GAP ANALYSIS OF ADOPTION OF REMOTE SENSING FOR DEVELOPMENT IN AFRICA

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EXECUTIVE SUMMARY

Remote Sensing (RS) technology holds immense potential for Africa's development across various sectors including agriculture, forestry, mining, and urban planning. Analysis reveals significant economic value, especially in agriculture upto 2.6 Billion USD and forestry upto 2 Billion USD via precision agricultural techniques and forest management, with the mining sector likely to gain upto 680 Million USD from the adoption of RS technology (Panaglobal, 2022). Public Health is also seen as a potential beneficiary of utilisation of RS data in Africa. However, numerous challenges still persist including limited access to quality RS data and resource constraints.

Initiatives like Digital Earth Africa (DE) through their Open Data Cube (ODC) initiative and partnerships with African governments aim to accelerate the adoption of RS technology. Similarly, policy alignment will be crucial for maximising the benefits of RS, as seen across various sectors in Africa including the dominant mining sector where only a fraction of countries, 9% of key mineral producers, utilise geoinformation effectively. Bridging the gap between RS technicians and policymakers is also essential for future applications in precision agriculture, land management and urban planning, and biodiversity and forest management. A further use case analysis of application of NDVI and NDWI is demonstrated across four countries including Uganda, Swaziland, Central Africa Republic and Chad situated across the four predominant climatic conditions in Africa; equatorial, tropical, temperate and desert. The aim of this analysis is to statistically and empirically demonstrate the richness of RS data and its potential areas of applications in Africa.

Consequently, an integrated approach is urgently needed in order to harness, analyse, adopt and apply RS data effectively for Africa's developmental aspirations outlined in the AU Agenda 2063; namely lighting up and powering, feeding, industrialising, integrating and improving the quality of life for the African people and for fulfilment of the UN SDGs in Africa. Strengthening geospatial infrastructure and capacity building across sectors thus remain incredibly valuable tools for achieving sustainable socio-economic transformation in Africa.

LIST OF ABBREVIATIONS/ACRONYMS

ABE
Automatic Boundary Extraction

ACMAD
African Centre of Meteorological Application for Development

AEIN
Africa Environmental Information Network

AFREF
African Reference Frame

AGRHYMET
Agro-Hydro-Meteorological Regional Centre

ARD
Analysis Ready Data

ASAL
Arid and Semi-Arid Land

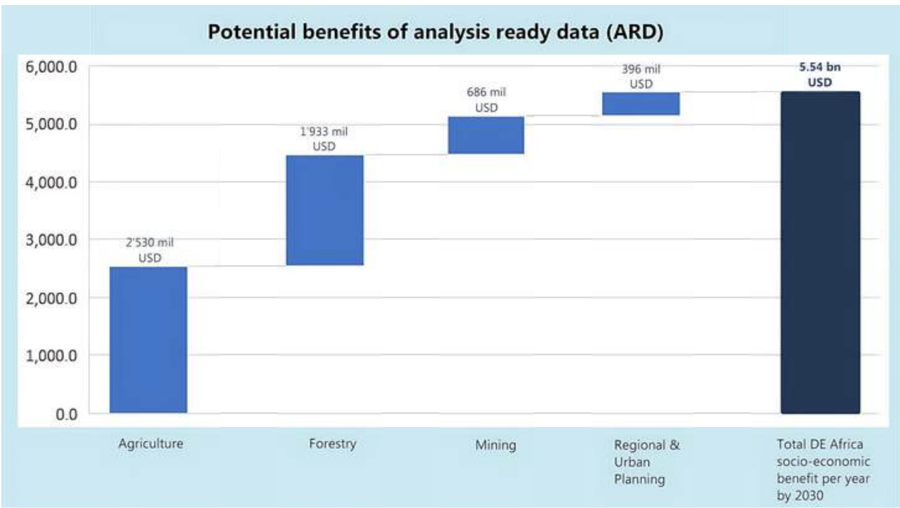
ASI
Agenzia Spaziale Italiana

CEDARE
Center for Environment and Development for the Arab Region and Europe

CENATEL
Centre for Remote Sensing and Forest Cover Monitoring

SITUATIONAL ANALYSIS

Remote Sensing (RS) is a critical technology applicable for the study of earth surface data through electromagnetic energy and other processes, and extraction of information for the GIS system (Acharya and Lee, 2019). Remote sensing data can be leveraged across various fields and sectors of development including for sustainable biodiversity, environmental conservation and climate change monitoring, precision agriculture and water resource management, as well as disaster management and response. Elizabeth Molly Brown et al. (2007) in a USAID-backed review of remote sensing needs and applications in Africa describes RS applications as entailing acquisition, maintenance and archiving, dissemination and distribution, and analysis and interpretation of remote sensing data. Panaglobo Consulting's 2022 insight report on the use of analysis-ready data from Earth Observation (EO) for the development of African nations reveals the Digital Earth Africa's RS data portends immense multisectoral economic opportunities. For instance, the agricultural sector stood to gain at least 2.6Billion USD besides increased yields from efficient water use and resilience in the face of climate change, the forest and biodiversity sector also would attract upto 2Billion USD as a result of the applicability of RS analysis-ready data for carbon sequestration, control of forest fires as well as the utilisation of RS data in timber market. Other key sectors highlighted include the Mining sector with a potential gain of upto 680 Million USD with critical areas of applicability of RS data in the mining sector being health and work conditions monitoring and regulations of mining. Land registration and mapping, regional and urban planning also stand as key areas of application of RS by informing controlled urbanisation strategies, safety and security of urban residents as well as management of urban environments.



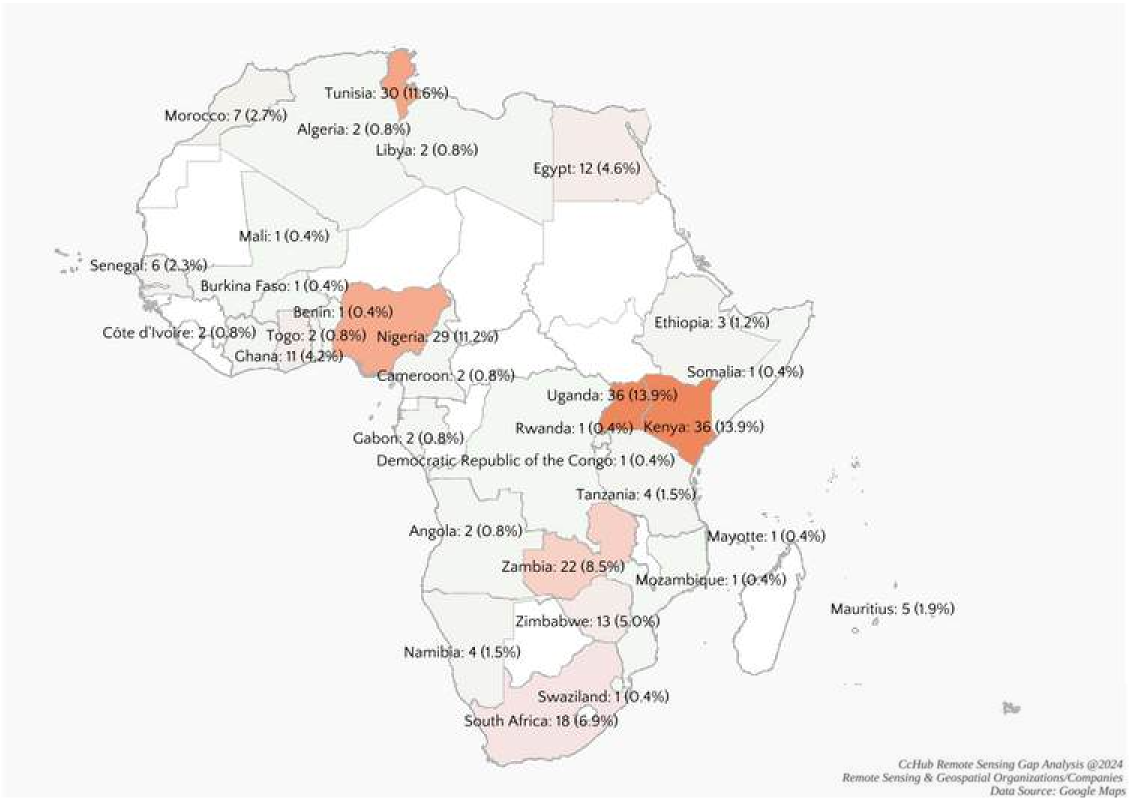
Potential Benefits of RS analysis ready data (ARD) in Africa
Source: Panaglobo Consulting, 2022

An analysis of the spatial data infrastructures (SDI) in Africa observed a persistent gap of available spatial data online (Guigoz et al., 2015). The analysis utilised 14 key SDI indicators namely: availability of digital data, capacity building, willingness to share, human capital, awareness, delivery mechanism, funding, leadership, vision, institutional arrangements, socio-political stability, interoperability, metadata, and country's initiatives connected to SDI (Eelderink, 2006), and found relatively weak scores for African countries across a majority of the indicators compared to the rest of the world with variations across African countries. Ray et al.'s study thus recommends an improvement in the statistical information from Africa and calls for the establishment of comprehensive geospatial data infrastructure through among others political commitment to SDI by the African governments attainable through continuous Earth Observation (EO) data dissemination and promotion, reinforcement and strengthening of United Nations Economic Commission for Africa (UNECA), which is the entity responsible for enabling and manning SDI in Africa, with the right resources to develop proper SDI strategy in Africa, establishment of an online African SDI monitoring platform through among others centralised SDI monitoring surveys, visual mechanisms for comparativemonitoring of SDI status of African countries e.g. visual maps, dashboards, as well as establishment of capacity building for SDI both at national and continental levels. In addition, the analysis also outlines some of the most critical needs for having an integrated SDI capacity for Africa…"(1) environmental pressure is increasing very fast and necessitates urgent solutions for which multi-disciplinary and transnational environmental data is needed; (2) technical infrastructures are emerging and the time is right to have SDI concepts and tools adopted; (3) there is a great opportunity from the proximity to Europe and its advanced SDI involvement (e.g., INSPIRE directive, participation in many projects promoting SDI particularly in Africa); (4) several SDI actors and initiatives already exist in Africa…" (Ray et al., 2015). In order to attain quality RS analysis ready data and superimpose such data on an integrated continental SDI, a reliable and functional RS and geospatial infrastructure is a prerequisite.

Molly Elizabeth Brown et al. 's analysis (2007) found the existence of multiple national, regional and continental institutions, networks, enterprises and initiatives focused on the acquisition, processing, interpretation, analysis, dissemination and utilisation of RS data in Africa. However, in terms of prominence and significance, Brown et al.'s study identifies at least three centres of RS research in Africa namely the AGRHYMET Regional Center [ARC] in Niamey, Niger; the Regional Centre for Mapping of Resources for Development [RCMRD] in Nairobi, Kenya; and the Southern African Development Community [SADC] Regional Remote Sensing Unit [RRSU] in Gaborone, Botswana. Similarly additional sources of information on RS data in Africa include UNECA which is the entity responsible for SDI in Africa through the Committee on Development Information, Science and Technology (CODIST) that converges African countries on SDI agenda (Ray et al., 2015) including its applications across key areas including data; geospatial data, people; human resources, access network; networking technology, policy; institutional framework and standards; technical standards (Rajabifard, 2002, Giuliani and Peduzzi, 2011 and Giuliani et al., 2013). Other critical RS infrastructure across Africa have included ESA's TIGER initiative that applies satellite data for informing authorities on vital resources and SERVIR-Africa majorly used for environmental and disaster monitoring. Of the 55 African countries only 13 had RS/GIS-based training institutes with Kenya having the largest stock of such institutions with a maximum of 10 RS/GIS training establishments thus accounting for at least 26.3% of such institutes on the continent. Nigeria closely followed with 6 thus accounting for 15.8% with other countries with a significant number of such institutions being South Africa (5), Tanzania (3), Namibia (3) and Tunisia (3).

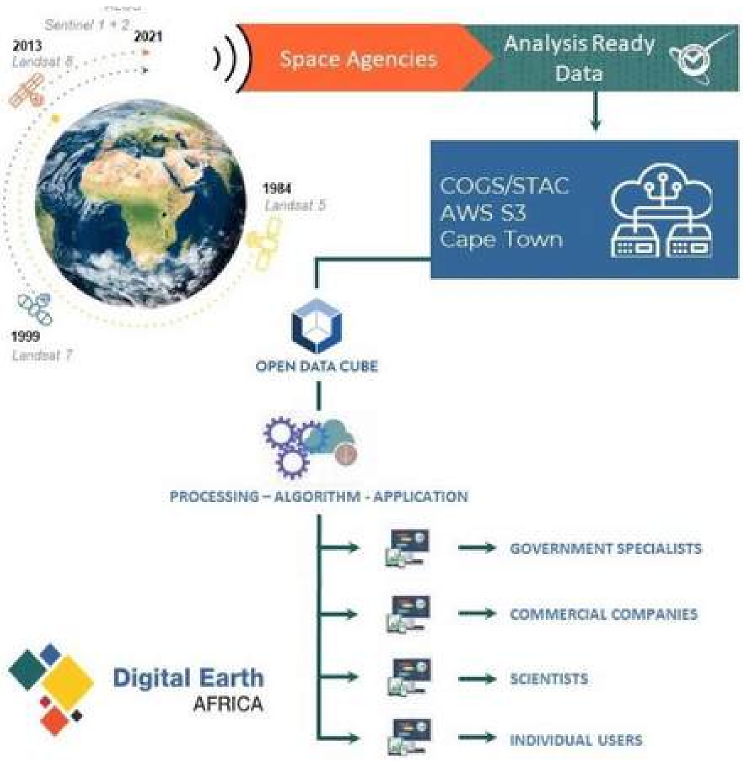
Mapping of RS/GIS Training Institutes in Africa as of 2024
Key: Darker Shades= higher density of institutes, Unshaded Areas= lack of readily available data
Source: CcHuB Analytics 2024

Similarly, Kenya and Uganda demonstrate a significant lead in the stockpile of RS/GIS-focused independent organisations and private companies with each country accounting for at least 13.9% (36) of all the RS/GIS entities in Africa. Other African countries with significant stockpile of RS/GIS companies as per Google Maps Data, those hosting more than 10 remote sensing and geospatial companies or organisations, include Tunisia accounting for 11.6% of all the RS/GIS firms operating in Africa thus translating to a total of 30 companies, Nigeria 11.2% (29), Zambia 8.5% (22), South Africa 6.9% (18), Zimbabwe 5.0% (13), Egypt 4.6% (12) and Ghana 4.2% (11).



Mapping of RS/GIS-focused Organisations and Private Companies in Africa as of 2024
Key: Darker Shades= higher density of firms, Unshaded Areas= lack of readily available data
Source: CcHuB Analytics 2024

In Spite of the centrality of RS data for decision-making in Africa, access to quality data and resource constraints experienced in the acquisition and deployment of RS analysis-ready data (ARD) remain major hindrances. Ray et al. (2015) underscores the critical steps needed to move beyond merely RS data availability in Africa to accessibility by all stakeholders in order to among others facilitate integration of RS data with other critical data and generate applicable knowledge. The Digital Earth Africa architecture stands as an existing case of a complete RS data life cycle in Africa including capture, acquisition, access, processing, interpretation and analysis, and application.



Architecture of Digital Earth Africa
Source: Digital Earth Africa, 2022

APPLICATION OF REMOTE SENSING FOR DEVELOPMENT IN AFRICA

As with any other sector policy-making on RS will form an important pillar for the actualisation of the immense opportunities that RS and other geospatial technologies offer. A review of policy adoption and the impact of geoinformation in the mining sector in Africa Moomen et al. (2019) of 23 mineral producing countries in Africa found a major misalignment in adoption of policy regimes that favour application and use of geoinformation to facilitate sustainable exploration and use of mineral resources in Africa. For instance, only 9% of the mineral producing countries in Africa had expressed interest in utilising geoinformation in their mining industries with only 13% having existent mining and environmental parametres. Application of remote sensing in agriculture in Africa is largely infant with only a few areas of application such as early warning systems for food security and desert locust prevention and rangeland production forecasting (Begue et al., 2020). This lean applicability of RS information in agriculture thus leaves immense opportunity for future use of RS in precision Agriculture. Begue et al., (2020) proposes the urgent need to bridge the gap between RS technicians and policy makers with areas for prioritisation in this effort being capacity building, political will and institutional commitment, public-private partnership and proofs of concept. Some of the key RS data required for precision agriculture in Africa (as proposed by Begue et al., 2020) include“1) Baseline maps, to ensure spatial consistency within heterogeneous datasets; 2) Land use and land cover maps produced at high spatial resolutions and updated on a regular basis, to monitor the land changes (evaluation, prospective), support the statistical sampling protocols (agricultural census), or manage the agricultural risks and opportunities; and 3) Biogeophysical maps of crop (phenology, biomass, growth anomalies, etc.) and environmental conditions (soil moisture, rainfall, topography, etc.) provided throughout the year for near real-time monitoring, early warning and decision-making.” For instance, an integrated analysis of Remote-Sensing-Based and Participatory Survey of forests, agricultural land dynamics and potential land conservation measures in Kloto District in Togo concluded that the existing low adoption of improved soil conservation, integrated water management and harvesting systems as well as the use of less productive and adaptive cultivars signified increasing degradation of cropland and crop productivity in the country (Koglo et al., 2018).

The study reviewed Landsat data on cash and food crops in Togo between 1985-2002, 2002-2017 and 1985-2017, with RS data showing significant net loss of the country's forest cover due to agricultural and other human activities including 23.6% forest cover loss under maize and cassava cultivation. As a result, the study proposed enhanced utilisation of integrated approaches to soil and land use management for sustainable and viable socio-ecological outcomes at the local levels (Koglo et al., 2018). Another critical application of RS technologies in Africa entail their application in land resource management and mapping. A case study for application of RS land mapping in Kajiado County, Kenya yielded positive outcomes. The study integrated smart sketch maps (SmartSKeMa), unmanned aerial vehicles (UAVs) and automatic boundary extraction techniques to develop land rights mapping (Koeva et al.,2020).

	Sketch Maps (SmartSkeMa)	UAV-Based Data Collection	Automated Boundary Delineation
1. Land Tenure	Green	Green	Green
2. Land Value	Yellow	Green	Green
3. Land Use	Green	Green	Green
4. Visible boundaries rather than fixed boundaries	Green	Green	Green
5. Aerial imagery rather than field surveys	Yellow	Green	Green
6. Accuracy relates to the purpose	Green	Green	Green
7. Updating and ongoing improvement	Green	Green	Green
8. Cheap	Green	Yellow	Yellow
9. Fast	Green	Yellow	Yellow
10. Accurate	Yellow	Green	Green

Integrated RS methodologies with fit-for-purpose analysis for land rights mapping in Kenya (Green indicates compliance with an aspect, yellow indicates that the application partially complies with an aspect)
Source: Koeva et al., 2020

SmartSkeMa was found to be a viable land data acquisition tool responsive to the needs of the local community. Similarly, the use of UAVs and ABEs for land rights mapping showed immense potential in ensuring access to current land data thus suitable for land administration and development of automatic land boundary maps (Koeva et al., 2020).

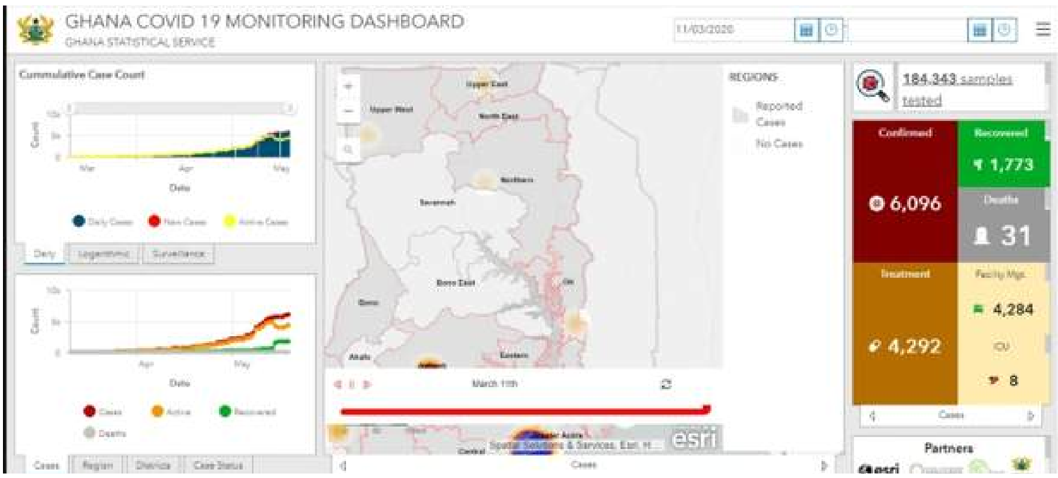
Cadastral boundaries delineated from UAV data captured in Kajiado County, Kenya
Source: Koeva et al., 2020

Live demonstration of SmartSkeMa spatial information drawing superimposed on a satellite image
Source: Koeva et al., 2020

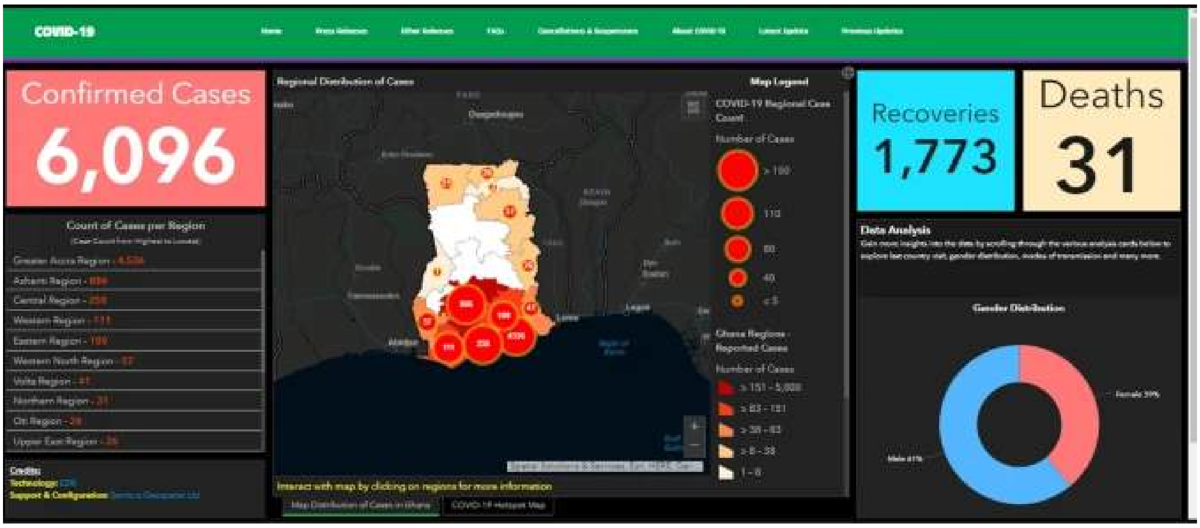
The African Union's Agenda 2063 highlights the key aspirations of Africans. The continental plan outlines 5 key areas of focus for the continent that forms a critical link with the UN Sustainable Development Goals (SDGs). The five critical areas include an aspiration to light up and power, feed, industrialise, integrate and improve the quality of life for the African people (Panaglobo, 2022). Digital Earth (DE) Africa propounds the need for Open Data Cube (ODC) approach to stocking and accessing analysis-ready data (ARD) in Africa. ODC approach enhances access and application of RS data and analytics for development globally. Currently DE Africa remains one of the foremost enablers of Earth Observation ARD in Africa and is currently partnering with a number of African countries to fastrack adoption and application of analysis ready RS data. The figure below showcases areas of potential application of RS data in relation to the AU Agenda 2063.

The AU Agenda 2063 also envisions an Africa with healthy and well nourished citizens. While application of RS in public health is largely complex, it is extremely rewarding. A review of the application areas for GIS technology in public health by Stephanie Fletcher-Lartey and Graziella Caprarelli (2016) found a positive outcome. Some of the most critical applications of RS in public health highlighted in the study included mapping and analysis of parasitic disease; the geographic distribution of a vector-borne disease is directly related to the habitat of the vector (Curran et al., 2000) as such integration of RS data on vector habitats, human population density, and field survey output is essential for the study of disease spread and patterns (Liang et al., 2002). RS data is also seen as an input for understanding the relationship between health, population and the environment as such facilitating the evaluation and quantification of health-related variables and environmental risk factors such as rainfall, temperature, vegetation cover, landscape wetness and land use (Fletcher and Caprarelli, 2016, Epstein & Chikwenhere, 1994). Al-Hamdan et al.'s (2012) study titled "Environmental public health applications using remotely sensed data" located an essential use of RS data for interventions related to environmental risk factors such as fine particulate matter, insolation and land surface temperature (LST) and their link with public health scenarios such as cognitive, stroke and other health outcomes. This study (Al-Hamad et al., 2012) integrated data from NASA observations, Environmental Protection Agency (EPA) ground level monitor, and North American Land Data Assimilation System (NLDAS) with public health data from REasons for Geographic And Racial Differences in Stroke (REGARDS).

Mhangera and Odindi (2014) analysing the societal value of the applicability of RS data in South Africa identified health, crime analysis, rural planning and agriculture, natural resource management and physical planning as potential areas of applications and underscores the critical and urgent need to link key patterns from expert knowledge on emerging challenges backed by progressive policies. For instance, the Malaria Early Warning System (MEWS) was identified as a key area of RS data application that provides real-time information on malaria epidemic ([Mhangera and Odindi, 2014]). RS technologies supportepidemiological analysis through among others assessment of diseases, observation of spatio-temporal trends, vulnerability mapping, stratification of risk factors, intervention, and resource allocation (Renaldi et al., 2006). Some of the most critical cases of public health application of RS data in Africa included that by Hay et al. (2000) where colour infrared aerial photography images were used to spot the (habitats) of Aedes sollecitans (Eastern Saltmarsh mosquito) and Brown and Sethi's (2002) application of digital aerial photographs to survey the spread of mosquitoes. Malone (2005) also indicates the applicability of the climate forecast system in the study of veterinary diseases such as fasciolosis (Liver rot) and human diseases such as schistosomiasis (snail fever). The Government of Ghana has also applied various GIS technologies including RS data techniques for tracking, monitoring and combating Covid-19 cases since 2020 with key areas of applications being Covid-19 tracking dashboards, mobile applications and drones (Sarfo et at., 2020). Two Ghanaian government-backed RS dashboards were available for the public including that by the Ghana Statistical Service; showcasing data on Covid-19 cumulative case count, spatial distribution of the cases on a map, trend analysis of cases (cumulated, active, recovered, and death), explanatory information of reported cases and information on health spot in the country and the Ghana Health Service dashboard which encompassed regional breakdown of confirmed cases, aggregated figures of confirmed cases, recoveries and deaths, spatial distribution of confirmed cases with data symbolised per category indicating intensity of the phenomenon per region and finally information on Covi-19 segregated into gender (Sarfo rt al., 2020). Members of the public also had access to free to download RS-enabled mobile applications which were usable for identification, tracing and early detection of the spread of Covid-19 across the country.



Ghana Statistical Service Covid-19 dashboard (as at May 20, 2020)
Source: Sarfo et al., 2020



Ghana Health Service Covid-19 dashboard (as at May 20, 2020)
Source: Sarfo et al., 2020

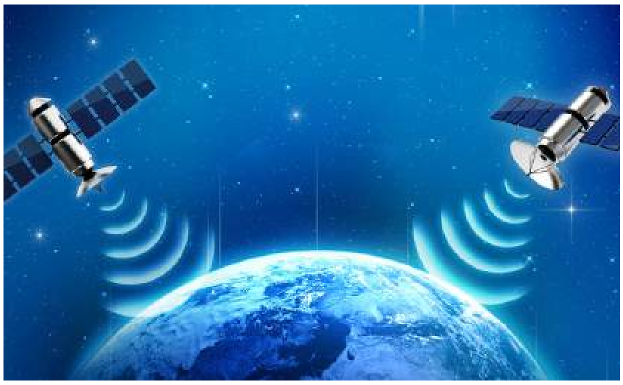
Target Not necessarily the indicator	Agenda 2063	Goals African Union Development Agency Agenda 2063 / The Africa we want	Areas supported by EO
• Poverty, inequality and hunger • Modern and livable habitats and basic quality services		1. A high standard of living, quality of life and well being for all	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

Areas of potential application for RS data in relation to the AU Agenda 2063
Source: Panaglobal, 2022

USE CASE ANALYSIS OF APPLICATION OF NDVI AND NDWI RS DATA IN AFRICA

An analysis by Co-Creation HuB Research (2024) on the potency of RS data for precision agriculture, precision-ecological ecosystems and water resource management discovered critical pointers. The study, relying on Landsat 9 and Landsat 8 data, analysed two critical indices namely Normalised Difference Vegetation Index (NDVI) and Normalised Difference Water Index (NDWI) across several African countries. Normalised Difference Vegetation Index (NDVI) reflects vegetation health and is calculated using the formula; $NDVI=NIR-R/NIR+R$. The study primarily relied on LANDSAT/LC09/C02/T1 imagery for this analysis, which relies on bands 5 (Near-Infrared) and 4 (Red) for calculations. On the other hand Normalised Difference Water Index (NDWI) is key for assessing water availability and is calculated using the formula; $NDWI=G-NIR/G+NIR$. Data from LANDSAT/LC08/C01/T1_SR imagery was utilised for this particular analysis. LANDSAT/LC08/C01/T1_SR utilises bands 5 (Green) and 3 (Near-Infrared) for calculations. Consequently, a comparative analysis of four case study countries was developed with consideration of Africa''s foremost climatic zones; Equatorial Climate (Togo), Tropical Climate (Central African Republic), Temperate Climate (Swaziland) and Desert Climate (Chad).

Remote sensing data for our use case was obtained from Google Earth Engine (GEE). While relative success in RS data acquisition for most African countries across the 2020-2024 timeframe was registered, there were some instances where complete datasets for specific years or entire countries were unavailable. Acquisition of the relevant data was followed by data cleaning and validation of the RS data obtained through Google Maps to ensure the identified entities focused on Earth Science activities across the African continent.



The remote sensing data was then processed to calculate monthly NDVI and NDWI averages for specific years within the relevant countries.

The case study analysis offers insights into vegetation cover and water availability within distinct climatic zones. The findings presented here contribute to a more comprehensive understanding of environmental dynamics within the African continent. The areas of application of NDVI and NDWI RS data are multiple with key among them being theutilisation of NDVI RS data to unveil seasonal variations, anomalies, and changes in vegetation health patterns. NDVI is thus critical for the analysis of regional spatial differences, revealing patterns such as rainfall, land use, and soil quality. This index is primarily applied in drought monitoring, crop yield estimations, and land management practices.

Similarly NDWI also holds immense potential with the index being centralto understanding seasonal variations, particularly in mapping water availability patterns across different regions. It aids in monitoring water bodies and wetlands by estimating the shrinking or expansion of these water bodies. This index is mainly used in drought monitoring, water resource management, and flood inundation mapping.

NORMALISED DIFFERENCE VEGETATION INDEX (NDVI)

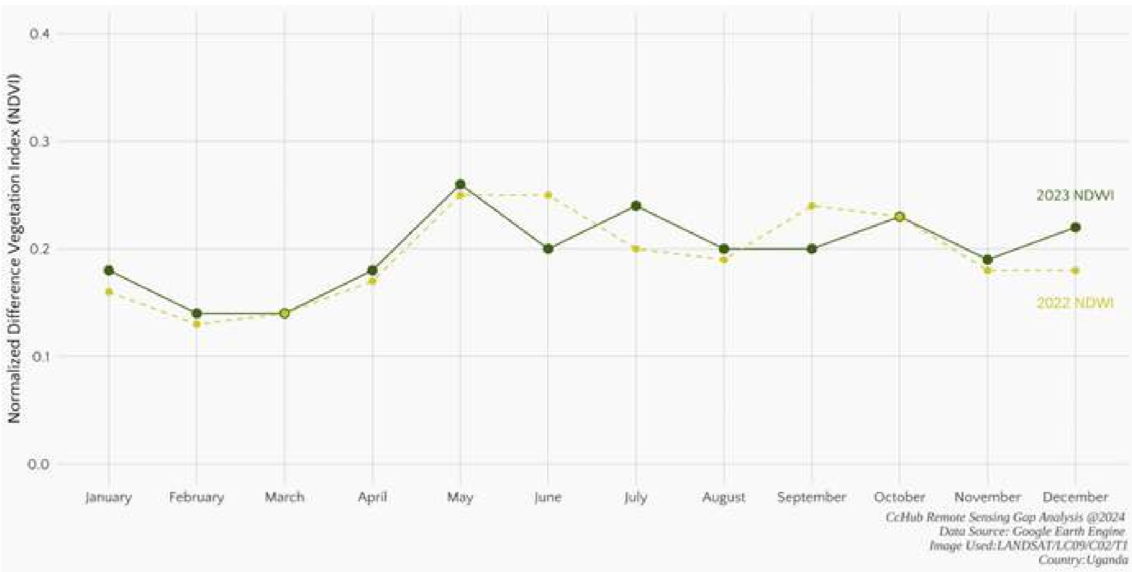
The analysis below highlights the average Normalised Difference Vegetation Index (NDVI) values for the respective African countries for each month in 2022 and 2023. Analysis of the NDVItrends aids in the identification of changes in vegetation cover in the countries within the two years under analysis.

CLIMATIC ZONE ANALYSIS USING REMOTE SENSING INDICES DATA IN AFRICA

Consequently an integrated analysis of the country-based utilisation of NDVI and NDWI RS data across the four main climatic zones in Africa including Equatorial Climate, Tropical Climate, Temperate Climate and the Desert Climate was implemented. The countries of focus entailed Uganda, Swaziland, Central Africa Republic (CAR) and Chad with the output outlayed below.

Equatorial Climate - Uganda

Uganda exhibited a pattern consistent with an equatorial climate in both 2022 and 2023. NDVI values generally increased from March to May, indicating a relatively constant growing season throughout the year. The month of May boasted the highest NDVI in both years, with a slight increase in overall vegetation health observed in 2023 (0.21) compared to 2022 (0.20). However, some variations were observed, with the months of June and September of 2023 showing lower NDVI compared to similar months in 2022, suggesting potential fluctuations in vegetation cover during those specific months.



Average NDVI values for Uganda for the period covering 2022 and 2023
Source: CcHuB Analysis 2024

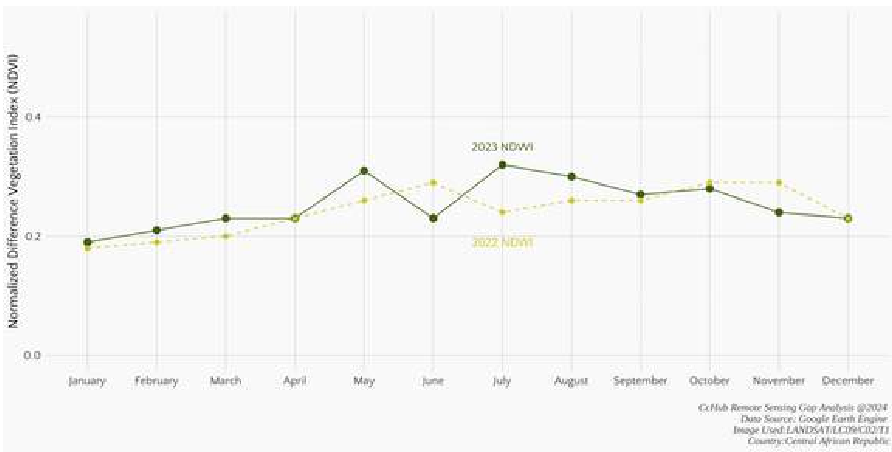
Temperate Climate - Swaziland

Swaziland's NDVI values fluctuated throughout the year in both 2022 and 2023, with no clear growing season trend. While overall NDVI was slightly higher in 2023 (0.22) compared to 2022 (0.21), several months in 2023 exhibited lower NDVI compared to 2022, including February, June, July, and November. This suggests potential variations in vegetation cover throughout the year between the two years.

Average NDVI values for Swaziland for the period covering 2022 and 2023
Source: CcHuB Analysis 2024

Tropical Climate - Central African Republic

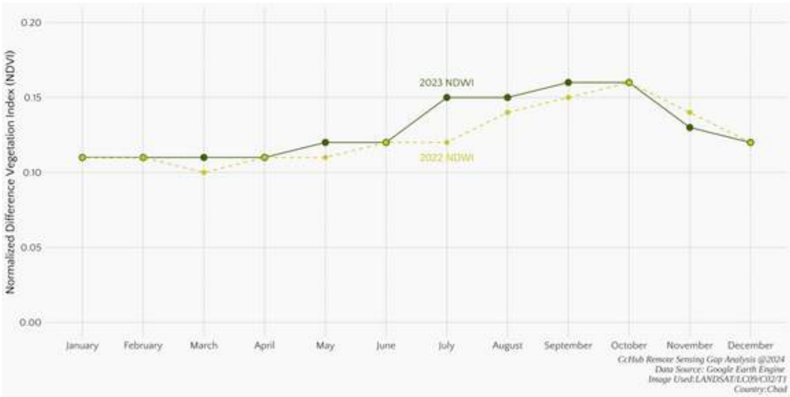
The Central African Republic displayed a distinct growing season in both 2022 and 2023, evident from the rise in NDVI values from January to May. While the month of May observed the peak NDVI in both years, overall vegetation health in 2023 (0.25) was slightly higher compared to 2022 (0.24). Interestingly, some months in 2023, like June and November, exhibited lower NDVI values compared to 2022, suggesting potential variations in vegetation cover throughout the year across the two years of study.



Average NDVI values for Central Africa Republic for the period covering 2022 and 2023
Source: CcHuB Analysis 2024

Desert Climate - Chad

Chad is characterised by desert climate. The country exhibited minimal seasonal variations in NDVI throughout both 2022 and 2023. While there was a slight increase in average NDVI in 2023 (0.13) compared to 2022 (0.12), the difference was negligible. Even though July showed the highest NDVI in both years, most months across the two years had insignificant NDVI variations indicating the largely expected low vegetation cover and minimal rainfall in a desert environment.



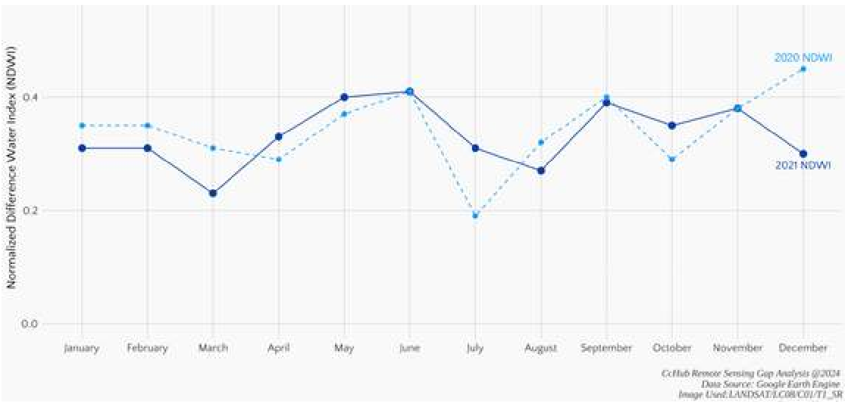
Average NDVI values for Central Africa Republic for the period covering 2022 and 2023
Source: CcHuB Analysis 2024

Normalised Difference Water Index (NDWI)

Analysis of the NDWI trends not only yields the identification of changes in water availability but also unveils key insights into potential drought conditions, water resource management strategies, and flood inundation mapping.

Equatorial Climate - Uganda

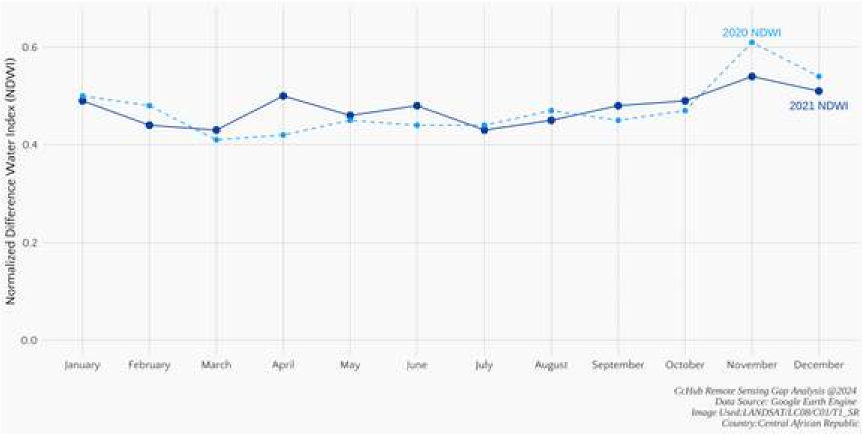
While Uganda maintained a generally high NDWI throughout 2020 and 2021, indicating well-watered conditions, a significant decrease was observed in March 2021 compared to March 2020, potentially suggesting a seasonal dry period. Additionally, a slight increase in NDWI was observed in April 2021 compared to April 2020, which could be indicative of a faster recovery from the dry season due to the equatorial climate's consistent rainfall patterns



Average NDWI values for Uganda for the period covering 2020 and 2021
Source: CcHuB Analysis 2024

Tropical Climate - Central African Republic

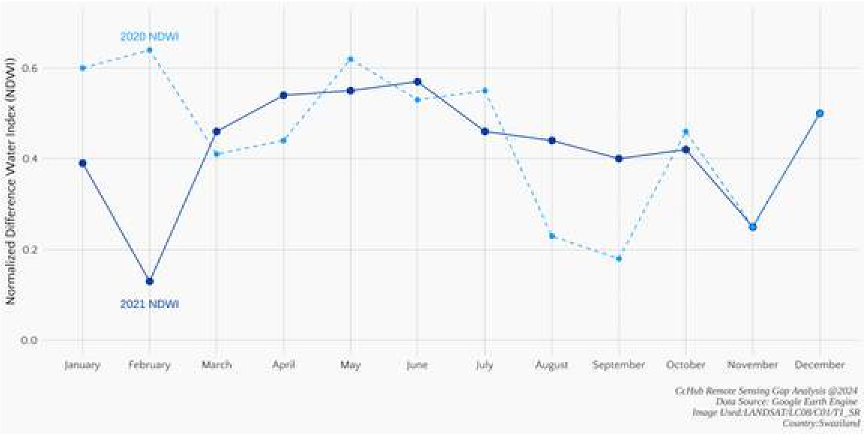
The Central African Republic exhibited consistently high NDWI values throughout 2020 and 2021, indicative of a persistently well-watered environment characteristic of a tropical climate. However, a slight decrease in NDWI was observed during November 2021 compared to November 2020, which could be a signal of a brief period of reduced moisture availability.



Average NDWI values for Central Africa Republic for the period covering 2020 and 2021
Source: CcHuB Analysis 2024

Temperate Climate - Swaziland

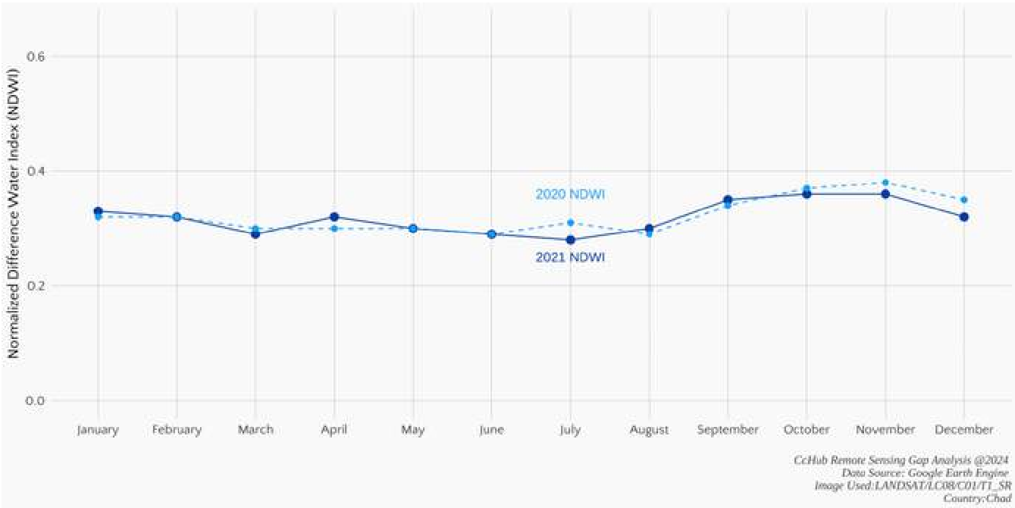
Swaziland exhibited a significant decline in NDWI values during the austral summer (December to February) of 2021 compared to 2020, suggesting a potentially drier summer season. This aligns with the characteristics of a temperate climate with distinct wet and dry seasons. In contrast, the austral winter (June to August) of 2021 showed increased NDWI compared to 2020, which could indicate a wetter winter.



Average NDWI values for Swaziland for the period covering 2020 and 2021
Source: CcHuB Analysis 2024

Desert Climate - Chad

Chad exhibited consistently low NDWI values throughout 2021, which aligns with the characteristics of a desert climate with minimal vegetation cover and limited water availability. The observed changes across the respective monthswere minor, suggesting little variation in moisture conditions throughout the year.



Average NDWI values for Chad for the period covering 2020 and 2021
Source: CcHuB Analysis 2024

FUTURE TRENDS IN THE ADOPTION AND APPLICATION OF REMOTE SENSING FOR DEVELOPMENT IN AFRICA

Given the key underlying benefits of adoption of RS data for development in Africa (Panaglobo, 2022), for fulfilling key developmental markers including the AU Agenda 2063 and UN SDGs, this analysis seeks to underscore the compelling need for continued adoption and application of RS data in Africa.

This analysis intends to achieve this by conducting a cross-sectoral impact logic for the adoption of RS technology in Africa. Similarly, a comprehensive mapping of key RS resources is also executed thus allowing an evidence-based RS adoption and policy making.

Gap Analysis of the Adoption and Application of RS Data for Development in Africa

SECTOR	AREAS OF RS APPLICATIONS	CASE STUDIES OF RS ADOPTION IN AFRICA	AREAS FOR FUTURE APPLICATION & ADOPTION OF RS TECHNOLOGIES IN AFRICA
Agriculture	• Crop yield management • Water use control for irrigation • Food Supply Chain Management e.g. crop monitoring for early warning • Crop Insurance	Garbal Service in Burkina Faso, Mali Afriscout Service in Kenya, Ethiopia and Tanzania Crop Monitor for early warning (CM4EW) in Uganda NASA Harvest's Crop Mapping in Kenya Southern Africa Development Community (SADC) Regional Remote Sensing Unit (RRSU), Gaborone (Brown et al., 2015) AGRHYMET Regional Centre, Niamey Big Data Ghana's GAIMS Platform Fruitlook South Africa Virtual Irrigation Academy (VIA) The Chameleon and Wetting Front Detector Sensors Tanzania, Mozambique and Zimbabwe **PULA**	• Intense use for precision agriculture and crop yield gap analysis (Ncube et al., 2018) • Improved linkage between remote sensing (RS) products and services for precision agriculture with agricultural and food security public policy making and implementation (Begue et al.,2020).
Forest Cover & Biodiversity Management	• Forest management including controlling deforestation, and improving afforestation and reforestation • Regulation of the Timber Market in Africa and reduction of illegal logging • Development of precision forestry • Biodiversity conservation and wildlife protection • Mitigation of forest fires • Mapping and Protection of indigenous communities	Mozambique Carbon Programme African Parks' anti-poaching efforts in Garamba National Park	Enhanced usage and integration of RS data for soil and land management for sustainable and socio-ecological systems (Koglo et al., 2018)

Mining & other Extractive Industries	• RS-enabled exploration and mapping of natural resources in Africa • Preparation and Extraction of Minerals eg. permitting, mine infrastructure monitoring, planning in extractive industries • Enhancing transparency in the Extractive industry through managing artisanal mining and controlling of illegal mining activities • Conservation and Rehabilitation of Post-mine sites	Application of EO in Mineral Exploration in Egypt Controlling illicit mining in Ghana Detecting Artisanal Mining Regional Centre for Mapping of Resources for Development (RCMRD), Nairobi	Enhancing access to up to date geoinformation on mining activities by mineral resource rich African countries including establishment of parametres for geoinformation in national mining policy frameworks and strengthening of the capacity of local communities to leverage mining geoinformation for decision making (Moomen, 2019)
Land Use Management & Planning	• Land Mapping and Registration • Land use and infrastructure development planning • Urban and Regional Planning	Rwanda Land Tenure Regularisation Programme Kenya Land Tenure Mapping (Case of Kajiado County) Lago (night time light)	Increased adoption of unmanned aerial vehicles (UAVs) and other emerging RS technologies e.g. automatic boundary extraction (ABE), Smart Sketch Mapping technology etc. for land mapping and urban planning in Africa (e.g. case of Kenya)
Public Health	Mapping and Analysis of Parasitic Diseases e.g. Understanding the geographic distribution of vector-borne diseases and Integration of RS data on vector habitats and human population density. Study of disease spread and patterns such as Evaluation of Health-Environment Relationship and Quantification of health-related variables and environmental risk factors. Assessment of factors like rainfall, temperature, vegetation cover, landscape wetness, and land use hence support in Interventions Related to Environmental Risk Factors as well as Monitoring of fine particulate matter, insolation, and land surface temperature. Linking environmental factors with public health outcomes (e.g., cognitive, stroke).	**South Africa** Malaria Early Warning System (MEWS) providing real-time information on malaria epidemics. Use of RS for epidemiological analysis, vulnerability mapping, and resource allocation. Identification of mosquito habitats using aerial photography (Hay et al., 2000; Brown and Sethi, 2002). **Ghana** Utilisation of GIS technologies, including RS, for tracking and combating Covid-19 since 2020 including development of Covid-19 tracking dashboards, mobile applications, and drones e.g. Government-backed RS dashboards by Ghana Statistical Service and Ghana Health Service.	**Enhanced Disease Monitoring** Real-time monitoring of various diseases beyond Covid-19 and malaria. Predictive modelling and early warning systems for emerging health threats. **Environmental and Climate Change Monitoring** Monitoring environmental changes and their impacts on public health. Development of predictive models for climate-related diseases using RS data **Urban Health Planning** Integration of RS technology in urban health planning for disease prevention and management.

		Various African Regions Application of RS in epidemiological analysis of diseases like fasciolosis and schistosomiasis (Malone, 2005). Use of RS for understanding climate-related impacts on diseases.	Use of RS data in disaster management and mitigation planning in urban areas e.g. disease outbreaks, pandemics and epidemics control in urban areas. **Precision Public Health** Utilisation of RS data for personalised healthcare and precision public health interventions. Targeted interventions based on spatial analysis of health-related data. **Health Equity and Access** Use of RS technology to address health inequities and improve access to healthcare services in underserved areas. Spatial analysis to identify healthcare resource gaps and optimise resource allocation. **One Health Approach** Integration of RS data in the One Health approach for holistic management of human, animal, and environmental health. Monitoring zoonotic diseases and their spread using RS technology.

Sources: Analysis Ready Data: A smart way to use Earth observation for Africa's rising nations, Insight Report, May 2022, by **Panaglobo Consulting for Digital Earth Africa**, Citizen Science and Remote Sensing for Crop Yield Gap Analysis by Beza, 2017, Innovative Remote Sensing Methodologies for Kenyan Land Tenure Mapping by Koeva et al., 2020, Brown et al., 2015,

Mapping of the African Remote Sensing Activities

National Remote Sensing Authorities, Satellites and Ground Recovery Stations, Regional Technical Centres and Private Sector Entities in Africa

COUNTRY	NATIONAL REMOTE SENSING AUTHORITIES/ FACILITIES	SATELLITES & GROUND RECEIVING STATIONS	UNIVERSITIES, RESEARCH & TRAINING INSTITUTES ON REMOTE SENSING	REGIONAL TECHNICAL CENTRES	PRIVATE SECTOR
Algeria	Centre National des Techniques Spatiales (CNTS)	AlSat-2 – fully operational, not only research. Approx. 25 Algerian aerospace engineers with EADS Astrium for 32 months, as part of contract between EADS Astrium and Algerian space agency (ASAL) for production of two small high-resolution EO satellites. Alsat-2 spacecraft7 , with scheduled five-year service life, will utilise Myriade small-satellite platform and provide B&W images with 2.5-meter ground resolution for CNTS (Centre National des Techniques Spatiales) Year of Launch: 2001	Map All research institutes focusing in RS in AFRICA	African Organization of Cartography and Remote Sensing (OACT)	
Benin	National Center for Remote Sensing and Forest Cover Monitoring (CENATEL)				
Botswana	Department of Surveys and Mapping, Ministry of Lands & Housing		Department of Surveys and Mapping, Ministry of Lands & Housing	SADC Regional Remote Sensing Unit (RRSU)	
Burkina Faso				Centre SIG et Télédétection Adjaratou	ABSYS-STAR

Cameroon	Centre de Teledetection et de Cartographie Forestiere (CETELCAF), Office National de Developpement des Forets (ONADEF)		Centre Universitaire de Recherche et d'Application en Télédétection (CURAT), Université de Cocody-Abidjan, http://centre-curat.salifa.com/		
Chad				Remote Sensing Unit, Lake Chad Basin Commission	
Congo				Observatoire Satellital des Forêts d'Afrique Centrale (OSFAC)	
DRC	Agence Nationale de Meterologie et de Télédétection par Satellite (METTELSAT), Ministère des Transports et Communications		Ecole régionale post-universitaire d'aménagement et de gestion intégrés des forêts et territoires tropicaux (ERAIFT), University of Kinshasa, http://www.unesco.org/mab/ecosyst/forest/eraift.shtml		
Egypt	National Authority for Remote Sensing and Space Sciences (NARSS)	EgyptSat-1, high resolution multispectral imager, built by NARSS in collaboration with Ukraine (Ukraine providing technical expertise and training). Total price: US$ 30 million8 . Year of Launch: 2007 Ground station in Aswan, built by NARSS to acquire & record data from SPOT constellation, as well as ERS2 and LANDSAT-7 satellites. Data collected in Aswan are transferred to processing facilities in Cairo for image archive, catalogue, and high-quality image generation in standard product formats. Footprint for reception is 2500 km diameter, covering northeast Africa, Mediterranean, and parts of Asia. Construction cost of the ground receiving station was estimated at LE15 million (in 1999). The station, at the time, was the 2nd in Africa – the 1st being in South Africa. Year of Launch: 1999		Center for Environment and Development for the Arab Region and Europe (CEDARE)	QSIT

Ethiopia	Ethiopia Mapping Authority (EMA)			International Livestock Research Institute (ILRI)	
Ghana	Centre for Remote Sensing and GIS, (CERSGIS) (formerly the Remote Sensing Applications Unit), University of Ghana				
Ivory Coast	Centre de Cartographie et de Télédétection (CCT), Bureau National d'Etudes Techniques et du Développement (BNETD)			**The Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)***	
Kenya	Department of Resource Surveys & Remote Sensing (DRSRS), Ministry of Environment and Natural Resources; Kenya Institute of Surveying and Mapping (KISM), Survey Department, Ministry of Lands	Malindi, Kenya (Broglio) space centre / San Marco Project, owned by the Agenzia Spaziale Italiana (ASI). ASI employs 230 workers, of whom about 20 are Italians. The Italian staff are backed by several Kenyan technicians who are trained and based at the facility. One of the satellites monitored at the station covers the Horn of Africa region from Djibouti to Madagascar. All remotely sensed data archived at the facility are available free of charge to the Kenyan research community and relevant government institutions. Year of Launch: 1964		Regional Centre for Mapping of Resources for Development (RCMRD) IGAD Climate Prediction and Applications Centre (ICPAC), formerly known as the Drought Monitoring Centre Nairobi (DMCN) Institute for Meteorological Training and Research (IMTR) International Livestock Research Institute (ILRI) World Agroforestry Center	ImageAfrica
Libya	Libyan Center for Remote Sensing and Space Science (LCRSSS)				

Mali			Département de Géographie, Université du Mali	International Crops Research Institute for Semi-Arid Tropics (ICRISAT)	
Mauritius	National Remote Sensing Centre, Ministry of Agriculture				
Morocco	Royal Center For Remote Sensing (CRTS)	Maroc-Tubsat6 - earth RS and vegetation detection with medium resolution of c.300m. Cooperation between CRTS Morocco & Institut für Luft-und Raumfahrttechnik in Berlin (Moroccan side responsible for payload & launch; German side for satellite bus). Year of Launch: 2008		African Regional Centre for Space Science and Technology Education (CRASTE-LF)	
Mozambique	Centro Nacional de Cartografia e Teledetecção (CENACARTA)		Department of Geography, Eduardo Mondlane University		
Namibia	National Remote Sensing Centre, Department of Forestry				
Niger	Département de Photogrammétrie et Télédétection, Institut Géographique National du Niger (IGNN), Ministère de l'Equipement, du Transport et de l'Amenagement du Territoire		Sahelian Agricultural, Hydrological and Meteorological Centre (AGRHYMET) African Centre of Meteorological Application for Development (ACMAD)		
Nigeria	National Space Research and Development Agency (NARSDA)	NigeriaSat-1 Year of Launch: 2003 NigeriaSat-2 Year of Launch: 2009	Space Applications and Environmental Science Laboratory (SPAEL), Obafemi Awolowo University, Ile-Ife, http://www.spaeloauife.org/ Federal University of Technology	Regional Centre for Training in Aerospace Surveys (RECTAS) African Regional Centre for Space Science and Technology Education (ARCSSTE-E) (2005 Annual Report) International Institute of Tropical Agriculture (IITA)	

Rwanda	Centre for GIS and Remote Sensing (CGIS), National University of Rwanda (NUR)	METEOSAT 8 (2nd generation) installed at CGIS-NUR. National Meteorological Service & National University of Rwanda (NUR) Faculty of Science main partners in this effort. Ground station receives complete coverage of Rwanda each 15 minutes with high spatial and spectral resolution. ITC provided technical support. Year of Launch: 2006	Center for GIS, National University of Rwanda		
Senegal	Centre de Suivi Ecologique (CSE)	Reception of radar satellite images, since December 2005. Collaboration between Centre de Suivi Ecologique (CSE) and European Space Agency. Year of Launch: 2005	Laboratoire d'Enseignement et de Recherche en Géomatique (LERG) de l'Université Cheikh Anta Diop de Dakar		MAPS geosystems
South Africa	CSIR Satellite Applications Centre (SAC); CSIR Earth Observation Data Centre (EODC), Institute for Satellite and Software Applications (ISSA); (National Space Agency soon to be established)	SumbandilaSAT Years of Launch: 2007	School of Architecture, Planning and Geomatics, University of Cape Town (Dr. Heinz Ruther) Department of Electrical and Electronic Engineering, Stellenbosch University	International Water Management Institute (IWMI)	MapIT
Swaziland			Department of Geography and Environmental Science, University of Swaziland		
Sudan	Technical Authority for Remote Sensing				
Tanzania			Department of Geology, University of Dar es Salaam	Southern and Eastern African Mineral Centre (SEAMIC)	
Tunisia	Centre National de Télédétection		Space Information System and Remote Sensing Laboratory (LTSIRS), National Engineering School of Tunis	Centre Régional de Télédétection des États de l’Afrique du Nord (CRTEAN)	

Uganda			Geography Department, Makerere University		
Zimbabwe	Geo-Information and Remote Sensing Institute (SIRDC)			SADC Drought Monitoring Centre	

Sources: **Brown et al., 2015**,

Existing Geospatial Services, Initiatives and Projects in Africa

Geospatial Support Services in Africa

SERVICE/PROVIDER	**TERRITORY**
Système de Gestion Intégré de l'Information Agricole et Rurale	Algeria
SWALIM	Somalia
ICRAF GeoNetwork	
ILRI GeoNetwork	
CARPE	
Global Forest Watch Statistics on natural forests and the trends in deforestation. The site provides global data with specific data for Cameroon and Central Africa. Map maps are available.	
Africover	
Harmonised land cover products; satellite imagery; image interpretation/Land Cover Classification System http://www.africover.org/	
Mapping Malaria risk in Africa (MARA)	
East Africa Livestock Early Warning System (LEWS)	
East Africa Livestock Early Warning System (LEWS)	
Desert Locust Early Warning System http://www.fao.org/ag/locusts/en/info/info/index.html	

Humanitarian Early Warning System Famine Early Warning Systems Network	
Timely, early warning and vulnerability information, Images, Tabular, Data - NDVI, RFE, WRSI - Atlas of Limpopo Basin, reports	
African Data Dissemination Service	
NDVI (Normalized Difference Vegetation Index), moisture, rainfall, malaria and other imagery for Africa	
East Africa an operational crop yield monitoring and forecasting system (CYMFS)	
Mapping malaria risk	
Rift Valley Fever Monitor	
EUMETCast	
Global Land Cover Facility (GLCF)	
Country and Region-Specific Food Security Monitoring Systems, (FIVIMS) Develops and distributes remotely sensed satellite data and products concerned with land cover from the local to global scales.	

UN Geospatial Programmes in Africa

ORGNISATION	REMOTE SENSING ACTIVITY/MANDATE
Food and Agriculture Organization (FAO)	Global Land Cover Network - Land Cover Network aimed at proving and developing cpacity for harmonised land cover products at National, Regional and Global level. Provide training and workshops to national staff who are involved in the project and capacity is built in the fields of image interpretation, Land Cover Classification System, data management and GIS.Provide internships to University students and provide guidance and assistance in research topics. Global Terrestrial Observing System (GTOS) GeoNetwork portal, metadata catalogue describing geospatial data, system for searching, editing and publishing geospatial information http://www.fao.org/geonetwork
UN Economic Commission for Africa (UNECA	Harnessing information for development; CODI-Geo http://geoinfo.uneca.org/

United Nations Environment Program(UNEP)	Organises workshops on disaster management, GNSS capacity building, tele-health, natural resources management, and space law.
UN Educational, Scientific and Cultural Organization (UNESCO)	Global Oceans observing system (GOOS)-AFRICA GOOS are a permanent global system for observations, modelling and analysis of marine and ocean variables to support operational ocean services worldwide. GOOS will provide accurate descriptions of the present state of the oceans, including living resources; continuous forecasts of the future conditions of the sea for as far ahead as possible; and the basis for forecasts of climate change. UNESCO Crosscutting Project on the Applications of Remote Sensing for Integrated Management of Ecosystems and Water Resources in Africa
UN Office for the Coordination of Humanitarian Affairs (OCHA)	Southern Africa Humanitarian Information Network (SAHIMS) Reliefweb http://www.reliefweb.int/
UN HABITAT	Global Land Tool Network (GLTN), http://www.gltn.net/ Global Urban Observatories
World Food Program (WFP)	Food Insecurity and Vulnerability Information and Mapping System,
World Health Organization (WHO)	Second Administrative Level Boundaries (SALB)

International Geospatial Associations in Africa

ASSOCIATION	ACTIVITY
Global Spatial Data Infrastructure Association (GSDI)	SDI-Africa Newsletter (monthly); GSDI Small Grants (annual); SDI-Africa: an implementation guide; Global Map/GSDI ESRI software grants
Institute of Electrical and Electronic Engineers: Geoscience and Remote Sensing (IEEE)	GEOSS II Workshop at Africa GIS2005.
International Association of Geodesy (IAG)	Support for the African Reference Frame (AFREF).
International Cartographic Association (ICA)	Mapping Africa for Africa (MAfA
International Council for Science - Regional Office for Africa (ICSU)	Promotes all activities of the ICSU family: IHDP, IGBP, WCRPD, IVERSITAS, START; host of workshops focusing on data archiving.
International Federation of Surveyors (FIG)	Workshops (e.g., Expert Group Meeting on Transparency in Land Administration – a Capacity Building Programme for Africa, Nairobi, Kenya, 29-31 January 2007)

International Society for Photogrammetry and Remote Sensing (ISPRS)	Rallying 'sister-society' support for joint capacity building efforts in Africa
International Steering Committee on Global Mapping (ISCGM)	Global Map/GSDI ESRI software grants; regional capacity building workshops
International Union of Geodesy and Geophysics (IUGG)	Geoscience in Africa (GIA)

Sources: **Brown et al., 2015**,

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