commercial Geographic Information System (GIS) mapping sector. Digital Earth Africa could make this sector a big beneficiary offering ease of use of decision ready products.

Rapidly growing populations and uncontrolled urbanisation often results in informal settlements. Municipal records struggle to keep pace with fast developments. According to the UN Slum Almanac, almost 60 per cent of the urban population in sub-Saharan Africa currently live in slums with unstable urban infrastructure and inadequate public services.[53] Issues that need to be addressed in these areas include poor living conditions, drinking water quality and availability, noise, air pollution, waste disposal problems and traffic congestion.

Spatial data on deprived areas in cities is typically limited and is often omitted in official statistics. However, such data is urgently required for monitoring, humanitarian response, health campaigns, and to support urban surveys and sampling. Digital Earth Africa is able to provide information about the location, size and growth of informal settlements including the time of settlement, spread, density of population and the presence of infrastructures. The platform offers spatial data concerning deprived areas in a standardised ready to use form that can easily be integrated with other existing data layers on vulnerability, pollution, health and statistics at local, regional and national scale to better understand local conditions, assets, and progress towards global and local development goals.

CASE STUDY

Rwanda Land Tenure Regularisation Program

The Rwanda Land Tenure Regularisation Programme (LTR) started as a pilot and was scaled up to a fully-fledged program. The purpose of the program was to enable the Government of Rwanda to register land and issue registered titles to every landholder and establish systems for maintenance of those titles.

The program was successfully completed in 2019 with a systematic land registration for the entire country including a digital archive of 11.4 million parcels of land, with 9.3 million of these parcels approved to titles and 7.2 million of them issued to rightful owners.

Rwanda is a compact country with high-density land occupation in fixed parcels that are easily identifiable from satellite and remote imagery. Defining the parcel involved demarcation of land through a participatory process of marking boundaries based on imagery of the area. This step included claimant, neighbors and village leaders. Each parcel was annotated and given a unique number to ensure consistency between satellite/aerial images and physical checking and to reduce potential land conflicts. This participatory approach made people feel empowered and there was a sense of ownership amongst the community.

Rwanda is the only country in Africa with an all–digital property register covering the entire country. Procedures for land registration and transfers have further been simplified with a web-based portal (Irembo), which also offers the prospect of generating real time performance reports for the operations.

The land and real estate market transactions are showing steady growth and leading to increased income streams that could support the cost recovery and financial sustainability. The project reached following goals:

- ✓ Established a formal system for regularising land ownership and identified and registered more than 10.3 million land parcels.
- ✓ Provided a legitimate cadaster of property ownership which will underpin long-term social stability.
- ✓ Drove down the cost per title to around $7 in Rwanda, an historic benchmark in land registration.
- ✓ Employed more than 110,000 people over the life of the project, 99 per cent of them hired from local communities.
- ✓ Ensured the rights of women and vulnerable groups were secured, 92 per cent of land certificates now include the name of a woman.

Source: Rwanda's Land Tenure Reform - Non-existent to Best Practice, Thierry Hoza Ngog, 2018
Rwanda LandTenure Regularization Case Study, Dr Polly Gillingham and Felicity Buckle, 2014

Infrastructure – public services and housing

Earth observation in support of sustainable development of rural and urban settlements

Sustainable cities

Africa's population is growing at approximately 2.5 per cent a year – more than twice as quickly as that of South Asia. Every two years, Africa's population grows by more than the entire population of South Africa. According to Organisation Economic Cooperation and Development (OECD) projections, Africa's cities will probably be home to another 1 billion people by 2050. [54]

Planners require information on land use and land cover to keep up with the fast-growing population. Such data is needed to select sites for functional needs, develop zoning regulations, prioritise resource allocation, monitor the state of the environment, and manage urban growth.

Image Unsplash.com

Urban growth has a demonstrable impact on land cover and land use, leading to increased motorised transport, higher energy consumption, loss of agricultural land, loss of biodiversity and an increase in water pollution. These changes pose severe threats to the realisation of urban sustainability and can ultimately contribute to climate change

Information based on medium-low resolution satellite imagery on rural and urban land-use change and spatial growth rates and direction can provide public planners with essential information about areas that require administrative attention, e.g., where they need to regulate construction and avoid encroachments on public land, or channel resources to create supporting infrastructure.

In sub-Saharan Africa only 58 per cent of the population has access to water services, 72 per cent is without basic sanitation. In fact, due to the growing urban population, the proportion of people with access to water mains or improved sanitation decreased in Eritrea, Malawi, Namibia, Nigeria, Rwanda, Sierra Leone, Zambia and Zimbabwe between 1990 and 2015. Electricity in Africa is available to 45 per cent, whereas only 18 per cent of households have internet access. The rural-urban gap in access to infrastructure services remains significant. Eighty-four per cent of urban dwellers have access to at least a basic source of drinking water, while only about 45 per cent of the rural population does. Seventy-five per cent of people living in cities have electricity, compared with only 25 per cent in rural areas.[55]

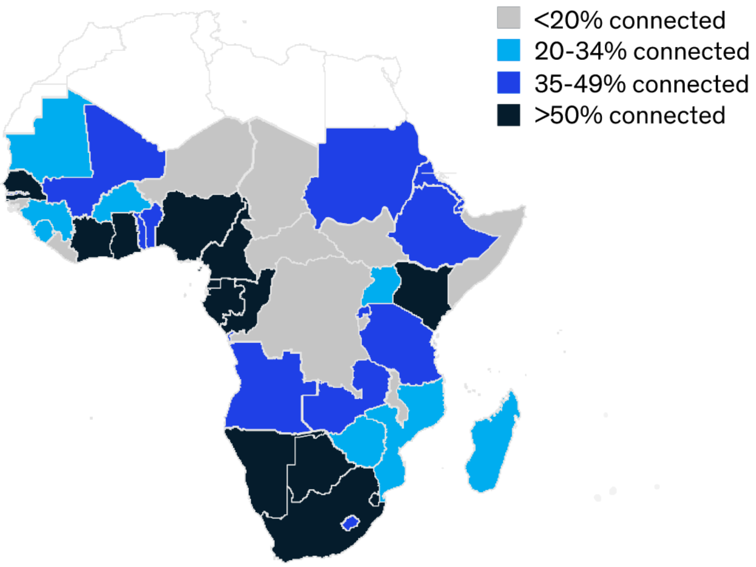


Figure 6: Electrification rate of Sub-Saharan Africa.

Successfully maintaining and establishing adequate services related to infrastructure, water supply, electricity, sanitation, sewage systems or poverty and education is essential for the overall development of a country. Farsighted governance and sustainable rural and urban development require a clear understanding of the current situation, the challenges and the dynamics.

According to a report by the Infrastructure Consortium for Africa (ICA), the average annual funding for infrastructure development in Africa between 2013 and 2017 was $77 billion. For our ARD benefit calculation we estimated a 1 per cent EO benefit, of which ARD accounts for 50 per cent, resulting in $385 million. These savings could build about 7,700 modest houses in an urban area in Kenya.

385

mil USD

Infrastructure development – potential analysis ready data benefit

If analysis ready data can support Africa's infrastructure development by 0.5 per cent, the annual benefit potential is $385 mil.

Literature suggests that land cover and land-use information from remote sensing data is a key component in the calibration of many urban growth models. The use of satellite imagery can support strategic planning and decision making for optimal site selection and route planning.

Furthermore, EO enables the calculation of physical parameters describing and quantifying the urban structure and pattern.

Satellite imagery is increasingly being used to map settlements and individual houses and model the number of residents based on the size and shape of the buildings they live in. This helps planners to establish adequate services related to the demand. Consistent, accurate and up-to-date ARD from DE Africa's data cube over urban and rural areas is an optimal basis for effective development planning and service provision.

Urban and regional planning

How Earth observation can support efforts to mitigate vulnerabilities – the environment and risk reduction

Urban planning

Inadequate infrastructure, unsafe housing, poor sanitation and underdeveloped health services can turn into disasters if natural hazards occur. Developing countries are disproportionally affected by natural hazards. The average share of people affected was 0.4 per cent in developed countries compared to 3.0 per cent in developing economies from 1980 to 2015.[56]

Rapid population growth, urbanisation, informal land occupation and poverty are among the key factors in increased exposure to risks and vulnerability. In many African countries, the rate of infrastructure development, regulatory policies and risk management capacity have not kept pace with the growing population and the effects of climate change.

Africa's urban population is the fastest growing in the world. Cities in sub-Saharan Africa are predicted to become increasingly concentrated risk areas, exposed to hazards such as heavy rains and floods, droughts, heat waves and storms.

Building resilience is one focus of urban and regional planning. By analysing EO data, planners can better understand the impact of past disasters and implement new, more resilient models.

Analysis ready data facilitates the tracking of environmental indicators by assessing green public spaces, waste sites, air quality, and urban temperatures. The degree of surface sealing is often used as a parameter for surface run-off and the subsequent risk of urban flooding. Green urban spaces can have an important cooling influence and reduce the urban heat island effect. Capabilities in determining and quantifying building stock, building types, roof materials and asphalt types can be fed into the assessment of climate-resilient housing.

Interferometric analysis – a methodology in land deformation analysis – can be used as an alert system for situational awareness to identify potential landslide activity in vulnerable areas.

Earth observation-based risk mapping and modelling not only benefit from enhancements in the quality of satellite data, but also from advances in computing power and improved modelling. Flood extent maps in combination with population exposure show detailed estimates of affected schools, hospitals, government buildings, etc. and the flood risk to the general population.

Regular monitoring using ARD can expose hot spots of change and vulnerability that may need special attention to reduce disaster risk and to plan adaptations to climate change. In addition, gained insights can feed into the decision making process at all government levels to establish a healthy environmental, resilient infrastructure, and social stability.

Appendix

Formulas used in this study – detailed explanations

AGRICULTURE – YIELD BENEFIT

363 bn USD x **3.6** % x **50** % x **28.4** % = **1.86** bn USD

Africa's estimated yield by 2030 = **$363 bn**

6% EO benefit for large farms
(20% share in Africa)

3% EO benefit for smallholder farmers
(80% share in Africa)

Average EO benefit => 20% of 6% + 80% of 3% = **3.6%**

50% ARD benefit

Median household income, representing investment-power needed to make optimal use of EO information, e.g., buy fertiliser, soil moisture sensors, machinery, etc.

We take Tunisia with its highest median household income in Africa as baseline and assign 80% investment power to it. All other African countries are given a percentage investment-power accordingly. Ethiopia with the lowest investment power gets a 2.4% rate assigned.
=> resulting in a median investment power for all African countries of = **28.4%**

Total ARD Benefit, $363 bn x 3.6% x 50% x 28.4% = $1.86 bn / year (by 2030)

AGRICULTURE – REDUCTION OF WATER USAGE

9.2 bn USD x **30** % x **5** % = **138** mil USD

Africa’s water usage in the agriculture sector = 184 bn m^3 / year

Value of withdrawn water if price is 0.05 USD/m^3 = **$9.2 bn**

Potential reduction of water withdrawal in agriculture through smarter technologies = **30%** (e.g., use of EO based moisture estimates), => 9.2 bn USD x **30%** = 2.76 bn USD

EO based data can be used as indicator for soil moisture levels. We assign a 10% impact of EO in water usage reduction of which 50% benefit is from ARD. => combined EO-ARD benefit = **5%**, $2.76 bn x **5%** = $138 mil

Total ARD Benefit = $138 mil / year

Regional distribution of water withdrawals

Region	Annual withdrawals by sector											
	Agriculture		Municipalities			Industry		Total				
	million m^3	% of total	million m^3	% of total	m^3 per inhabitant. (2004)	million m^3	% of total	million m^3	% of Africa	m^3 per inhabitant (2004)	% of internal resources
Northern	79 657	85	8 837	9	58	5 395	6	93 889	43.7	616	189.0
Sudano-Sahelian	52 369	95	2 133	4	19	445	1	54 948	25.7	486	35.0
Gulf of Guinea	8 821	71	2 459	20	13	1 115	9	12 395	5.8	63	1.3
Central	1 114	56	640	32	7	239	12	1 993	0.9	21	0.1
Eastern	12 445	88	1 549	11	8	221	1	14 215	6.6	77	5.0
Southern	15 134	70	5 194	24	48	1 330	6	21 657	10.0	202	8.0
Indian Ocean Islands	14 809	94	650	4	32	258	2	15 717	7.3	786	4.6
Africa	**184 349**	**86**	**21 462**	**10**	**25**	**9 003**	**4**	**214 814**	**100.0**	**247**	**5.5**

Source: FAO Water Reports, Irrigation in Africa in figures AQUASTAT, Survey

AGRICULTURE – REDUCTION OF SUPPLY CHAIN LOSSES

92.7 bn USD x **10** % x **5** % = **464** mil USD

Africa's agriculture gross production value 2018 = $309 bn / year

Agriculture supply chain loss, post-harvest to retail market = 30% ($309 bn / year x 30% = **$92.7 bn**)

Potential reduction of losses in the supply chain through improved coordination among food supply chain actors, regional and national governments, etc. potential improvements = **10%**
=> $92.7 bn USD x **10%** = $9.3 bn

EO can typically contribute to reduce losses in the agriculture supply chain by assessing yield on the field, type of crop, time of harvest, monitoring transport routes, etc.: EO contribution: 10%
50% of EO contribution is assigned to ARD benefit => combined EO-ARD benefit = **5%**

Total ARD Benefit, $92.7 bn x 10% x 5% = $464 mil / year

AGRICULTURE – CROP INSURANCE BENEFIT FOR LOSS ADJUSTMENT

2.18 bn USD x **4** % x **35** % = **30.5** mil USD

Africa's agriculture gross production value = $363 bn / year by 2030

Penetration of traditional agriculture insurance based on gross production value ~ 0.3% (2007) ~ 0.6% by 2030 (our assumption) => $363 bn x 0.6 % = **$2.18 bn**

Loss adjustment costs are typically 3 to 5% of paid premiums. We take **4%** for the calculation

EO can typically contribute a lot to reduce loss adjustment costs. Field damage assessments can be done quickly and cost effectively without field survey by using EO information. EO contribution: 70%
Of which 50% is from ARD benefit => combined EO-ARD benefit: **35%**

Total ARD Benefit = $30.5 mil / year

AGRICULTURE – CROP MICRO-INSURANCE BENEFIT

500 mil USD x **15** % x **50** % = **37.5** mil USD

New tech-based insurance (microinsurance) premiums by 2030 (assumption) = **$500 mil**
Assumption based on following facts: New providers of microinsurance products in the African market will have more than 10 mil customers by 2030. Value of government subsidies for alternative insurance models and input based payouts to smallholder farmers will stimulate the market and is essential to growth.

Microinsurance models are based on satellite data, crop models and historical climate data, etc., all based on EO information. For lack of statistical numbers we chose a counter-factual approach and estimate a **15%** benefit from EO data for this sector. => 500 mil USD x **15%** = $75 mil

ARD is estimated to have a portion of **50%** in EO’s benefit => 75 mil USD x **50%** = $37.5 mil

Total ARD Benefit = $37.5 mil / year

FORESTRY – REDUCED DEFORESTATION

1.6 bn tCO_2e x **6** % x **15** USD/tCO_2e = **1.44** bn USD

Deforestation Africa / year, expressed in bn tCO2e (GHG)
3.94 mil ha deforestation = 110 tC/ha (based on 30% tree cover model) x 3.67 (One ton of carbon equals = 3.67 tons of carbon dioxide) = 404 tCO2e,
=> 3.94 mil ha x 404 tCO2e = **1.6 bn tCO2e**

Potential deforestation reduction / year through ARD. EO benefit for reducing deforestation: 5 - 20%
"Forestry experts at EC, DG ENV, and German MoE suggest to use 5 to 20% EO benefit for deforestation avoidance" (PWC, GMES)

- we calculate with 12% EO benefit and 50% ARD benefit thereof = combined EO-ARD benefit = **6%**
  1.6 bn tCO2e x **6%** = 96 mil tCO2e.

Price per tCO2e: Average price for tCO2e in USD = **$15**
96 mil tCO2e x **$15** = $1.44 mil

Total ARD Benefit = $1.44 mil / year

FORESTRY – AFFORESTATION (PLANTATIONS)

4.4 mil tCO_2e x **5** % x **15** USD/tCO_2e = **3.3** mil USD

Plantation afforestation in Africa / year in tCO2e (GHG):

- Mixed Forest GHG sequestration per ha in 100 years = 2'270 tCO2e /100years => 22.7 tCO2e per year
- Average annual afforestation in Africa 194,000 ha/year

= 22.7 tCO2e x 194,000 ha = **4.40 mil tCO2e**

Assumed ARD benefit:
Assumed EO benefit for afforestation = 10%, thereof 50% ARD benefit = **5%**
=> **4.40 mil tCO2e** x **5%** = 220'000 tCO2e

Medium price for tCO2e = **$15**
=> 220'000 tCO2e x **$15** = **$3.3 mil**

Total ARD Benefit = $3.3 mil / year

FORESTRY – PRECISION FORESTRY FORMULA

5 bn USD x **5** % x **5** % = **12.5** mil USD

Value of forest plantations in Africa:
8 mil ha forest plantations expected by 2030 in Africa. Commercial value of forest per ha ~ $625 USD
=> 8 mil ha x 625 USD = **$5 bn**

Potential yield improvement through precision forestry: => Assumption = **5%**
$5 bn x **5%** = 250 mil USD

ARD benefits:
EO benefit = 10%, of which 50% benefit is from ARD => combined EO-ARD benefit = **5%**
=> $250 mil x **5%** = **$12.5 mil**

Total ARD Benefit = $12.5 mil / year

FORESTRY – ILLEGAL LOGGING

13 bn USD x **30** % x **5** % = **195** mil USD

Estimated value of illicit logging in Africa /year and illicit trade in Africa's forest is approx. **$13 bn**

Potential reduction of illicit logging through EO: Example from Amazonia shows that illegal logging can be reduced by up to 60% with use of EO and law enforcement
We calculate conservatively with **30%** => 13 bn USD x **30%** = $3.9 bn

Potential ARD contribution:
EO contribution 10% (other contributions 90% e.g. from law enforcement), of which 50% benefit is from ARD
Combined EO-ARD contribution: 10% x 50% = **5%**, => 3.9 bn USD x **5%** = **$195 mil**

Total ARD Benefit = $195 mil USD / year

FORESTRY – BIODIVERSITY LOSS THROUGH FOREST FIRES (BIODIVERSITY VALUE)

8 mil ha x **0.5** % x **1'250** USD/ha = **50** mil USD

Area affected by forest fires in Africa per year:
- Tropical forest in Africa = 200 mil ha
- Area affected by forest fires is 4% / year = **8 mil ha**

Percentage of potential reduction of forest fires through ARD:
- 20% reduction of forest fires due to improved fire management (SERVIR, NASA), also 10% by Copernicus 2019 we use 10% for our calculation
- Assumed EO contribution 10% = (10% x 10% x 50% = **0.5%** => 8 mil ha x 0.5% = 40'000 ha

Biodiversity value of forest per ha:
Socioeconomic and biodiversity value without Carbon value to avoid double counting = **$1,250 / ha**
=> 40'000 ha x **$1,250 / ha** = **$50 mil**

Total ARD Benefit = $50 mil USD / year

FORESTRY – BIODIVERSITY LOSS THROUGH FOREST FIRES (CARBON VALUE)

8 mil ha x **0.5** % x **6,060** USD/$tCO_2$3 = **242** mil USD

Area affected by forest fires in Africa per year:
- Tropical forest in Africa = 200 mil ha
- Area affected by forest fires is 4% / year = **8 mil ha**

Percentage of potential reduction of forest fires through ARD:
- 20% reduction of forest fires due to improved fire management (SERVIR, NASA), also 10% by Copernicus 2019 we use 10% for our calculation
- Assumed EO contribution 10% = (10% x 10% x 50% = **0.5%** => 8 mil ha x 0.5% = 40,000 ha

Carbon price / ha:
110 tC/ha 5) * 3.67 = 404 tCO2e, multiplied by $15/tCO2e 6) = **$6,060 / tCO2e**
=> 40,000 ha x **$6,060 / tCO2e** = **$242 mil**

Total ARD Benefit = 242 mil USD / year

MINING – GEOLOGICAL EXPLORATION AND MAPPING

1.3 bn USD x **30** % x **50** % = **195** mil USD

Geological Exploration budgets for Africa per year:
Exploration budget for non-ferrous metals in 2018 = **$1.3 bn**

Potential EO benefit for geological exploration:
a **30%** benefit was modelled based on expert recommendation

Potential ARD benefit (part of EO benefit = **50%**)
ARD facilitates Geological Exploration by a considerable factor!
Time saving, huge existing archive, SAR and optical data, etc.

Total ARD Benefit = $195 mil / year

MINING – ILLEGAL MINING / ILLICIT MINERAL TRADE

15 bn USD x **5** % x **50** % = **375** mil USD

Africa's loss through illicit mineral trade:
According to African Development Bank, **$15 bn** are lost through illicit mineral trading

For mitigation of illicit mineral trade
a **5%** EO impact was modelled based on recommendation from experts => **$15 bn** x **5%** = $750 mil

Potential ARD benefit (part of EO benefit) = 50%
The availability of free satellite data over the entire continent of Africa over many years up to the present makes ARD an immeasurable source of data to uncover illicit practices in the mining sector
750 mil USD x **50%** = **$375 mil**

Total ARD Benefit = $375 mil / year

MINING – INFRASTRUCTURE RISK MANAGEMENT

612 mil USD x **30** % x **50** % = **92** mil USD

Infrastructure monitoring budget of commercial mines in Africa:
According to experts: Each of the 408 large commercially operated mines in Africa spends an average of $1.5 mil per year for Infrastructure Risk Management => 408 x $1.5 mil = **$612 mil**

Potential EO benefit for mining infrastructure risk management:
30% EO benefit or cost reduction was modelled according to expert recommendation. Also applicable is a counter factual approach = 'what could not be monitored without satellite information'
=> **$612 mil** x **30%** = $183.6 mil

Potential ARD benefit (part of EO benefit) = **50%**
$183.6 mil x **50%** = **$92 mil**

Total ARD Benefit = 92 mil USD / year

MINING – ENVIRONMENTAL IMPACT OF MINING

960 mil USD x **5** % x **50** % = **24** mil USD

Environment related budgets in the mining sector:
Relative environmental investments range from 1.5% to 6.5% of total investment in the mining sector.
FDI (Foreign Direct Investments) in 2018 for entire Africa amounted to $48 bn
We take 2% of $48 bn as baseline = **$960 mil**

EO benefits for environment impact assessment, e.g., site rehabilitation, etc.:
Assuming environmental damage can be reduced by smart planning and monitoring of site rehabilitation a **5%** EO benefit is applied
$960 mil x **5%** = $48 mil

Potential ARD benefit (part of EO benefit) = **50%**
$48 mil x 50% = **$24 mil**

Total ARD Benefit = $24 mil / year

REGIONAL & URBAN PLANNING – LAND REGISTRATION

450 mil USD x **5** % x **50** % = **24** mil USD

Costs for improving land governance in Africa in a decade with political will from African governments and support from development partners are expected to be $4.5 bn, including:

- Securing tenure rights for community lands and individual plots.
- Increasing efficiency and transparency in land administration services by empowering local communities and traditional authorities.
- Developing capacity in land administration by encouraging policy reforms and providing training.

Costs for land registration: $4.5 bn : 10 years = **$450 mil** / year

EO cost benefit assumption: **5%** based on expert recommendation
=> **$450** mil x **5%** = $22.5 mil

Potential ARD benefit (part of EO benefit) = **50%**
$48 mil x **50%** = **$24 mil**

Total ARD Benefit = $24 mil / year

REGIONAL & URBAN PLANNING – INFRASTRUCTURE

77 bn USD x **1** % x **50** % = **385** mil USD

Average annual funding for infrastructure development in Africa between 2013 and 2017 was **$77 bn**, double the annual average in the first six years of this century.

Cost Benefit analyses estimate a range between 0.25 and 5% (e.g., Urban Atlas) benefit using EO.
An overall 1% improvement of benefit cost ratio can be applied for regional policy.
Our assumption = **1%**
$77 bn x **1%** = 770 mil USD

Potential ARD benefit (part of EO benefit) = **50%**
=> $770 mil x **50%** = **$385 mil**

Total ARD Benefit = $385 mil / year

Contributors / Acknowledgements

This report was developed as an output of the Digital Earth Africa Community.

Lead authors

Stefanie Grundner
Panaglobo Consulting

Joerg Widmer
Panaglobo Consulting

Shanti Reddy
Project Leader, Digital Earth Africa

Contributors

Adam Lewis
Digital Earth Africa

Lisa Hall
Digital Earth Africa

Steven Ramage
Group on Earth Observations

Meghan Halabisky
University of Washington, US

Nicolò Andreula
Disal Consulting

Pauline Fuchs-Gamboeck
Disal Consulting

Ludovica De Santis
Disal Consulting

The authors sincerely thank the many experts and respondents who kindly provided their valuable knowledge, assessment and comments on the various matters. They are listed below.

Prof. Tsehaie Woldai, University of Witwatersrand, South Africa
Phoebe Oduor, Regional Centre for Mapping of Resources for Development, Kenya
Lilian Ndungu, Regional Centre for Mapping of Resources for Development, Kenya
Angela Too, Regional Centre for Mapping of Resources for Development, Kenya
Duque Wilson*,* Mozambican Government, Mozambique
Reinaldo Zezela, Universidade Eduardo Mondlane, Mozambique
Jennifer Nkosi, Ministry of Agriculture, Malawi
Dr. Markus Enenkel, Disaster Risk Financing Specialist, Austria
Dr. Astrid Koch, DG DEFIS, European Commission
Ruth Oman, Ghana
Michel Massart, DG ENTR, European Commission
Prof. Catherine Nakalembe, University of Maryland, US
Karl Bedacht, Munich Re, Germany
Meshack Ndiritu, QuantumCai, Ethiopia
Tom Harvey, Global Forest Observation Initiative, Papua New Guinea
Dr. Kenneth Mubea, Digital Earth Africa, Kenya
Dr. Michaela Frei, Federal Institute for Geosciences and Natural Resources, Germany
Andres Espejo, The World Bank, US
Corné Eloff, Pinkmatter Solutions, South Africa
Kaspar Kundert, GIS Expert, Rwanda
Ian Jarvis, GEOGLAM, Switzerland
Roberto Zolho, Forest & Natural Resources Specialist, Mozambique
Aristides Muhate, Ministry of Agriculture and Rural Development, Mozambique.
Lucile Laquitaine, ReforestAction, France

We are grateful to **Catherine Hickley,** Journalist and Author, who helped refine the text.

[1] 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, Mahlatse Kganyago and Paidamwoyo Mhangara, 2019

[2] Afrigeoss - Strengthening the use of Earth Observations and bringing GEOSS to Africa, Group on Earth observations, 2017

[3] Winning in Africa's agricultural market, McKinsey, 2019 (https://www.mckinsey.com/industries/agriculture/our-insights/winning-in-africas-agricultural-market)

[4] Economic evaluation of the International Partnership Programme (IPP): Cost-Effectiveness Analysis, London Economics, 2019

[5] Precision Agriculture for Resource Use Efficiency in Smallholder Farming Systems in Sub-Saharan Africa: A Systematic Review, Cecilia Moraa Onyango, Justine Nyaga, Johanna Wetterlind, Kristin Piikki, 2021

[6] FAO STAT – Value of Agricultural Production (https://www.fao.org/faostat/en/#data/QV)

[7] Remote Sensing Products and Services in Support of Agricultural Public Policies in Africa: Overview and Challenges, Agnès Bégué, Louise Leroux, Mamy Soumaré, Jean-François Faure, Abdoul Aziz Diouf, Xavier Augusseau, Labaly Touré, Jean-Philippe Tonneau, 2020 (https://doi.org/10.3389/fsufs.2020.00058)

[8] More crop per drop: Farmer-learning and the promise of improved water use in agriculture, Frank van Steenbergen, Petra Schmitter, 2021

[9] Reducing Food Loss Along African Agricultural Value Chains, Deloitte, 2015

[10] Penetration of Agricultural Insurance, by Development Status, based on Cummins and Mahul 2009; World Bank Survey

[11] Distributing Agri Micro-insurance in East Africa – Lessons Learned, presentation by Rahab Kariuki, ACRE, 2018 (https://www.indexinsuranceforum.org/sites/default/files/ACRE%20Africa%20at%20UR2018%20Mexico%2014th%20May%202018.pdf)

[12] Government Support to Agricultural Insurance – Challenges and options for developing countries, The Worldbank, Oliver Mahul, Charles J. Stutley, 2010

[13] Government Support to Agricultural Insurance – Challenges and options for developing countries, The Worldbank, Oliver Mahul, Charles J. Stutley, 2010

[14] Regional Cropland Assessment and Monitoring Service (https://www.servirglobal.net/ServiceCatalogue/details/5c19008a935208d9a25c1275)

[15] Agricultural insurance for smallholder farmers - Digital innovations for scale, GSMA AgriTech Programm, Rishi Raithatha and Jan Priebe, 2020

[16] Forests in Sub-Saharan Africa: Challenges & Opportunities, World Bank Africa Region, 2017

[17] Atlas of our changing environment, UNEP, 2008

[18] Global Forest Resources Assessment, FAO, 2020

[19] Policy Paths towards Second-Generation Measurement, Reporting and Verification (MRV 2.0), The World Bank Group, 2021, (https://www.forestcarbonpartnership.org/sites/fcp/files/policy_brief_r5.pdf)

20 Source (194’000 ha: Lessons Learnt on Sustainable Forest Management in Africa – Forest Plantations in Sub-Saharan Africa, S.A.O. Chamshama, F.O.C. Nwonwu, 2004)

21 The Sustainable Forest Management Framework for Africa (2020-2030), African Union Commission

22 How Forestry contributes to the African Development Bank’s High 5 Priorities: Challenges and Opportunities, African Development Bank Group, 2018

23 Illicit trade in natural resources in Africa — A forthcoming report from the African Natural Resources Center, African Development Bank, October 2016

24 Global Forest Resources Assessment, Main Report, FAO, 2010

25 Precision forestry: A revolution in the woods, McKinsey, 2018

26 Past, present and future of industrial plantation forestry and implication on future timber harvesting technology, Andrew McEwan, Enrico Marchi, Raffaele Spinelli, Michal Brink, 2020

27 The Future of Plantations in Africa, Paul Jacovelli, 2014

28 A Ticket to Recovery: Reinventing Africa’s Tourism Industry, International Finance Corporation, 2021 (https://www.ifc.org/wps/wcm/connect/news_ext_content/ifc_external_corporate_site/news+and+events/news/reinventing-africa-tourism)

29 Why should biodiversity be Africa’s top priority? Al-Hamndou Dorsoum, African Development Bank, 2020

30 Shrinking spaces for the world’s largest land animal, IUCN, 2021 (https://www.iucn.org/news/species-survival-commission/202108/shrinking-spaces-worlds-largest-land-animal)

31 SERVIR-Mekong’s Geospatial Technology Helps to Combat Forest Fires in Chiang Rai, Thailand, 2021 / (https://servir.adpc.net/news/servir-mekongs-geospatial-technology-helps-combat-forest-fires-chiang-rai-thailand)

32 United Nations, Markets Insider, BCG analysis / (https://www.bcg.com/publications/2020/the-staggering-value-of-forests-and-how-to-save-them)

33 Why African countries must invest more in earth sciences, The Conversation, 2021

34 Advances in optical earth observation for geological mapping: A Review, South African Journal of Geomatics, Vol. 5, No. 1, South African Journal of Geomatics, Vol. 5, No. 1, L. Ngcofe1, A. Van Niekerk, February 2016

35 (https://www.spglobal.com/marketintelligence/en/documents/world-exploration-trends-march-2019.pdf)

36 Orogenic Gold in Transpression and Transtension Zones: Field and Remote Sensing Studies of the Barramiya–Mueilha Sector, Egypt by Basem Zoheir, Mohamed Abd El-Wahed, Amin Beiranvand Pour and Amr Abdelnasser

37 Business risks facing mining and metals 2015–2016, Ernest and Young, 2015

38 Central Africa: Criminals are cashing in on COVID-19 surge in gold prices, Interpol, 2021 (https://www.interpol.int/News-and-Events/News/2021/Central-Africa-Criminals-are-cashing-in-on-COVID-19-surge-in-gold-prices)

[39] 2020 State of the Artisanal and Small-Scale Mining Sector, World Bank, 2020

[40] Injuries among Artisanal and Small-Scale Gold Miners in Ghana, E. Kyeremateng-Amoah, Edith E. Clarke, 2015

[41] Illicit trade in natural resources in Africa — A forthcoming report from the African Natural Resources Center, African Development Bank Group, 2016

[42] Low worker wages and high inequality, Ben Radley, 2020 (https://africasacountry.com/2020/06/low-worker-wages-and-high-inequality)

[43] Artisanal Gold Mining without Mercury Pollution, United Nations Industrial Development Organization (UNIDO), Kerry J. Timmins, 2003 (http://www.natural-resources.org/minerals/cd/docs/unido/asm_mercury.pdf)

[44] Environmental expenditures in EU industries: Time series data for the costs of environmental legislation for selected industries over time Final report, Nov 2015

[45] Price Waterhouse Coopers: “A socio-economic Benefits Analysis of GMES - Cost-Benefit Analysis for GMES European Commission: Directorate-General for Enterprise & Industry

[46] (https://www.nature.org/en-us/get-involved/how-to-help/plant-a-billion)

[47] Agriculture in Africa 2021, Oxford Business Group, 2021 (https://www.readkong.com/page/agriculture-in-africa-2021-in-collaboration-with-april-4422883)

[48] Cadastre: A catalyst for economic growth, Bryn A Fosburgh, 2011 (https://www.geospatialworld.net/article/cadastre-a-catalyst-for-economic-growth)

[49] Land, The World Bank, 2020 (https://www.worldbank.org/en/topic/land#1)

[50] Securing Africa's Land for Shared Prosperity, The World Bank, 2013

[51] Advances in remote sensing applications for urban sustainability, Nada Kadhim, Monjur Mourshed, Michaela Bray, 2016

[52] Earth Observation for Sustainable Urban Planning in Developing Countries: Needs, Trends, and Future Directions in: Journal of Planning Literature, Walter Musakwa, Adriaan Van Niekerk, 2014

[53] Slum Almanac 2015 2016 - Tracking Improvement in the Lives of Slum Dwellers, UN Habitat, 2016 (https://unhabitat.org/sites/default/files/documents/2019-05/slum_almanac_2015-2016_psup.pdf)

[54] Population growth rate in Africa 2000-2020, Statista, 2021 (https://www.statista.com/statistics/1224179/population-growth-in-africa)

[55] Quality Infrastructure in 21st Century Africa, OECD/ACET, 2021

[56] UK Space Agency International Partnership Programme - Space for Disaster Resilience in Developing Countries, UK Space Agency, 2018