GSC Advanced Research and Reviews

eISSN: 2582-4597 CODEN (USA): GARRC2

Cross Ref DOI: 10.30574/gscarr

Journal homepage: https://gsconlinepress.com/journals/gscarr/

(REVIEW ARTICLE)

Check for updates

Utilizing satellite imagery for economic development in Africa: Advances, challenges and future directions

Oluwaseyi Adelusi [1, 2, *], Oluwole Olakunle Ajayi [3], Michael Adelusi [4], Oluwatosin Mudele [5], Busayo Wright-Ajayi [6], Ajani Olawale [7], Victor Akangbe [8], Oluwatosin Adelusi [9] and Abiodun Mudele [10]

[1] *Dell Technologies, Round Rock, Texas, USA.*
[2] *Inspire Girls in Technology Foundation, Nigeria.*
[3] *Department of Sustainability and Social Justice, Clark University, Worcester, Massachusetts, USA.*
[4] *Department of Computer Science, University of Lincoln, United Kingdom.*
[5] *School of Computing, Engineering and Built Environment, Glasgow Caledonian University, Glasgow, United Kingdom.*
[6] *Department of Urban Studies, Worcester State University, Worcester, Massachusetts, USA.*
[7] *Numa Italia S.R.L, Milan, Italy.*
[8] *O'Neill School of Public and Environmental Affairs, Indiana University, Bloomington, USA*
[9] *College of Business and Technology at Western Illinois University, USA*
[10] *Dochase Adx, Lagos, Nigeria.*

GSC Advanced Research and Reviews, 2025, 22(02), 088-093

Publication history: Received on 17 December 2024; revised on 04 February 2025; accepted on 07 February 2025

Article DOI: https://doi.org/10.30574/gscarr.2025.22.2.0032

Abstract

Satellite imagery provides unmatched insights into numerous areas important to Africa's economic development. In this paper, we address recent advancements, ongoing issues, and possibilities for the application of satellite imagery for economic development in Africa. The first section covers satellite technology developments such as high-resolution imaging, multi-spectral and hyperspectral capabilities, synthetic aperture radar (SAR), and fusion with AI. Next, we present data accessibility, technical expertise, integration with local knowledge, and policy frameworks as satellite imaging adoption hurdles. Finally, we recommend integrating new technologies, boosting spatial and temporal resolutions, collaboration, capacity-building, and policy frameworks. By overcoming these obstacles and preparing ahead, African states can use satellite pictures to boost economic growth.

Keywords: Satellite Imagery; Economic Development; Technology; Africa

1. Introduction

Satellite photos of Earth at night have been used by scientists to investigate human and environmental occurrences for many years (Levin *et al*., 2020,). Economic analysts and researchers have realized in the past decade that satellite-derived variables (e.g. Nighttime light, urban extent and structures, etc) can measure economic growth, map poverty, analyze inequality, and answer many questions that were otherwise difficult to research, especially in data-poor areas. Interestingly, previous studies showed that the study of the Earth from its dark side would reveal the world economy before reaching our atmosphere (Mveyange, 2015). For example, in the case of night-time light, satellite image pixels represent a portion of the Earth. Each pixel has a nighttime brightness digital number linked with it. Pixel numbers increase with brightness. When averaged over all pixels in a country, these figures describe its nighttime activities. Comparing such an indicator across countries and time becomes a barometer of economic development and variations (Cauwels *et al*., 2014).

* Corresponding author: Oluwaseyi Adelusi

Even though most economic activity happens during the day, night lights are relevant to economics because of their high association (Gibson *et al*., 2021). Nightlights show how an economy expands or contracts over space. As economies grow, more areas are lighted, and more pixels record light. In crisis zones, more land turns black, and more pixels lose light (Levin *et al*., 2020). While rural regions urbanize, cities agglomerate, infrastructure modernizes, and satellite sensors detect more light in the night sky. However, night lighting and economic progress are not necessarily linked. Previous research found that wealthier countries are brighter than developing ones, but there are exceptions. Nordic countries have consistently been the brightest per capita (Bhandari and Roychowdhury, 2011; McArthur and Sachs, 2001).

In accounting for country-specific night light features, an interesting link emerges that shows the astonishing switch from constructing physical capital to cultivating human capital as a country grows (Pierskalla *et al*., 2017). Countries in early development build roads, bridges, railroad stations, airports, power systems, and telecommunications, which radiate light at night. Satellite photographs show a brighter night sky as the economy grows (Nye, 2010). Big data unlocks innovative methods for extracting information and comprehending global dynamics. The advancements in data science, particularly through machine learning, facilitate the analysis of trends and enhance decision-making processes (Provost and Fawcett, 2013). As data science advances, this type of data can be used to analyse local effects, geographical spillovers, and economic activities in remote Earth regions where the only trustworthy information comes from hundreds of miles above (Donaldson and Storeygard, 2016).

The rich and diversified ecology of Africa presents several issues, including water access, increasing urban expansion, active deforestation, and food shortages. In a time when these difficulties are affecting communities, new global crises endanger the African economy and impair global progress (Omisore, 2018). From 3.2% to 1.8%, economic growth would stall, plunging 27 million people into extreme poverty, according to the United Nations Economic Commission for Africa, Earth Observation (EO) data from satellite photography is the foundation of huge data and a key shift in data availability and use to assist in responding to these essential concerns (Sudmanns *et al*., 2019). Technology is creating new data analytics and visualization possibilities. Africa's EO data availability, access, quality, and usefulness remain to limit its potential (Kganyago and Mhangara, 2019). This paper thereby aims to review the utilization of satellite imagery for African economic growth.

2. Challenges of utilizing satellite imagery for economic development in Africa

Satellite imaging provides unparalleled insights into agriculture, forestry, urban planning, and natural resource management in developing and underdeveloped countries, notably in Africa. However, using satellite data effectively is difficult (Kganyago and Mhangara, 2019). This review discusses the challenges of using satellite imagery for African economic development as listed below.

2.1. Data Accessibility and Affordability

In Africa, data accessibility and pricing are major barriers to satellite imaging use. High-resolution satellite imagery (e.g. Planet images) can be expensive for many African organizations (Burke *et al*., 2021). Access to free satellite data is typically constrained by proprietary interests and license agreements leading to compounded access issues. Unaffordable satellite data, non-promotion of data sharing, and stakeholder non-collaboration reduce dataset consumption (Turner *et al*., 2015).

2.2. Technical Expertise and Capacity Building:

Another issue is the remote sensing and geospatial analytic skills gap. In many African countries, satellite imaging experts are few. Many ambitious professionals are unprepared to use satellite data due to poor training and educational resources. These issues arise because capacity-building activities are not funded (Agbaje *et al*., 2019). Additionally, professionals in Africa and beyond rarely share and collaborate to acquire skills and information.

2.3. Integration with Ground-based Data and Local Knowledge

Integrating satellite data with ground-based and local knowledge improves analysis accuracy and relevance. Data integration, validation, and context-specific analytical models, especially in Africa, are obstacles. Weak multidisciplinary techniques that mix satellite imaging with ground-truthing exacerbate these issues (Castro, 2020). Lack of strong collaboration between satellite imagery professionals, field researchers, and local communities to ensure data accuracy (Dickinson *et al*., 2012). Indeed, most African nations lack comprehensive validation methods and analytical models that can accommodate diverse geographical and socio-economic circumstances.

2.4. Policy and Regulatory Frameworks

The lack of defined satellite data policies and restrictions hinders its use, especially in Africa. This is compounded by data ownership, intellectual property rights, and privacy issues, which make potential users uncertain and hesitant across the continent (Chingozha, 2020). Government and regulatory authorities' lack of collaboration makes satellite data collection, use, and distribution standards ambiguous and untransparent. Most African countries lack space for data sharing, standard data formats, and legal and ethical data ownership and privacy issues (Hlomani and Ncube, 2023).

3. Advances in utilizing satellite imagery for economic development in Africa

Recent advances in satellite photography offer new prospects for African economic development. Satellite data is essential for tackling socio-economic issues across the continent, from improving agricultural output to infrastructure development and environmental control (Andries *et al*., 2022). The following paragraphs discuss current achievements in using satellite imagery for African economic development and provide pointers to how African governments and development players should begin to think about applying these data.

3.1. High-Resolution Imaging

Satellite imagery technology has advanced significantly with high-resolution imaging systems. These devices can clearly and precisely photograph the Earth's surface, enabling more accurate and detailed assessments (Tatem *et al*., 2008). High-resolution satellite photography aids land use planning, natural resource management, and urban development in Africa. High-resolution imaging technologies help policymakers and planners make informed decisions that boost economic growth by giving current land cover, infrastructure, and environmental data (Prakash *et al*., 2020).

3.2. Synthetic Aperture Radar (SAR) Technology

In areas with persistent cloud cover or low visibility, e.g. central Madagascar in Africa, Synthetic Aperture Radar (SAR) technology can overcome the limitations of optical satellite images. SAR sensors can penetrate clouds and vegetation, providing year-round land surface monitoring (De Beyer, 2015). SAR is utilized for flood mapping, land subsidence monitoring, and disaster response in Africa. SAR helps governments and humanitarian groups prepare for and respond to natural catastrophes by providing fast and accurate environmental hazards and risks information, reducing their socio-economic impact on populations (Adjei-Darko, 2017).

3.3. Integration with Geographic Information Systems (GIS) and Remote Sensing Platforms

Satellite imagery may now be integrated and analysed with demographic, socio-economic, and infrastructural statistics thanks to GIS and remote sensing platforms. This integration helps academics and policymakers understand complicated human-environmental interactions, detect regional patterns and trends, and devise targeted socio-economic solutions (Codjoe, 2007). GIS and remote sensing technologies can help African nations maximize resource allocation, infrastructure planning, and inclusive economic growth (Ayanlade *et al*., 2008).

4. Future directions in utilizing satellite imagery for economic development in Africa

As satellite imagery technology advances, Africa's economic development can benefit greatly. Future directions and initiatives can improve satellite image adoption to address socio-economic issues and promote sustainable growth across the continent. Future directions in utilizing satellite imagery in Africa are presented in this section

4.1. Integration of Emerging Technologies

Satellite imaging analysis using artificial intelligence and machine learning can transform satellite data analysis. Large datasets may be analysed faster and more accurately using advanced algorithms to identify essential features and patterns (Sisodiya *et al*., 2020). Africa may leverage AI-powered satellite imagery analysis for land use classification, agricultural monitoring, infrastructure planning, and disaster response. On top of satellite imaging, Internet of Things (IoT) devices and sensor networks can provide real-time, ground-level data on environmental conditions, infrastructure performance, and socioeconomic indices (Salcedo-Sanz *et al*., 2020). IoT data streams and satellite imagery help policymakers and planners understand complex systems and dynamics, improving decision-making and resource allocation. In addition, technologies that are being developed to tackle other adjacent but economically relevant variables like disease spread can ingest information from satellite imagery to provide better precision (Mudele *et al*., 2020; Mudele *et al*., 2021a; Mudele *et al*., 2021b; Mudele *et al*., 2021c; Ajayi *et al*., 2024)

4.2. Enhanced Spatial and Temporal Resolution

Upcoming satellite networks like SpaceX's Starlink and Amazon's Project Kuiper will improve satellite photography data's spatial and temporal resolution (Garrity and Husar, 2021). Thousand-of-small satellite constellations orbiting the Earth at low altitudes enable more frequent and comprehensive surface studies. This greater spatial and temporal resolution can aid precision agriculture, urban planning, environmental monitoring, and disaster management in Africa (Rashed and Bang, 2022).

4.3. Data Fusion and Integration

Combining satellite imagery with ground-based sensors, aerial surveys, and social media feeds can improve satellite data processing (Burke *et al*., 2021). Fusing diverse data sources helps researchers and planners comprehend complex socio-economic and environmental systems and make data-driven decisions. To store, process, and analyse huge amounts of satellite imagery data, cloud-based data platforms and analytics tools are scalable and cost-effective. African nations can simplify satellite imagery access and adoption by using cloud computing infrastructure to solve data storage, processing power, and technical skill issues (Froehlich *et al*., 2022).

4.4. Capacity Building and Knowledge Sharing

For technical capability and knowledge in satellite data use, remote sensing, GIS, and satellite imagery analysis training and education programs are important. Governments, universities, and international organizations can work together to create and implement African-specific capacity-building programs (Agbaje *et al*., 2019). To maximise the economic development benefits of satellite imagery in Africa, stakeholders like governments, academics, industry, and civil society organisations must share and collaborate knowledge (Mansell and Tremblay, 2013). Sharing best practices, lessons learned, and success stories can encourage innovation and collaboration in African countries, allowing them to exchange knowledge and resources.

5. Conclusion

Finally, satellite imaging offers tremendous prospects and problems for African economic development. Despite satellite technology advances and high-quality imagery, data accessibility, technical skills, and policy frameworks limit its potential. Despite these limitations, African countries can use satellite imagery to promote sustainable and inclusive economic growth by embracing this discussion's future directions. With strategic investments in technology, capacity building, and collaboration and supportive policy and institutional frameworks, Africa can use satellite imagery to solve development problems, improve livelihoods, and build a better future. Satellite imaging can drive economic development in Africa for generations with concentrated efforts and innovation

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed

References

[1] Adjei-Darko, P. (2017). Remote sensing and geographic information systems for flood risk mapping and near real-time flooding extent assessment in the greater Accra metropolitan area.

[2] Agbaje, G., Alabi, O., & Offiong, E. (2019). Education and Training in Applied Remote Sensing in Africa: The ARCSSTE-E Experience. ISPRS international journal of geo-information, 8(8), 350.

[3] Agbaje, G., Alabi, O., & Offiong, E. (2019). Education and Training in Applied Remote Sensing in Africa: The ARCSSTE-E Experience. ISPRS international journal of geo-information, 8(8), 350.

[4] Ajayi, O. O., Wright-Ajayi, B., Mosaku, L. A., Davies, G. K., Moneke, K. C., Adeleke, O. R., Shaba, D. S., & Mudele, O. (2024). Application of satellite imagery for vector-borne disease monitoring in sub-Saharan Africa: An overview. GSC Advanced Research and Reviews, 18(3), 400–411

[5] Andries, A., Morse, S., Murphy, R. J., Lynch, J., & Woolliams, E. R. (2022). Using data from earth observation to support sustainable development indicators: An analysis of the literature and challenges for the future. Sustainability, 14(3), 1191.

[6] Ayanlade, A., Orimoogunje, I. O. O., & Borisade, P. B. (2008). Geospatial data infrastructure for sustainable development in sub-Saharan countries. International Journal of Digital Earth, 1(3), 247-258.

[7] Bhandari, L., & Roychowdhury, K. (2011). Night lights and economic activity in India: A study using DMSP-OLS night-time images. Proceedings of the Asia-Pacific advanced network, 32(0), 218.

[8] Burke, M., Driscoll, A., Lobell, D. B., & Ermon, S. (2021). Using satellite imagery to understand and promote sustainable development. Science, 371(6535), eabe8628.

[9] Burke, M., Driscoll, A., Lobell, D. B., & Ermon, S. (2021). Using satellite imagery to understand and promote sustainable development. Science, 371(6535), eabe8628.

[10] Castro, A. C. (2020). Pan-tropical modelling of land cover and land-use change trajectories for newly deforested areas (Doctoral dissertation, King's College London).

[11] Cauwels, P., Pestalozzi, N., & Sornette, D. (2014). Dynamics and spatial distribution of global nighttime lights. EPJ Data Science, 3, 1-26.

[12] Chingozha, T. (2020). Land rights in sub-Saharan Africa: measuring impact with satellite images, machine learning and citizen science (Doctoral dissertation, Stellenbosch: Stellenbosch University).

[13] Codjoe, S. N. A. (2007). Integrating remote sensing, GIS, census, and socioeconomic data in studying the population–land use/cover nexus in Ghana: A literature update. Africa Development, 32(2).

[14] De Beyer, L. H. (2015). Integrated use of polarimetric Synthetic Aperture Radar (SAR) and optical image data for land cover mapping using an object-based approach (Doctoral dissertation, Stellenbosch: Stellenbosch University).

[15] Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., ... & Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. Frontiers in Ecology and the Environment, 10(6), 291-297.

[16] Donaldson, D., & Storeygard, A. (2016). The view from above: Applications of satellite data in economics. Journal of Economic Perspectives, 30(4), 171-198.

[17] Froehlich, A., Ringas, N., & Wilson, J. (2022). How space can support African civil societies: Security, peace, and development through Efficient Governance Supported by space applications. Acta Astronautica, 195, 532-539.

[18] Garrity, J., & Husar, A. (2021). Digital connectivity and low earth orbit satellite constellations: Opportunities for Asia and the Pacific.

[19] Gibson, J., Olivia, S., Boe-Gibson, G., & Li, C. (2021). Which night lights data should we use in economics, and where?. Journal of Development Economics, 149, 102602.

[20] Hlomani, H., & Ncube, C. B. (2023). Data Regulation in Africa: Free Flow of Data, Open Data Regimes and Cybersecurity. In Data Governance and Policy in Africa (pp. 97-130). Cham: Springer International Publishing.

[21] Kganyago, M., & Mhangara, P. (2019). The role of African emerging space agencies in earth observation capacity building for facilitating the implementation and monitoring of the African development agenda: The case of African earth observation program. ISPRS International Journal of Geo-Information, 8(7), 292.

[22] Levin, N., Kyba, C. C., Zhang, Q., de Miguel, A. S., Román, M. O., Li, X., ... & Elvidge, C. D. (2020). Remote sensing of night lights: A review and an outlook for the future. Remote Sensing of Environment, 237, 111443.

[23] Mansell, R., & Tremblay, G. (2013). Renewing the knowledge societies vision for peace and sustainable development. Unesco.

[24] McArthur, J. W., & Sachs, J. D. (2001). The growth competitiveness index: measuring technological advancement and the stages of development. The global competitiveness report, 2002, 28-51.

[25] Mudele, O., Bayer, F.M., Zanandrez, L.F., Eiras, A.E., & Gamba, P. (2020). Modeling the Temporal Population Distribution of Ae. aegypti Mosquito Using Big Earth Observation Data. IEEE Access, 8, 14182-14194.

[26] Mudele, O., Frery, A.C., Zanandrez, L.F., Eiras, A.E., & Gamba, P. (2021a). Dengue vector population forecasting using multisource earth observation products and recurrent neural networks. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 14, 4390-4404.

[27] Mudele, O., Frery, A. C., Zanandrez, L. F. R., Eiras, A. E., & Gamba, P. (2021b). Modeling dengue vector population with earth observation data and a generalized linear model. Acta Tropica, 215, 105809.

[28] Mudele, O., Andreo, V., Porcasi, X., Scavuzzo, C. M., Lopez, L., & Gamba, P. (2021c). Predicting Aedes aegypti eggs count using remote sensing data and a generalized linear model. In 2021 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) (pp. 84–87).

[29] Mveyange, A. (2015). Night lights and regional income inequality in Africa (No. 2015/085). WIDER Working Paper.

[30] Nye, D. E. (2010). When the lights went out: A history of blackouts in America. Mit Press.

[31] Omisore, A. G. (2018). Attaining Sustainable Development Goals in sub-Saharan Africa; The need to address environmental challenges. Environmental development, 25, 138-145.

[32] Pierskalla, J., Schultz, A., & Wibbels, E. (2017). Order, distance, and local development over the long run. Quarterly Journal of Political Science, 12(4), 375-404.

[33] Prakash, M., Ramage, S., Kavvada, A., & Goodman, S. (2020). Open Earth observations for sustainable urban development. Remote sensing, 12(10), 1646.

[34] Provost, F., & Fawcett, T. (2013). Data science and its relationship to big data and data-driven decision making. Big data, 1(1), 51-59.

[35] Rashed, M. I., & Bang, H. (2022). A study of autonomous small satellite constellations for disaster management and deep space strategy. Remote Sensing, 14(23), 6148.

[36] Salcedo-Sanz, S., Ghamisi, P., Piles, M., Werner, M., Cuadra, L., Moreno-Martínez, A., ... & Camps-Valls, G. (2020). Machine learning information fusion in Earth observation: A comprehensive review of methods, applications and data sources. Information Fusion, 63, 256-272.

[37] Sisodiya, N., Dube, N., & Thakkar, P. (2020). Next-generation artificial intelligence techniques for satellite data processing. Artificial Intelligence Techniques for Satellite Image Analysis, 235-254.

[38] Sudmanns, M., Tiede, D., Lang, S., Bergstedt, H., Trost, G., Augustin, H., ... & Blaschke, T. (2019). Big Earth data: disruptive changes in Earth observation data management and analysis? International Journal of Digital Earth.

[39] Tatem, A. J., Goetz, S. J., & Hay, S. I. (2008). Fifty years of earth observation satellites: Views from above have lead to countless advances on the ground in both scientific knowledge and daily life. American scientist, 96(5), 390.

[40] Turner, W., Rondinini, C., Pettorelli, N., Mora, B., Leidner, A. K., Szantoi, Z., ... & Woodcock, C. (2015). Free and open-access satellite data are key to biodiversity conservation. Biological Conservation, 182, 173-176.

[41] Zhao, Y., Liu, Z., & Wu, J. (2020). Grassland ecosystem services: a systematic review of research advances and future directions. Landscape Ecology, 35, 793-814.