Whose Priorities? Examining Inequities in Earth Observation Advancements Across Africa

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Key Points:

- Satellite Earth Observations can support critical programs across multiple sectors, including agriculture, environmental monitoring, early warning systems, and disaster response. Additionally, this technology can help cultivate job opportunities in related fields.
- In Africa, the satellite Earth observation sector was estimated to be worth 1.4 billion USD in 2023. However, it's unclear who primarily benefits from this market. There's potential for increased value and benefits if more African leadership is involved, particularly in agriculture-related applications.
- Systematic analysis shows most Africa Earth Observations (EO) activities are directed by non-African entities, despite growth in African space programs. To develop a more comprehensive landscape map, authors invite organizations and companies in EO to submit their information at `https://go.umd.edu/EoAI_MLforAgricultureinAfrica`

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Abstract

Earth Observation (EO) technology continues to gain momentum for applications like crop monitoring and food security mapping across Africa. However, the development of these systems and the direction of the sector, even for locally relevant datasets, applications, and solutions, has been and remains largely externally driven. We utilized a database of "leading organizations" in EO for Machine Learning" and partnerships in African space programs to investigate the landscape of EO for Agriculture in Africa. We analyze key actors based on origin, activities, funding sources, and other factors. Results reveal an imbalance where most African EO activities are directed by non-African entities, highlighting data sovereignty issues and the need for enhanced local capacity building. Across the EO pipeline, African participation and leadership are limited despite national efforts to launch satellites and expand space programs. Analysis of a sample of organizations involved in the EO sector worldwide showed that 71% had active initiatives focused on the continent, despite only 1 organization being headquartered locally. Only around 1/3 of active satellites for African countries were contracted locally, and reports show that users face barriers to accessing their data. By mapping participation and funding flows, this research elucidates how African countries can exert greater control over EO data, build sustainable expertise, and harness EO technology to serve national development priorities. As the EO sector evolves rapidly, African voices must help shape the applications and priorities for these powerful technologies.

Plain Language Summary

Africa bears the heaviest food insecurity burden worldwide, with hunger affecting an estimated 278 million people in Africa in 2021.

Satellite systems observe the Earth and can support critical programs in agriculture, monitoring, environmental monitoring, improving early warning, and accelerating disaster response. However, most of the Earth observation (EO) work in Africa is driven by non-African organizations.

We analyzed "leading organizations" in EO and Machine Learning (ML) dominating services, revenue and application development, and partnerships in African Space programs.

Results from the sample show that the majority, 90%, of African EO projects are led by non-African organizations. Even when African countries launch satellites, they depend heavily on non-African partners.

Only 35% of active satellites operated by African organizations were contracted by African organizations, resulting in a loss of authority over their citizens' data for many African agencies. The direction of satellite projects by non-African organizations makes it harder to apply the data and products to national needs and priorities. It also hinders Africa's development of local experts and facilities for utilizing EO data.

We illustrate complicated links between players in Africa's EO sector and discuss ways for African countries to gain more control over EO data and technology.

1 Introduction

Food security is a paramount concern in Sub-Saharan Africa, where over half the population comprises smallholder farmers, and agriculture contributes about 17% to the GDP (World Bank, 2023). Escalating extreme climatic events, inadequate agricultural production and political instability continue to jeopardize farmers' livelihoods (Nakalembe, 2020). The United Nations Food and Agriculture Organization (FAO) reported a global food production increase of 2.3% in 2019. Yet, Africa experienced a 4.6% production decrease and stagnation due to regional conflicts, socioeconomic conditions, climate change, and pests (FAO, 2020). Inadequate access to inputs, information services, and heavy reliance on rainfall exacerbates poor agricultural production, perpetuating food insecurity (FAO, 2020). FAO's 2022 report highlighted a rise in global hunger, with 103 million more people between 2019 and 2020 and 46 million more in 2021 (WFP et al., 2022). The reports show persistent regional disparities, with Africa bearing the heaviest burden, with hunger affecting an estimated 278 million people in Africa in 2021 (WFP et al., 2022).

Given these challenges, there's a critical need for timely early warning systems and scalable data-driven strategies to bolster decision-making in African agriculture and disaster assessment and management (Nakalembe, 2020). This entails accurate crop production estimation, early detection of crop failure, and support for response initiatives such as risk financing (Nakalembe et al., 2021).

1.1 Importance of Earth Observations (EO) to food security in Africa

While many factors influence food security, Earth Observations (EO) data and tools have emerged as critical tools that provide the critical data needed to address and track food systems' ever-growing complexity, particularly in Africa. Satellite data, machine learning, and cloud computing advancements offer unprecedented geospatial mapping potential, even in data-scarce regions (Gorelick et al., 2017; Nakalembe & Kerner, 2023). Evidence shows that EO can significantly enhance food security programs through various mechanisms. These include early warning systems for detection of environmental stressors at unprecedented spatial and temporal scale (Blakeley et al., 2020; Nakalembe et al., 2021; Becker-Reshef et al., 2020), satellite-based indices for more accurate crop insurance (Skakun et al., 2016), improved crop yield estimation (Lobell et al., 2020), land use and land cover change monitoring, and water resource management (Nakalembe & Kerner, 2023). While EO is not a panacea, its integration into agricultural and food security programs has shown significant potential to improve decision-making, resource allocation, and risk management in African contexts (Whitcraft et al., 2019; Nakalembe et al., 2021). The synergy between EO technologies and other interventions offers a more comprehensive approach to addressing food security challenges in Africa.

Traditional survey ground-based methods for agricultural monitoring, such as crop cuts for yield estimation, often face limitations in providing timely, comprehensive, and scalable insights, especially in remote and conflict-affected areas (Lobell et al., 2015). These methods, while valuable, can be time-consuming and costly and may not always capture the full spatial and temporal variability of agricultural landscapes. Additionally, results and insights from these traditional approaches often become available several months to years after the growing season, limiting their usefulness for timely decision-making. Satellite EO complements these ground-based approaches, offering continuous and spatially extensive observations that are particularly useful for generating critical crop datasets in heterogeneous areas with limited accessibility (Nakalembe et al., 2021). Moreover, integrating and designing data collection protocols to harness EO enhances our ability to conduct more timely large-scale agricultural assessments.

The global satellite industry is evolving, transitioning from government dominance to commercial participation, with launch costs to Low Earth Orbit (LEO) declining significantly. The development of commercial launch systems has substantially reduced costs, as evidenced by SpaceX's Falcon 9 offering launches at $2,720/kg to LEO in 2018, compared to NASA's space shuttle cost of $54,500/kg in 2011 (Jones, 2018). This trend of cost reduction is further supported by (Adilov et al., 2022), which reports that average per kg launch costs decreased from approximately $25,628 in 2000 to $4,793 in 2020 (in 2020 dollars), with commercial launches experiencing even steeper declines. The study estimates an annual cost reduction rate of 4.4% when adjusted for altitude, projecting that average launch costs could fall below $1,000 per kg between 2045 and 2076 if trends continue. These declining costs are driving increased commercial activity in space, as highlighted by the 2024 State of the Satellite Industry Report, which notes that 2,781 commercial satellites were deployed during 2023, representing a 20% increase from the previous year (Satellite Industry Association, 2024). This rapid growth, attributed to technological innovations that continued to drive increased affordability and productivity are enabling accessibility through programs like NASA's Commercial Smallsat Data Acquisition (CSDA) Program (`https://www.earthdata.nasa.gov/esds/csda`), which recognizes commercial smallsat data as a cost-effective complement to Earth observations by NASA, ESA, and other agencies. Additionally, Norway's International Climate & Forests Initiative (NICFI) (`https://www.planet.com/nicfi/`) allows non-commercial access to Planet's high-resolution, analysis-ready mosaics of global tropics, aiding efforts to reduce deforestation, combat climate change, and promote sustainable development (Barbaroux, 2016). MAXAR's Open Data Program supports disaster response by providing pre- and post-event satellite imagery (Bennett et al., 2022). African countries increasingly engage in space activities, diversifying the industry. However, reliance on externally designed programs, methods, projects, and funding dependence raises concerns and questions about technological disparities and unequal benefits distribution.

Balancing technological advancements with inclusive development remains challenging in Africa's rapidly growing EO and ag-tech sectors. In this paper, we investigate the landscape of EO technology, focusing on its applications in the agriculture sector in Africa. Specifically, we analyze the representation of African-led organizations in self-identified "leading organizations" and actors across the EO sector to derive insights into leadership, ownership, and data management policies. This research aims to document imbalances and opportunities to strengthen sustainable, ethical EO advancement in the region by mapping key actors and analyzing engagement across the EO pipeline.

2 Background

2.1 Evolution of Global Space and EO Sectors

Historically, space programs were primarily driven by governmental defense and communications needs. However, in the last decade, private companies like SpaceX have transformed the industry by significantly reducing launch costs through innovations like reusable rocket technology (Jones, 2018). Moreover, developing nanosatellites and cube satellites has further reduced barriers to accessing space. These spacecrafts' smaller size and weight have dramatically lowered manufacturing and launch costs. This expanded access to space has allowed more countries, including developing nations in the Global South, to construct capabilities tailored to national needs and priorities (Barbaroux, 2016).

As the commercial space industry has expanded, the costs of accessing EO data have declined with the rise of internet-based and cloud computing platforms (Gorelick et al., 2017; Nakalembe & Kerner, 2023). The ability to download and analyze satellite imagery without expensive physical infrastructure has opened up new opportunities to apply space-based assets and EO data analytics across diverse sectors beyond traditional aerospace (Gorelick et al., 2017). In tandem with the expanding commercial space industry, EO technology has gained momentum for applications like crop monitoring, land use mapping, and food security modeling. Public programs like the USDA Foreign Agricultural Service had long provided crop production forecasts globally. However, large-scale initiatives such as GEOGLAM (Group on Earth Observations Global Agricultural Monitoring Initiative) (`https://earthobservations.org/geoglam.php`), NASA Harvest and Copernicus4GEOGLAM demonstrate EO's additional potential for strengthening real-time agricultural decision-making (Becker-Reshef et al., 2020).

2.2 Growth of African Space Industry and Satellite Programs

Privately owned satellites and platforms funded by African governments provide distinct advantages, including the ability to task satellites for targeted data collection over regions of interest. They also enable timely and responsive EO unhindered by restrictions on data sharing or tasking priorities (Croshier, 2023). These satellites can support wider socioeconomic growth, strengthen national security, improve communication infrastructure, foster human capital development, and promote technology advancements (Croshier, 2023).

They also facilitate international cooperation and build institutional capacity in space technology, thereby helping to stimulate local EO-services sectors and research.

The African space industry is rapidly evolving, with over 50 satellites launched by African countries since 1998 (SPACEHUBS AFRICA, 2023). More countries are establishing national space agencies and strategic programs to develop EO satellites specifically intended to serve needs like agricultural and environmental monitoring (Kenya Space Agency, 2023). A 2016 survey of the African EO industry provides valuable context for understanding the sector's evolution (Woldai, 2020). Their study, which surveyed 78 companies across 21 African countries, revealed a growing private sector with 96% of respondents working directly with EO satellite data or derived products. The majority were small to medium enterprises with revenues of 55.7% (39) less than USD 100,000 in 2015 and only 5.7% (4) with revenue over USD one million. Companies primarily focused on downstream/GIS services (84%), consultancy (75%), and value-adding services using satellite data (64%).

According to (Africanews.space, 2023a), the African space economy is now valued at USD 19.49 Billion, the industry is expected to grow by over 16% by 2026, outpacing Africa's GDP growth rates. Across the continent, the space economy employs some 19,000 people in different sectors, including governments that employ more than 11,000 staff and whose national budgets are growing exponentially (Africanews.space, 2023a). In 2023, the African Union Commission (AUC) launched the collaborative Africa Space Agency following the African Space Strategy of 2015, which envisioned a space program that is user-focused, competitive, efficient, and innovative (Ifejika Speranza et al., 2023; Africanews.space, 2023b).

This evolution highlights the rapid advancement of the African EO sector but also underscores persistent disparities between smaller local firms and larger, often foreign-based, companies.

2.3 Challenges of EO for Africa

EO technologies and satellite-based services offer great potential to help African countries achieve development goals and climate adaptation priorities (Munsami, 2022). However, fully realizing these benefits requires African nations to leverage internal resources and solicit external funding carefully. This external funding carries risks of dependence if not managed strategically with a longer-term view (Group on Earth Observations, 2019).

However, the funding landscape for African EO companies presents significant challenges. (Woldai, 2020) identified key financial barriers to growth for African EO companies. These included customers recognizing benefits but lacking budgets (80% of respondents), lack of development funding (65%), and the high cost of EO data (58%). African countries must have sufficient operational budgets and establish supportive policy frameworks to effectively translate existing personnel expertise into domestic EO programs. These budgets should cover essential needs such as computing infrastructure, office space, internet connectivity, field monitoring costs, and competitive salaries. This funding is also crucial for retaining trained experts in the public sector, preventing the loss of skilled officers to international NGOs and private industry, and building sustainable domestic EO capabilities (Croshier, 2023).

The exponential growth globally in the EO sector driven by advancing technology amplifies concerns for African countries regarding data sovereignty, biased research priorities, equitable access, and ethics (Nakalembe & Kerner, 2023). Truly empowering technology development requires first developing local scientific infrastructure and steering capacity building rather than importing external solutions (Mellor, 1993; Ifejika Speranza et al., 2023). Otherwise, resource-constrained focus regions remain vulnerable to extractive practices and data colonialism that primarily serve external organizations (Lynch et al., 2023).

This context motivates analyzing EO sector participation that provides insight into funding flows to pave pathways for ethical, sustainable advancement that amplifies African countries' priorities. Through a comprehensive review of the EO sector in Africa, this paper highlights the urgency of addressing potential negative consequences stemming from an externally driven EO sector. Perpetual external leadership can cripple local innovation and companies and can lead to the exploitation of vulnerable communities. Farmers may be exposed to unfair insurance practices enabled by EO or inadequate compensation for their data without proper protections. There's a risk that their information could be utilized by government or industry actors for purposes that don't benefit them directly or impede upon their freedom to make their own decisions. The limited space for local initiatives in developing and implementing these systems further exacerbates these concerns (Abate et al., 2023). Recognizing these challenges, it becomes imperative to implement measures for regulating the EO sector, ensuring the protection of local interests, including jobs and safeguards.

Figure 1: Radiant Earth Foundation's Machine Learning for Earth Observation Market Map 2021

3 Materials and Methods

3.1 Data and Sources

A curated list of organizational actors extracted from the Machine Learning for Earth Observation (MLforEO) Market map (Figure 1) developed by Radiant Earth Foundation was utilized to commence the analysis. Radiant Earth Foundation is a non-profit organization that facilitates open sharing of geospatial training data to advance artificial intelligence and machine learning applications for EO. This list was chosen as our initial dataset because no other comprehensive, open-access compilation of actors in this field existed during our research. Furthermore, the organization's active crowdsourcing effort to update the market map promised a broad and up-to-date representation of the sector (Nakanuku-Diggs, 2021).

The initial list comprised of URLs and logos for 290 entities, including government agencies, private sector companies, NGOs, university institutions, and international NGOs engaged in geospatial machine learning analysis and technology services (Nakanuku-Diggs, 2021). This list, accessible at `https://medium.com/radiant-earth-insights/2021-machine-learning-for-earth-observation-market-map-release-339cf87300b2`, generated in 2021, formed the foundation of our database, encompassing entities categorized as Commercial or Non-Commercial and activities spanning data analysis, services, analytics, labeling, competition, and data access and storage platforms.

It is vital to recognize that our reliance on the Radiant Earth MLforEO Market map brings inherent limitations that necessitate consideration when interpreting our findings. One significant limitation pertains to the potential for discrepancies in reporting practices, divergent definitions, and varying levels of awareness regarding sector players. These factors can impact the comprehensiveness of the database, potentially resulting in the under-representation of specific organizations or activities. The variability in reporting standards, distinct interpretations of organizational categories, and differential visibility levels among sector players could introduce bias or data gaps within the dataset.

Furthermore, this dataset is biased towards organizations within Radiant Earth's network at the time of collection. The crowd-sourced nature of the data and the rapidly evolving sector suggest that this database likely contains outdated or incomplete information. New organizations are constantly emerging, and existing ones are pivoting their activities, making maintaining a fully up-to-date database challenging. This bias and incomplete data collection could explain the apparent lack of African organizations. It's worth noting that the "leading organizations" are self-identified, with no evidence to validate these claims. Additionally, a survey of African countries conducted by (Woldai, 2020) on African companies could have provided an interesting dimension to this dataset. Unfortunately, this survey was developed for internal use by the European Commission and is not publicly accessible, further limiting our understanding of the African geospatial sector.

Despite these limitations, the Radiant Earth database is valuable for understanding the EO sector's landscape. It forms the basis for systematically analyzing organizational actors involved in EO applications, addressing a critical gap in academic knowledge. While acknowledging limitations, considering these factors when interpreting results and validating information through cross-referencing can help mitigate potential inaccuracies and biases.

The initial list of 317 EO for ML organization links was refined to 284 by removing duplicates. We then supplemented this with 17 additional qualifying companies from the authors' knowledge, including Digital Earth Africa and Pula, bringing the total to 299 EO companies and government actors. To ensure a more accurate representation of the EO and ML ecosystem, we excluded large International Non-Governmental Organizations (INGOs) and regional hubs due to their complex funding structures. For instance, Vito is funded by the European Space Agency (ESA), while NASA funds the Harvest and SERVIR programs. Similarly, USAID supports RCMRD's SERVIR activities. Including these organizations would have introduced complexities we couldn't disentangle. The lists of organizations can be accessed via `10.5281/zenodo.13145805` (Nakalembe et al., 2024), including the source and any relevant links. This dataset is the foundation for our analysis, enabling us to delve into the intricate relationships within the EO sector and its impact on agriculture and food security applications in Africa.

To analyze global satellite ownership and management, with a focus on African programs, we utilized the Union of Concerned Scientists (UCS) Satellite Database (as of May 2023) (Grimwood et al., 2023). This publicly available, quarterly-updated resource provides information on operational satellites, including country of origin, operator, contractor, purpose, and UN registration status. We used this data to create alluvial diagrams illustrating international relationships in African satellite programs and to compare African satellite operations with global trends. This analysis complemented our examination of the MLforEO Market map, offering insights into Africa's position in the global space sector, the backbone of the EO sector, and its unique priorities. This dataset is accessible here `10.5281/zenodo.13145805`.

3.2 Methods

From the final list of 299 companies, we randomly selected 31 for analysis using a stratified sampling approach. The stratification focused on entities with agriculture and food security applications. We used a random number generator function (RAND()) in Excel, followed by rank ordering of the results. Organizations were selected from this ranking until the sample included 31 organizations (10% of the original database) involved in early warning or food security.

We collected publicly available data from each selected organization's website to ensure a focus on agriculture-related organizations while providing a manageable dataset for in-depth analysis (validated July 2024). This information included basic details (URL, name, headquarters location), involvement in agriculture or food security, African countries with reported projects, organization type, funding structure, research activities, startup status, industry focus, data capabilities (analysis, storage, image labeling), competition platform involvement, and participation in early warning systems.

Descriptive statistics are derived to provide insights into the geographic distribution of headquarters locations, the presence of partners, and reported active project presence across African countries. In addition, the involvement of organizations in different stages of the EO pipeline was summarized, providing a comprehensive view of their contributions. Entity types (Industry, Initiative, Research, Startup) were categorized and presented using descriptive statistics.

Descriptive statistics were utilized to present the number of African countries operating satellites, the distribution of launch locations, and the proportions of various satellite operators (commercial, government, civil, and military). Furthermore, the accessibility and data policies of satellite data were summarized to shed light on the availability and openness of data for research purposes.

4 Results

4.1 EO and ML Actors for Agricultural Monitoring in Africa

Table 1 and Figure 3 provide an overview of the distribution of organizations along the stages of the EO pipeline and their funding sources. Our analysis reveals overlap in organizational activities across the EO pipeline. 90.32% of sampled organizations are involved in data analytics, suggesting potential duplication of efforts, especially given the limited number of data sources and products in the private sector. Early warning systems are predominantly managed by commercially funded organizations 83.3%, with only 16.7% receiving public or government funding. This trend extends across all observed categories, where commercial funding is the dominant source of support.

In Figure 2, we distinguish between established industry players and startups. We define the industry as developed commercial organizations with over 20 employees or those operational for over 10 years. In contrast, startups are newer, small entities unaffiliated with a larger institution or organization. This distinction is crucial as it highlights different funding dynamics, operational focus, and market approaches between these groups.

Figure 4 depicts the geographical relationships between actors, organizational headquarters, and engagement in African countries. Of the 31 organizations in our sample, 22 were actively operating in Africa across 30 countries, constituting roughly two-thirds of the sample. Our sample only included one Africa-based organization, Syecomp, headquartered in Ghana. While Syecomp reports diverse partnerships, we found evidence of funding only through a Mastercard Foundation Fund for Rural Prosperity

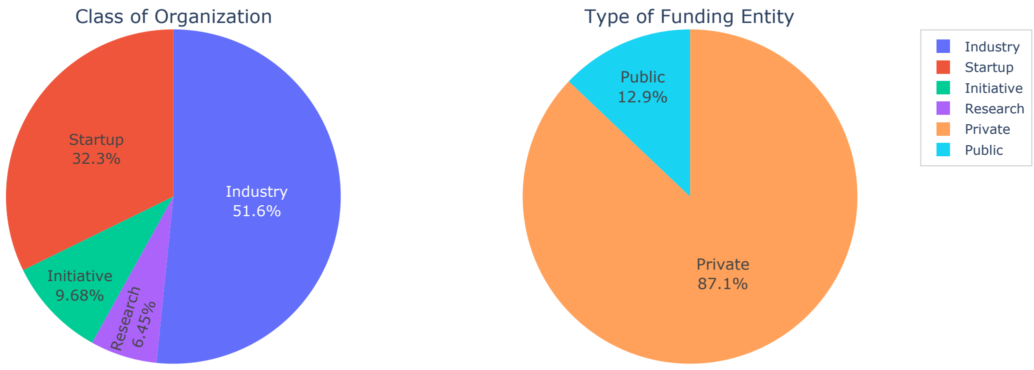

Figure 2: Organizations in study sample by funding type

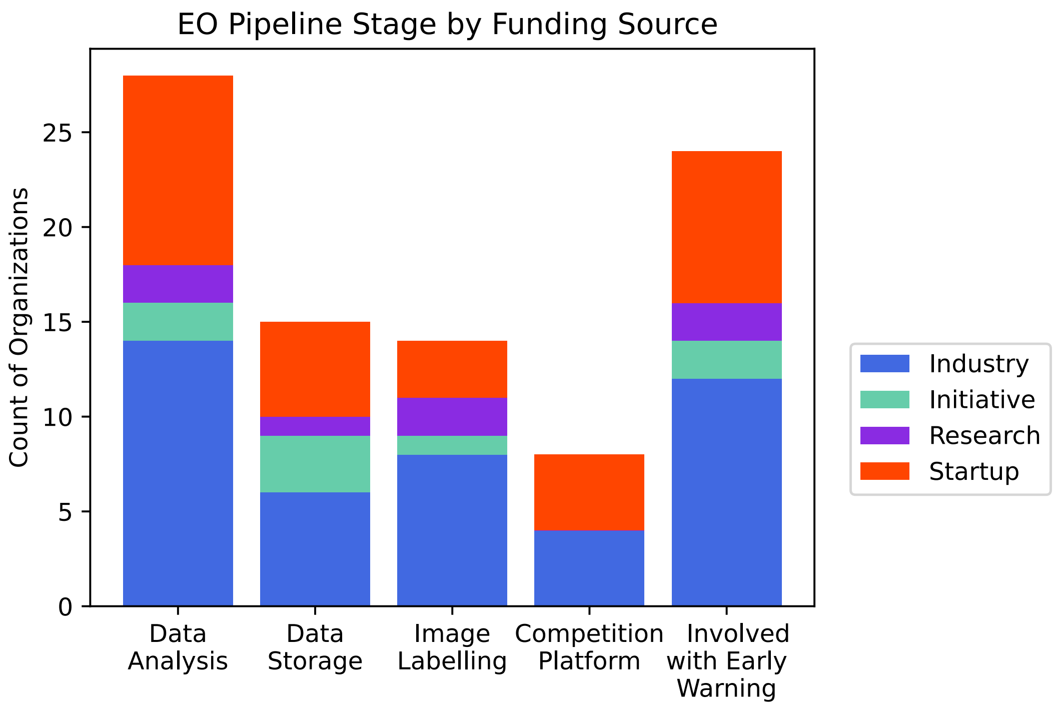

Figure 3: EO Pipeline Stage by Funding Source in study sample

Category	**% of Sample**
Stage of EO Pipeline	
Data Storage	48.38%
Image Labelling	45.16%
Data Analysis	90.32%
Involved with Early Warning	77.41%
Competition Platform	25.81%
Type of Organization	
Research	6.45%
Startup	32.36%
Industry	51.61%
Initiative	9.68%

Table 1: Distribution of organizations across EO pipeline stages and organizational goals in study sample

grant. This observation underscores a broader trend as many services in this sector appear to be grant-funded rather than generating revenue from direct service provision. This funding model raises important questions about these services' long-term sustainability and accessibility to smallholder farmers, who often cannot afford pay-as-you-go services. This highlights the need for further research into sustainable funding models to support the continued development and accessibility of EO and ML technologies in African agriculture and food security.

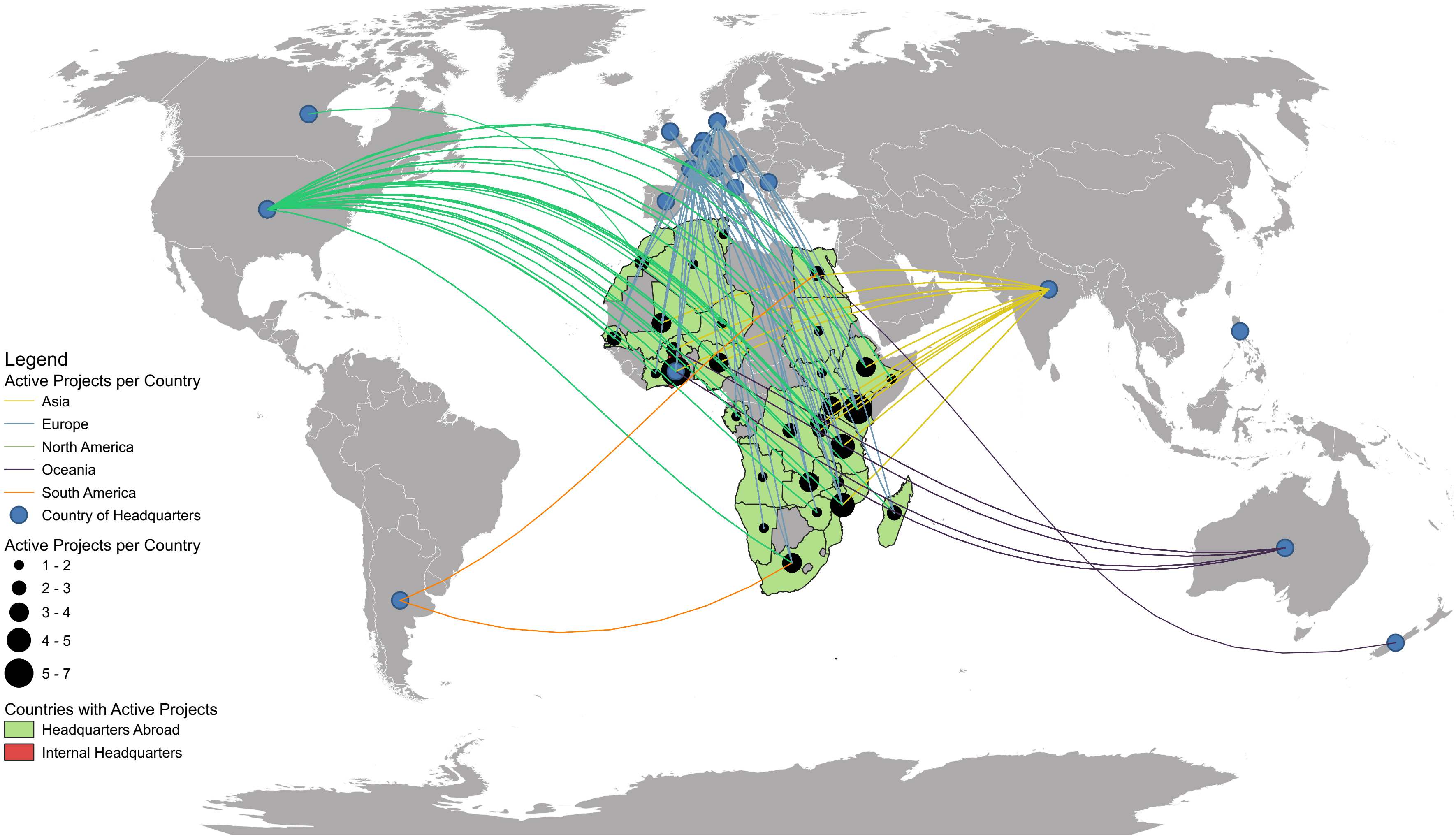

Figure 4: World connection map showing the distribution of countries where headquarters of actors are located and the number of active projects across Africa

Further, defining the nature and status of programming is challenging, as organizations have broad and inconsistent definitions of what constitutes ”active programming” or ”focus countries”. There is little continuity regarding the level of detail most organizations publicly share about their activities, specifically their locations, data ownership policies, and funding streams with local partners. For example, Cropin, an Indian ag-tech company, reports active projects in 11 African countries to help organizations digitize farm data. However, details on the precise nature of these partnerships and activities are limited. Similarly, Impact Observatory and DrivenData have sparse publicly available information about their work in Africa. External project websites provide some insights but still lack specifics on partnerships.

4.2 Tracing Partnerships in African Space Programs

The alluvial diagrams in Figure 5 illustrate the complex international relationships in African satellite programs based on data from the Union of Concerned Scientists Satellite Database (Grimwood et al., 2023). The diagrams show linkages between 29 active satellites, their countries of contractor/developer, owner/operator, and United Nations registry, evidencing complex contractor, owner, and registry relationships for African satellites, with many international linkages between various nations. This highlights the frequent cooperation on satellite development between African countries and non-African partners.

Two versions are shown: North Africa (left) and Sub-Saharan Africa (right). The colored flows connect each satellite’s owner/operator country to its country of contractor and UN registry country. Wider flows indicate a greater number of satellites following that country-to-country pathway.

The diagrams reveal extensive and complex international collaborations underlying many African satellites. For example, the Tunisian satellite ChallengeOne had a Tunisian contractor and owner but was registered under Russia in the UN. The Algerian-owned/operated and registered Alsat-2A and Alsat-2B satellites were contracted to the French/UK company EADS Astrium (later acquired by Airbus).

The diagram highlights the reliance on non-African entities, with only a few satellites fully owned, operated and registered directly by a single African nation. While reflecting growing African space capabilities, the alluvial diagram also reveals external influences and diffusion of control across the satellite value chain and a clear need to stronger partnerships.

These relationships provide insights into data sovereignty issues and dependence on foreign expertise to realize Africa's space ambitions.

Moreover, while many international organizations report engagement in Africa, the publicly available details are often vague or incomplete. More transparency on local partnerships, funding, data policies, and the nature of programming would provide better insights into actual levels of involvement and alignment with African priorities. Enhanced clarity, consistency, and reporting from organizations would strengthen understanding of Africa's space sector and capacity-building landscape.

67% African-operated satellites are registered with the UN, compared to 86% of satellites worldwide. The remaining 14% unregistered satellites globally are primarily from China and the United States. South Africa has the most unregistered satellites at 5, primarily government-used (Table 2).

53% of satellites currently operated by African countries are for EO purposes, compared to only 20% worldwide, highlighting a stronger interest in environmental monitoring across Africa.

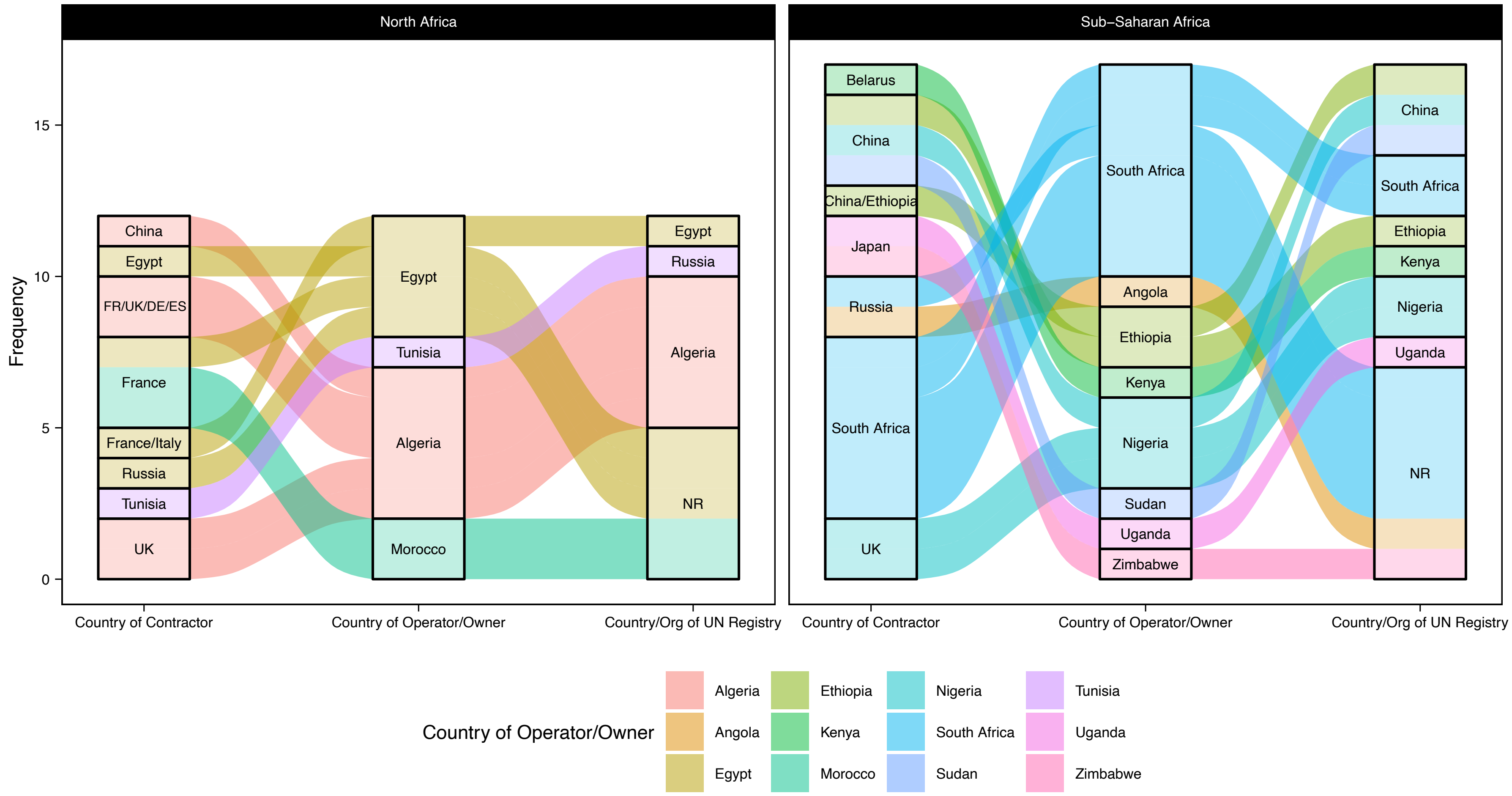

Figure 5: Tracing Partnerships in African Space Programs: An alluvial diagram illustrating the interplay among stakeholders engaged in developing satellites for African countries. NR are satellites not registered with the UN.

Category	**%Global**	**%Africa**
Communications	66%	20%
Technology Development	7.45%	13.33%
Earth Observation	21.15%	66.67%
Navigation/Positioning	2.82%	0%
Surveillance/Unknown	0.33%	0%
Users of EO satellites		
Civil	3.80%	5.00%
Governmental	25.38%	85.00%
Commercial	51.02%	5.00%
Military	19.63%	5.00%

Table 2: Distribution and User Demographics of Global and African Satellites Based on the Union of Concerned Scientists (UCS) Database

Interesting contrasts emerge when comparing countries' engagement across the early and downstream stages of the EO pipeline. Kenya has 8 identified EO projects in our sample, yet only recently launched its first satellite in 2023, relying on various international stakeholders for contracting and operations. In contrast, Tanzania has 8 identified projects but no current national satellite capabilities, though launch plans are underway (Okafor, 2023). This diverges from countries like South Africa and Egypt, with more established space programs spanning the entire EO pipeline.

South Africa stands out for having internally contracted 6 out of 7 active satellites and at least 3 satellite offices affiliated with the 5 identified projects. Egypt also has a proportional presence, with 4 projects and 4 satellites.

Although national satellite programs are expanding, their data is often underutilized in on-the-ground projects, reflecting a disconnect between data sovereignty and reliance on non-African entities. This limits local benefits. Numerous organizations use freely available sources like Landsat and Sentinel rather than data from African satellites due to excessive bureaucratic red tape around external organizations' use of government data (Woldai, 2020). This gap is evident in Ethiopia, where the 5 identified projects in our sample do not appear to leverage data from the country's 3 satellites, operated via China. The 5 EU/US-based project leads may have limited awareness of or access to Ethiopian satellite data.

Furthermore, Ethiopia's lack of operational infrastructure and human capital hinders utilizing its data, even though satellite operation and downstream use are misaligned. Insights cannot be fully leveraged for local needs without adequate ground stations, processing facilities, and skilled personnel to handle national satellite data. Finally, limited public accessibility and unclear mechanisms to request data from Ethiopian satellites prevent project integration. Greater transparency and availability of national data would facilitate its use in research and decision-making.

Overall, the analysis reveals discrepancies between some African countries' satellite ownership and their capacity to fully utilize resulting EO data domestically. Having national satellite programs does not directly translate into actionable, accessible insights that benefit local priorities and policies. Across the EO pipeline, African countries display varying levels of data control, infrastructure, and expertise to extract value from their space-based assets. For example, countries like Ethiopia and Tunisia operate satellites, yet appear to under-leverage the data in downstream projects, with a paucity of demonstrated research on national systems' utility and applications. In contrast, South Africa exerts more end-to-end control over its smaller satellite fleet.

Additionally, most identified projects rely solely on open-access data from NASA and ESA rather than African-owned sources. Bridging the gaps between satellite operation and optimized downstream use will require enhancing data accessibility, developing processing infrastructure, and growing local skills. Targeted capacity building and regional cooperation could help align and strengthen capabilities across the EO value chain. This will empower more African countries to fully harness space-based data to serve national development needs and priorities.

5 Discussion

This analysis reveals that the EO sector in Africa is currently dominated by external, non-African actors across most of the value chain. From satellite contracting to on-the-ground projects, participation of African entities is limited. This imbalance has implications for data sovereignty, capacity building, and aligning EO applications with local needs.

Despite national efforts to launch satellites, most African countries lack end-to-end control over their EO data pipelines. This constrains their ability to leverage insights for national priorities and policies. Enhancing data accessibility, infrastructure, and local skills development could help bridge the divide between satellite operation and utilization.

The prevalence of international partnerships provides opportunities for knowledge transfer if adequately structured. However, short-term funding cycles often emphasize innovation over sustained operations. This risks perpetuating dependence on external support versus building self-reliance. Impactful capacity building requires integrating local institutions as equal partners throughout the EO pipeline.

Furthermore, unclear data policies and access limitations hinder the integration of African satellite data into downstream applications. Greater transparency and availability of national data would facilitate its use in research and decision-making.

Overall, the results spotlight gaps between the stated goals of sustainable capacity building and realities on the ground. Moreover, ethical, equitable EO development in Africa necessitates increased regional leadership, public-sector investment, and participatory priority setting. These technologies can effectively empower rather than extract by giving African voices greater influence throughout the EO lifecycle.

6 Conclusion

As documented, the satellite EO sector is rapidly evolving across Africa. However, most African countries lack complete control over their end-to-end EO data pipelines. This constraint limits their ability to determine how EO data is collected, processed, shared, and used - whether directly or indirectly via international partnerships. Upholding data sovereignty, maintaining quality standards, and ensuring equitable access is thus critical to empowering African countries and companies to derive actionable insights tailored to their unique development contexts. Control over the EO value chain enables leveraging these technologies to inform data-driven policies and priorities aligned with national needs. Continental efforts like the African Union's space program could further invest in developing national capabilities and funding sustainable EO programs. Building comprehensive capacity from satellite tasking to data analysis and application will be vital to maximizing the benefits of space-based platforms and preventing extractive practices.

Resource constraints necessitate systemic, end-to-end thinking to maximize benefits from space programs. Developing supporting infrastructure and ground systems, training talent, and evaluating EO product quality are expensive yet crucial undertakings. This is especially important in agriculture, where data accuracy guides productivity and food security decisions for vulnerable communities. Furthermore, inclusive EO and ag-tech data access aligned with open data-sharing principles can uplift marginalized groups. Making data open stimulates research and innovation from local universities and the private sector and increases the potential for impactful insights available to smallholder farmers. This inevitable can unlock knowledge to improve yields, inform land management, and ultimately empower livelihoods.

However, EO's rapid growth could potentially amplify disparities without thoughtful governance. Without concerted efforts to ensure equitable access and address biases, these technologies risk exacerbating inequalities. To fully realize EO and agricultural technology's positive potential, their evolution in Africa must be accompanied by measures promoting inclusivity, bridging digital divides, and engaging vulnerable groups. With responsible and ethical data-driven innovation, EO can be harnessed responsibly to contribute to development agendas across Africa.

7 Limitations of this Study

This study has certain limitations that should be acknowledged. First, business sector analysis is more common in finance than academia. As a result, limited peer-reviewed methodologies exist for databases like Radiant Earth's organizational categorizations. Due to the lack of alternative data sources, we relied heavily on this data despite inconsistencies in reporting, definitions, awareness of sector players, or inherent regional biases. This potentially hinders fully capturing global organizational involvement.

Second, while we initially intended to incorporate budgetary information, these data are often not publicly accessible and have issues with double counting. The available budget information for our sample was, therefore, insufficient for comprehensive analysis.

Additionally, this study primarily focused on publicly available information regarding EO missions and capacity building without extensively exploring other aspects of African space economies. Future research could investigate trends in investment, economic impacts, and market dynamics to provide richer insights.

Furthermore, comparing this data to information on development and investment in regional educational institutions could reveal valuable relationships between education, research, capacity building, and advancement of the African space sector.

8 Open Research

The database of organizational actors, "Actors and Satellites in the African Earth Observations Sector: Insights from the 2021 Radiant Earth ML for EO Market Map and the Union of Concerned Scientists Database" analyzed in this study, is available on Zenodo, an open-access repository developed under the European OpenAIRE program (10.5281/zenodo.13145805) accessible here: https://zenodo.org/uploads/13145805 (Nakalembe et al., 2024). The dataset comprises information on 310 space-centric earth observation organizations, including headquarters locations,

For the 31 organizations in our sample, we provide additional details, including the African countries where their projects are active, the type of initiative or program, other focus areas, organizational classification (commercial, government, or nongovernmental), funding source (public or private), organizational type (research, startup, or established industry), capabilities (data analysis, data storage, image labeling, competition platforms), involvement in early warning systems, data accessibility, availability of global products, and whether they build commercial satellites.

Openly sharing the compiled organizational data aims to promote transparency, reproducibility, and additional investigations into the evolving landscape of earth observation activities globally and across Africa. Analyses of this dataset's relationships, funding flows, and priorities can provide further insights to guide equitable advancement of earth observation capabilities.

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