An Insight into Satellite Remote Sensing Applications for Sustainable Development Goals (SDGs) in Africa

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Abstract
Satellite remote sensing has the potential to significantly contribute to the advancement of the SDGs in Africa by offering valuable information that supports evidence-based decision-making, facilitates progress monitoring, and fosters sustainable development across multiple sectors. It emerges as a potent instrument for tackling critical challenges and unlocking opportunities, thus promoting inclusive and sustainable development throughout the region. The role of satellite Earth Observation in ensuring the sustainability of environmental, social, and economic systems has become increasingly urgent. The rapid population growth, particularly in Africa is placing immense pressure on the environment thereby depleting its natural regulatory capacities. The escalating consumption rates in Africa countries contribute significantly to greenhouse gas emissions, which are the primary drivers of climate change. Moreover, water pollution and excessive consumption further expose human development to heightened vulnerability, as the availability of usable water approaches critical levels. Increased hunger and poverty rate in rural areas and in some cities in the African continent have prompted insecurity to the human population. The expanding industrialization in both developed and developing nations has led to increased energy needs. Additionally, the demand for energy reflects global inequality, as developing countries strive to catch up with the advancements of the Western world.

Keywords: Energy, Electromagnetic wave, Satellite Remote Sensing.

Resumen
La teledetección satelital tiene el potencial de contribuir significativamente al avance de los ODS en África al ofrecer información valiosa que respalda la toma de decisiones basada en evidencia, facilita el seguimiento del progreso y fomenta el desarrollo sostenible en múltiples sectores. Surge como un instrumento potente para abordar desafíos críticos y desbloquear oportunidades, promoviendo así el desarrollo inclusivo y sostenible en toda la región. El papel de la observación de la Tierra por satélite para garantizar la sostenibilidad de los sistemas ambientales, sociales y económicos se ha vuelto cada vez más urgente. El rápido crecimiento demográfico, particularmente en África, está ejerciendo una inmensa presión sobre el medio ambiente, agotando así sus capacidades reguladoras naturales. Las crecientes tasas de consumo en los países africanos contribuyen significativamente a las emisiones de gases de efecto invernadero, que son los principales impulsores del cambio climático. Además, la contaminación del agua y el consumo excesivo exponen aún más el desarrollo humano a una mayor vulnerabilidad, a medida que la disponibilidad de agua utilizable se acerca a niveles críticos. El aumento del hambre y la pobreza en las zonas rurales y en algunas ciudades del continente africano han provocado inseguridad en la población humana. La creciente industrialización tanto en los países desarrollados como en los países en desarrollo ha llevado a un aumento de las necesidades energéticas. Además, la demanda de energía refleja la desigualdad global, a medida que los países en desarrollo se esfuerzan por ponerse al día con los avances del mundo occidental.

Palabras clave: Energía, Onda electromagnética, Teledetección por satélite.

I. INTRODUCTION TO SATELLITE REMOTE SENSING AND SDGs

Satellite remote sensing refers to the use of satellites or spacecraft to collect information about the Earth's surface and atmosphere from a distance. It involves the acquisition of data and images using sensors onboard satellites, which are then transmitted back to Earth for analysis and interpretation. Satellite remote sensing provides a valuable means of monitoring and studying various aspects of the Earth, including land, oceans, atmosphere, and their interactions [1, 2].

Satellites used for remote sensing are equipped with specialized sensors that detect and measure electromagnetic radiation reflected or emitted by the Earth's surface. These sensors can operate in different regions of the electromagnetic spectrum, including visible, near-infrared, thermal infrared, and microwave wavelengths. Each region provides unique information about the Earth's features and processes. When satellite sensors capture data, they record the intensity of electromagnetic radiation reflected or emitted by different objects and surfaces on the Earth's surface. This data is then processed and analyzed to generate images, maps, and quantitative/qualitative measurements. Satellite remote sensing enables scientists, researchers, and decision-makers to study various phenomena and parameters, such as land cover and land use, vegetation health, ocean temperature, atmospheric composition, climate patterns, etc., [3, 4].

Satellite remote sensing offers several advantages over traditional ground-based measurements. It provides a synoptic and repetitive view of large areas, allowing for the monitoring of changes over time [5]. It also enables observations in remote or inaccessible regions, making it particularly useful for studying vast and diverse environments. Furthermore, satellite data can be integrated with other geospatial information, such as geographic information systems (GIS), to gain a comprehensive understanding of Earth's processes and support various applications in fields like agriculture, environmental monitoring, disaster management, and urban planning [4, 6, 7]. Overall, satellite remote sensing plays a crucial role in sustainable development goals (SDGs) by gathering critical information about the Earth's surface and atmosphere, contributing to scientific research, resource management, and decision-making processes [3, 8].

Sustainable Development Goals (SDGs) are a set of 17 global goals established by the United Nations (UN) in 2015 as part of the 2030 agenda for Sustainable Development [2, 9]. The SDGs are a call to action for all countries and stakeholders to work together to achieve a more sustainable and equitable world by addressing pressing socio-economic and environmental challenges. The goals cover a wide range of interconnected issues which have been grouped under the 5Ps (People, Planet, Partnership, Peace and Prosperity). These include poverty eradication, climate action, education, gender equality, sustainable cities and responsible consumption (see Figure 1).

FIGURE 1. The 5Ps under the SDGs.

Satellite/microwave remote sensing play a crucial role in supporting SDGs across all the continents including Africa [9, 10, 11]. However, the African region remains a focal point, as most parts in the American, Asian/Australian and European sectors have made substantial progress in addressing major socio-economic and environmental challenges some years ago. The SDGs provide valuable information for monitoring and managing various aspects of the environment, agriculture, water resources, climate change, and urban development, among others. Some key applications of satellite/microwave remote sensing for SDGs in Africa are listed as follows:

- Agriculture and Food Security which includes: Crop monitoring and yield prediction using satellite data (e.g., NDVI, vegetation indices), drought and flood monitoring for early warning systems and Land cover mapping and land use planning.
- Water Resources Management encompassing monitoring water availability and quality in lakes, rivers, and reservoirs, estimation of evapotranspiration and water use efficiency, wetland mapping and monitoring.
- Climate Change which includes: Monitoring deforestation and forest degradation, assessment of carbon stocks and greenhouse gas emissions, monitoring changes in glaciers and polar ice caps.
- Urban Development and Infrastructure Planning which encompasses urban growth monitoring and land use change analysis, assessment of informal settlements and slums, infrastructure planning and monitoring (e.g., transportation, energy).
- Disaster Risk Management: Mapping and monitoring of natural hazards (e.g., earthquakes, volcanic eruptions), flood mapping and damage assessment, post-disaster recovery and resilience planning.

However, assessing the progress of the SDGs in Africa requires a comprehensive analysis of various indicators and targets. Progress can vary across different goals and regions within the African continent. While this literature can provide some general information, it's important to note that specific data and reports are regularly published by organizations such as the United Nations (UN) and African Union (AU) to track progress on the SDGs in Africa.

II. THE AFRICAN PERSPECTIVE OF REMOTE SENSING AND SDGs

In Africa, the Regional Centre for Mapping of Resources for Development (RCMRD), one of the oldest inter-governmental organizations for remote sensing and mapping resources recently turned 44 years. Remote sensing encompasses both the challenges and opportunities specific to the continent. Remote sensing has gained increasing importance in Africa due to its potential to address various environmental, social, and economic challenges [1, 11, 12]. The following points present some key aspects of the African perspective on the use of satellite remote sensing applications in addressing the SDGs:

- Natural Resource Management: Africa is home to diverse and unique ecosystems, making remote sensing crucial for monitoring and managing natural resources. It aids in assessing vegetation health, monitoring forest cover, identifying water resources, and managing biodiversity. Remote sensing provides valuable data for sustainable land and resource management, which is essential for African countries to achieve their development goals.

- Agriculture and Food Security: Agriculture is a major sector in Africa, and remote sensing plays a significant role in enhancing agricultural practices. It helps monitor crop conditions, assess soil moisture, identify pest outbreaks, and predict yields. These information enables informed decision-making, resource optimization, and early warning systems for food security, supporting sustainable agricultural development in the region.
- Climate Change and Environmental Monitoring: Africa is particularly vulnerable to the impacts of climate change, including droughts, desertification, and land degradation. Remote sensing enables the monitoring of climate patterns, land cover changes, and the impacts of natural disasters. These information aids in assessing climate change impacts, developing adaptation strategies, and supporting disaster management efforts.
- Infrastructure Development: Africa's rapid urbanization and infrastructure development require effective planning and management. Remote sensing provides essential data for mapping urban areas, monitoring infrastructure growth, and addressing issues such as informal settlements and urban sprawl. It supports sustainable urban planning, transportation management, and infrastructure resilience.
- Data Accessibility and Capacity Building: Access to quality and up-to-date satellite data remains a challenge in Africa. However, efforts are being made to enhance data accessibility, capacity building, and technology transfer. Partnerships between African institutions, international organizations, and space agencies aim to build local expertise, develop data sharing platforms, and promote collaboration in remote sensing research and applications.
- Bridging the Digital Divide: Remote sensing can help bridge the digital divide in Africa by providing access to critical information for remote and marginalized areas. It allows for monitoring and management of resources in regions with limited ground-based infrastructure. By leveraging satellite-based data, remote sensing offers an opportunity to overcome spatial and technological barriers in data collection and analysis.

Furthermore, the African perspective of remote sensing recognizes the importance of leveraging this technology to address the continent's unique challenges, promote sustainable development, and achieve the SDGs. It involves building local capacity, enhancing data accessibility, and fostering collaboration to harness the full potential of remote sensing applications in Africa [13. 14].

III. COMPONENTS OF REMOTE SENSING

Remote sensing systems consist of two basic components namely: the platform and the sensors. However there are several other essential components that work together to acquire, process, and analyze remote sensing data. A description of all the key components of remote sensing is given below:

- Platform: The platform carries the sensor through the air, space, or water to acquire remote sensing data. It can be a satellite, aircraft, drone, or ground-based system. The choice of platform depends on the desired spatial coverage, resolution, and temporal frequency of data acquisition.
- Sensor: The sensor is the instrument that detects and records the electromagnetic radiation reflected, emitted, or scattered by the target. Sensors can be passive (relying on ambient radiation) or active (emitting their own radiation). They are designed to measure specific wavelengths or frequency ranges and capture the electromagnetic energy in the form of digital images or other data formats.
- Energy Source: The energy source provides the electromagnetic radiation used for remote sensing. It can be natural, such as sunlight, or artificial, like RADAR or LiDAR systems. The type of energy source determines the wavelength or frequency of the radiation.
- Target: The target refers to the object or area on the Earth's surface or atmosphere that is being observed or measured through remote sensing. It can include land features, vegetation, water bodies, atmospheric components, or human-made structures.
- Data Transmission: Remote sensing data acquired by the sensor is transmitted to the ground or receiving station. This can be done in real-time for certain applications or stored onboard the platform for later retrieval and transmission.
- Data Processing and Analysis: Remote sensing data undergoes processing and analysis to enhance its quality, extract meaningful information, and generate useful products. This involves calibration, correction, image enhancement, feature extraction, classification, and other computational techniques.
- Data Interpretation: Data interpretation is the process of analyzing and understanding the information derived from remote sensing data. It involves visual interpretation of images by experts to identify features, patterns, or changes. Interpretation can be qualitative or quantitative, depending on the objectives of the analysis.
- Data Integration: Remote sensing data is often integrated with other geospatial data, such as maps, topographic data, or socioeconomic data, to provide a more comprehensive understanding of the target and its context. Integration allows for multidimensional analysis and modeling.
- Applications and Decision Making: The derived information from remote sensing data supports various applications and decision-making processes

in fields such as environmental monitoring, agriculture, urban planning, disaster management, and natural resource management. It provides valuable insights for policy-making, resource allocation, and sustainable development practices.

IV. PROCESSES OF REMOTE SENSING

Remote sensing involves several processes that occur from the acquisition of data to the extraction of information and analysis [15, 16, 17]. Here is a general description of the key processes involved in remote sensing:

- Data Acquisition: Remote sensing data is acquired through sensors that detect and measure electromagnetic radiation. Sensors can be mounted on satellites, aircraft, drones, or ground-based platforms. They capture radiation reflected or emitted by the Earth's surface and atmosphere. Different sensors operate in various regions of the electromagnetic spectrum, such as visible, infrared, microwave, or radar.
- Data Preprocessing: Once the data is acquired, preprocessing steps are applied to enhance the quality and usability of the data. This may involve radiometric and geometric corrections to remove sensor-specific distortions, atmospheric corrections to account for the effects of the atmosphere, and calibration to convert the raw data into physically meaningful values.
- Image Processing and Analysis: In this stage, the acquired data is processed to generate images, maps, or other derived products. Image processing techniques are used to enhance the visual quality of the data, apply filters, perform geometric transformations, and extract features of interest. Digital image analysis methods, such as classification, object detection, and change detection, are applied to extract meaningful information from the data.
- Interpretation and Analysis: Once the data is processed, it is interpreted and analyzed to extract valuable information. This involves the visual interpretation of images by experts to identify and analyze features, land cover types, or changes over time. Quantitative analysis techniques, such as statistical analysis or machine learning algorithms, may be applied to derive further insights from the data.
- Data Integration and Modeling: Remote sensing data is often integrated with other geospatial data, such as topographic maps, climate data, or socio-economic data, to provide a comprehensive understanding of the Earth's features and processes. Data integration allows for more informed analysis and modeling to address specific research or application objectives.
- Data Visualization and Presentation: The results of remote sensing analysis are often visualized through maps, graphs, or other graphical representations. This facilitates effective communication of findings to stakeholders, decision-makers, and the general public.
- Validation and Accuracy Assessment: Validation and accuracy assessment are important steps to evaluate the quality and reliability of the remote sensing results. Field measurements, ground truth data, or comparison with existing datasets are used to validate the accuracy of the derived information.
- Interpretation and Decision Making: The information derived from remote sensing data supports decision-making processes in various fields, such as environmental monitoring, agriculture, urban planning, and disaster management. It provides valuable insights into land cover changes, vegetation health, natural resource mapping, and other parameters that inform sustainable development and resource management practices.

V. TYPES OF REMOTE SENSING

Remote sensing can be classified into two broad types based on the source of electromagnetic radiation used for data acquisition and the specific applications they serve.

1. Passive Remote Sensing:
   - Optical Remote Sensing: This type uses sensors that detect reflected sunlight or emitted radiation in the visible, near-infrared, and thermal infrared regions of the electromagnetic spectrum. It is widely used for land cover mapping, vegetation monitoring, and urban analysis.
   - Hyperspectral Remote Sensing: Hyperspectral sensors capture data across numerous narrow and contiguous spectral bands, allowing detailed analysis of materials and their properties. It is valuable for mineral exploration, environmental monitoring, and precision agriculture.
   - Thermal Remote Sensing: Thermal sensors measure the emitted radiation from objects to determine their temperature. It is used for applications such as monitoring land surface temperature, assessing heat loss in buildings, and identifying active wildfires.
2. Active Remote Sensing:
   - Radar Remote Sensing: Radar sensors transmit microwave pulses and measure the backscattered signal, allowing the estimation of surface roughness, soil moisture, and the detection of objects regardless of weather or daylight conditions. It is utilized in applications like land cover mapping, flood monitoring, and disaster management. Reference:
   - LiDAR (Light Detection and Ranging): LiDAR systems emit laser pulses and measure the time taken for the reflected signals to calculate the distance to objects. It is used for generating high-resolution digital elevation models, vegetation structure analysis, and urban planning.
3. Other Types:

- Sonar Remote Sensing: Sonar systems use sound waves in water to measure water depths, map the seafloor, and detect underwater objects. It is employed in marine research, navigation, and offshore industries.
- Infrared Remote Sensing: Infrared sensors capture thermal radiation in the mid-infrared or far-infrared regions to identify temperature variations and study atmospheric properties. It is utilized for weather forecasting, climate studies, and atmospheric monitoring.

VI. THE ELECTROMAGNETIC SPECTRUM

The electromagnetic spectrum refers to the range of all possible frequencies of electromagnetic radiation, which includes various forms of energy, from low-frequency radio waves to high-frequency gamma rays. Electromagnetic radiation consists of oscillating electric and magnetic fields that propagate through space. The electromagnetic spectrum is typically divided into different regions based on the wavelength or frequency of the radiation. The electromagnetic spectrum is shown in Figure 2.

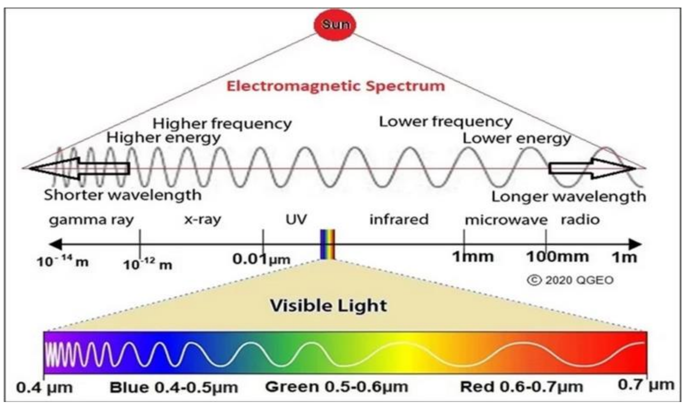

Figure 2. The electromagnetic spectrum.

It is important to note that different regions of the electromagnetic spectrum have specific interactions with matter and varying abilities to penetrate and be detected by different materials. This characteristic is leveraged in various fields, where different wavelengths are used to study and understand different aspects of the Earth's surface, atmosphere, and celestial objects. Understanding the electromagnetic spectrum and its different regions is fundamental to many scientific disciplines and technological applications, enabling us to harness electromagnetic radiation for communication, imaging, and exploration [18].

VII. THE CONCEPT OF ENERGY

The concept of energy is fundamental to various scientific disciplines and plays a crucial role in understanding the natural world using different techniques especially remote sensing. Energy can be defined as the ability to do work or bring about a change. It exists in different forms, and it can be transformed from one form to another. The concept of energy is deeply connected to the laws of physics, particularly the law of conservation of energy, which states that energy cannot be created or destroyed, only converted from one form to another. There are various forms of energy, for example: Light, thermal, sound energy, etc. which can be transferred from system to another.

Energy transfer refers to the movement of energy from one system or object to another. Energy can be transferred through various mechanisms, and understanding these processes is crucial for comprehending how energy flows and interacts in different systems. There are four basic form of energy transfer namely:

- Conduction: Conduction is the transfer of energy through direct physical contact between objects or substances. It occurs when higher-energy particles transfer energy to lower-energy particles through collisions. The transfer of thermal energy in solids, such as when a metal spoon heats up when placed in hot soup, is an example of conduction.
- Convection: Convection is the transfer of energy through the movement of fluids (liquids or gases). It involves the transfer of both heat and mass. In convection, the more energetic particles in the fluid rise while the less energetic particles sink, creating a circular motion known as convection currents. This process is responsible for the transfer of heat in fluids, such as the circulation of hot air in a room when a heater is turned on.
- Radiation: Radiation is the transfer of energy through electromagnetic waves. Unlike conduction and convection, radiation does not require a medium to propagate. Energy is emitted in the form of electromagnetic waves, such as visible light, infrared radiation, or radio waves. The Sun's energy reaching the Earth through sunlight is an example of energy transfer through radiation.
- Transmission: Transmission refers to the transfer of energy through a medium without direct physical contact. It occurs when energy is transferred from one point to another by passing through a material or medium, such as sound waves traveling through air or electromagnetic waves traveling through a fiber optic cable.

It is important to note that energy transfer processes can often occur simultaneously or in combination, depending on the system and the context. The understanding of energy transfer is crucial in various fields, including physics, engineering, and environmental science. However, out of all the mode of energy transfer, radiation is the most suitable for remote sensing.

VIII. THE WAVE AND PARTICLE MODEL OF ENERGY

The wave model of energy is based on the concept that energy can be transmitted through space and matter in the form of waves. Waves carry energy from one location to another without physically displacing the medium through which they propagate. Maxwell's electromagnetic wave theory, is a fundamental concept in physics that describes the behavior of electromagnetic waves. In early 1860, Maxwell, J.S., introduced the concept of the wave model of energy. Electromagnetic waves travel in a vacuum at the speed of light (3×10^8m/s or 1,860,000 miles/s). Electromagnetic radiation consists of Electromagnetic waves in two fluctuating fields namely (electric field and magnetic field). From the wave model of energy:

$$c = \lambda f$$

$$\lambda = c/f\,, \tag{1}$$

therefore,

$$f = c/\lambda.\,. \tag{2}$$

Where c = speed of light in vacuum; f = frequency and λ = wavelength of the wave.

The wave model of energy provides a framework for understanding the propagation, properties, and interactions of waves, whether they are electromagnetic or mechanical. By applying this model, scientists and engineers can analyze and utilize the energy carried by waves for various applications, ranging from communication systems to medical imaging to energy harvesting.

On the other hand, the particle model of energy is a conceptual framework that describes energy in terms of discrete particles or packets of energy called "energy particles" or "energy quanta." This model is particularly associated with the quantum theory of energy, which revolutionized our understanding of the microscopic world. In the particle model, energy is viewed as being quantized rather than continuous. It suggests that energy exists in discrete units, or particles, which cannot be further subdivided. These particles are often referred to as photons in the context of electromagnetic energy. According to the particle model, energy transfer occurs through the exchange of energy particles. When an energy transfer occurs, energy is transferred from one system or object to another in discrete amounts. For example, in the context of light, the particle model suggests that light is composed of photons, each carrying a specific amount of energy. When light interacts with matter, photons are absorbed or emitted, leading to energy exchange. This model has significant implications in various areas of physics, including particle physics, atomic and molecular physics, and quantum optics. It helps explain phenomena such as the photoelectric effect, where light incident on a material surface can eject electrons, and the emission and absorption spectra of atoms.

From this model, electromagnetic energy can also be described in terms of Joules (J) and electron volts (eV).

$$1ev = 1.602 \times 10^{-19} J.$$

The rate of transfer of energy from one place to another is termed the flux of energy or power measured in watts (W). The amount of energy is generalized by Planck’s general equation as:

$$E = \mathfrak{h} f \tag{3}$$

Where, E = wave energy and $\mathfrak{h}$ = Planck’s constant. Substituting (1) into (3) gives

$$E = \mathfrak{h} c/\lambda\,. \tag{4}$$

It is important to note that the particle model and the wave model of energy (such as Maxwell's wave model) are both used to understand different aspects of energy behavior. In some contexts, such as with electromagnetic radiation, both models are combined in the form of wave-particle duality, where energy can exhibit both wave-like and particle-like properties.

IX. THE PROGRESS OF SATELLITE REMOTE SENSING FOR SDGs IN AFRICA

In recent years, there has been quite a substantial progress made by some African countries in addressing the SDGs using satellite remote sensing through satellite launch initiatives. As of June 2023, South Africa has made significant strides in satellite technology and space research. The country has launched several satellites, including ZACUBE-1, ZACUBE-2, and SUNSAT, which have contributed to various Earth observation applications such as, maritime monitoring, and communications. Nigeria has been actively involved in satellite development and launch. The country successfully launched its first satellite, NigeriaSat-1, in 2003. Since then, it has launched additional satellites such as NigeriaSat-2, NigeriaSat-X, and NigeriaEduSat-1. These are affordable Satellites, which have been utilized for applications like agriculture, disaster management, and urban planning. Kenya has shown progress in satellite technology and space applications. The country launched its first satellite, 1st Kenyan University Nano Satellite Precursor Flight (1KUNS-PF), in 2018. The satellite aims to provide educational and research opportunities while addressing national development challenges**.** Egypt has a history of satellite launches for various applications. The country launched its first Earth observation satellite, EgyptSat-1, in 2007. EgyptSat-2 followed in 2014, contributing to applications such as agriculture monitoring, urban planning, and disaster management. Algeria has made notable progress in satellite launch and utilization. The country launched its first Earth observation satellite, AlSAT-1, in 2002. It has since launched several satellites, including AlSAT-2A, AlSAT-2B, and AlSAT-Nano, which have been used for various applications such as land and coastal monitoring, environmental studies, and resource management.

It is worth noting that these examples are not exhaustive, as other African countries have also been involved in satellite launch initiatives and space-related activities to address the SDGs. While some others have announced plans to launch its first Earth observation satellite in the nearest future, for example the Republic of Djibouti is set to launch Djibouti-

1A and 1B satellites. Also, Cote d'ivoire has announced plans to launch its first satellite (YAM-SAT-C1 01) within the next two years. However, the progress of each country varies based on their respective strategies, resources, and national priorities. Figure 3a and 3b shows the African countries with their number of satellite launched as of June, 2023.

Figure 3a. Chart showing Africa countries with launched satellites as at June, 2023.

X. CHALLENGES OF REMOTE SENSING FOR SDGs IN AFRICA

Remote sensing applications for achieving the SDGs in Africa face several challenges, which can vary across different goals and regions [19, 20]. The following points below highlights some common challenges associated with remote sensing application for addressing the SDGs in Africa and provide further insights into specific issues faced in Africa.

- Data Availability and Accessibility: Limited availability of high-quality, up-to-date, and openly accessible remote sensing data can hinder SDG monitoring and assessment. Challenges include issues of data acquisition, data costs, data sharing, and data interoperability.
- Capacity Building and Technical Expertise: Insufficient technical skills and capacity among users and decision-makers to effectively utilize remote sensing data for SDG monitoring and implementation. Enhancing technical expertise through training and capacity building programs is crucial.

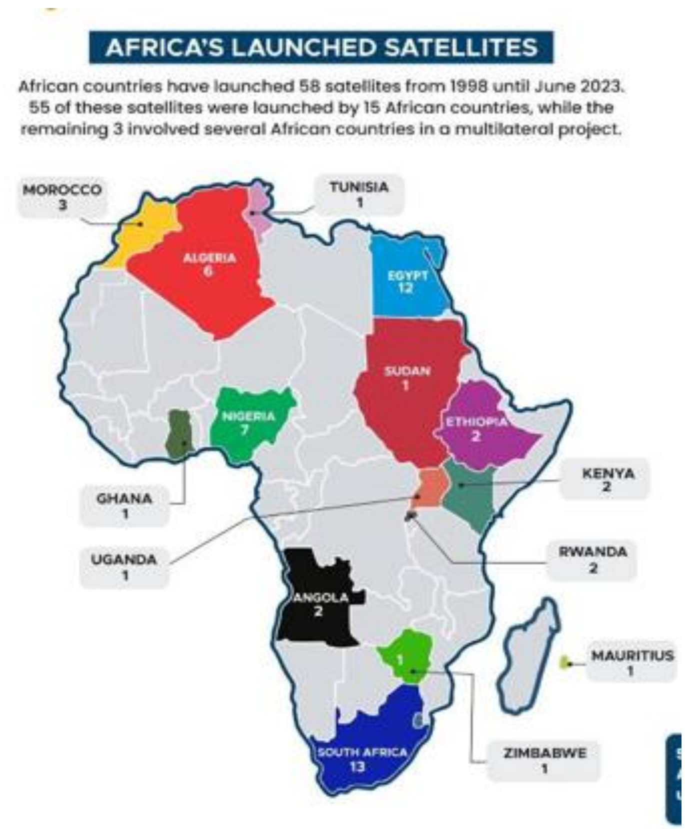

Figure 3b. Map of Africa showing countries with numbers of satellite launched as at June, 2023.

- Data Interpretation and Analysis: Remote sensing data interpretation and analysis require expertise in image processing, data fusion, and information extraction techniques. Limited availability of trained personnel and appropriate algorithms for data analysis can pose challenges in generating accurate and reliable information.
- Spatial and Temporal Resolution: Remote sensing data with suitable spatial and temporal resolution are crucial for addressing specific SDG targets and indicators. Limited availability of high-resolution data at local scales and insufficient temporal coverage can affect monitoring and assessment efforts.
- Data Integration and Validation: Integrating remote sensing data with other data sources and validating the accuracy of derived information can be challenging. Harmonizing remote sensing data with

ground-based measurements and other geospatial data requires careful consideration of uncertainties and biases.

- Policy and Institutional Frameworks: The lack of appropriate policy and institutional frameworks can impede the integration of remote sensing into SDG implementation strategies. Collaboration and coordination among various stakeholders, including government agencies, research institutions, and international organizations are crucial.

XI. CONCLUSIONS

Satellite remote sensing has emerged as a valuable tool for addressing the SDGs in Africa. It enables the collection of valuable data and information about the Earth's surface from space, providing insights and supporting decision-making processes across various sectors. In Africa, satellite remote sensing plays a crucial role in achieving SDGs related to land management, agriculture, water resources, urban planning, disaster management, and climate change. It aids in monitoring land cover and land use changes, mapping forests and biodiversity, assessing crop health and food security, monitoring water availability and quality, mapping urban areas and infrastructure, managing natural disasters, and understanding climate patterns and their impacts. By utilizing satellite data and remote sensing techniques, African countries can gather information at regional, national, and local scales, enabling evidence-based decision-making and policy formulation. This technology facilitates the identification of areas requiring intervention, supports resource management, and helps track progress towards SDG targets. Moreover, satellite remote sensing enhances data accessibility, especially for remote and underserved regions, bridging the information gap and facilitating more inclusive and equitable development. In recent years, African countries have made significant progress in satellite launch initiatives, establishing national space agencies, and building capacity in remote sensing applications. Collaboration between African countries, international organizations, and space agencies has led to increased data sharing, technology transfer, and knowledge exchange, further enhancing the utilization of satellite remote sensing for SDGs in Africa. Despite the advancements, challenges remain, including limited access to high-quality satellite data, the need for capacity building, infrastructural development, and the integration of remote sensing into government policy frameworks. Addressing these challenges requires sustained efforts, investment, and partnerships to unlock the full potential of satellite remote sensing for achieving the SDGs in Africa.

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