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ASSESSING EO NEEDS AND GAPS AT INSTITUTIONAL LEVEL & RECOMMENDATIONS FOR PRIVATE SECTOR UPTAKE

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ACRONYMS

AAFC: Agriculture and AgriFood Canada
AARSE: African Association of Remote Sensing of the Environment
ACP: African, Caribbean, Pacific
AFA: Agriculture and Food Authority
AfriGEO: Africa GeoPortal
AFRIGIST: African Regional Institute for Geospatial Information Science and Technology
AfSA: African Space Agency
AI: Artificial Intelligence
AUC: African Union Commission
ASI: Italian Space Agency
AWS: Amazon Web Services
CAP: Common Agriculture Policy
CEOS: Committee on Earth Observation Satellites
COMESA: Common Market for Eastern and Southern Africa
CoGeoS: Comoros, Madagacar and Mauritius
DE Africa: Digital Earth Africa
DRSRS: Directorate of Resource Surveys and Remote Sensing
EAC: East Africa Community
EC: European Commission
ECAAS: Enabling Crop Analytics at Scale
ECV: Essential climate Variables
EDF: European Development Fund
EO: Earth Observation
EOCap4Africa: Earth Observation in Africa: Capacity building for the conservation of ecosystems and their services
ESA: European Space Agency
ESG: Environmental Societal Governance
EU: European Union
Eumetsat: European Organisation for the Exploitation of Meteorological Satellites
EUR: Euro
GCOS: Global Climate Observing System
GDP: Gross Domestic Product
GEO: Group on Earth Observation
GEOSS: Global Earth Observation System
GPSDD: Global Partnership for Sustainable Data
DG INTPA: Directorate General International Partnerships
GEE: Google Earth Engine
GIS: Geographic Information Systems
GMES: Global Monitoring for Environment and Security
GNSS: Global Navigation Satellite System
GPS: Global Positioning System
IGAD: Intergovernmental Authority on Development
IKUNS: Kenyan Italian Nanosatellite University
IoT: Internet of Things
JAXA: Japan Aerospace Exploration Agency
JNAMP: Join National Resource Mapping project
KAOP: Kenya Agriculture Observatory Platform
KARLO: Kenya Agricultural and Livestock Research Organization
KCAA: Kenya Civil Aviation Authority
KeNIA: Kenya National Innovation Authority
KEPHIS: Kenya Plan Health Inspectorate Service
KFS: Kenya Forestry Services
KILMO: Kenyan Innovation for Low Input Maize Production
KIRDI: Kenya Industrial Research and Development Institute

KMD: Kenya Meteorological Department
KNBS: Kenya National Bureau of Statistics
KSA: Kenya Space Agency
KWS: Kenya Wildlife Service
LEOP: Launch and Early Orbit Phase
LIS: Land Information System
MIDST: Monitoring for Information and Decisions using Space Technology
Misland: Monitoring Integrated Services for Land Degradation
ML: Machine Learning
MGP: Maxar Geospatial Platform
MoU: Memorandum of Understanding
MSMEs: Micro, Small or Medium-Sized Enterprises
NASA: National Astronomical and Scientific Authority
NEMA: National Environment Management Authority
NGO: Non-Governmental Organization
NOOA: National Oceanic and Atmospheric Agency
RARS: Regional Advanced Retransmission Systems
RCMRD: Regional Centre for Mapping of Resources for Development
R&D: Research & Development
RECs: Regional Economic Communities
REDD+: Reducing Emissions from Deforestation and Forest Degradation
SANSA: South African Space Agency
SAWIDREA: Satellite and Weather Information for Disaster Resilience in East Africa
SMEs: Small and Medium Enterprises
SPIDER: Space-based Information for Disaster Management and Emergency Response
SSA: Sub-Saharan Africa
SSP: Sayarilabs Payload Processor
STEM: Science, Technology, Engineering, and Mathematics
TAF: Technical Assistance Facility
TT&C: Telemetry Tracking and Control
UKSA: United Kingdom Space Agency
UNESCO: United Nations Educational, Scientific and Cultural Organization
UNOOSA: United Nations Office for Outer Space Affairs
UoN: University of Nairobi
WeMAST: Wetland Monitoring and Assessment Service for Transboudary Basins
WMO: World Meteorological Organization

1. Executive Summary

The objective of this study is to assess Earth Observation (EO) needs and gaps at the institutional level in Kenya and to evaluate the current use of EO data in the private sector. The goal is to provide recommendations to enhance EO data uptake and usage across sectors. This assessment builds on prior studies and focuses on Kenya's specific EO needs and the barriers limiting its full utilisation in various sectors.

Kenya’s EO landscape is shaped by its socio-economic and geographic diversity, with distinct applications in agriculture, water resources, climate monitoring, and disaster management. While Kenya has made strides in adopting EO technologies, challenges remain due to limited local capacity, high costs for high-resolution data, and gaps in technical skills, particularly in advanced areas such as hyperspectral imaging and SAR data processing. The involvement of the Kenya Space Agency (KSA) and its strategic framework has laid the groundwork for further development, although more resources and collaboration are required.

The assessment found that Kenya’s institutional users have varying levels of access to EO data, with government agencies relying heavily on freely available data from international sources like the European Union’s Copernicus programme. However, the private sector faces affordability and accessibility challenges, particularly for high-resolution commercial imagery needed for local-level applications. While some national supply capabilities exist, especially in downstream services, much of the EO data used in Kenya still originates from foreign sources, leading to concerns around data security and sustainability.

The gap analysis highlights significant discrepancies between current EO services and the growing demand, especially in sectors like agriculture, climate monitoring, and infrastructure development. The key barriers include limited computational resources, high costs of commercial satellite data, and a lack of localised, high-resolution applications. Moreover, the infrastructure and technical capacity required to process and analyse EO data at the scale needed for local decision-making remain underdeveloped. These gaps are exacerbated by Kenya's limited investment in its space sector, with a particular need for capacity building in emerging EO technologies.

To be finalized in V3

2. Study background

2.1. Objectives of the study

This Technical Assistance Facility (TAF) Assignment #7 is part of the Joint EU-African initiative in the field of Space and Earth Observation (EO). The primary objective of this assignment is to **assess the EO needs and gaps at the institutional level in Kenya, evaluate the current utilization of EO data in the private sector, and issue recommendations to enhance the use and uptake of EO data.**

Building on the previous TAF#4 assignment, which assessed the maturity and development levels of national space sectors across several Sub-Saharan African (SSA) countries, including Kenya, this study will focus specifically on Kenya.

This study involves a comprehensive analysis to identify the specific EO needs and gaps at the institutional and private sector level. It will evaluate how EO data is currently used by institutions and pinpoint areas where improvements are needed. Additionally, the study will assess the private sector's capabilities, skills, and other factors that enable the use of EO data. By identifying these needs and gaps, the study will provide targeted recommendations to improve the uptake and use of EO data by both institutional and private sector users.

The assessment will cover several key areas, including:

- National institutional and industry requirements and capacities for EO data utilization.
- Current EO data usage, including capabilities and enabling factors.
- Identification of gaps and barriers in EO data utilization.
- Recommendations for improving infrastructure, training, policy development, and other areas to enhance EO data use.

2.2. Benefits of the study

The assessment of Earth Observation (EO) needs and gaps at the institutional and private sector level in Kenya, coupled with recommendations for the EO data uptake, presents several **significant benefits**. Firstly, it provides a clear understanding of the current state of EO data utilization, **identifying critical areas where enhancements are required**. This enables policymakers to develop targeted strategies and allocate resources effectively, ensuring optimal use of EO data for societal benefits, such as improved agricultural practices, disaster management, and environmental monitoring.

For the private sector, the study's recommendations will **foster innovation and economic growth** by addressing barriers such as funding constraints and regulatory challenges. By enhancing the private sector's ability to leverage EO technologies, the study promotes the development of new products and services, driving competitiveness and market expansion. This creates opportunities for SMEs and startups to thrive, contributing to job creation and sustainable development.

Additionally, the study supports the alignment of Kenya's EO capabilities with international standards, **facilitating greater collaboration with global partners** and access to international funding and expertise. By providing a roadmap for strategic investments and policy interventions, the study ensures the long-term sustainability and growth of Kenya's EO sector, ultimately benefiting both the economy

and society at large. Moreover, it highlights benefits in terms of EU-Kenya collaboration and identified was to strengthen these relationships, fostering deeper ties and mutual growth.

2.3. Methodology

The methodology employed for assessing the EO needs and gaps at both institutional and private sector levels in Kenya is designed to provide a comprehensive understanding of the EO landscape while identifying areas for improvement and enhancement. The assessment is structured into several main tasks:

Task 1 - Background Research and Context Analysis: The study begins with background research to delve into Kenya's national context (Section 4), encompassing its historical, socio-economic, and geopolitical landscape, alongside current strategic priorities. This includes an in-depth examination of the EO ecosystem and key stakeholders, as well as assessing regional and international collaborations in space and EO. This foundational analysis informs subsequent phases of the study, highlighting implications for the space sector and identifying synergies across various sectors.

Task 2 - Preliminary Assessment of EO Needs and Supply: The project team proceeds with a preliminary assessment of EO needs and requirements for both institutional and private stakeholders. This phase begins by delineating EO market verticals, such as security, agriculture, climate change, maritime, health, and infrastructure development, providing detailed descriptions of each sector's characteristics and specific needs. The assessment includes the documentation of practical use cases within each vertical, demonstrating current or potential applications of EO data.

Furthermore, the assessment evaluates the current supply of EO data and services across different market segments. This entails identifying the types of EO data accessible to users in Kenya and assessing them based on criteria like quality, frequency, and accessibility. This analysis aims to provide insights into the existing capabilities and resources available to fulfil the identified EO needs effectively.

Task 3 - Stakeholders Consultations: Onsite consultations with key stakeholders are conducted to gather additional insights, validate, and refine the preliminary assessment. Targeted meetings and a workshop took place in Kenya, with an onsite visit to engage with local stakeholders from both the public and private sectors.

Task 4 - Gap Analysis: The collected information on both requirements and current supply is analysed to identify gaps between current EO capabilities and the needs for each vertical identified. This gap analysis highlights areas where additional EO resources, tools, or data are required, comparing stakeholder needs with available EO data to pinpoint discrepancies and unmet demands.

Task 5 – Conclusions and recommendations: Based on the gap analysis findings, targeted recommendations are developed to enhance the uptake and usage of EO data by public and private users in Kenya. These recommendations are compiled into a final report, outlining actionable steps, responsible stakeholders, and necessary resource allocation to ensure successful implementation.

3. Kenya's national context analysis

3.1. Kenya's socio-economic profile

3.1.1. History and demography

Kenya has a rich and complex history shaped significantly by colonialism. The country was a British colony from 1895 until gaining independence in 1963. The colonial period was marked by land alienation, forced labour, and the establishment of settler agriculture, which left lasting economic and social inequalities. Post-independence, Kenya experienced political turbulence, including the Mau Mau uprising against British rule and subsequent internal conflicts. However, it also saw significant economic development and modernisation. Culturally, Kenya is diverse, home to over 40 ethnic groups, with the Kikuyu, Luo, and Luhya being among the largest.

The current political regime is a multiparty democracy, with periodic elections and a strong executive branch. As of 2024, Kenya's population is approximately 56 million[1], characterized by a youthful demographic, with around 75% of the population under the age of 35, projected to reach almost 19 million by 2035. This composition presents both opportunities and challenges for the country's development.

Implications for the space sector

With a diverse population and rapid urbanization, space plays a role in:

- **Innovation hubs and clusters**: Nairobi, as a key innovation hub, benefits from satellite data to foster tech-driven startups and SMEs.
- **Urban planning:** EO data aids in managing urban sprawl and infrastructure development to accommodate growing urban populations.
- **Food security:** EO data helps improve agricultural productivity which is crucial to support Kenya's growing population, particularly in rural areas where agriculture remains a primary livelihood.
- **National security and defence:** Satellite imagery and communication systems enhance border surveillance, disaster response and the management of natural resources, contributing to national stability.

3.1.2. Geography

Located in East Africa, Kenya borders Ethiopia to the north, Somalia to the east, Tanzania to the south, Uganda to the west, and South Sudan to the northwest. It has a coastline along the Indian Ocean. The country's geography is diverse, featuring a low-lying coastal region, the fertile central highlands, and the arid and semi-aid northern and northeastern regions. Its ecosystems include savannas, mountain

[1] World Bank, Population, total - Kenya

ranges, and lush forests. This diversity supports a rich array of wildlife, making Kenya renowned for its national parks and game reserves, which are crucial for conservation.

Implications for the space sector

Space based applications provide valuable solutions to respond to Kenya's diverse geography:

- **Agriculture:** monitoring of crops, water resources and support farmers to optimise yields.
- **Maritime surveillance:** enhance coastal and marine resource management and security through satellite technologies.
- **Environmental conservation:** protect biodiversity and forestry by using EO data for wildlife tracking and forest management.
- **Disaster management:** provide early warnings and responses to natural disasters such as droughts and floods.

3.1.3. Economy

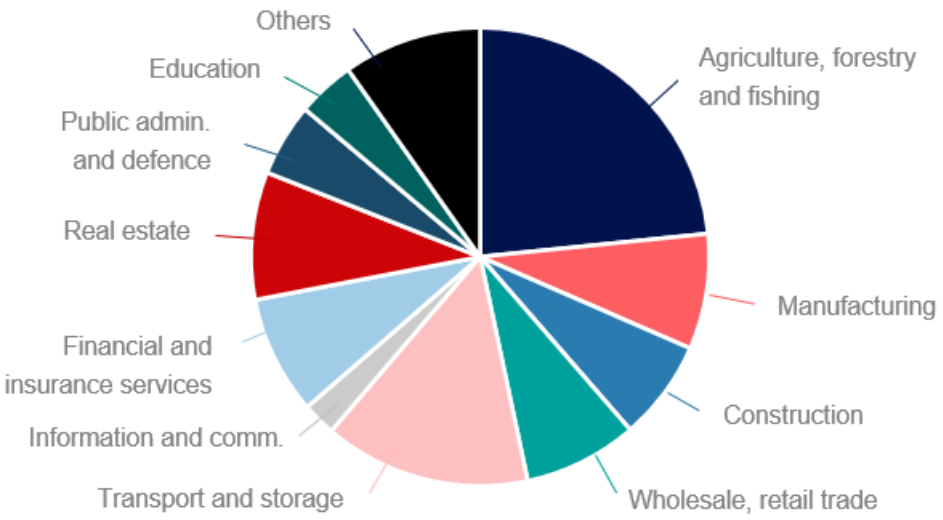
In 2007, the Kenyan government unveiled Vision 2030, a long-term development blueprint aimed at transforming Kenya into a newly industrialized, middle-income country by 2030. Investment in infrastructure has been a priority for the Kenyan government, with significant expenditure on transportation networks, energy projects, and ICT infrastructure.

Despite these advancements, Kenya faces several challenges. The country experiences high levels of poverty and unemployment, particularly among the youth. About 36% of the population lives below the poverty line. The informal sector is vast, providing livelihoods for many but often lacking job security and social protections, and not contributing to the tax base. Furthermore, there are significant regional disparities in development, with northern and northeastern regions being particularly underdeveloped.

In 2023, the key sectors driving the Kenyan economy include agriculture, forestry and fishing, which accounts for 22% of its GDP. It reflects Kenya's traditional reliance on agriculture as the backbone of the economy, and suggests a large rural population engaged in farming and related activities. The wholesale and retail trade sector represent 7,5% of Kenya's GDP, highlighting the importance of the informal economy in urban areas.

[2] World Bank Group, GDP - Kenya
[3] IMF, Real GDP growth in 2024

Figure 1: Percentage contributions to GDP per activity, 2023



Source: National Bureau of Statistics, 2024, Economic Survey of Kenya

Kenya imports a substantial amount of goods to meet domestic demand, with key imports including machinery, petroleum products, motor vehicles, iron and steel. The country also imports food products, highlighting challenges in achieving food security. Conversely, Kenya's main exports are agricultural products, including tea, coffee, and horticultural goods, alongside textiles and apparel[4].

Figure 3: Kenya top 5 exports in 2023 (KSh billions)

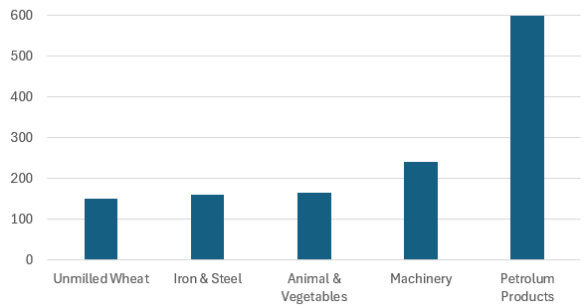
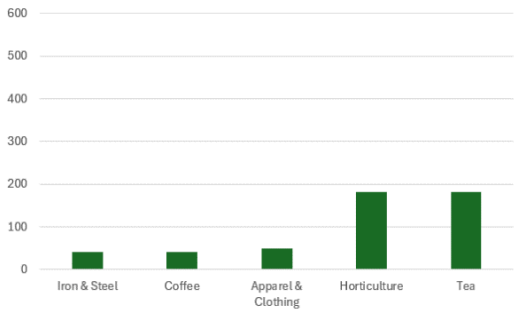


Figure 2: Kenya top 5 imports in 2023 (KSh billions)



Source: National Bureau of Statistics, 2024, Economic Survey of Kenya

Foreign direct investment (FDI) continues to grow, particularly in the technology and renewable energy sectors. However, corruption, bureaucratic inefficiencies, and political instability remain significant barriers to economic growth and development. Addressing these issues is crucial for sustainable socio-economic progress and improved living standards for the Kenyan population.

[4] National Bureau of Statistics, 2024, Economic Survey of Kenya

Implications for the space sector

Space technologies and associated services support the country's economic growth through:

- **Agricultural monitoring:** using EO technologies to boost agricultural productivity and sustainability.
- **Connectivity**: satcom improves connectivity in remote areas, supporting enterprises business and government initiatives.
- **Technology innovations:** foster SMEs and startups in the space sector, driving innovation and job creation.
- **Infrastructure development:** satellite solutions (data, PNT…) aids in planning and monitoring transportation and urban development projects, enhancing regional integration and trade.

3.1.4. National political situation

The reintroduction of multi-party politics in the early 1990s heralded a new era of democratic governance. In recent decades, Kenya has experienced significant political and economic transformations. The transition of power in 2002, and later in 2013, underscored the maturing democratic processes. However, current tensions and political instability have emerged due to the government's plan to raise taxes as part of the Finance Bill 2024. The protests, which began in mid-June 2024, escalated into riots, with demonstrators demanding President William Ruto's resignation. Despite these challenges, the 2010 constitution has strengthened democratic institutions, enhancing checks and balances within the government.

As of now, President William Ruto, elected in 2022, leads the government. His administration has prioritized economic development, technological innovation, and infrastructure expansion. These efforts have critical implications for Kenya's space sector, with the government recognizing space technology's potential in driving economic growth, environmental monitoring, and disaster management. The Kenya Space Agency (KSA), established in 2018, plays a pivotal role in this vision, aiming to harness space technology to address national challenges and support socio-economic development.

3.1.5. Regional policy

Kenya maintains robust relations with several neighbouring countries, contributing to regional stability and economic integration.

Kenya's involvement in the African Union (AU) underscores its commitment to regional peace and development. Through initiatives like the African Union Mission in Somalia (AMISOM), Kenya actively contributes to stabilizing the region. Moreover, Kenya partners with Ethiopia, South Sudan, and Uganda in the Intergovernmental Authority on Development (IGAD), focusing on drought resilience, infrastructure development, and conflict resolution. Kenya's regional partnerships extend to collaborative projects with various African nations. For instance, the LAPSSET Corridor Program, involving Ethiopia and South Sudan, aims to boost regional integration through infrastructure development. Kenya also engages with Nigeria and Ghana in technology and innovation initiatives, reflecting its strategic focus on leveraging partnerships to drive growth and stability across the continent.

One of Kenya's strongest allies is Uganda, with which it shares substantial trade ties and infrastructure projects, such as the Standard Gauge Railway aimed at enhancing connectivity. Kenya also enjoys favourable relations with Tanzania, another key economic partner within the East African Community (EAC). Both nations collaborate on initiatives such as the Northern Corridor, facilitating trade and transportation across the region. Rwanda and Kenya have also developed a positive relationship, particularly in areas of trade and investment, bolstered by the EAC framework.

Conversely, Kenya's relations with Somalia have been strained, primarily due to maritime boundary disputes and security concerns related to Al-Shabaab. The contested maritime boundary in the Indian Ocean has led to a prolonged legal battle at the International Court of Justice, impacting diplomatic ties. In addition, periodic border conflicts and issues related to the presence of Somali refugees in Kenya further complicate relations. A further point of contention exists with Ethiopia, with periodic disputes over the utilization of shared resources such as the Omo River. However, both countries generally strive to maintain a working relationship, recognizing the mutual benefits of cooperation, especially in trade and regional security.

3.1.6. International policy

Kenya maintains diverse and dynamic diplomatic relations with several international players, leveraging these partnerships to enhance its development across various sectors:

- **China**: Kenya has engaged in significant infrastructure projects, including the Standard Gauge Railway, and investments in sectors like energy and manufacturing.
- **U.S**.: Supports Kenya through initiatives in security, health, and trade, highlighted by the African Growth and Opportunity Act (AGOA) boosting Kenyan exports to the U.S. The U.S. recently designated Kenya as a major non-NATO ally, facilitating military technology access and highlighting Kenya's strategic importance[5]. It underscores Kenya's role in regional stability, combating extremist groups, and contributing to international peacekeeping efforts.
- **E.U**.: Kenya's relationship with Europe, particularly the E.U. focuses on trade agreements, development aid, and environmental sustainability projects.
- **Japan**: It's engagement with Kenya includes technical assistance, capacity building, and significant investments in infrastructure and technology transfer.
- **Russia**: collaborates with Kenya in areas such as energy, education, and industrial development, fostering scientific research and technological advancements.
- **India**: Kenya has strengthened ties with India, focusing on trade, healthcare, and educational exchanges, reflecting a growing South-South cooperation.

3.2. Space policy framework

3.2.1. National space policy framework

Kenya's space strategic priorities are driven by the Kenya Space Agency (KSA). It is responsible for developing and implementing the nation's space strategies. Over the years, KSA has created several

[5] Politico, 2024. A new military era for the US and Kenya, kind of?

strategic frameworks to outline the country's priorities. The latest of these is the Strategic Plan 2023-2027. It highlights Kenya's focus on utilizing space technologies for national development, enhancing satellite communications, Earth observation, and navigation services, fostering innovation, and building local capacity in space science and technology.

Kenya's key policy documents impacting on the space sector are summarised below:

KSA Strategic Plan 2023-2027 serves as a foundational framework guiding Kenya's engagement in space activities, aimed at advancing national capabilities and fostering economic growth. This initiative includes a roadmap, strategic objectives and strategies to realize the vision of "effective utilization of space capabilities for national development".

It identifies five main goals:

- Enhance the coordination and governance of the space sector
- Enhance national space capability
- Increase utilization of space science, technology and applications
- Enhance resource mobilization and investment in the space sector
- Enhance Agency corporate positioning and sustainability

And six priority pillars:

- Agriculture
- Transforming Micro, Small and Medium Enterprises Economy
- Housing and Settlement
- Healthcare
- Digital Superhighway and Creative Economy
- Environment and Climate Change

The Strategy mentions leveraging the development of space applications to achieve Sustainable Development Goals (SDG).

KSA Space Act 2024: provides a legal framework for regulating and overseeing national space activities. While the Act sets the stage for KSA's operational mandate, detailed strategic priorities, resource allocation, and support mechanisms will be further articulated in subsequent operational directives and policies.

Kenya Vision 2030: to support this vision, the government introduced the Big Four Agenda in 2019, focusing on driving growth and enhancing the nation's development. Under the Economic Pillar of Vision 2030, the government identified six key sectors expected to catalyse this growth:

- Agriculture and livestock
- Wholesale and retail trade
- Manufacturing
- Tourism
- Financial services
- Business process offshoring and IT-enabled services

3.2.2. Regional space policy framework

Kenya's space activities are part of a broader continental effort guided by the African Union Commission (AUC) and the upcoming African Space Agency (AfSA). In alignment with continental ambitions, Kenya follows the directives of the African space strategies which focus on leveraging space technologies for sustainable development. Key thematic areas include maritime and water resource monitoring, disaster management, environmental protection, and economic development. By adhering to these continental strategies, Kenya aims to address shared challenges and capitalize on collective opportunities in space technology, thereby contributing to the overall growth and development of the African space sector.

Kenya's space activities and policy framework are shaped by regional and continental strategies that emphasize the strategic role of space technology in socio-economic development. The African Space Policy and Strategy, alongside the African Union's Agenda 2063, underscore the need for Kenya to harness space technologies to drive innovation and regional integration. For instance, integrating satellite data into agricultural practices aligns with STISA-2024's focus on advancing science and technology to boost productivity and resilience. Additionally, the African Union Climate Change and Resilient Development Strategy highlights the importance of using EO data to address environmental challenges, a critical concern for Kenya given its vulnerability to climate change. Moreover, the African Blue Economy Strategy and the 2050 Africa Integrated Maritime Strategy call for the use of space technologies to enhance maritime surveillance and resource management. By aligning with these regional frameworks, Kenya can strengthen its space policy to support sustainable development, improve regional cooperation, and effectively tackle pressing challenges such as climate change and maritime security.

Policy documents impacting on the space sector are summarised below:

Table 1: Policy documents impacting Kenyan Space Sector

Body	Policy	Description
AUC	**Africa Space Policy (2016)**	• Provides guiding principles for an African Space Programme that supports the goals of Agenda 2063 and the implementation of STISA 2024 • During the implementation of the African space programme, 8 objectives need to be achieved: address user needs; access space services; develop regional market; ensure good governance; coordinate and standardize; promote cooperation
AUC	**African Space Strategy (2019)**	• Complements the Space Policy and provides directions for a formal African space programme • The strategy focuses on four key areas of science and technology: EO, navigation, satellite communications, and space science and astronomy • Actions to be implemented include: leverage space benefits; strengthen RD&I; develop human capital; build infrastructure; foster coordination; promote partnerships; ensure funding etc.
AUC	**African Union agenda 2063 (2015)**	• Identifies priority areas, sets specific targets, defines strategies and policy measures requires to boose Africa's economic growth • Includes 15 projects encompassing infrastructure, education, science, technology, art and culture • The Africa outer space strategy aims to strengthen Africa's use of outer space to bolster its development, notably through: climate change and environment management; infrastructure and resource management; safety and security; innovation culture; development and employment; etc.
AUC	**African Union Climate Change and Resilient Development Strategy (2022)**	• Coordinates and supports the continent's response to climate change, covering the period 2022-2032 • Composed of four axis: strengthening governance and policy; adopting pathways towards transformative climate resilient development; enhancing means of implementation towards climate resilient development; leveraging regional flagship initiatives

AUC	**2050 Africa Integrated Maritime Strategy (2012)**	• Establish a secure and safe maritime environment to address threats such as piracy, illegal fishing, human trafficking, and other maritime crimes • Utilize Africa's vast maritime resources to boost economic growth, create jobs, and foster sustainable development in sectors such as fisheries, shipping, and tourism • Foster collaboration among African nations and with international partners to achieve integrated maritime governance, policy harmonization, and effective management of shared maritime resources
EAC	**East Africa Community Vision 2050 (2019)**	• Articulation of long-term prospect has focused on identifying policy measures and instruments required to facilitate the formulation of a plausible vision for the Eastern Africa region. One vision consists of enhancing human capital by establishing a centre of excellence in Electronics and Space Science
Experts and regional inst.	**Science, Technology and Innovation Strategy for Africa (2014)**	• Responsibility is a high-level panel of scientists and members of regional institutions (NEPAD Agency, the African Academy of Sciences, African Development Bank, etc.) • Identifies six priorities that contribute to the achievement of the AU Vision • Constitutes in accelerating Africa's transition to an innovation-led, knowledge-based economy • Defines four implementation actions: infrastructure development; technical competencies ; innovation and entrepreneurship ; enabling environment
AU-IBAR	**African Blue Economy Strategy (2019)**	• Guides sustainable development and the utilisation of aquatic resources in Africa, contributing to continental transformation and growth through advancing knowledge on marine and aquatic biotechnology, etc. • Composed of five thematic technical reports: fisheries, aquaculture, conservation; shipping and transportation; coastal and maritime tourism; sustainable energy and mineral resources; policies and governance

3.2.3. EU/Africa policy framework

Kenya's space initiatives are further bolstered by the collaborative efforts between the European Union (EU) and Africa. The "Towards a Comprehensive Strategy with Africa" initiative, along with the Horizon Europe framework, exemplifies this cooperation. These strategic programmes emphasize mutual benefits and shared goals, providing support for the development of space activities in Africa through grants and technical assistance. The EU leverages its space programmes and freely available data to aid African countries, including Kenya, in achieving their space ambitions. This partnership enhances Kenya's capacity to implement advanced space technologies, contributing to the broader objectives of socio-economic development and technological advancement in Africa.

Table 2: EU/Africa Policy Framework

Body	Policy	Description
EC	**Towards a Comprehensive Strategy with Africa (approved 2022)**	• Address economic, political, social, technological, demographic, climate, and environmental challenges in Africa. • Advance shared global commitments such as the 2030 Agenda, the Paris Agreement, and Agenda 2063. • Strengthen political alliance through AU-EU summits and dialogues. • Promote people-to-people contacts and cultural exchanges. • Build partnerships in key areas: Digital Transformation, Sustainable Growth and Jobs, Security, Governance, and Resilience etc. • Implement ten actionable items across critical sectors to enhance cooperation and development between the EU and Africa.
EC	**Horizon Europe – Africa initiative (2023/2024 – work programme)**	• The Africa Initiative highlights four priority areas for AU-EU research and innovation cooperation: public health, green transition, innovation and technology, and research and innovation capacity • Encompass 30 calls with a budget of €300 million • Synergies are envisioned between Horizon Europe Africa Initiative and existing future programmes funded by DG INTPA, such as African Research Initiative for Scientific Excellence and ACP Innovation Fund

3.3. Kenya's national EO ecosystem

Institutional stakeholders

Kenya's space initiatives are overseen by the **Kenya Space Agency (KSA)**, established in 2018 under the Ministry of Defence. In 2023, KSA had a budget of €1.9 million, with €0.11 million[6] allocated for EO activities. A situational analysis from KSA's Space Strategy identified several key challenges and weaknesses to be addressed, notably low funding and resource allocations to the national space programme, low investments in the space sector; inadequate coordination and synergy between public sector entities utilizing space applications, inadequate corporate positioning and sustainability of the Agency; and inadequate governance of the space sector in general. In 2024, Kenya is one of the smaller investors in the space sector among African countries with active space programs, ranking 10th and trailing behind South Africa, Nigeria, Egypt, Ethiopia, Angola, Algeria, Morocco, Rwanda, and Zimbabwe.

KSA collaborates with other government entities to enhance their capacity in using space-derived data for decision-making. Partnerships include:

- **Ministry of Environment, Climate Change & Forestry:** Developing forest cover monitoring products with Kenya Forestry Services (KFS) using Landsat, ALOS, Sentinel-2, and Sentinel-1 for cloud-covered areas.
- **Ministry of Agriculture:** Supporting the Agriculture and Food Authority (AFA) with crop mapping, monitoring, and yield estimation using space-derived data.
- **Directorate of Resource Surveys and Remote Sensing (DRSRS):** Providing early warning information on food security and geo-hazards using EO data, LiDAR, and hyperspectral sensing.

In addition, several other governmental bodies are users of satellite EO imagery and derived solutions, including the Kenya National Bureau of Statistics (KNBS), Kenya Wildlife Service (KWS), National Environment Management Authority (NEMA), Department of Surveys of Kenya, and the Kenya Meteorological Department (KMD).

Academia

Kenya is home to over 40 organisations offering GIS training, including private companies, academia, international and non-profit organisations. A total of **20 universities** offer courses related to EO. These are mostly master's programs supporting courses in fields such as Geospatial Engineering, GIS, Informatics and Remote Sensing.

Key academic hubs include the University of Nairobi (UoN), Moi University, the Technical University of Kenya, and Kenyatta University. The University of Nairobi and the Technical University of Kenya regularly conduct training on remote sensing technologies and GIS in collaboration with the Regional Centre for Mapping of Resources for Development (RCMRD) and international partners. Through the Esri "100 African Universities Programme," which provides software and learning resources to promote

[6] Euroconsult, Governance Space Programme, 2023.

a "university-wide approach" to GIS education, Kenyatta University has significantly expanded its GIS capabilities. The university now integrates GIS into over 15 areas of study, and has developed a University Geographical Data Portal to provide easy access to various mapping projects and initiatives.

Regional and continental agencies

Kenyan space activities are embedded within a dynamic regional and continental landscape, characterized by a multitude of actors including intergovernmental agencies, regional economic communities, and other specialized institutions. This interconnected framework offers numerous opportunities to Kenya for collaboration and strategic partnerships to advance its space capabilities.

Table 3: Regional and Continental Government EO Agencies

Body	Description
Intergovernmental Agencies	
African Union Commission (AUC)	• The AUC plays a crucial role in shaping the continental agenda for space and EO activities. • It promotes the development and utilization of EO technologies to address Africa's socio-economic and environmental challenges.
African Space Agency (AfSA)	• The AfSA, an upcoming body under the African Union, aims to coordinate and enhance space activities across Africa. • Kenya stands to benefit from the shared resources, expertise, and strategic direction provided by AfSA, facilitating the development of its own space capabilities
Regional Economic Communities (RECs):	
East African Community (EAC)	• Kenya is a founding member of the EAC, which focuses on regional integration and cooperation. • EAC promotes the use of EO data for various applications, including agriculture, environmental monitoring, and infrastructure development, benefiting all member states.
Common Market for Eastern and Southern Africa (COMESA)	• Kenya participates in initiatives aimed at enhancing regional trade and economic integration. • COMESA supports the use of EO technologies for improving trade logistics, monitoring environmental changes, and managing natural resources.
Intergovernmental Authority on Development (IGAD)	• Focuses on development and environmental issues in the Horn of Africa. • Its efforts include using EO data for disaster risk management, climate change adaptation, and sustainable development, aligning with Kenya's national priorities.
Other specialized institutions:	
Regional Centre for Mapping of Resources for Development (RCMRD)	• Headquartered in Nairobi, the RCMRD is a key institution that provides training, advisory services, and research in EO and geospatial technologies. • Kenya benefits from RCMRD's expertise in areas such as land management, environmental monitoring, and disaster management. • The RCMRD GeoPortal distributes geospatial datasets and maps for Eastern and Southern Africa, covering topics like disease spread, demographics, soil mapping, and land transformations.
Pan African University Space Science Hub	• Offers advanced education and research opportunities in space science and technology. This hub supports the development of skilled professionals and researchers in Kenya, contributing to the growth of the country's space sector.

3.4. Space-related international and regional partnerships

KSA have numerous opportunities to establish linkages with both regional and international partners, enhancing their space capabilities and contributing to broader global efforts in space technology and applications.

3.4.1. International partnerships

- **China:** Kenya is part of a broad China-Africa space cooperation framework, where China provides technical support, training, and technology transfer to African scientists and engineers in areas such as telecommunications, weather forecasting, and natural resource management.
- **Japan:** KSA has partnered with the Japan Aerospace Exploration Agency (JAXA) on satellite development, space science research and technical assistance. Kenya's first satellite, 1KUNS-PF, was developed in collaboration with University of Nairobi and JAXA. In addition, Kenya participates in the KiboCUBE programme, a collaboration between UNOOSA and JAXA, offering education and research institutions from developing countries the opportunity to deploy cubesats from the ISS using the Japanese Kibo module.
- **U.S.** : Kenya has collaborated with NASA in various projects, providing expertise and support to enhance Kenya's EO capabilities. Initiatives such as NASA's SERVIR program, which supports environmental management and disaster resilience using EO data, exemplify this cooperation. In addition, through various NASA initiatives and educational outreach programmes, Kenyan students, scientists, and engineers receive training and capacity-building opportunities.
- **Russia**: has shown interest in partnering with Kenya in space research and satellite development, aiming to bolster Kenya's space capabilities. Russian space companies expressed their interest in supporting Africa's space technology development.
- **Australia:** is the key backer of the Digital Earth Africa initiative, in addition to contribution from regional agencies (AFRIGIST, AGRHYMET, CSE, OSS, RCMRD) and the South African space agency (SANSA). The objective of the initiative is to provide free data and operational services using EO to deliver decision-ready products and enabling stakeholders to address social, environmental and economic changes on the continent.
- **Egypt:** Kenya and Egypt have established collaborative efforts in space initiatives that contribute to Africa's overall development and space advancement. One prominent example is their cooperation within the framework of the African Development Accelerate Program, which aims to promote joint technological and scientific endeavors across the continent. Moreover, Kenya and Egypt work together on the Climate Camera Project, a significant initiative proposed in collaboration with UNOOSA (United Nations Office for Outer Space Affairs) and Airbus. This project focuses on using space-based technologies to monitor and combat climate change, reflecting both countries' commitment to sustainable development and environmental preservation.
- **India:** One key area of collaboration is in the use of satellite technology for sustainable development. India has provided capacity-building support to Kenyan scientists and engineers, enabling knowledge transfer in satellite design, construction, and space applications. Through training programs and technical assistance, Kenya has been able to enhance its satellite capabilities, including applications for weather monitoring, disaster management, and agricultural planning. Additionally, Kenya and India collaborate on remote sensing projects aimed at improving

land and resource management across Africa. These initiatives help address key challenges such as food security, water resource management, and climate change by leveraging space technology for efficient data gathering and analysis.

3.4.2. EU-Africa initiatives

KSA collaborates with ESA on multiple fronts, including satellite technology, space science research and capacity building. Kenyan government bodies have benefited directly from participation to these various initiatives:

- The EU supports Kenya through programmes like the Global Monitoring for Environment and Security (GMES) & Africa initiative, enhancing Kenya's EO infrastructure and data usage for sustainable development. Through the programme, the RCMRD leads projects such as the Land Degradation Monitoring Project, which uses EO data to support sustainable land management.
- Within the ClimSA programme, the Kenya Meteorological Department benefits from improved climate services and data-sharing crucial for agriculture and disaster preparedness.
- The KWS enhances protected area management using EO data under BIOPAMA, while AfriGEO initiatives support agricultural monitoring across the country.
- EO Africa focuses on capacity-building, enhancing local expertise in EO technologies.

Kenya also collaborates with individual European countries, such as Germany, France and Italy, collaborating on joint research initiatives, capacity building, and technical support in space applications for environmental monitoring and disaster management.

Table 4: EU/Africa Initiatives in EO

Initiative	Funding Entities	Partners	Budget	Description / Objectives
GMES & Africa	**Joint EC-AUC initiative**	ESA, Copernicus, EUMETSAT, and national space agencies in Africa, scientific institutions and organisations	€30M for Phase I & €24.65M Phase 2	• Programme starting and end date: 2017 - 2025 with upcoming extension • Vector for the implementation of the EU-Africa Joint Strategy and the African space Strategy and Policy, and part of the 2050 Africa Integrated Maritime Strategy • Adapts Copernicus to the African context to address climate change, water, energy, natural resources, environmental and security concerns • Promotes sustainable management of natural resources by improving the decision-making process.
ClimSA	**EU's 11th European Development Fund (EDF)**	Coordinator: Organisation of African, Caribbean and Pacific States –OACPs Technical implementing partners: WMOs, EC's JRC, EUMETSAT	€85M	• Programme starting and end date: 2021 – 2027 • Provides the eight Regional Climate Centres (RCCs) with collaborative solutions to manage climate-related risk. • Contributes to strengthen the production, availability, delivery and application of science-based information to improve the quality and quantity of regional climate forecasting and services. • Covers the ACP region with 48 Member States.
AfriGEO	**EC and ESA**	GEO Plenary, RCMRD, AU / Partners: GEO Member States and	n.a	• Programme starting and end date: 2012 – to date • Coordinates the implementation of the Global Earth Observation System (GEOSS) and related EO activities in Africa

		Participating Organisations in Africa		• Contributes to Africa's efforts to bridge the digital divide and build a knowledge-based economy using GEO networks and the GEOSS infrastructure • Aims to foster open data-sharing policies and practices, increase the use of EO data and information, build both human and technological capabilities to ensure that the entire African continent benefits from better access, understand and use EO data, information and services
EOA – EO Africa	**EC and ESA**	AUC, African and European research communities	€750,000 through grants	• Programme starting and end date: 2021 – 2024 • Corresponds to the African Framework for Research Innovation, Communities and Applications in EO • Helps Africa developing the cutting-edge digital technology it needs to process and utilize European EO satellite data of the Copernicus Programme • Aims to foster partnerships, facilitate R&D, leverage tools to provide open access to data and knowledge to African public authorities, reinforce capability through trainings and enhance data accessibility. • Executed in coordination with GMES & Africa

4. Kenya's EO supply and needs assessment

4.1. Methodology outline

This section provides an overview of the methodology employed to evaluate user needs, supply capabilities and the identification of gaps between them.

4.1.1. Approach for supply assessment

The satellite-based EO ecosystem in Kenya takes into consideration the **whole value-chain from satellite manufacturing, to operations, data and services generation, and final end utilization**. The sector is also influenced by investment (from both government and the private sector) and the end-user demands for EO-based solutions. As with all countries, EO supply can be considered based on national supply (again from the government and private sector), and international government and commercial solutions being provided into the country.

The Kenya ecosystem outlined below is divided by upstream and downstream supply, and then supply from within the country, or from international organizations. In both cases of upstream and downstream supply, government and commercial actors are taken into account.

- **Upstream** considers the manufacture and launch of satellite systems. It also includes investment in the ground segment (and for the purposes of this study) ground segment services, i.e. supporting satellite operators and data downlink
- **Downstream** considers data handling and processing, and the provision of data and services to end users. This takes into account both free data solutions and services being provided for the public good, and the sale of commercial data and solutions into industry or government.

The assessment can be summarized in the following matrix. Each of these individual segments are discussed in the following sections:

Table 5: Kenya Ecosystem Summary Matrix

	Kenya National Organizations		International Organization Supply into Kenya	
	Government	**Commercial**	**Government**	**Commercial**
Upstream	Kenya Govt. manufacturing of satellite systems and ground segment	Kenya commercial manufacturing of satellite systems and ground segment	Intl. Govts. manufacturing of satellite systems and ground segment for Kenya	Commercial manufacturing of satellite systems and ground segment for Kenya
Downstream	Kenya Govt. provision of EO-based data and services	Kenya commercial companies provision of EO-based data and services	Intl. Govts. provision of EO-based data and services	Commercial companies provision of EO-based data and services into Kenya

Kenya's capacity supply is then analysed by **evaluating Kenya's capacity to capture, transform and deliver data according to the five key requirement criteria** explained in the next section 4.1.3 (Accessibility, Affordability, Reliability, Suitability, and Security). A score is provided per information cycle which provides us a clear understanding of capacity supply across Kenya.

4.1.2. Approach for users' needs assessment

The approach includes a detailed analysis of the vertical markets in Kenya for which there is current or anticipated EO utilization. It includes: climate and environment monitoring, infrastructure monitoring, water, health and disaster management. In each case specific user requirements and use cases are identified, how the services or applications or being built, and the end-user communities.

For each market segment there is an assessment related to the five key requirements criteria:

- **Accessibility**: How data and services are easily accessed;
- **Affordability:** Pricing of satellite data. For free data, whether the data is provided by local or international organizations;
- **Reliability**: How dependable are current EO-based or integrated solutions;
- **Suitability:** The ability of EO-based or of integrated solutions to fulfil the requirements that it is set out to do;
- **Security:** Security requirements for utilization.

A score is provided per use case which provides us a clear understanding of user demand across various market verticals. This framework allows for an objective assessment of EO requirements in the Kenyan context. These requirements have been rated in order to be compared and consolidated in a later stage according to the scorecard detailed below.

Table 6: Requirement Scorecard for User Needs Assessment

	LOW	MEDIUM	HIGH
Accessibility	Unavailable or limited availability of data and services with risk of impact on service	Available data and services but with no guaranteed access and minimum impact on service	Available data and services guaranteed access and required level of service
Affordability	Data is only available at high costs for Kenyan end-users.	Data is available at relatively affordable costs for Kenyan end-users.	Data is very affordable or free for Kenyan end-users.
Reliability	No guarantee of data, no network redundancies	Some guarantee of data, some network redundancies	Guaranteed data availability with network redundancies
Suitability	Available data is not useful for the application with impractical spectral resolution, ground resolution or revisit. Services are unavailable for end-users.	Data is somewhat useful for the application with spectral resolution, ground resolution or revisit at acceptable margins. Services are offered at acceptable levels of capability.	Available data is very relevant for the application with spectral resolution, ground resolution or revisit at ideal margins. Services are offered at optimal levels of capability.
Security	Data and services are offered from foreign sources.	Data or services are offered from foreign sources.	Data and services are supplied by local organizations.

With regards to suitability of data, the ground, spectral and temporal resolutions must be matched to the needs of each application according to its different data requirements to maximize the value that EO offers. Optical data offers the advantage of imaging in spectral bands and the ability to produce true-color imaging and view specific areas of the electromagnetic spectrum, such as near infrared, for vegetation mapping. Optical data relies on natural radiation; therefore, sunlight is required. Atmospheric conditions, such as cloud cover, can prohibit data collection. Radar data offers the ability to penetrate clouds at any time of day, delivering an image through most atmospheric conditions. Radar sensors also respond to surface texture so that where there is sufficient contrast, small objects can be detected even when using lower resolution datasets.

4.2. Supply assessment

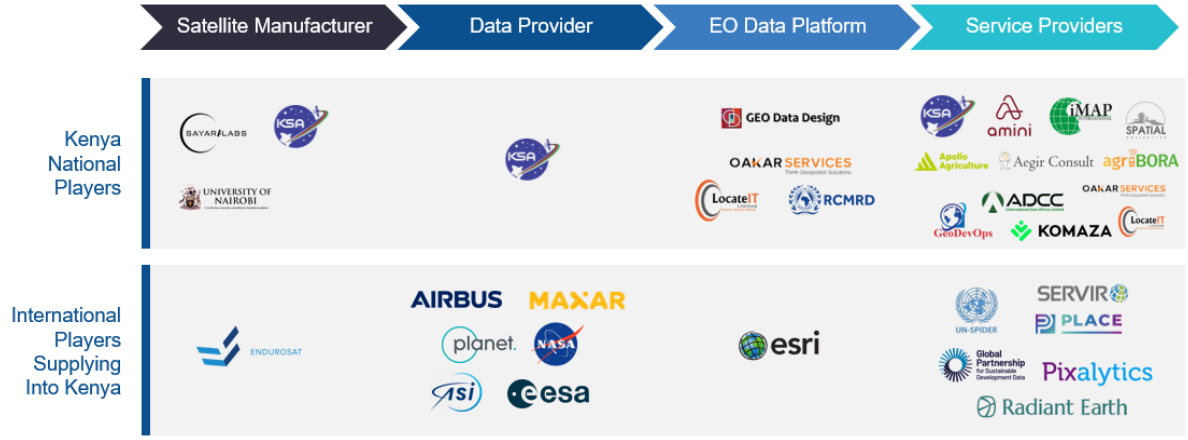
As in most cases with countries with a nascent EO programme, upstream supply in Kenya is limited. The country's one operational EO satellite, Taifa-1, whilst funded by the KSA was manufactured by an international provider of satellite-as-a-service solutions, Endurosat (Bulgaria.) The contract with Endurosat included a technology transfer element to support the advancement of a satellite manufacturing capability in the country with Kenyan engineers working on the project. This 3U Cubesat features five multispectral bands and a panchromatic band, with 32m and 16m ground resolutions, and focuses on environmental monitoring, land use mapping, and agriculture.

Individuals involved in the mission went on to form the company, SayariLabs, which has gone on to build hardware for other satellite missions. In addition, the University of Nairobi (and other national university partners) is building up cubesat manufacturing capabilities on several projects.

Kenyan national engagement is more involved is in the utilization of EO data and building value-added EO products and services for various end-users. **The downstream sector is relatively more developed than the upstream:** whilst the upstream tends to rely on the ability to build national satellite

missions, the downstream is able to leverage freely available datasets (from Copernicus Sentinels and Landsat) to build solutions for (mostly) local end-users. From a government standpoint the KSA and the Ministry of Agriculture and Livestock Development, the Kenya Forest Service (KFS), the Kenya Meteorological Department (KMD), and others are using EO data to support various activities centered around environmental applications, agriculture and land use planning / management. In the case of the commercial, private sector, numerous companies are becoming more engaged with satellite-based EO solutions delivery in what is a dynamic and growing environment. Several have heritage in the wider geospatial / aerial imagery business, and are being supported by engagement in activities such as GMES & Africa. These companies serve a mostly national government clientele.

Figure 4: Mapping of the Kenya EO supply Ecosystem (sample of companies)



4.2.1. Kenya Government Upstream

Kenyan government engagement in satellite manufacturing is limited. The country has launched three satellites, one of which being operational. Two further satellites are scheduled for launch from 2026.

- **1KUNS-PF satellite:** Launched in 2018, this satellite was a technology demonstrator for EO which remained in service for two years. It was funded under KSA's nanosatellite development programme and manufactured by the University of Nairobi.
- **Tafiti:** As a successor to 1KUNS-PF, the university was awarded Ksh 3 million (€ 21.1k) in 2020 for the development of a **3U satellite named Tafiti**, it will carry a multispectral payload. Its launch date is still yet to be announced.
- **WildTrackCube-SIMBA satellite:** Under the same IKUNS programme, the University of Nairobi also developed the **WildTrackCube-SIMBA satellite (IKUNS 3)** in collaboration with Machakos University, and Sapienza University in Italy. Not EO-specific, the satellite was developed to demonstrate an IoT system for wildlife monitoring. The 1U satellite was launched in 2021.
- **NaSPUoN-0GPM2030 satellite:** In 2023, the university of Nairobi was the recipient of an award from the "Accessing space with Vega C" program to develop another 3U cubesat by UNOOSA and Avio S.p.A. The cubesat will be a demonstration EO satellite to be launched in 2030 with the goal of building national capacity for Kenya and demonstrating new technologies such as

an inflatable antenna. The satellite will be developed by the university of Nairobi with the support from the University of Arizona and Space Trust.

- **Taifa-1:** The country's one operating EO satellite, Taifa-1 was launched in 2023. It was funded and initially designed by the Kenyan Space Agency (KSA), and built with the support of Endurosat. Building on this experience – which contained a technology transfer element - the agency plans to develop infrastructure to support system engineering efforts within the country. It targets building a satellite Assembly Integrating and Test (AIT) within five years and a satellite mission control centre in the same time period. The satellite's primary purpose is to support agriculture and disaster management applications in Kenya.

Additionally, **Kenya collaborates on two satellite projects with Egypt** under **the AfDevSat initiative** and the **EKU-Climcam project**, aimed at addressing African challenges and developing an EO camera system for the ISS, respectively.

Furthermore, to support satellite operations, Kenya hosts several ground facilities:

- **Luigi Broglio Malindi Space Center**: Located near Malindi, the space center is operated by the Italian Space Agency (ASI). The center's presence in Kenya dates back to 1966 and is currently governed by an intergovernmental agreement between Italy and Kenya. Under the agreement, Italy provides equipment and operates the Center, and also has the responsibility to train and employ local staff. In turn Kenya provides the site, upon payment of a modest fee and is able to utilize the facility to support engineering training. The center comprises of 3 ground stations: (1) an S-band antenna with a 10m dish to serve EO programs from ASI specifically, (2) an S/X/L band station with a 10m dish to serve Arianespace launchers, (3) an X-Band station with a 6m dish to serve other international programs (ERS2, Spot, Landsat).
- **RCMRD**: operates an eStation for processing environmental data from EO satellites. The station is also part of the GMES & Africa initiative.
- **RARS Station at ICPAC:** Satellite and Weather Information for Disaster Resilience in East Africa (SAWIDREA) installed a RARS (Regional Advanced Retransmission Systems) station within the IGAD Climate Prediction and Applications Centre (ICPAC). The centre was opened in 2021 in Nairobi to receive satellite data for the improvement of the quality of weather forecasts within the region. It also offers climate services and early warnings to 11 East African countries for disaster resilience.
- **Kenya Space Agency Station:** Currently under construction to be commissioned within the next year, the space centre will feature a UHF, VHF and X-BAND antennae in support of national programs.
- **University of Nairobi:** The university hosts a UHF/VHF antenna to communicate with their nanosatellite projects.

The previously operational Longonot station, managed by the UoN Department of Physics and KSA, is no longer active.

4.2.2. Kenya Commercial Upstream

There is one Kenyan company of note engaged in the Kenyan upstream space ecosystem, **SayariLabs**. It was founded in 2020 by engineers engaged with the KSA on the Taifa-1 project. SayariLabs also developed hardware for the JANUS-1 satellite. JANUS-1 is a demonstrator 6U cubesat operated by

Antaris (India) to explore various software technology such as edge computing. For the satellite, SayariLabs built the Sayarilabs Payload Processor (SPP), a communication board for satellite downlink. In addition to this, the company has also developed an on-board computer, an electrical power subsystem, structures and mechanisms although these are yet to be space proven. Other services the company plans to offer in the future include satellite data provision, ground station services and AIT services.

In addition, another Kenyan company, Amini, has expressed interest in launching a satellite constellation in 2025. Amini envisages a constellation of at least six satellites to provide imagery to support mostly land cover applications (drought, flood, soil, and crop health.) The company currently provides environmental analysis to agricultural insurers in Africa using publicly available data. Little is known about the constellation; it would appear the timeline is ambitious.

4.2.3. Kenya Government Downstream

There is a limited amount of Kenyan government engagement in supporting EO downstream activity, most of which is through KSA. KSA's EO programme is still being developed with most actions today limited to coordinating and promoting utilization of satellite imagery for digital mapping. Building on these efforts, KSA has also several specific projects which utilize imagery which respond to national policy interests across water security, agriculture and infrastructure monitoring:

- **Space4water**: was initiated in 2018 to address Kenya water security. The project saw the mapping of Kenya's Wajir county to identify populations most affected by water scarcity using public data from Landsat and Sentinel images. KSA plans to replicate the project in other Arid and Semi-Arid Areas within the country. A report on the project was published in 2023 with an action plan indicating potential sites for rainwater collection and tanks.
- **The Agricultural Data Collection and Exchange project**: Radiant Earth (a DC-based geospatial company), PLACE (A DC-based non-profit), Spatial Collective, and the KSA are collaborating on a pilot project to collect high-resolution agricultural data for open access in Kenya. Today it uses drones to capture imagery in Murang'a Town to automate the identification of field boundaries. As of yet, the project does not use satellite data. The project is funded by the Grand Challenges, from the Bill & Melinda Gates Foundation.
- **Monitoring for Information and Decisions using Space Technology (MIDST)**: Started in 2020, it aims to improve decision-making in natural resources management, urban planning and disaster response. This included analysis on the Aberdares forest and on the urban growth rate for Nakuru Municipality and its surroundings.
- **National Data Cube**: Following its participation to Digital Earth Africa (discussed during the international provision of downstream solutions section) KSA hopes to host their own national open data cube within 2 years. This project is still in its early planning phase with an initial workshop hosted in June 2023. with an early workshop hosted in 2023.
- **Kenya Forest Service**: The KSA has signed a strategic partnership with Kenya Forest Service towards utilisation of space and space technologies to develop forestry solutions. KSA and the KFS will be using Google Earth Engine (GEE) platforms to co-develop products to support resources management. This includes forest fires monitoring and mapping, land cover land use imagery, and forest types (natural, plantation, bamboo, and mangroves) monitoring.

- **KilimoSTAT & ECAAS**: The Ministry of Agriculture and Livestock Development has developed an Intergovernmental Network on Open Data for Agriculture and Nutrition to boost capacity of farmers in collaboration with NASA and Strathmore University. The Ministry issues the National crop monitor (KilimoSTAT), with support from NASA SERVIR, the RCMRD, and GEOGLAM. KilimoSTAT is regional cropland assessment and monitoring service, a water quality monitoring service, a land use cover and change mapping service, and a climate change vulnerability assessment service. The Ministry also manages the ECAAS (Enabling Crop Analytics at Scale) Field Mapper in collaboration with KSA and NASA, which provides consistent agriculture assessments for farmers.

Outside of KSA, there is some limited activity supporting downstream applications development within academia and other government departments. For instance, the University of Nairobi was the beneficiary of a Ksh 500,000 (€3,500) to explore the potential of EO with AI/ML in mapping crops of small-scale farms. There are five further supporting universities also receiving Ksh 500,000 each: Taita Taveta University, Dedan Kimathi University of Technology, Jomo Kenyatta University of Agriculture and Technology, and Egerton University.

4.2.4. Kenya Commercial Downstream

There are 15-20 companies in Kenya engaged in downstream value-added services. Certainly, this area of the value-chain has greater interest relative to the upstream. This is typical of the global context: supporting the upstream requires company investment which only makes sense if there are national funds available to build space infrastructure; whereas developing solutions can leverage freely available datasets, it is far less capital intensive, with multiple potential customers.

The companies are a mixture of EO specialized companies and those which may have EO as part of their overall activity (for instance, they could be engaged in wider geospatial solutions, engineering consulting, GIS or aerial mapping). In most cases,the companies are relatively small (<10 people), and mainly focused on one or two vertical markets. More established companies, such as Oaker and Ramani, tend to come from the wider **geospatial/surveying business** prior to starting to utilize satellite-based EO.

Kenyan companies are focused mostly on the utilization of EO in agriculture, environmental management, and infrastructure. Most companies rely on free data sources from Landsat and Sentinel, with only a few utilizing commercial data from operators such as Airbus. In **agriculture**, companies like Apollo Agriculture, Aegir Consulting, and Amini are using satellite data to support farmers through data consolidation, improving credibility, and adopting precision farming. In the **environmental** sector, companies such as GeoDevOps, and LocateIT are engaged in climate reporting, ecological monitoring, and water resource management, often in partnership with outside organizations and initiatives like Digital Earth Africa. The primary customers across these sectors are government agencies, except in agriculture, where smallholder farmers are also seen as an end user. The following table outlines a sample of these commercial downstream players operating within Kenya.

Table 7: Selection of Commercial Downstream Companies within Kenya

Company		AG	INF	ENV	Other	Notes
ADCC	Consulting firm offering GIS services (Topographic Mapping, Utility Mapping, Image Processing, Water Quality Mapping, etc.). Prior reseller of Digital Globe (now Maxar) imagery.		■		■	• Conducted work in transportation (roads management, topographic mapping), water & electricity, and smart city development (city modeling, property mapping) primarily for local municipalities and governing bodies. • Work in cadastral mapping, image consulting, mining and forest management.
Aegir Consult	Geo-informatics, GIS, and geospatial technologies. Services include using GIS technologies, Analysis and Data visualization.	■				• Through their AgriTech platform, Aegir provides precision farming and crop monitoring services with real-time data on soil health, weather patterns, and crop conditions.
AgriBORA	Agri-fin-tech company with roots in Germany and Kenya.	■			■	• Farm intelligence (growth monitoring, yield prediction) using their agriBORA platform. • Alizeti project with ESA and DLR (€200k grant) to support 6 producers of high-value crops (soya, sorghum, potatoes, sunflowers, maize, tea). • Financial services include insurance and consultancy (surveys). Also work to connect suppliers and farmers in Kenya's fragmented ecosystem through their digital hub.
Amini	Currently provides environmental analysis to agricultural insurers in Africa using publicly available data. Successfully raised $4 million in 2023.	■		■		• Uses satellite, aerial and IoT data for precision agriculture. Organized competition with Zindi inciting participants to collect data on key crops across select African countries. • Aims to launch constellation in 2025 (6 sats) for Africa-focused environmental data. • Climate reporting services and supply chain management services. This involves reporting the environmental footprint. Environmental partners include Pale Blue Dot.
Apollo Agriculture	Agtech/Fintech company founded in 2016. Serves farmers in Kenya and Zambia. Advises farmers regarding the use of fertilizers and informs about early warning for pests and diseases.	■			■	• Provides customized precision agriculture tools. Its primary business is in evaluating the credit worthiness of Kenyan farmers for smallholder farmers. Focused on providing credit services to small-scale farmers in rural areas. • Does not work work with satellite-EO as yet, but looking how to integrate the technology.
GEO Data Design	Formed in 2000, GEO Data Design acts as a reseller for Maxar, Airbus and Planet data within Africa.	■	■			• Their GEM geo-analytics platform has used satellite imagery for a variety of applications including mining exploration, utility mapping and forest inventory. Most recently, the company has included some tools catered towards defense and disaster management. • The company is based in South Africa but provides services throughout the entire region.

Company		AG	INF	ENV	Other	Notes
GeoDevOps Limited	Mapping services company based in Nairobi. They use Esri based ArcGIS Desktop/ArcGIS Online to map, visualize and analyze geo-information.	■	■	■		• FarmingPRO platform to help farmers map, digitize and integrate their farmlands to a cloud platform for crop monitoring. Farmers receive historical records of their fields and predictions of soil conditions, crop health, terrain, and weather. • Africa Coastal Geo-Watch platform to map of Africa's coastal ecosystems. The map provides classification of mangroves, seagrass etc. And how this is changing. • KenyaWEBGIS, a public portal featuring layers of geospatial data, including projects in urban and rural areas and along coastlines.
IMAP International	GIS company serving commercial, government and non-profit organizations in the region.	■	■			• Provides a Land Information System (LIS) service for cadastral and land-use mapping primarily for property appraisers, and government agencies. They also conduct topographical and hydrographical surveys.
LocateIT	Geo-ICT company primarily catered towards government users. Their main product offering is the CDIS platform, which is a software suite designed to help Kenyan counties address development business processes holistically. The platform primarily relies on Airbus satellite imagery. Locate IT is also a reseller of Airbus data. Also provides solutions based on GIS or Airborne sensors.	■	■	■		• Part of a consortium comprising 17 partners, for AfriCultuReS, funded by the EU. It aims to implement an integrated agricultural monitoring and early warning system. • CAMIS module focuses on agriculture management for govt. agencies. It used to characterize the types of farms by type, yield and harvesting date. • Conducted study on Kenya's Mau forest to assess and monitor forest loss patterns. The goal was to derive options for phased restoration of the forest. • Working with ClimSA on the monitoring of Rift Valley lakes, Naivasha, Baringo to monitor lake level changes. • Coastal Geomorphology and Shoreline erosion monitoring for island states of Comoros, Madagascar and Mauritius (CoGeoS)
Oakar Services	Oakar Services is a geospatial consulting firm and an official reseller of Planet and Maxar satellite data. The company offers services across East Africa. Total staff of 32.	■	■	■		• Its Geospatial Portal solution offers data visualization tools. It has been used previously for monitoring water quality, natural resources, and more. • AgrowTech platform consists of services such as crop identification, monitoring, and yield estimation primarily catered towards farmers. • Other products include its Maxar Geospatial Platform (MGP) and Spectra Geospatial MobileMapper aimed at providing satellite data to end users.
Ramani	The largest aerial survey company in East Africa. Speciality is in Urban planning, Infrastructure, Roads, rails, Ports and have a presence in Kenya, Tanzania, Uganda, Democratic Republic of Congo and other neighbouring countries using their two aircrafts. Total staff of 43.	■	■	■		• The use of EO data is limited to projects/contracts where aerial surveys are not feasible (aerial coverage, spatial resolution). • Successfully worked in various industry sectors: Transport and Engineering (Road & Rail), Exploration and Mining, Conservation, Telecommunication, Agriculture, Energy (oil pipeline, wind, electric), Spatial Planning (land use, urban, regional, transport and environmental).

Company		AG	INF	ENV	Other	Notes
Spatial Collective	A Nairobi-based, geospatial and technology consulting company in operation for over a decade.					• Kenya Digital Public Works: urban geographic data for the Kenya Informal Settlement Improvement Project. • Community Mapping Urban Risks in Mwanza Tanzania, includes flood risk modelling. • Open Cities Zanzibar: open spatial data about the environment, critical infrastructure, and natural hazards of Zanzibar. • Using Active Learning to Map Agricultural Fields in Africa: digitizing of crop field boundaries visible in high-resolution satellite imagery.

4.2.5. International Government Provision in the Upstream

Kenya's satellite manufacturing capabilities have been supported by international government partnerships. These collaborations focus on building local expertise and infrastructure to support Kenya's space industry. In particular, the Italian Space Agency (ASI) has supported several projects in Kenya:

- ASI collaborates with the KSA through the **IKUNS project** (Kenyan Italian Nanosatellite University) aimed at developing an EO CubeSat and training Kenyan engineers. This resulted in the development of the 1KUNS-PF CubeSat, the first Kenyan satellite developed by the University of Nairobi with technical support from the University of Rome.
- Kenyan students are also invited to study at Sapienza University (Rome) in **space systems design and satellite operations**. Through this program, Kenyan students from the University of Nairobi and Machakos University saw the development of the WildTrackCube-SIMBA satellite.
- ASI hosts the **Luigi Broglio Space Center** near Malindi. The facility supports Telemetry Tracking and Control (TT&C) of several ASI-led satellite missions. It also supports ESA Launch and Early Orbit Phase (LEOP) following Kourou launches. For the purposes of EO, the station can also acquire satellite imagery, such as from COSMO-Skymed. The Center is also used as a training facility for ASI to train Kenyan engineers.

In addition to ASI, the Kenyan space programme has also been supported by Japan (JAXA) for the launch of 1KUNS-PF as part of their KiboCUBE programme. This initiative, established in 2015 by UNOOSA and JAXA, allows developing countries to develop and launch their own CubeSats.

4.2.6. International Commercial Provision in the Upstream

The Taifa-1 satellite was developed through a collaboration with Endurosat, which provided the satellite and training for local engineers. The training provided by Endurosat aims to build Kenya's national manufacturing expertise. Additionally, Avio supports the University of Nairobi's "NaSPUoN-0GPM2030" satellite project by offering a free launch on the Vega C rocket in 2030. These efforts underscore the importance of external collaboration in advancing Kenya's satellite technology and capabilities.

4.2.7. International Government Provision in the Downstream

The Kenyan government and industry benefit from engagement in several international initiative supporting EO engagement. All Kenyan organiations are able to access and leverage free data solutions from the Copernicus Sentinel missions, and Landsat series data through the USGS. Several other initiatives provide more applied products. In the case of the International Charter for Space and Major Disasters and U.N. SPIDER (U.N. Platform for Space-based Information for Disaster Management and Emergency Response) they provide ad-hoc support for disaster management response. In the case of GMES & Africa, Kenyan EO service providers may participate in the initiative with grants awarded from the EU.

- **GMES & Africa:** The EU initiative “promotes sustainable management of natural resources by improving the decision-making process, access and relevant use of EO data”. Several Kenyan service providers have benefited from engagement within GMES & Africa, several noting that

it is provides their main use of satellite-based EO (as opposed to other forms of data collection). For instance, LocateIT supports development of Monitoring Integrated Services for Land Degradation (Misland), a webportal and dashboard supported by JRC and funded through GMES & Africa. The project looks to define areas of environment Susceptibility. It is also engaged in the Wetland Monitoring and Assessment Service for Transboundary Basins in Southern Africa (WeMAST) webportal. The project aims to design an integrated platform for wetland assessment and monitoring that will support sustainable management of selected river basins. Oaker, meanwhile, conducted mapping of the Indian Ocean consortium led by Mauritius Oceanography institute on Coastal vulnerability and bathymetry mapping using LiDAR.

- **UN-SPIDER:** Facilitates the use of space-based technologies for disaster management and emergency response. The RCMRD acts as the host for UN-SPIDER's Regional Support Office within Kenya. The centre is involved in six practices: flood mapping, crop yield forecasting, flood forecasting, drought monitoring and land degradation monitoring. Examples of activities in the context of UN-SPIDER for the benefit of Kenya include:
    - *Monitoring of desert Locusts and loss assessments in cooperation with the Chinese Academy of Sciences (2020)*. A Vegetation Pests and Diseases Monitoring and Forecasting System was developed, integrating multisource EO data.
    - *Assessment of impact of drought in the Nsakani dam using Sentinel-2 satellite data (2017)*. Results demonstrated \significant reduction in the city's main source of water.
- **International Charter for Space and Major Disasters:** Since its inception in 2000, the Charter has been activated seven times to support disaster management efforts in Kenya. Six of the seven related to flooding event, with the seventh being in support of the flood-induced landslide event in the Pokot region in 2019. In this case the Charter was activated on behalf of the Kenya Defense Forces. The last time the Charter was activites was in April 2024 to support flood monitoring following the banks bursting on The Old Kijabe Dam.
- **NASA SERVIR:** SERVIR is a joint initiative of NASA and the USAID to use satellite data and geospatial technologies to strengthen communities. Kenya hosts the Regional Cropland Assessment and Monitoring Service in East Africa. It utilizes satellite data from CHIRPS, LANDSAT-5/8, MODIS and Sentinel-1 to develop national and regional crop monitors. Additional activities include supporting the Quality Agricultural Index Insurance Certification for East Africa (QUIIC) program and the Kenya Government crop insurance.
- **UK's Sustainable Aggregate Supply (EO4SAS):** Kenya has access to the UK's Sustainable Aggregate Supply (EO4SAS) program led by Pixalytics and the UKSA to improve the management of its land resources. Collaborators include the Nairobi Design Institute and NIRAS Africa, based in Kenya. The program is being funded through the UKSA's International Partnership Programme.

In addition, Kenya benefits from its participation to "The Africa Regional Data Cube" or Digital Earth Africa (DE Africa). DE Africa was developed by the Committee on Earth Observation Satellites (CEOS) in partnership with Global Partnership for Sustainable Data (GPSDD), GEO and Amazon Web Services (AWS). Its mandate is to democratize the capacity to use EO for a number of strategic purposes, such as climate monitoring and bolstering the African economy. The platform is intended to improve the understanding of the continent's changing landscape, providing insights and analysis for more informed strategic decision-making. Currently, Digital Earth Africa uses open and free data from the Landsat-series and Sentinels which is made available at continental scale. It also provides EO-based products

including water observations, cropland extent map, agriculture normalized difference vegetation index (NDVI), coastline mapping and elevation data.

4.2.8. International Commercial Provision in the Downstream

All Kenyan organisations can access commercial imagery from international operators and data providers. Procurement of commercial imagery can be achieved directly from the companies, or through a locally acting reseller partner. As governments tend to prefer locally, it is common for an international commercial operator to partner with a company in the country to provide solutions.

- **Planet:** Planet resellers in Kenya include GEO Data Design and Oakar Services. The company has also made partnerships with organizations within Kenya such as ZEP-RE, a reinsurance company, and with Kenya's Joint National Resource Mapping project (JNAMP).
- **Maxar:** Maxar has partnerships with GEO Data Design and Oakar Services who act as resellers within the region for their entire fleet of satellites. Worldview 1&2 data is also available in the RCMRD.
- **Airbus:** Airbus data is available through LocateIT who acts both as a reseller and as a value-added services provider within the region. GEO Data Design also sells Airbus imagery as a reseller.

4.2.9. Mapping Kenyan Supply

The EO-based solutions and services in Kenya are enabled by the same factors that have supported the industry globally over the last decade: the availability of free EO data sources – in particular Landsat and Copernicus Sentinels – and advancement in cloud-based storage in analysis tools, such as AWS and Google Earth Engine. For Kenyan EO downstream entities, there has been a push towards integration of greater satellite-based EO into their respective services offering due to these drivers.

When reviewing overall data supply, the ability to capture data, this is close to 100% from external sources. Mostly this is from the aforementioned international government solutions, with a limited amount of commercial imagery utilization. The services which are then developed utilizing this data and delivered to end-users also has a bias towards provision from organization outside of Kenya. Within Kenya there are service provides working on specific projects (both with Kenyan stakeholders, and with programs such as GMES & Africa to deliver services into Kenya) but this tends to be more ad-hoc rather than using EO operationally. In many cases it is not that Kenyan service providers do not have the skill set to derive satellite EO services, but rather a question of budget to procure commercial EO solutions, a lack of computing resources, or if the needs of the end-user can be met through the use of alternative technologies (such as land surveying and aerial imagery.)

Table 8: Mapping of Government and Commercial EO Supply

		Local Government and Commercial Supply			External Government and Commercial Supply			Rationale
		Low	Med	High	Low	Med	High	
Capturing Data The ability to be able to access satellite imagery from various operators. Data can be free from government operators or commercial. It reflects the ability to access the data needed in order to build the desired services, tools and/or applications.	**Accessibility**	X					X	Kenyans can access external government data through various programs. There exists a handful of commercial data resellers in the country. There is limited local supply
	Affordability	X				X		Whilst freely available Landsat and Sentinel data is available for Kenyan users, higher resolution commercial imagery can be cost-restrictive.
	Reliability	X				X		Many of Kenya's satellite supply relies on external government satellites which have legacy programs backed by government funding.
	Suitability	X				X		Many 3rd party satellites are not built with Kenya in mind. However, the generic nature of Landsat and Sentinel-series means that its data is still widely applicable in Kenya. Greater access to commercial higher resolution datasets is required, but costs/budget is a factor in wider utilization.
	Security	X			X			For Kenya's case, the fact that most data comes from foreign sources outside of Kenya's control may be cause for security concerns.
Transforming & Managing Data This pertains to the ability to process and analyse satellite data into usable and actionable information.	**Accessibility**		X			X		Kenya has access to external services through agency programs (e.g. GMES & Africa). Local capabilities exist although are more limited, and alternative technology may be used.
	Affordability	X			X			If not offered through free external government programs, services are likely cost-restrictive for many Kenyan applications, restricting wider utilization. Computational resources can be factor for services development
	Reliability		X			X		Much of the services supplied into Kenya are for national/regional level monitoring, less at the local level. More locally developed solutions tend to focus on more traditional surveying methods.

		Local Government and Commercial Supply			External Government and Commercial Supply			Rationale
		Low	Med	High	Low	Med	High	
	Suitability	X				X		Computational power for extensive processing is limited in Kenya. Time series applications over wide areas require extensive datasets which cannot always be supported operationally.
	Security	X			X			Much of the EO services in Kenya are mostly derived from data outside of Kenya's control.
Delivering Data This refers to the ability to provide reporting services, especially for operational activities. It pertains to the means of which end users interact with satellite data and services.	**Accessibility**	X				X		There are limited operational use cases using EO being developed in the country, with a preference to more traditional surveying techniques. There is a limited adoption of Digital Earth Africa, more activity around GMES & Africa.
	Affordability	X				X		Local companies have the capacity to deliver EO based solutions, but will only do so if there is a (governmental) demand. Some issues remain with regards to heritage practises in government relying on in-situ collection.
	Reliability	X				X		Most services generated by local industry are ad-hoc. Companies will use aerial solutions in lieu of satellite, but this limits coverage of the service. External provision is useful at regional scale, but lacks granularity for reporting at local levels (using higher res. data) that a lot of users want.
	Suitability	X				X		Copernicus Sentinels can go a long way to supporting applications development, but higher resolution imagery delivered and higher frequency (and greater computational resources) are needed to deliver many solutions.
	Security	X			X			Much of the EO services in Kenya are mostly derived from data outside of Kenya's control.

4.3. Needs assessment per EO market verticals

Kenya faces several unique challenges and opportunities that shape its EO market demand. The country is significantly impacted by climate change, has experienced severe drought and water security challenges. It is also home to rich biodiversity and varied ecosystems which it aims to protect whilst developing its economy. Agriculture is a vital sector, contributing about 22% of the country's GDP in 2023 and representing a significant portion of its exports. Additionally, Kenya is undergoing several urban and transportation development projects, often in collaboration with neighbouring countries. The key EO applications and services in Kenya focus on addressing these critical needs and leveraging opportunities for sustainable development.

4.3.1. Climate / Environment monitoring

Environmental monitoring applications use EO data to monitor the Earth's atmospheric, terrestrial, and oceanic variables to further the understanding of the Earth's dynamics. EO plays a key role in supporting data collection to monitor many of the 55 U.N. Global Climate Observing System (GCOS) Essential Climate Variables (ECVs). Applications are geared toward science and research, along with operational services such as weather forecasting and air quality monitoring. From a user standpoint the market is highly government-centric both for data utilization and services generations. Space agencies, weather organizations and associated research institutions work with EO data to undertake research on the various climate variables, or to build and deliver public good services.

Environmental applications mostly monitor variables to understand their ecosystem interaction and evolution in the medium to long-term to understand climate trends. Utilizing global coverage time-series EO data is an important tool in being able to understand these trends, and support the prediction for future outcomes. The variability in the environmental parameter to be measured means that there is a wide range of satellite imagery being used to support the research, applications and services development. In most cases there is a reliance on science-based missions launched by space agencies such as NASA and ESA (such as MODIS, Sentinels, Earth Explorers etc.), with data made available freely to the research community. Similarly, operational environment/weather solutions leverage satellite launched by organizations such as NOAA and EUMETSAT. The African continent is assisted by the weather services derived from EUMETSAT satellites in particular, benefitting from the GEO positioning of its weather satellites.

A relatively new area of interest in the sphere of environment monitoring is in support of Environmental Societal Governance (or ESG), unlike the aforementioned applications, here there is a focus on industry as well as government utilization. In the industrial context there are a couple of application areas which are garnering some interest: emissions monitoring from industrial sites, and in support of carbon markets. Concerns emissions monitoring, GHGSat (Canada) are the most advanced of companies tackling the application, its data at 25m ground resolution is expected to be enough for methane source detection. Carbon credits is a new application area which, whilst displaying potential, is currently underdeveloped. It works on the premise of monitoring land areas for reporting on biomass, monitoring crops for carbon credits, deforestation/illegal logging/forest carbon projects etc.

Monitoring forests has global, national and local implications. At a global scale understanding the role of forests in the carbon cycle is a key application. Forests can be carbon sinks if it absorbs more carbon than it releases – most forest are sinks, but how much carbon they sequester is not well understood, and nor how this dynamic is trending. By a similar measure, monitoring deforestation and the impacts this can have on the carbon cycle and environment is important. To this regard there are several EO based initiatives supporting monitoring of forest, such as the World Resources Institute led “Global Forest Watch”, and U.N. REDD ("reducing emissions from deforestation in developing countries") initiative is a framework for developing countries to reduce emissions and remove GHGs through improved forest management practices.

Climate and Environmental Services in Kenya

During the consultation process, Wildlife population monitoring and habitat assessment; and, biodiversity monitoring, ecosystems were highlighted as key areas of interest in Kenya. There are concerns over changes in soil moisture, land degradation, rangelands (grasslands, wetlands etc. that are grazed by livestock or wild animals) and what this means for long-term economic and climate sustainability.

Carbon credit estimation is a further area growing in importance. To support the application land-use land-cover applications are required to monitor changes as to how land is being managed. Forestry is one of many important resources for the country's economy. Most activity today are aimed at protecting Kenya’s forests from outside factors and supporting reforestation efforts. The Kenya Forest Service, in collaboration with the Kenya Space Agency, utilizes remote sensing data to enhance forest restoration efforts, including monitoring forest fires, mapping land cover changes, and identifying different forest types. These protection efforts are often supported by international organizations outside of Kenya. For example, Langland Conservation employs high-resolution imagery to track deforestation in the Nyakweri Forest, and the University of Leicester's Forest Alert System uses data from Sentinel-2A and 2B satellites to issue deforestation alerts government officials.

Several companies are engaged in environmental activities. Much of this is conducted by an outside organization in collaboration with local organizations, such as Pale Blue Dot with Amini or Planet with Kenya’s Joint National Resource Mapping project (JNAMP). Other companies are contributing to environmental monitoring and management, primarily servicing government authorities. GeoDevOps, for example, has conducted ecological reviews of Kenya's coastal ecosystems, providing insights for conservation efforts. LocateIT has been involved in mapping water access and monitoring waterborne diseases, supporting initiatives aimed at improving public health and resource management. Additionally, through Digital Earth Africa, Kenyan companies like LocateIT and Esri Eastern Africa have utilized satellite data to enhance environmental monitoring and land use planning. These collaborations typically serve local authorities and organizations like the Ministry of Environment and Forestry to make data-driven decisions.

4.3.2. Agriculture

The agriculture sector is not new to EO: the U.S. Landsat program started to monitor the land from space in 1972, and aerial solutions are used frequently. EO for agricultural purposes comes down to land mapping and change detection. Agricultural monitoring at the national/regional levels is well established, and solutions can be built with moderate resolutions data (10m-20m) – Landsat and Sentinel-2 are the main workhorses. Examples of usage include E.U. agricultural reporting for the Common Agriculture Policy (CAP) or Agriculture and AgriFood Canada (AAFC's) crop inventory maps. Such maps are generally produced once or twice a year, with less stringent requirements for revisit. These contracts tends to lead back to traditional large volume contracts and with a limited number of governmental departments globally who has the willingness to pay for Earth observation based solutions.

Globally, there is also a growing concern over food security, a changing climate, increased droughts in farmed regions, wildfires etc. all add to this concern. How EO can support the application is being explored by space agencies and IGOs. How, for instance, can EO track climate trends which may have implications for global agricultural supply. More locally, the development of GPS or GNSS systems integrated for agricultural activities and enabled by broadband connectivity brought to light the benefits of utilizing AgTech to support precision agriculture to improve farming efficiencies. Crop yield data collected on-board combine harvesters, when combined with satellite navigation, can pin-point areas within a field which display lower/normal/higher yield. This information feeds land management plans in order to identify areas in which are under/over irrigated, or where too much/little fertilizer is being used etc. The consideration of satellite imagery use in precision agriculture has been around for a long time, but has been limited by the capability of supply to produce an operational (i.e. continuous) services at the right price. Only with the emergence of low-cost constellations can the application begin to be fully developed. Ideally a wide-area coverage, multispectral dataset at around 5m ground resolution is required (such as the upcoming Earth Daily constellation). A similar dataset could also support parametric insurance claims by providing regular imagery to understand the impacts of natural phenomena (flood, drought, fire) on agricultural lands.

Agricultural services in Kenya

The agricultural sector in Kenya is highly fragmented, with over 7 million smallholder farms. This has led to the utilization of satellite-based solutions aimed at consolidating farm data and providing platforms to enhance farmers' credibility.

Three areas of concern within the agriculture sector with relevance to EO are identified: crops health monitoring, detection of invasive species and parametric insurance claims. Crop health monitoring covers both regional scale monitoring aimed at mitigating against the impacts of factors such as soil and land degradation, and more localize (precision) agriculture applications aimed at monitoring crop health. There are also efforts aimed at supporting the research of invasive species and at supporting insurance claims, but as of yet, operational use cases remain limited. To serve these applications areas, high coverage space-based EO datasets with suitable ground resolution and revisit, at a low cost (or free) are required: for

invasive species monitoring getting to multiple weekly collections at <1m ground resolution would be ideal; 5m weekly data would suffice to support insurance. As of now, this resolution is unobtained for many small scale farmers, as such space-based EO remains limited within this use case.

Yet, service providers in Kenya are active in the sector. For instance, Apollo Agriculture offers credit and insurance services tailored to smallholder farmers, leveraging satellite data for risk assessment. In addition, Aegir Consulting and Amini focus on precision farming, providing data-driven insights. Companies such as IMAP International and LocateIT provide tools for characterizing and delineating farmland. Public clients include county governments, the Ministry of Agriculture, Livestock, and Fisheries, and the Kenya Plant Health Inspectorate Service (KEPHIS). Service provider, Ramani, is also monitoring sugarcane in Western Kenya to ensure that farmers do not harvest before the sugar content is at its optimum prior to its sale. The sector has also attracted international investments, such as the AfriCultuReS program funded by the European Union and the Alizeti project, both of which aim to enhance agricultural resilience and sustainability through advanced satellite technologies.

4.3.3. Water Resources

This section considers water as a resource: how much water there is, where it is, and how it can be managed. Water quality is considered in the following “Health” section. Water quantity is how much water there is, this has implications for how water as a resource can or should be utilized. It has implications for industry, especially agriculture, as well as national water security. This is a major concern in parts of the world which are prone to drought and at the forefront of climate change.

Most applications for water management rely on coarser resolution optical imagery. Such as, Landsat, Sentinel-2 and Sentinel-3 to support monitoring of lakes and river systems, as well as coastal monitoring. Imagery is utilized to measure various parameters such as water body identification, water extent, mapping watersheds and bathymetry. With temporal coverage these can be monitoring at various scales from weekly to seasonally and utilized annually to establish climate trends.

Meteorology satellites also support the application to establish temperature, precipitation etc. and again with time series data to be able to indicate how these parameters are changing, and the implications this may have on water security. Digital elevation data also has a role to accurate monitor watersheds, and their evolution. Higher resolution commercial optical and SAR datasets may be utilized for detailed water extent mapping, and the monitoring of coastal zones to monitor ecosystem / biodiversity changes, and to support the aquaculture industry.

Water Resources services in Kenya

Kenyan services providers and users point to several key application areas within the water resources sector: being able to monitor lake and river water level to understand water volumes; being able to assess the vulnerability of water resources (wetlands, lakes, drainage networks, surface water modelling) and support coastal zone monitoring and aquaculture (changes to

coral reefs, seagrass beds, mangroves etc. and suitability of areas for fish cages.) This includes monitoring for maritime algal blooms and anthropogenic pollution (such as oil leaks.)

Despite these requirements, and concerns over water security, applications being developed in Kenya using EO remains limited. There are cases in which water resources are monitoring in the contexts of drought and flooding: International agencies such as NASA, ESA, and UN-SPIDER, along with nonprofits like the Global Partnership for Sustainable Development Data, provide support during flood and drought events. The Kenya Space Agency also leads initiatives like the Space4Water program, which maps the country's water sources to help mitigate water scarcity.

4.3.4. Health

In the context of this study health covers three areas:

- **Monitoring air quality:** Air quality monitoring relates to measuring the level of aerosols in the atmosphere including natural /human pollutants. There are implications for healthcare, safety, and security. Air quality data allows for monitoring and mitigating the effects on respiratory diseases and population wellbeing. Air quality services are nominally provided through weather agencies for free. Satellite imagery to support the application includes meteorology satellite in GEO and LEO, as well as dedicated instrumentation, such as Sentinel-5P TROPOMI sensor, Sentinel-4, NASA's TEMPO sensor and so on. Additionally, in-situ data collection is valuable – data can be collected across numerous variables from ground-bases sites – but spatial resolution of site placement can be an issue.
- **Monitoring water quality**: this relates the safety of water for either drinking or recreational usage, it can be impacted by a number of factors such as the amount of precipitation, surface run-off, wildfires and industrial practices (such as agriculture). Applications rely on coarser resolution optical imagery: Sentinel-2 and Sentinel-3 to support monitoring of lakes and reservoirs. Satellite imagery is utilized to measure various environment parameters such as algal blooms, water composition and turbidity. With temporal coverage these can be monitoring at various scales from weekly to seasonally and utilized annually to establish climate trends.
- **Epidemiology:** monitoring diseases is the least established of three applications. It is mostly an R&D activity, with a few pilot studies being completed using satellite-based EO. The principle is in being able to map and monitor the various environmental variable which could spawn vector-borne diseases, such as Malaria. The various variables could include, proximity to water bodies, types of vegetation, air temperature and humidity, soil moisture and so on; and then being able to monitor at regional scales to highlight areas which may offer the conditions for diseases to develop.

Health services in Kenya

During consultations with Kenyan stakeholders, health emerged as a key area of concern, particularly in terms of how much potential EO technology has in supporting national goals, especially in support of epidemiology and disease control.

In the context of epidemiology, malaria is a primary focus, with initiatives aimed at modeling and predicting at-risk areas, monitoring cases, and spatially tracking the disease. The overarching goal is to improve risk management related to malaria. Additionally, EO can assist in mapping health facilities and planning resource mobilization in response to outbreaks, such as determining the optimal locations for distributing mosquito nets. Despite these promising applications, the current use of EO solutions in this field remains limited.

For monitoring water quality in Kenya, there is a need to detect harmful algal blooms, coral bleaching, and anthropogenic pollution such as oil pollution and microplastics. The Ministry of Agriculture and Livestock Development runs the KilimoSTAT program, in collaboration with NASA SERVIR, to monitor water quality across the nation. Companies such as Amini, ADCC, and LocateIT also work with local government agencies to support efforts to preserve water quality.

To support air quality measurements, the Kenya Meteorological Department can generate air quality maps for Ozone, compounds of Nitrogen and Carbon particulate matter (PM10, PM2.5) Compounds of Sulphur etc. Air quality index (AQI). PM2.5 data can also be obtained in real-time by organizations such as IQAir, a Swiss air quality technology company.

4.3.5. Security & Disaster Management

For the purpose of this study “security” considers two closely related sub-sectors.

- **Defense and Security**, and support to intelligence communities, it is inclusive of state security i.e. counterterrorism and law enforcement. There is a focus on very high resolution optical and SAR data utilization and derived analytics, at high revisit, geolocation accuracy and delivered with low latency. Maritime Domain Awareness supports the above-mentioned communities, but is specific to the maritime domain. Whilst the user groups are likely to be similar there is an emphasis on certain EO technologies, especially SAR often used in combination with other space-based applications, AIS tracking and RF (Radio Frequency) monitoring. Specific applications included “dark vessel tracking” and monitoring activities to counter piracy or illegal fishing.
- **Disaster Management**, also support security and intelligence communities, as well as incorporating civil government utilization as well as IGOs and NGOs. This sector includes natural and technological disasters and humanitarian relief. According to the International Charter, “Space and Major Disasters,” and the Copernicus “Emergency Management Service”, more than 60% of requests are related to flooding and wildfires.

The purpose of very high-resolution imagery (<1m), whether it is optical or SAR VHR is to delineate ground objects in the greatest detail possible whereas high geolocation accuracy allows for the positioning of each object in its actual geographical location. There is an exception to the rule in that ship detection on an ocean can be achieved with coarser resolution SAR imagery. Defense and security is also likely to be a primary user of upcoming datasets in the hyperspectral and thermal imaging realms.

The high-resolution nature of the data means that the primary data sources for such applications are government operated defense or dual-use missions, or commercial data supply. Indeed, defense and security is the single largest market for commercial EO. In the case of Disaster Management, commercial operators may support users pro bono, or data can be access through mechanisms such as the International Charter.

Security services in Kenya

In Kenya, disaster management, and in particular disaster risk reduction is a key area of interest. Mapping and monitoring of activity to support predictive disaster modelling and post-disaster relief efforts are highlighted during consultation with Kenyan stakeholders. Application needs include:

- Hazard modelling and forecasting leading to early warning systems: areas likely to flood to determine risk areas, provision of disaster simulations, forecasting of flooding, droughts etc.
- Continued monitoring of disaster events, such as forest fires and flood extent.
- Assessments of coping capacity: placement of evacuation centres and health facilities (i.e. resources allocation) impacts on water supply.
- Coordination and response, including distribution of aid, where to align resources
- Post-disaster impact assessments: impacts on population, communities, infrastructure and industries such as agriculture
- Insurance exposure datasets: For instance**,** service provider Ramani provided flood damage assessments to a law firm to demonstrate frequency of flooding over a specific AOI.

To achieve this, a wide range of datasets are called for, including freely available Sentinel-1 and Sentinel-2, but with greater emphasis on higher resolution commercial optical and SAR. Ideally optional data <50cm ground resolution and 1m SAR from satellites such as TerraSAR-X. Auxiliary data sets such as population information, building data, and DEMs are needed. Often these data sets can be lacking (or come at a high cost) to build a systematic, operational approach to disaster management.

Kenya's space-based remote sensing ecosystem for disaster management is supported by international collaboration. RCMRD serves as the host for the UN-SPIDER program, playing a key role in coordinating disaster response activities in the region. Kenya has also activated the International Charter for Space and Major Disasters seven times to support the country following flooding and landslide events. Additionally, commercial entities such as Spatial Collective and GEO Data Design contribute to the ecosystem by developing tools for flood mapping and defense, utilizing both paid and open-access satellite data.

To note that supporting Imagery intelligence (IMINT) was not recalled during the consultation phase. It is expected that Kenya has similar requirements as other comparable nations.

4.3.6. Infrastructure Development

Infrastructure covers different applications, from cadaster and cartography to urban monitoring evolving towards smart cities. It also encompasses monitoring of large infrastructure projects (ports, airports, roads, railroad, etc.) and supporting post-disaster recovery. End-users include national government and various levels, IGOs, and engineering firms in the private sector. Of interest in developing regions is the ability to be able to monitor specific sites for which funding has been allocated to support development.

Infrastructure services in Kenya

EO supports cartography, utility mapping, cadastral mapping, and urban planning. User and service providers loosely outline two application categories: mapping and monitoring.

- Mapping is required to assess suitability of infrastructure projects in the planning phase, such as for corridors of alignment (such as power lines, rail, roads and pipelines); and to survey new building and road etc. placement. Mapping is also need for cadastral purposes and to support land information management systems. EO data required is diverse, up-to-date imagery of various scales (>1m to 10m) is used. There is also an important role of elevation/terrain data.
- Monitoring considers the ongoing construction of infrastructure projects, being able to monitor urban growth and informal settlement vulnerability. Also considered is encroachment on to existing infrastructure, such as vegetation over electricity transmission lines. Here there is greater emphasis on higher resolution data sets delivered with greater frequency.

Given the challenges posed by the lack of specific property addresses, land agents and government officials often face difficulties in their operations. In many areas of Kenya, especially in informal settlements and rural regions, the absence of a standardized addressing system makes it challenging to identify, manage, and regulate land parcels. This lack of clear property boundaries can lead to disputes over land ownership. Moreover, government officials tasked with urban planning, and infrastructure development struggle to coordinate and implement projects efficiently without reliable location data.

To address this, several companies are focusing on these services. ADCC and Smart People Africa provide data for infrastructure development. In the realm of land information services, companies like IMAP International, GeoDevOps Limited, LocateIT, and Spatial Collective cater primarily to property appraisers and government agencies. Their work includes delineating land properties and conducting community mapping, which is especially valuable for applications such as informal settlement planning. Ramani has also supported the

government on infrastructure projects such as by provided surveys of airports – today achieved by aerial imagery. It has also worked on road survey project with the KSA.

Where there is limited information over a specific AOI, or information is hard to obtain, there is an advantage to satellite utilization. This tends to be more the case in developing regions, fragile countries or in conflict areas. For instance, the World Bank monitors settlements to understand how populations are moving. This could occur post-disaster or conflict. It also lends money to nations to build infrastructure and monitors progress to release funds. Both these types of application require satellite imagery.

Data utilization depends on the scale of projects. For wider area monitoring freely available data from Sentinel-2 would suffice, however, to be able to monitor at the building scale commercial solutions will be procured. There is interest in upcoming thermal imagery solutions to support mapping of urban heat islands, building efficiencies and settlements monitoring. Infrastructure and engineering can also be considered a first area for civil usage of digital elevation products (DEM/DTM), and for subsidence monitoring using InSAR (INterferometric SAR).

4.3.7. Summary of Kenyan EO needs & applications

This section provides an initial analysis of how well current EO solutions align with user needs. EO applications and services identified are summarized in the table below.

Table 9: Summary of EO needs and associated applications

	Description	Users	Example of Applications
Climate / Env. monitoring	Monitoring the Earth's atmospheric, terrestrial, and oceanic variables to understand Earth's dynamics.	Space agencies, Government, research institutions, NGOs	• Understand ecosystem and climate evolution in the medium to long-term. • Monitoring of sensitive ecosystems: wetlands, rangelands, wildlife protected areas etc. • Monitor emissions and carbon markets operationally. Classify and identify changes to forest biomass and forest activities.
Agriculture	Monitoring crop health, soil moisture, and productivity for industry and food security. Mitigate against the impacts of invasive species and support insurance claims.	Farm industry, Ministry of agriculture, Insurance companies, KALRO, agricultural agencies, I/NGOs	• Reporting for national crop inventory maps for policy planning / food security. • Support private sector agriculture, ensure food production and profitability, improve farming efficiencies. • Possibilities to support invasive species monitoring and parametric insurance claims.
Water resources	Monitoring and managing water bodies (lake, river levels, extent), watersheds and coastal zones	Water authorities, WRM organizations, IGOs, communities, river basin authorities, fishing industry, shipping.	• Determine water quantity to determine how it can or should be utilized. • Monitoring lakes, wetlands and coastal zones to understand climate-driven changes and support aquaculture.

Health	Monitoring of land and water ecosystems for variables associated with disease outbreaks (such as Malaria), harmful algal blooms in water bodies, air quality	Water authorities, IGOs, communities, health authorities.	• Air quality monitoring, provision of Air Quality Index (AQI) data. • Ensure water quality for either drinking or recreational usage. • Provide detection, early warning, for outbreaks of vector-borne diseases
Security / Disaster Mngt.	Leveraging EO data for maritime security, image intelligence, early warning systems, risk assessment and post-disaster response	Emergency services, government civil and defence departments, Kenya Red Cross	• Support disaster prediction, management and mitigation efforts. • Support IMINT gathering to support security, defence and law enforcement. • Maritime Domain Awareness, alien ship detection, counter piracy.
Infrastructure	Satellite imagery if used for mapping, and then monitoring of infrastructure. To support planning phase for developments, and how construction is progressing.	City planners, IGOs, government agencies, Engineering firms	• Mapping to support development of infrastructure projects (roads, utility networks, railroad, etc.) Support collection of cadastre data for land information management systems. • Monitoring of construction, urban growth, informal settlement vulnerability.

4.3.8. User Demand Assumptions

Table 10: Mapping of EO needs

CLIMATE / ENVIRONMENT MONITORING		Low	Med	High	Rationale
Monitoring Climate Variables Reliable and free satellite data is crucial for enabling continuous monitoring, trend analysis, and predictive modelling for conservation and sustainability efforts. Consistent observations are crucial over long periods of time.	**Accessibility**			X	Data is accessible through several portals such as Digital Earth Africa, NASA, free meteo etc.
	Affordability			X	Data is free with several government and non-profit organizations / IGO s supplying services into Kenya.
	Reliability		X		Data and services are from government sources, both provided outside, and internal to Kenya. For Kenya specific solutions national expertise would be required
	Suitability		X		Whilst the data is suitable. Understanding longer term climate impacts to Kenya require a further layer of value-adding specific to content contexts.
	Security		X		Most services are supplied from outside Kenya, but local private and public entities are also involved.
Monitoring Ecosystems Wildlife population monitoring and habitat assessment; and, biodiversity monitoring, ecosystems. Concerns over changes in soil moisture, land degradation, rangelands (grasslands, wetlands etc. that are grazed by livestock or wild animals) and what this means for long-term economic and climate sustainability.	**Accessibility**		X		Whilst much can be achieved with free, coarser resolution data, access to higher resolution data sets is an issue.
	Affordability	X			High-spectral, temporal and spatial resolution is needed for localised habitat monitoring – comes at a higher cost.
	Reliability	X			There are limited cases where solutions would be considered operational. More ad-hoc R&D
	Suitability	X			Without access to higher resolution datasets the suitability of services delivered may not suffice.
	Security		X		Service are supported by external programs, but necessity for local private and public entities to be involved.
Carbon Credits / Forest Monitoring Carbon credit estimation requires land-use land-cover applications to monitor changes as to how land is being managed. Monitoring forests, biomass estimation, forest status mapping, speciation, canopy cover data is also required.	**Accessibility**		X		For forest monitoring, multispectral data from Sentinel-2 can suffice. Getting into biomass, higher resolution and LiDAR is called for.
	Affordability		X		Moving away from Sentinel-2, LiDAR (today aerial) and higher res optical and SAR comes at a cost.
	Reliability	X			There is some limited LiDAR, thermal imagery is also lacking. Plus limited higher resolution access.
	Suitability	X			Without LiDAR and higher resolution data, cannot achieve accurate biomass estimate at scale.
	Security				

AGRICULTURE		Low	Med	High	Rationale
Agricultural reporting for national crop inventory maps (mostly government utilization) Reliable satellite data is crucial for agricultural agencies to generate accurate national crop inventory maps, supporting effective monitoring and management of crop distribution and types for informed policy planning and for food security.	**Accessibility**			X	Data is accessible through several portals such as Digital Earth Africa or NASA programs. Sentinel-2 is a key workhorse for agriculture applicatons
	Affordability			X	Data is free with several government and non-profit organizations supplying services into Kenya.
	Reliability		X		Regional scale analysis can make do with Sentinel-2 (unlike most precision ag applications)
	Suitability		X		There are several service providers in the company supporting solutions in addition to government depts.
	Security			X	Services are offered by both local government entities and international government programs.
Precision Agriculture (mostly industry utilization) Higher resolution satellite data (~5m) with frequent revisit especially over growing seasons. Allows for being able to monitor crop stress, and guide in-field activities. Supports making data-driven decisions to enhance productivity and sustainability.	**Accessibility**		X		Some free data (again Sentinel-2) can be used to support monitoring, but higher resolution is preferred for precision agriculture, meaning commercial data.
	Affordability	X			The use of commercial imagery is likely to restrict utilization. Though users call for solutions to support crop health
	Reliability	X			Reliance on 3rd party commercial solutions. Less operational, more ad-hoc. More operators are coming to the market with an agriculture focus.
	Suitability	X			Commercial data is there to support service development, but at a cost. No 5m high coverage data.
	Security		X		There is a reliance on being able to access 3rd party commercial data solutions.
Insurance and Invasive species monitoring Grouped together as they are connected with lower levels of maturity in the global context. EO data can be utilized to assess insurance claims caused by natural events (flood, drought, fire etc.). Invasive species monitoring required detection of early changes in vegetation health.	**Accessibility**		X		Sentinel-2 data can support wider-area insurance claims. Otherwise, higher resolution data is required.
	Affordability		X		Similar where free data can suffice, there is some applicability, however, there is more emphasis on commercial data.
	Reliability	X			Applications today utilize mixed data sets with more limited EO usage. Services are less operational and more focused on pilots of specific AOIs.
	Suitability	X			Getting to 5m wide area coverage data would be preferred. Not available today. Higher resolution wide coverage needed for invasive species monitoring.
	Security		X		Reliance on 3rd party datasets, but several Kenyan service providers are becoming engaged in the application.

WATER		Low	Med	High	
Monitor water quantity Monitoring lake and river water level to understand water volumes and extent. As rainfall is increasingly scarce in East Africa, existing groundwater supplies become the main source of water. Satellites, in combination with in-situ sensors, are used to manage water resources as well as guide the construction of infrastructure in strategic areas to prevent watershed impacts, and to forecast droughts.	**Accessibility**		X		For mapping water extent and changes over time, Sentinel-2 / Landsat works. Altimetry for water heights (although aerial LiDAR being used more today)
	Affordability			X	The application can mostly work with freely available imagery.
	Reliability	X			Some auxiliary data, such as DEMs to support watershed modelling, are lacking. Need for aerial LiDAR (which will push up costs)
	Suitability	X			Computing resources can be lacking to support time-series analytics over wider areas. Again, elevation data an issue.
	Security		X		A reliance on 3rd party solutions – limited activity today being conducted by Kenyan organizations.
Water habitats and ecosystems Monitoring lakes, wetlands and coastal zones to understand climate-driven changes and support aquaculture. Assessing the vulnerability of water habitats and ecosystem. Applications can include oil spill / pollution monitoring.	**Accessibility**		X		Leverages free ocean colour mission data (MODIS, Sentinel-3), but higher resolution required for detailed mapping. Some reliance on Planetscope.
	Affordability		X		Costs are a limited factor for using higher resolutons products e.g. to support coastal habitat mapping
	Reliability		X		Reliability is a question of scale – wide area coverage requirements can largely be met. But operational solutions and local/smaller-scales are a challenge
	Suitability		X		Satellite EO can go some way to answering problems. But where accurate height data, or more spatial resolution is needed, suitability becomes an issue.
	Security		X		A reliance on 3rd party solutions – limited activity today being conducted by Kenyan organizations.

HEALTH		Low	Med	High	
Monitoring Air Quality Measuring the level of aerosols in the atmosphere including natural /human pollutants. There are implications for healthcare, safety, and security. Air quality data allows for monitoring and mitigating the effects on respiratory diseases and population wellbeing.	**Accessibility**			X	Leverage openly available meteorology and Earth-science sensors.
	Affordability			X	Data is available for free under WMO principles. Services also free through the govt. and third parties.
	Reliability		X		Mostly reliable on a national scale, services are less tailored to local area monitoring.
	Suitability		X		Mostly suitable, government data is limited in being able to provide indicators of pollution sources.
	Security			X	Although 3rd party data, meteorology satellite programs are budgeted for and will continue
Monitoring Water Quality Relates to the safety of water for either drinking or recreational usage, it can be impacted by a number of factors such as the amount of precipitation, surface run-off, wildfires and industrial practices (such as agriculture). Satellite imagery is utilized to measure various environmental parameters such as algal blooms, water composition and turbidity.	**Accessibility**		X		Leverage freely available data. Sentinel-2 imagery is a key dataset. But 10m not always ideal to monitor smaller water bodies
	Affordability		X		Services mostly rely on free data. Affordability can be an issue for computational resources to run time series analytics. Inhibiting the ability to scale solutions.
	Reliability	X			This inability to scale means that services today are most ad-hoc, there isn't an operationally capability
	Suitability		X		Data supply is mostly suitable. For more detailed mapping higher resolution commercial data would be required.
	Security		X		A reliance on 3rd party solutions – limited activity today being conducted by Kenyan organizations.
Disease control / Epidemiology Using EO to map and monitor the various environmental variables which could spawn vector-borne diseases, such as Malaria. The various variables could include, proximity to water bodies, types of vegetation, air temperature and humidity, soil moisture etc. and then being able to monitor at regional scales to highlight areas which may offer the conditions for diseases to develop.	**Accessibility**		X		To build applications much can be done with openly available Copernicus imagery.
	Affordability		X		Services mostly rely on free data. Affordability can be an issue for computational resources to run time series analytics. Inhibiting the ability to scale solutions.
	Reliability	X			Limited activity today. Computational resources, being able to analyse for numerous variables over time series data is an issue.
	Suitability		X		Data supply is mostly suitable. For more detailed mapping higher resolution commercial data would be required.
	Security		X		A reliance on 3rd party solutions – limited activity today being conducted by Kenyan organizations.

SECURITY / DISASTER MANAGEMENT		Low	Med	High	
Support disaster management In Kenya, government agencies, humanitarian organizations, and research institutions use satellite EO data for disaster prediction and mitigation, focusing on hazards like droughts, floods, and landslides. Organizations often use publicly available, free data, which provides broad coverage and frequent updates.	**Accessibility**		X		Free data is typically used to support local entities against disasters. Services are provided by RCMRD in service of Kenyans. Limited predictive activity
	Affordability		X		"Some" free data in the event of a disaster, several government and non-profit organizations supply services. Limited availability of higher resolutions datasets due to cost, also less focus on preparedness
	Reliability		X		Data and services are often from reliable government sources post-disaster, but getting to modelling, prediction there is limited ad-hoc effort
	Suitability	X			Ideally greater availability of higher resolutions datasets, more accurate elevation data, auxiliary data is needed to build an operational capability.
	Security	X			Heavy reliance on 3rd party government bodies which mostly focus on post-disaster recovery rather than pre-disaster preparedness.
Supporting Image Intelligence (IMINT) IMINT is the main applications in support of Defense and intelligence departments. There is an emphasis on very high resolutions optical and SAR data delivered in a timely fashion.	**Accessibility**			X	High resolution commercial datasets are available and are used by defense departments globally.
	Affordability		X		However, they come at a cost. Defense tends to relatively larger budgets, but price of data is still a factor in extent of usage.
	Reliability	X			It is unclear if there are service providers or bodies in the country working on specific IMINT services, such as maritime domain awareness applications
	Suitability		X		Commercial high resolution data is suitable, however, it again comes down to cost.
	Security	X			There are ways to receive high resolution commercial datasets in the country, but there is a reliance on these.

INFRASTRUCTURE DEVELOPMENT		Low	Med	High	
Mapping for infrastructure development Mapping to support development of infrastructure projects (roads, utility networks, railroad, etc.) Support collection of cadastre data for land information management systems.	**Accessibility**		X		For regional level mapping, freely available Sentinel-2 will suffice. Otherwise, there is greater demand for higher resolution optical imagery and DTMs
	Affordability		X		The costs associated to higher resolution commercial imagery inhibits use beyond regional scale mapping
	Reliability		X		For certain mapping activities over wider scales, services can be generated. More localized scales are problematic.
	Suitability		X		As above, higher resolution data sets are needed to support cadastre, detailed urban planning etc.
	Security		X		The data is there from 3rd parties, but at a cost. There is the capability for Kenyan companies to provide services. Noting companies supporting the sector with aerial imagery.
Monitoring of ongoing activities Satellites are used to track construction progress, ensure compliance with design specifications and identify potential structural weaknesses. Activities include Monitoring of construction, urban growth, informal settlement vulnerability.	**Accessibility**		X		For regional level monitoing, freely available Sentinel-2 will suffice. Otherwise, there is greater demand for higher resolution optical imagery and DTMs
	Affordability	X			The costs associated to higher resolution commercial imagery inhibits use beyond regional scale mapping
	Reliability	X			Services are ad-hoc, there is limited operational capabilities. Data cost is a restrictor.
	Suitability	X			High frequency, <1m ground resolution data is needed to build desired services.
	Security		X		The data is there from 3rd parties, but at a cost. There is the capability for Kenyan companies to provide services.

4.4. Gap assessment

To assess EO gaps at an institutional level, and to address how to support the private sector, the service needs are compared to the status of EO services in Kenya. This includes the assessment of EO services being generated in Kenya or supplied into Kenya from external organizations. In addition, two further factors are considered:

- **Development of EO services at the global level**: There is a need for several services in Kenya, which, even in a global context remain at the R&D level or have yet to move beyond pilot studies. These service areas do not use satellite-based EO data and services operationally. This includes areas such as disease control, or Carbon markets. These service areas may emerge in the next 5-10 years as global service providers and governments explore these areas.
- **Identified structural gaps**: During the consultation process Kenyan stakeholders identified several cross-cutting structural issues which can inhibit the development and utilization of EO services in Kenya. These relate to computing resources, affordability and mechanisms to promote institutional change with regards to space-based technology adoption.

These factors are then combined with the scoring (high, medium, low) as indicated in the tables labelled “Mapping of Government and Commercial EO Supply” (Table 8), and “Mapping of EO needs” (Table 10) provided in this report. This leads to a ranking of service areas which are more mature, versus those that remain underdeveloped.

4.4.1. EO Services Development at the Global Level

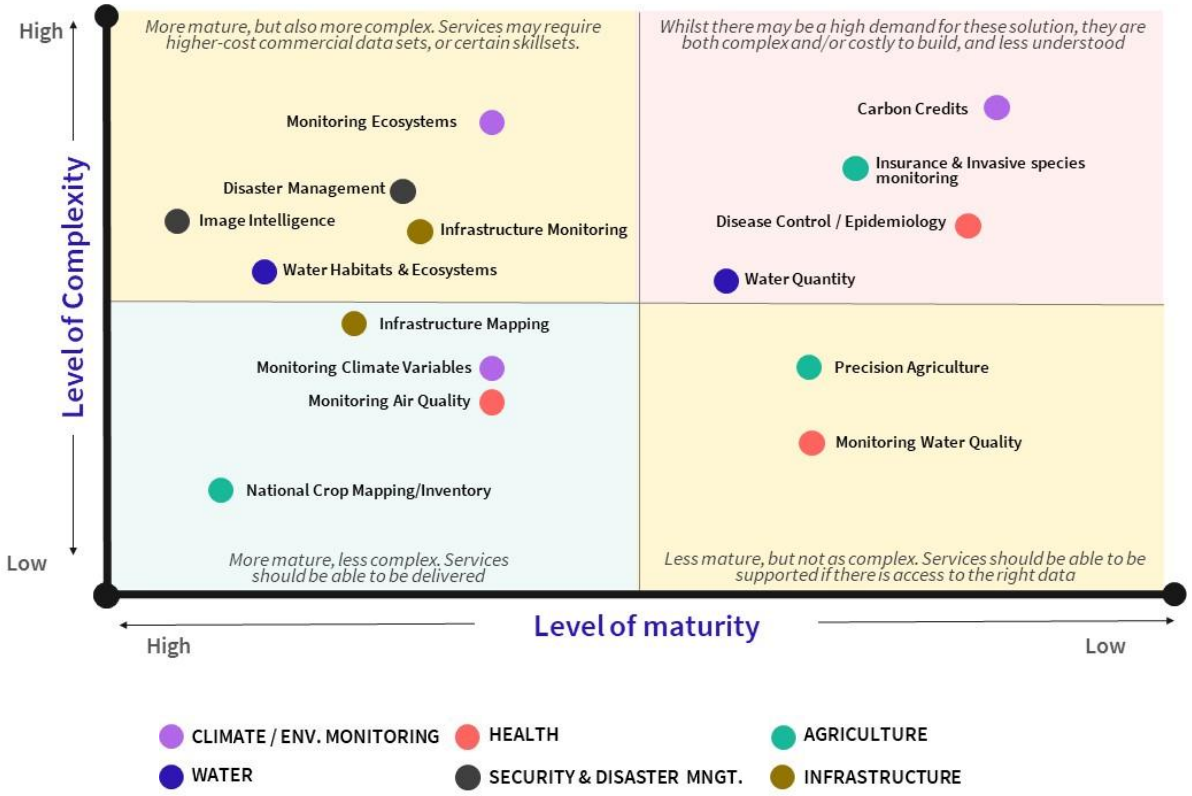
Before getting into Kenya’s gap assessment, it is important to acknowledge EO services development gaps globally. The simple reality is that some of the applications areas within the vertical markets identified to be important to Kenyan stakeholders are not fully operational, or less mature globally.

These global gaps in capability tend to come down to one of two factors:

- The services to be developed rely on utilization of extensive high resolution datasets, meaning commercial imagery is needed. This comes at a cost which can inhibit services development;
- The specific data set/s to build the solutions are not available, or fully operational. Further work is needed to explore how EO can play a role in supporting applications.

The matrix below explains these factors and the impact that have on the various EO-derived services’ maturity. It demonstrates the range in the current capabilities: from more established and mature applications (such as national air quality monitoring, or crop mapping); to areas which are considered R&D (such as understanding how EO can be used to support Carbon credits, insurance end-users and invasive species monitoring).

Figure 5: Global Earth Observation Services Maturity Matrix



There is variation in each of these application areas. For instance, infrastructure mapping can refer to simple land-use or cartographic mapping, or more complex site planning which may need my diverse datasets – the matrix only presents a general overview. However, it demonstrates that certain application areas identified as being important to Kenyan stakeholders (invasive species monitoring, supporting Carbon credits etc.) are a challenge to build in the global context, and are further away from being operational.

It also demonstrates the levels of application and services maturity within the vertical markets. In most cases, within the sectors assessed, there are application areas which are more mature than others. In many cases this is a factor of granularity. For example, larger scale (national/regional) mapping applications tend to be more established, being built from freely available data and services. However, more local-level monitoring applications – which are important for many Kenyan stakeholders – require higher resolutions and higher revisits, which inadvertently means the use of commercial data. This increases the costs to develop the services, a key inhibitor for adoption.

- **Climate / Environment Monitoring**: the application covers **monitoring climate variables**. Many applications are supported by data and services from freely available government Earth science and operational satellites. For regional / national scale climate monitoring, many applications can be considered mature and available to Kenyan users. However, the **monitoring of ecosystems** implies more localized and specialized monitoring. This requires further specialized knowledge and may potentially need commercial data and services. For example, there is a minimum level of granularity and knowledge required to support wildlife monitoring, understanding changing in rangelands and wetlands etc. Even further specialized, and mostly still at the R&D / pilot study level, is EO in support of **Carbon Credits**.

Understanding how EO can support the application is a question at a global level, and one in which several commercial EO companies are looking to explore. One thing currently lacking is high resolution (<5m ground resolution), high coverage (at least global, weekly) data with spectral resolution to support vegetation mapping (such as to understand changes to forest cover). Other datasets such as those meant to support ground-based Carbon gas monitoring are limited.

- **Agriculture**: supporting **national crop mapping/inventory** can be considered one of the more operationally mature use cases for EO. Numerous countries globally produce at least an annual crop map to support agriculture stakeholders. However, **precision agriculture** applications to support the agriculture industry are less mature. As the name implies, higher resolution data is required with higher revisit – this means using commercial data resulting in higher services costs. The application area is emerging with several new EO operators and services companies exploring the commercial potential of the application. With regards to **insurance and invasive species monitoring,** the application is still considered more R&D. While they are both considered important and potentially commercially lucrative application areas, they require access to different types of data that are currently available. In both cases having higher resolution (<5m for insurance, and higher for invasive species) at sub-weekly revisit with global coverage are needed at a minimum.
- **Water:** applications concerning water habitats, and water quantity are not well established**.** Monitoring **water habitats and ecosystems** involves a more local level of monitoring with greater granularity: it is similar in requirements to monitoring ecosystems. **Water quantity monitoring** is less of a mature application. There are needs for more diverse datasets (such as radar altimetry) combined with data on precipitation, snow accumulation, land surface temperature etc. In Europe and North America water quantity monitoring is supported by extensive in-situ collection (such as from river gauges), however, this infrastructure can be lacking in Kenya. This means that there is greater emphasis on remote sensing data collection.
- **Health:** Applications such as **monitoring air quality** are more established, they utilize data collected from national meteorology programs, such as EUMETSAT and NOAA. Services are then delivered through national weather agencies. The science behind **monitoring water quality** is also well understood. However, it should be noted that the monitoring of in-land water bodies sometimes requires higher resolution data (it depends on the size of the water body needed to be monitored) which increases the cost of the service. Supporting **disease control / epidemiology** with EO is less established. There exists R&D and pilot studies within government agencies (such as ESA) but they remain non-operational. There is a logic in understanding how EO can support (in particular) vector-borne diseases mitigation by providing insights on the various environment variables that could initiate outbreaks.
- **Security and Disaster Management:** Both have needs for higher resolution, high revisit datasets which require either access to proprietary satellites, or the procurement of commercial data solutions. It means that whilst the application areas are relatively mature and understood, services come at a higher cost. This is the case in support of **image intelligence** applications. To support **disaster management**, some level of solutions may be provided free of charge post-disaster (such as through the International Charter). However, to support disaster preparedness, mitigation costs can run high.
- **Infrastructure:** applications to support the market are well understood. Within **infrastructure mapping**, applications to support cadastre, land-use etc. are amongst the most established

application areas. Adoption of EO is often a question of scale: regional-scale land-use mapping can make do with freely available datasets, local/urban-scale mapping needs higher resolution commercial solutions. For **infrastructure monitoring**, where continued imaging is required over time, service costs tend to be high due to the need to support change detection applications. This is of high importance in Kenya – to be able to monitor changes to the urban landscape and to support large-scale construction projects.

4.4.2. Identified Structural Gaps from Consultation Process

In addition to these global issues related to EO utilization in the identified vertical markets, there are further horizontal issues which factor into the Kenyan context. In several cases, Kenyan organizations *can have* access to EO data, however, use of the technology is not necessarily the most cost-effective or preferred solution.

There are other enabling factors which inhibit EO usage related to the means to transform and managing data and delivery solutions. These gaps are not specific to any one market, they are cross-cutting, restricting the rate of EO adoption:

Limitations to EO Data Accessibility

While some satellite solutions are available to Kenyan organizations, stakeholders point out that satellite-based EO is one source of information. Other solutions (such as airborne remote sensing, or ground-based land surveying) are utilized if they are considered more capable or cost effective. Several downstream organisations in Kenya are from the wider geospatial / aerial surveying world, and are adept at utilizing these other technologies. In such instances, satellites may only be utilized when wide-coverage land surveying is needed. There are several factors which inhibit further EO usage:

- **Suitability of data to meet demand**: for local area monitoring, higher ground resolution and revisit is needed. Getting to 5m ground resolution (and below) with a daily to weekly revisit are the key requirements to move from national/regional scale monitoring to more localized monitoring (to support precision agriculture, infrastructure monitoring in the urban environment, as well as water quality and ecosystem monitoring at smaller scales).
- **There are limited funds for commercial procurement.** Commercial data (e.g. from Airbus, Maxar and Planet) is utilised on a project-by-project basis. Funds are limited to support operational applications that require higher resolution data. Additionally, data reselling companies in Kenya point out that the availability of Sentinel-2 data for free had a negative impact on their business. It led companies to drop agreements with satellite operators that required guarantees of fixed volumes of data to be sold. The use of commercial imagery is also restricted by the needs to order minimum sizes, although newer EO service companies and operators (such as Skywatch, Umbra etc.) are looking to address this issue.
- **A dependency on 3rd party data** – even for free data solutions – can present further problems to support service development. Kenyan organizations note that they are not necessarily at the top of satellite tasking priorities, or that the use of standardized analytics-ready-data built in Europe, may not be appropriate to Kenya (e.g. issues in orthorectification, or utilizing different classification methods.)
- **Lack of auxiliary data**: there are limitations to more applied solutions that are currently available being used in the Kenyan context. Digital Elevation Model (DEM) data is lacking in

the country; global forest data or soil moisture maps (such as provided through Digital Earth African) do not have the resolutions required to support low-scale applications; plus, statistical data on populations, building footprints etc. is considered not up to date.

The Role of the Government

In some instances, there appears to be a resistance to using satellite-based EO – there is a hesitancy to alter practises and adopt new technologies. The Kenyan government traditionally relies on in-situ reporting or aerial imagery for its decision-making processes. One service provider highlighted that in Kenya, legal and institutional frameworks mandate spatial plans for local governments, but EO solutions are not used to support their development. Other service providers note that their only engagement with satellite-based EO often stems from participation in European-led, application-based projects, such as those under GMES & Africa. Further concerns lie with the government tendering processes.

By addressing these challenges, it is believed that the utilization of EO technologies and the overall market size in Kenya could expand significantly. For this to occur, efforts on EO outreach, and in demonstrating the cost-benefits of the technology is required. Service providers feel confident that they are well positioned to enhance EO service generation if there is sufficient demand.

- **There is a lengthy process for awarding contracts from government bodies**, the transparency of the contracting process, and the time required for proposal development. Service providers express unease about the role of the Regional Centre for Mapping of Resources for Development (RCMRD), viewing it as a competitor despite its status as an intergovernmental organization. This concern is compounded by the fact that RCMRD has previously secured contracts that commercial service providers also bid for. Additionally, delays in payment for contracts with government institutions further complicate the landscape.
- **Government in support of outreach:** there are few avenues to support capacity building and demonstrate the capabilities of EO technology to government institutions. Collaborations between the government and national EO service providers are lacking. For instance, service providers mention how EO can support application areas more efficiently than other more costly alternatives that the government currently rely on (such as in-situ land surveying). Conversations on how EO can support the government in various aspect of climate change adaption and mitigation are also limited.

Computing and Human Resources

Organizations recognize the need to adapt computing infrastructure to support the transition to a "big data" environment. Internet connectivity also brings limitations in the creation and delivery of services; being able to exchange files, large datasets etc. Significant investment is required at both the government and company levels to effectively manage extensive datasets. For companies to commit to these investments, they seek assurances from the government regarding ongoing projects that will utilize EO imagery.

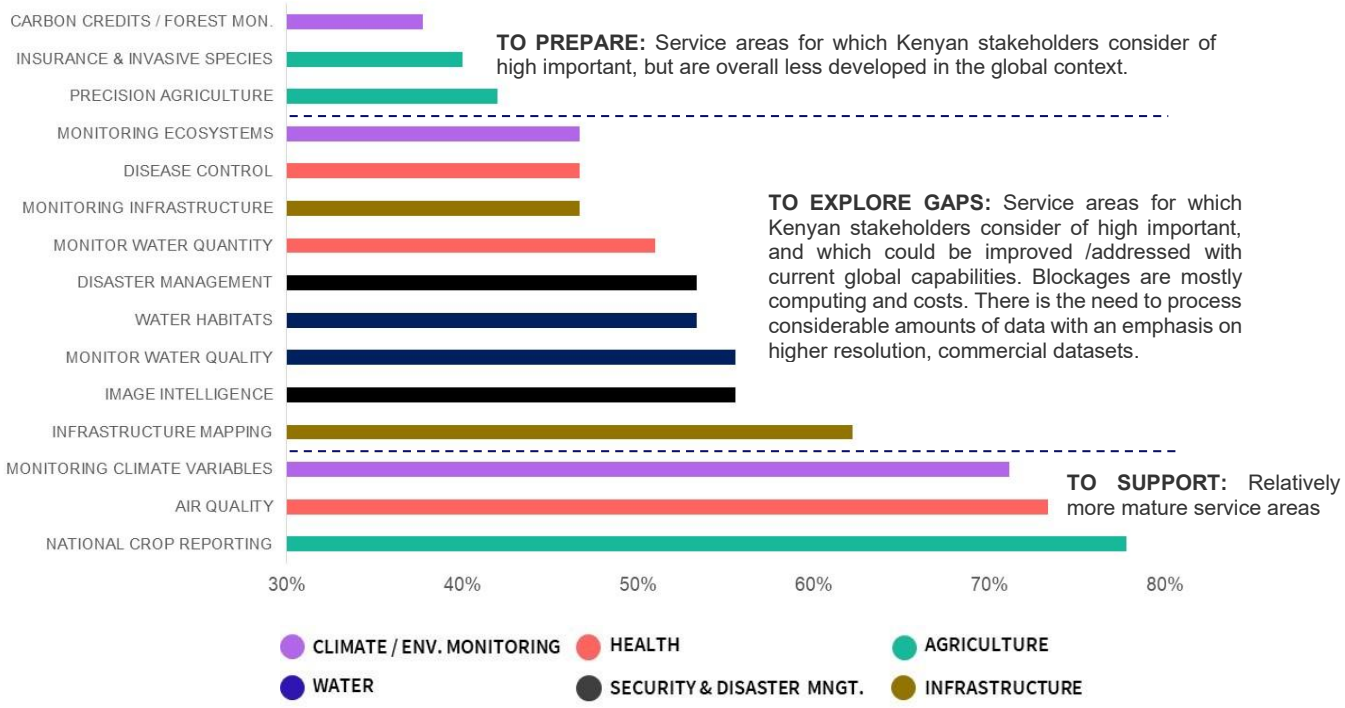
Additionally, funding is essential for integrating innovations such as AI and machine learning into their operations. Companies struggle to shift from a traditional surveying focus to a broader geoinformation approach, including innovative EO analysis, due to challenges in technical know-how and limited resources to facilitate this transformation.

Furthermore, to support EO utilization a greater emphasis on human capital is required. Service companies note that there are limited skills in the country to leverage SAR data, as well as newer sensors typologies covering hyperspectral, thermal imaging and LiDAR. In addition to more technical aspects of EO and data processing, skills are needed to address project management, proposal writing, communications etc. There are limited training opportunities to be able to address these challenges.

4.4.3. Relating Global EO Services Development and Structural Gaps to the Vertical Markets

For the purpose of the gap assessment, all the vertical market application areas are deemed to be important to Kenya based on the literature review and consultation with Kenyan stakeholders: i.e., this study does not say that one market is more or less important than the next. Each of the application areas are reviewed based on the ability for an organization (government or private sector) to deliver EO-based solutions to support end-users in the vertical markets. These are then divided into three segments which relate to the maturity and capabilities to build and deliver these solutions.

Figure 6: Gap Criticality Based on Current Supply Supporting the Identified Vertical Markets



To Support

These are the application areas within the vertical markets identified in this study which are considered to be more mature both in the Kenyan and global contexts. They are service areas which are considered to be “public good” application areas and are supported by free data solutions (such as Copernicus Sentinels and meteorology data). They are national / regional-scale applications used to provide information at a country-wide level. It is not to say all is perfect – these application areas (especially

monitoring climate variables) are very diverse, and it is important to adapt and support new research areas, understand what new data sets can bring etc. to support further development and utilization.

These application areas also become less developed and utilized as the scale of EO mapping moves from regional to localized levels. This is the key difference between applications such as national crop reporting and precision agriculture; also, a key different between monitoring climate variables and more local ecosystems. Reducing scales tends to call for higher resolution (mostly commercial) datasets, at a higher cost. Air quality is no different: understanding air quality at regional levels can leverage meteorological data, but to understand the sources of pollution at a local-level, higher resolution datasets are required.

To Explore Gaps

Most of the application areas covered fit into this area. These are applications which have a degree of maturity in the global context but are considered underdeveloped in Kenya. There are several reasons for the lack of utilization, however, it usually starts with problems related to funds and computing resources.

These applications require mapping and monitoring at localized levels which in turn requires higher ground resolution commercial imagery (which comes at higher costs). There is often not enough funds or commercial demand to support developing applications in these areas. The cost-benefit of the effect of space-based EP on these applications tend to be misunderstood and as such, alternative solutions tend to be favoured, especially by government users. Service providers may look to other forms of data collection to support application development as that is what their government customers are accustomed to.

The transition to monitoring applications requires the procurement and processing of larger quantities of satellite imagery which in turn requires funds and greater computing resources. This is the key difference between planning for future infrastructure projects and monitoring ongoing projects. In the first instance, much can be achieved by being able to access suitable datasets. In the latter, further costs are incurred through the need of revisit satellite imagery and related data processing.

Interestingly there are three water-related application areas to explore. Whilst the end-users for each application area may be different, EO requirements are largely similar: the need for <10m grounds resolution imagery with some spectral granularity in the near-infrared. For monitoring water quality on larger water bodies, Sentinel-2 should be sufficient. However, the application is not a focus of many EO services companies operating in the country.

There may also be a more limited Kenyan internal capability to support the processing and utilization of datasets beyond visible-NIR optical imagery, such as being able to process SAR data to support applications development. Auxiliary data sets to support EO applications may also be lacking (elevation data, cadastral maps etc.). Additionally, several applications such as disease control / epidemiology remain R&D focused and not fully operational even at the global level. Overall, there remains a strong R&D component to support some applications development.

To Prepare

Here are applications, whilst of importance to Kenya, are not fully operational at a global level. The objective for Kenyan stakeholders is to monitor the progress of these application areas and prepare for how they can be applied in the Kenyan context. There can be opportunities for these stakeholders to be part of, or support pilot studies to support applications development. As with applications in the "explore" section, data costs and computing resources are also likely to be a factor for development and utilization in the country.

Of the applications in this range, precision agriculture is perhaps the most surprising (supporting Carbon markets and invasive species monitoring remain very much at the R&D level). It is mostly a factor of data suitability that is holding back the application from being operational at a global scale. Whilst certain data sets can be used to support precision agriculture applications over specific AOIs (Maxar, Airbus and Planet data can all be used this way), it is less suited to developing solutions which can be scaled globally. New solutions, such as the Earth Daily Analytics constellation with wide area coverage at 5m ground resolution will look to address this application – it will be launched in 2025.