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The Impact of Satellite Communications on Environmental Hazard Control: Tool for the Realization of African Union Agenda 2063 Aspirations

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Abstract

Africa is a developing economy and as such, emphasis has been placed on the achievement of revolutionary goals that will place her on a similar rank as the developed economies. Pertaining to this objective, Heads of States and government all over Africa instigated the African Union (AU) Agenda 2063, which is a framework put in place to achieve a continental transformation over the next 40 years. The use of satellites has been proven to be a major influence on economic growth since it facilitates the exchange of information. Environmental hazards such as climate changes, pollution, and inefficient waste management can be classified as one of the drawbacks to achieving this economic growth we hope to accomplish. The purpose of this paper is to analyze and examine satellite communication as a tool for the attainment of an integrated, prosperous and peaceful Africa by means of combatting environmental hazards in the continent.

Keywords

AU Agenda 2063, Satellite Communications, Environmental hazards, Robust Satellite Techniques, Remote Sensing

1. Introduction

Africa is a continent blessed and enriched with the highest concentration of natural resources such as gold, uranium, petroleum, cobalt, and silver to mention a few. However, even with these resources, Africa is still referred to as the poorest and least developed of the continents, contributing a GDP of 2.4% of the global economy [1]. Since 1963, Africa has made serious referendums towards promoting the Pan African spirit indigenously whilst emancipating its territories from all forms of oppression (political, economic, racial and gender-related). In 2016, the most recent referendum with a plan tagged "Agenda 2063—The Africa We Want" brought about aspirations to be achieved over the next 50 years. This Agenda seeks to cover a broad scope involving the social, economic, and environmental dimensions as well as cultural, political and other African concerns. It is not a surprise that the environment plays a major role in the procurement of the AU Agenda. Africa is a continent blessed with natural endowments and a unique environment. However, environmental hazards due to climate change, pollution, poor waste control, etc. have become the order of the day due to urbanization and industrialization, thereby disempowering individuals and causing disruptions in lives, which would eventually lead to limitations in the African evolution. To attain the desired growth and development needed to engender an economic boost, advances towards environmental sustainability should be scrutinized. In this paper, we steer towards the environmental scope and its relevance in the achievement of the AU Agenda 2063.

1.1. The African Aspiration for 2063

In the year 2013, the African union came up with a plan, an agenda to transform the African continent over a period of 50 years, driving at implementing both past and present initiatives for growth and sustainable development amongst the African populace and the continent in general. The guiding vision for Agenda 2063 is the AU Vision of "An integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in international arena" [2].

The seven goals for fulfilling this vision were born which are listed below:

1) A Prosperous Africa, based on inclusive growth and sustainable development;

2) An integrated continent, politically united, based on the ideals of Pan Africanism and the vision of Africa's Renaissance;

3) An Africa of good governance, democracy, respect for human rights, justice and the rule of law;

4) A Peaceful and Secure Africa;

5) Africa with a strong cultural identity, common heritage, values and ethics;

6) An Africa whose development is people driven, relying on the potential offered by people, especially its women and youth and caring for children;

7) An Africa as a strong, united, resilient and influential global player and partner.

1.2. Conventional Approach towards Environmental Hazard Control

Environmental hazard can be termed as anything, substance or event that has the capacity to cause harm to the people or the environment. For instance, natural disasters such as earthquakes, landslides and pollution are caused by human activities. Towards the realization of environmental sustainability, various policies and approaches have been set to foster environmental protection. It is impossible to combat all forms of environmental hazards using a single approach as it can be categorized into climatic hazards, pollution, poor waste control and natural disasters. Numerous implementations have been carried out concerning these categories.

About environmental pollution education, Rich *et al.* [3] propose a decision-making approach that will aid communities in producing decisions for a sustainable environment. They believe that these decisions are scientifically sound and politically durable. In addition, they aim towards communal empowerment. Following up on combatting water pollution, Mitchell [4] presents a review on various case studies involving the employment of Integrated Urban Water Management (IUWM). This concept takes an approach towards the integration of viewing water supply, drainage, urban water services and sanitation into a single physical system. Chowdhary *et al.* [5] provide a review article on treatment methods of distillery wastewater (DWW) pollutants. They emphasize the role which distillery industries play in environmental pollution, as they discharge wastewater containing organic and inorganic pollutants. They also discuss the available and emerging analytical techniques for DWW pollutants detection.

In the aspect of controlling disasters such as floods, drought and fire, landslides and desertification accompanied with soil erosion, which are highly related to human intervention, a method used to eliminate such adversities is afforestation, as deforestation is a major contributor to the aforementioned problems [6]. Pertaining to waste management, there have been laws and enactments to safeguard our environment and control environmental hazards. Taking India as a case study, a "Hazardous Waste Management Rule" had been enacted since 1989 [7]. This law allows recyclable waste to be stored properly in a container with a seal for a period of 3 months and for special condition, the waste may be stored for a longer period. Pollutants that were not recyclable had to be incinerated. The firms that provided the incineration services were to be certified by the regulatory body.

One thing common to all these methodologies is that they do not have preventive techniques, meaning that preventive measures are not included in these methods. Recognizing this challenge, studies began in the area of science and technology to come up with solutions that would help predict and prevent hazardous situations that are likely to happen or are peculiar to certain districts and communities.

1.3. ICT's Era On-Environmental Hazard Control

Information and Communication Technology has revolutionized the way we communicate and see the world for a couple decades. The world is moving towards "smart" technologies with the application of the Internet of Things (IoT), which can be implemented in everything. Ibiteye *et al.*, contend that computer technology has gained recognition worldwide whether it is being used for teaching, financing, chatting, emailing and among others [7]. Furthermore, IoT can also be employed in the management and control of environmental hazards. Prior to the achievement of economic sustainability, researchers and scientists have carried out various tasks towards the implementation of IoT in environmental hazard control. An illustration can be derived from Mahdi Ikhlayel [8]. He suggests the establishment of E-waste (waste electrical and electronic component) management systems. The system is an approach towards the control of solid and e-waste management systems, thereby refining the environment and putting hazards in check. In addition, monitoring systems are established in order to monitor the environment, thereby ensuring environmental protection.

1.4. Satellite Communication at a Glance

As the term implies, satellite communication involves the use of satellites for communication. These satellites play a vital role in exchanging information globally as they are involved with long-distance communications. Through the usage of radio waves, satellites transmit signals to positioned antennas on earth, which in turn processes the information. **Figure 1** shows some of the many services that a satellite can deliver.

The figure above summarizes the many applications of a satellite communication system, which are but not limited to:

- Internet Access;
- Distance Learning;

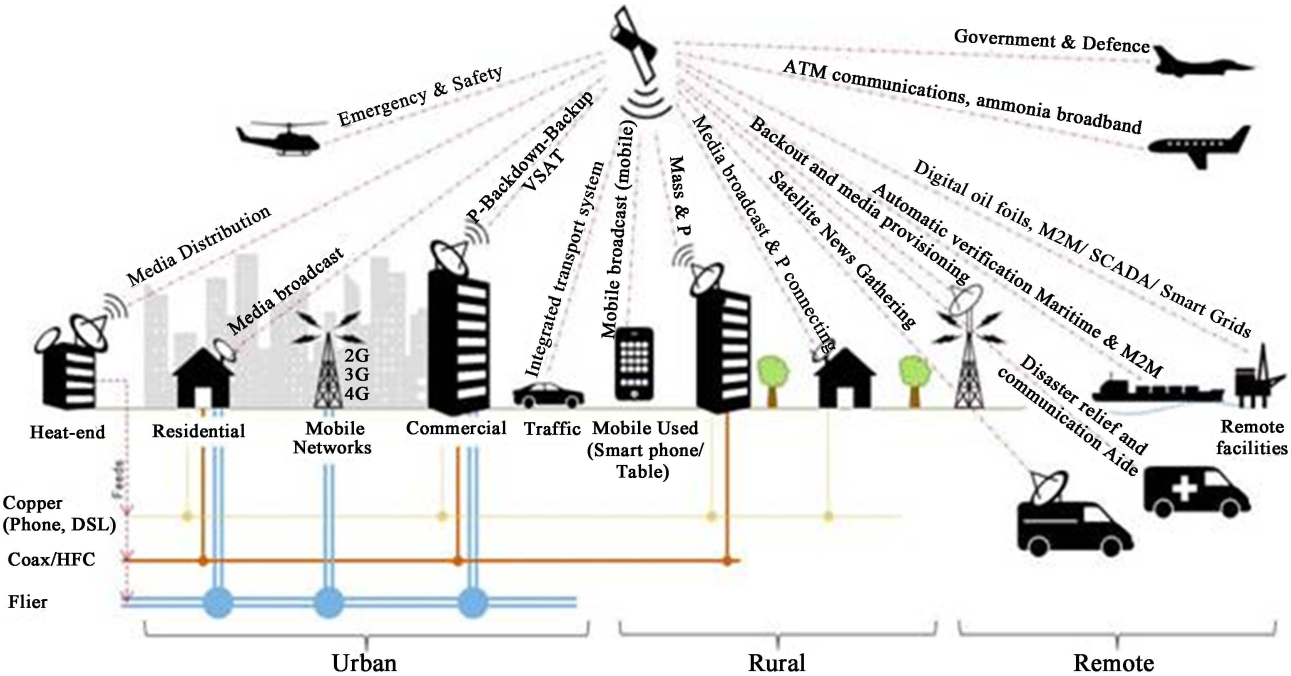

Figure 1. A typical satellite communication system [10].

- Telemedicine and E-Health;
- Air-Transport Network;
- Crime Control and Theft Management, etc.

The applications of a satellite communication system are numerous but for the purpose of this paper, we would narrow these applications to environmental hazard control.

2. Satellite Communications in Environmental Hazard Control

The applications of satellite communication are numerous, thereby establishing a relationship with environmental hazard control. Satellites are classified as the key tools for attaining environmental information. They are employed in environmental applications, which involve observation of the air, water, soil and the climate by means of radio-based remote sensors. There are various other satellite techniques engaged in eliminating environmental hazards. One of the techniques used is the Robust Satellite Technique [9]. This method makes use of different satellite sensors in different geographical areas, which aid in monitoring, prediction and prevention of hazards. Another technique is the implementation of satellite remote sensing. Satellites have a very wide continuous coverage span with availability of pre-event, reference imagery, variety of complimentary sensor (radar and optical and high and low spatial resolution), availability of increasingly sophisticated and easy-to-use software algorithms. Moreover, Satellites overcome access problems, have increased safety (minimal field work) and possess portable sensors which allow the acquisition of stereo-images or elevation data. This depicts why satellite remote sensing would be easier and more dependable in the prevention of environmental hazards. Satellite remote detecting is second to none a groundbreaking and effective device to guarantee procurement of pictures over wide regions in brief time and with awesome redundancy that can be utilized in ecological studies [10].

Attempts to engage satellite communication in environmental hazard control are already being made. In Nigeria, Akinyede *et al.* [11] developed a satellite-based monitoring system which would provide an evaluation of recent conditions, alongside the causes and development of environmental problems. In order to achieve this, data concerning the environmental state were periodically obtained from Nigeria's Earth observation satellites (NigeriaSat-1, NigeriaSat-X and NigeriaSat-2). This obtained information was useful for assessing environmental challenges, and used to take preventive measures against the occurrence of hazards. Furthermore, Li and Cao [12] developed a satellite system for effective environment monitoring in China, thereby acting as a support to the response to degradation of the environment while promoting harmony between nature and humanity.

Since there is no specific method of combatting all forms of environmental hazards, we would analyze the implementation of satellite for environmental hazard control in the various hazard categories, which include pollution, poor waste control and natural disasters.

2.1. Environmental Monitoring

In order to achieve a hazard-free environment, the first stage is environmental monitoring which involves detection of potential risks on the environment. It basically deals with observations of environmental conditions (presence of pollutants, chemicals and toxins) in specified regions and locations. Moreover, it is a crucial factor determining the quality of the environment and knowing if it is improving or depreciating. To carry out this process, gathering information necessary for evaluation is required, and this is the most tedious task in the method. Nevertheless, satellite communications play a huge role in the attainment of data for various regions and implementations are already on going.

Akinyede *et al.* [11] proposed in their study an operationalized system of collecting information based on the data gathered from Nigeria's earth observation satellites (NigeriaSat-1, NigeriaSat-X and NigeriaSat-2) in addition to existing government policies on environmental issues to sustain environmental monitoring and management in Nigeria. The aim of the paper was to develop a sustainable satellite-based environmental monitoring system in Nigeria. They discovered that using the satellite for environmental monitoring creates an opportunity for the investigation and assessment of situations, the effect and causes of environmental concerns in time and space. Their research was able to validate the fact that data obtained from Nigeria's satellite can be used to study the effects and causes of environmental issues affecting Nigeria and propose solutions that can be used to mitigate against the effects of such problems.

Li and Cao [13] in their study, discussed the existing system of satellite environmental monitoring and problems of load design and low data utilization efficiency and the demand for environmental monitoring satellites. The aim of the study was to develop an effective system of environmental monitoring satellite system. From this study, it was discovered that the need of satellite for remote sensing is on the rise. Based on this study, it was concluded that improving the already available system of environmental monitoring can aid and support rapid response to environmental degradation.

Zotin *et al.* [14] in their study, discussed the use of elastic grid method of observing data mapping for satellite monitoring. The aim of the study was to discover the problems associated with using the current methods of using remote sensing to asses and map environmental risk region on plant ecosystem. It was discovered that that data collected form OMI spectrometer can be used to send signals to industries to minimize production level and predict possible emissions. It was also gathered from the study that some features of H_2CO cannot be distinguished using OMPS due to the size of its spectral pixel. It was concluded that environmental risk mapping can be used to minimize the effects of harmful industrial emissions to the ecosystem.

Manzo *et al.* [15] conducted research on the use of data from multiple sources for the chemical analyses of landfill regions. The aim of the study was to use in situ-chemical analysis for the detection of environmental points of interest (EPI). It was observed that the combination of remote and field data can discover EPI which detected points where further chemical analysis needs to be carried out. It was also discovered that remote sensing can aid in the detection of EPI for study and analysis. The detection of EPI helps in the minimization of the release greenhouse gases (GHG). It was concluded that remote sensing is not a replacement for chemical analysis.

Adamo *et al.* [16] conducted a study on Taranto city. The aim of the paper was to review the existing methods, techniques and tools for water monitoring and provide new and inexpensive methods of water monitoring.it was discovered that the water body in the city is usually polluted as a result of the waste generated from the industry situated along the Apulia region coast which was the case in point of the study. It was concluded that it is a matter of necessity to develop cheaper means of monitoring the system in order to improve the living conditions of the residents.

Boubacar *et al.* [17] proposed the use of remote sensing for collecting information from the field about a disaster. The case in point for this research was Mopti region, Mali West Africa. It was discovered that the results obtained that there is a relationship between the water level (Niger River) and the outbreak of cholera. The higher the water level, the higher the chances of contaminating the diseases at a rate of 66%. It was concluded that the use of remote sensing can aid the in the prevention of communicable diseases as it relates to the environment through the use of data obtained from the field and satellite.

Skouloudis and Rickerby [18] conducted research on detection of regions of interest using In-situ and remote sensing networks for environmental monitoring and the analysis and study of the outbreak of leptospirosis. It was discovered that satellite helps in rapid response to the field in case of an outbreak. It was concluded that satellite helps in predicting the possibility of having an outbreak so that adequate steps can be taken to either prevent the outbreak or minimize its effects.

Li *et al.* [19] conducted research on the load variation of non-point source (NPS) pollutant in urban areas using remote sensing. The aim of the paper was to conduct research on the Bao'an District in Shenzhen, China to find out variations in land use, using data that was obtained using remote sensing and the use of Localized long-term hydrologic impact assessment (L-THIA) model to study how land use has contributed to NPS pollution. The research involved the use of the L-THIA model with rectified curve number (CN) values to obtain the daily precipitation data and measured event mean concentration (EMC) and analysis of the spatial and temporal variations of NPS pollutant loads using Microsoft Excel 2013. It was discovered from this study that as a result of urbanization, there was a great degree of change in the non-point source pollution load as regards magnitude and spatial distribution. It was concluded that land use indeed affects pollutants.

2.2. Pollution

Pollution is recognized as the most common form of environmental hazard due to the ease with which it can be established. Pollutions are mostly manmade and can be categorized into three different classes: air, water and land. Laws and policies have been previously put in place to minimize environmental pollution, but it has become a known fact that mere rules are unable to eliminate the occurrence of pollution. With satellite communication, a technique termed, "Remote Sensing Technique" was proven the most efficient method for minimizing pollution. This implies that satellites can be seen as effective tools for reducing pollution. With this viewpoint, scientists and researchers came together to develop sustainable means, by which pollution can be mitigated using satellites.

2.2.1. Air Pollution

Air pollution is mostly due to hazardous gases or pollutants released into the atmosphere, thereby rendering the environment unsafe for both humans and nature. Industries such as distillery industries, manufacturing industries, and so on play a large role in poisoning the atmosphere. According to research carried out, satellites can be positioned to monitor and detect pollutants in the atmosphere and take preventive measures.

Research conducted by Christopher *et al.* [20] prescribed satellite remote-sensing of air pollution in Mega-Cities. They proposed the use of Moderate Resolution Imaging Spectrometer (MODIS) Aerosol Optical Thickness (AOT) data from TERRA/AQUA satellites to monitor and observe particulate matter air quality over megacities. The MODIS AOT prove to be very effective because they were useful in discerning various categories of air quality, which could be good, moderate or unhealthy. The results derived showed that acclimatization of fire and emission products derived from satellites were useful in improving particulate matter air quality, which is a cost-effective means. Although the research was a successful one, unresolved research concerns are left unattended.

Zaman *et al.* [21] suggested the use of satellite data for upscaling urban air pollution in Malaysia. They established an empirical model for the estimation of particulate matter concentration and also employed MODIS sensors and meteorological variables to test Aerosol Optical Depth (AOT), thereby predicting pollution levels in Malaysia. The addition of the meteorological factors helped to improve these pollution levels and the results attained aided in mapping the pollution levels across Malaysia.

Engel-Cox *et al.* [22] employed satellite imagery alongside ground-based data to monitor air quality in the urban scale. This includes monitoring air pollutants concentration and transportation, mainly particulate matter. They provided case studies based on the implementation of satellites for air quality monitoring. They concluded that the use of satellite imagery can be harnessed as a forecasting tool for the prediction of increasing pollutants, which possess the capability of affecting sensitive populations. Le *et al.* [23] also combined the use of satellite remote sensing data and ground-based measurements for the deduction of fire-air pollution relationships in particular areas in Vietnam. They were able to derive data concerning active fires from satellites in order to relate to the subsequent atmospheric pollution in the selected regions. The results enabled them to map out areas with peak fire activity and predict particulate matter concentration.

Sannazzoro *et al.* [24] suggested the used of Robust Satellite Techniques (RST) for the detection of dust outbreaks which posed a threat to the Mediterranean region and Arabian Peninsula. They processed data from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) and compared the resulting dust maps to aerosol products, which are satellite-based. The output of the methodology proved that the RST technique is an efficient tool in the prediction and detection of dust outbreaks from space. They embrace promotion and advancements of the technique for its execution in the structure of operational warning systems. Kourtidis *et al.* [25] developed a method called the Enhanced Ratio Method (ERM), which permits the development of inventories for spatial emission. Tao *et al.* [26] carried out a study on urban pollution and haze clouds in Beijing, utilizing integrated satellite observations. Their study revealed the presence of haze pollution in Beijing area, as well as the causes which were because of a mixture of pollutants, floating dust and growth of fine particles. Vadrevu *et al.* [27] proposed the use of satellite remote sensing datasets for the assessment of intense pollution in Southeast Asia. They retrieved aerosols and Carbon monoxide via satellites as they lacked ground measurements. Results from the assessment produced satellite-based monitoring and mapping of pollution across Southeast Asia.

Ialongo *et al.* [28] applied space-based sulfur dioxide in the reduction of air pollution due to emissions from metal smelting. The results derived reveals that satellite-based observations are useful in detecting sulfur dioxide emissions and aided in the development of sulfur-removing technologies. Furthermore, it can be implemented in maintaining environmental policies, which would result in sustainable development. Aliyu and Botai [29] carried out a study to evaluate the aerosol and carbon monoxide substances in the atmosphere with the aid of multi-satellite datasets, while using portable pollutant monitors. The study suggests an alternative means for the measurement and monitoring of air pollution as well as mitigating threats to air quality. Evans *et al.* [30] assessed mortality with respect to exposure to air pollution for a long period of time with the aid of remote sensing data. They derived data from MODIS and MISR satellite instruments for obtaining PM level concentrations. The study revealed the importance of using pollution concentrations from satellites for the assessment of the impacts of air pollution on population health.

Liu *et al.* [31] conducted research for the analysis of properties and formation of air pollution in China with the aid of satellite and ground-based observations. They were able to investigate the meteorological conditions, pollutants source and the aerosol properties via this research. In the study, the formation process of air pollution was revealed, and they believed that the obtained data would be useful in the validation of air quality models in the region and also providing the government guidance for the prevention of pollution. Christodoulakis *et al.* [32] proposed the utilization of satellite observations rather than ground-based data for quantifying air pollution effects and environmental factors on various materials. They believe that this approach would expand the use of Dose Response Functions (DRFs) to areas where situ measurements are non-existent. They plan to carry out more research work for improving accuracy of estimations derived from satellite observations. Luo *et al.* [33] employed the use of Tropospheric Emission Spectrometer (TES) satellite observations for analyzing ammonia and carbon monoxide in the atmosphere, in conjunction with GEOS-Chem model simulations for a particular year for the seasonal evaluation of pollutant sources recommended in the model. Yang *et al.* [34] carried out a study on the Nested Air Quality Prediction Modeling System (NAQPMS) with sensitivity experiments alongside satellite-based data for air quality monitoring, while also utilizing remote sensing satellite data. Their sole aim was to provide an insight into the formation process of particulate matter pollution across Northeast China. Through the study, the significance of satellites in environmental impacts (air quality management) was brought into the limelight.

2.2.2. Particulate Material Pollution

Particulate Material pollution is also known as particle pollution, are made of microscopic particles that could either be liquid or solid suspended in the atmosphere. It affects both the atmospheric conditions and human health conditions. As a result of its adverse effects on human health such as lung infection and cancers as well as the ease with which it enters the blood vessels unfiltered, it is one of the most hazardous forms air pollutions. Sources of particulate materials include soot, dust, dirt, smoke and so on. Not all these particles can be seen with the ordinary eye. According to [35] [36] [37] [38] [39] and [40] [41] [42] recent epidemiological studies globally have ascribed the increased cases of mortality and morbidity of cardiovascular and respiratory organs to particulate air pollution.

Hoogh *et al.* [35] estimate the amount particulate material concentration at a resolution of 1 × 1 km across 10 different regions of the study area. The estimation was made possible by the use of a Multiangle Implementation of Atmospheric Correction (MAIAC) spectral aerosol optical depth (AOD) data and a spatiotemporal predictor data in a four-step method. The estimation was successful, however there was no way to prove the estimation's validity. Huang *et al.* [36] as with [35] estimates the amount of particulate material concentration but [36] uses high level machine language in the study area. [36] Developed a random forest model using a recent Multi-angle implementation of atmospheric correction (MAIAC) aerosol optical depth (AOD), meteorological parameters, land cover and ground particulate material measurements. The authors also validated their model's ability to predict past values of particulate material (PM) concentration by using a 10-fold cross validation. They were able to achieve accurate results in predicting past values of PM and providing reliable information for epidemiological studies.

Liang *et al.* [37] attempts to use database of particulate material to access the effects of exposure to ambient particulate material. It was gathered from this paper that the effect of long-term exposure was more severe than short term exposure. He and Christakos [38] estimate the concentration of particulate material in the study area using BME-STP (a combination of Bayesian Maximum Entropy and spatiotemporal projection) supported by supplementary information provide (Artificial Neural Network) ANN and (Land use Regression) LUR models.

Chen *et al.* [39] propounded a relationship between fine particle extinction and its volume and developed a multi-factor remote sensing formula of dry particle material mass concentration near the ground. To confirm this method the authors applied AOD and Fine Mode Fraction (FMF) given by the MODerate resolution Imaging Spectroradiometer (MODIS). The application of the FMF in this method may thoroughly undervalue particle material because the involved fine particle fraction in the whole aerosol may be less than that of particle material. Zhang and Li [40] these authors attempt to use two types of Moderate Resolution Imaging Spectroradiometer (MODIS) and AOD data. Authors also used random forest model (non-parametric machine learning algorithms) and two traditional regression models between particulate material and AOD. The predictive abilities were compared by using cross validation.

Chen *et al.* [41] carried out the approximation of historical and spatial concentration of particulate matter with an aerodynamic diameter less than 1 micrometer (these are referred to as PM1) with the study area from 2005 to 2014. The authors used two types of Moderate Resolution Imaging Spectroradiometer (MODIS) and a combination of aerosol optical depth (AOD) data, Dark Target (DT) and Deep Blue (DB). The obtained values for PM1 data was combined AOD data and other spatial and historical predictors using an established generalized additive model (GAM). They also used a 10-fold cross-validation to measure the prognostic ability of their method. The results obtained would help the government of the study area understand the health condition its citizenry.

Meng *et al.* [42] developed a linear mixed effect model by integrating aerosol optical depth (AOD), meteorological information and the land use regression (LUR) model to calculate ground particulate material levels on high spatiotemporal resolution. The result obtained can be used to ascertain exposure effects for short-term and long-term epidemiological studies. Liu *et al.* [43] realized that there are more than 5800 tons of heavy metals were emitted in 2015 from the case study areas. The researchers reported the emission index from industry sectors.

Wu *et al.* [44] aims to harness the economic advantages of particulate material as well as protect the environment. The authors found out that the relationship between particulate air pollution and the economic advantage is an inverted U curve. The intensity of particulate air pollution decreases from economic urbanization, population urbanization to spatial urbanization. The researchers made use of remote sensing data and statistical yearbook from 2000 to 2011.

2.2.3. Oil Spillage

Oil spillage is the release of hydrocarbons into the environment, which could be on land or water thereby posing a threat to the ecosystem. Oil spills are usually to do human activities in the petroleum production industry. The impact of oil spills on the environment can cause disastrous consequences and this has brought about attention in the aspect of mitigating this threat. However, monitoring and detection of these spills is achievable via the implementation of satellite-based techniques.

Casciello *et al.* [45] devised a new means for detection and monitoring of oil spills based on the Robust Satellite Techniques (RST). This method was highly efficient in detecting polluted areas because of accidents, which occurred in Rio de la Plata basin with high accuracy. The obtained results confirmed the efficacy of the developed model for the creation of opportunities for constructing a real-time oil spill monitoring system. Adamu *et al.* [46] proposed the use of vegetation spectral techniques derived from satellite data for monitoring and detecting the effects of oil spills on vegetation. They believe that this technique would be highly efficient in reducing the impact of oil spills on the environment by applying early mitigation responses. The results obtained from the study proved the importance of satellite data in oil spill detection, thereby aiding in mitigation techniques and improving vegetation quality. However, they plan to carry out further studies while considering physical environmental factors.

Soydan *et al.* [47] employed two approaches to Hyperspectral target detection methods, which include anomaly detection methods and signature-based target detection approach for determination of oil spills in the selected region of the Gulf of Mexico. They compared both approaches to identify oil slicks in the region of interest (ROI). The derived results revealed that the signature-based target detection approach performed better in the detection, location and quantification of oil spills when compared to the anomaly detection method. Gade *et al.* [48] prescribed the utilization of satellite data for mapping out regions in the Indonesian waters with high oil pollution density. The findings of the study validated the significance of the proposed approach in assessing oil pollution in the regions of interest, thereby acting as an effective tool for oil pollution detection and monitoring. They plan on carrying out further improvements on the study, which would enable them to identify strongly affected coastal areas. Arellano *et al.* [49] employed hyperspectral satellite images for the detection of hydrocarbon pollution in the Amazon Forest. The results showed that the approach was highly efficient in identifying hydrocarbon pollution in the tropical forest.

Asadzadeh and Roberto de Souza Filho [50] suggested the use of spectral remote sensing data in a variety of infrared wavelengths as a tool for characterizing seepage systems which would be used as an exploration indicator of hydrocarbon accumulations. They employed two seepage systems namely, micro- and macro seepage. In the study, they aim to showcase the hidden capabilities of the technique and encourage its implementation in ensuring the reduction of environmental pollution and global warming. Emengini *et al.* [51] applied remote sensing of plant stress for the detection of environmental pollution as a result of oil spillage. They investigated the capabilities of the remote sensing technique for differentiating two forms of plant stress namely, oil pollution and waterlogging. To this effect, tests were carried out on vegetation by subjecting them to oil pollution, waterlogging and a combination of both by utilizing hyperspectral and thermal remote sensing. The research work emphasizes the importance of remote sensing for the detection of oil pollution on vegetation. However, further research is expected to be carried out based on different plant species and various factors.

Dutta *et al.* [52] Made use of synthetic aperture radius imageries in conjunction with a new method that involves segmentation and amalgamation process for extracting oil indices from the images. The researchers intend to use this methodology to utilize the RISAT-1 data for monitoring oil spills. The result of this research is satisfactory as oil spills could be identified visually.

2.2.4. Water Pollution

Asides air pollution, this form of pollution has proven to be one of the most common out of them all. Due to urbanization and increase in the number of industries, water bodies become polluted by chemicals and toxic waste, which would eventually lead to contamination. Water pollution has gained great attention as it has led to the loss of lives, which is why scientists and researchers are continuously searching for a means to mitigate its effect. Satellite communication can be applied to monitor water pollution as well as treat it.

Subiyanto *et al.* [53] carried out water pollution analysis in estuaries inlet of Semarang Eastern Flood Canal by integrating remote sensing technology. They obtained satellite images to assess the water quality by retrieving information about the presence of Chlorophyll-a and Total Suspended Solid (TSS) in the waters. On deriving these results from the satellite image, they compared the outcomes with the tested laboratory analysis. This allowed them to map out areas with concentrated Chlorophyll-a and TSS, while classifying regions from the least polluted to the most polluted category.

Chang *et al.* [54] developed a satellite-based cyber-physical system for the smart treatment of wastewater. The model was used to collect a large amount of information concerning water quality with remote sensing technologies. Also, the model was capable of providing early-warning responses to aid immediate recycling of wastewater and promoting the quality of the water body. They believe that this model would improve the sustainability of the urban infrastructure by enhancing communication between the drinking water supply and wastewater treatment.

Asian *et al.* [55] presented a study on monitoring the quality of water within the MENA region by implementing nanosatellites. The research is aimed at providing a cost-efficient means for monitoring water quality while encouraging real-time transmission. They believe that the project would promote technical and scientific collaborations between the teams in the involved regions. Sukojo and Sianipar [56] proposed the use of satellite imagery for analyzing water pollution in River Lamong Estuary, Surabaya. They sought to improve the quality of water in the region as the increasing number of industries in the region led to water degradation. The results of the study proved that there were contaminated areas in the region and with the aid of satellite imagery; they were able to map out those areas for management and control.

Park *et al.* [57], proposed the use of LANDSAT to estimate storm-water pollutant loads in situations where information is not available in case of water-storm specific to certain locations. In such situations, satellite imagery is the best method to use. It was obtained from the study that land use has significant effect on water pollutant loading on storm specific sites. It was concluded that the land use data is very vital to estimating storm-water pollutant loading in a water shed. Rei Liu *et al.* [58], conducted research on the use of satellite remote sensing for monitoring water environment by using the UAV platform. The aim of the study was to monitor water bodies using a space-earth based integrated monitoring system. It was observed from the study that the proposed method aids in the prediction of environmental risks associated with water bodies.

2.3. Natural Disasters

With the advent and continuous developments in satellite technology such as remote sensing technology, Geographic Information Systems (GIS) etc., a major environmental hazard, one that occurs naturally, one which is referred to as natural disaster, can be monitored, and possibly predicted in other to reduce the damage that occurs due to this event. These natural disasters have a strong impact on the economy of the region they occur [59], so it is important to monitor and possibly avoid them, and to reduce the damage that could be done via prediction when possible. Remote sensing plays a unique role in the survey and monitoring of natural disasters, especially geologic hazards, with the advantage of producing visual results that aid in the extraction of disasters information [60]. Earth observation data is an asset of great value in the Disaster Management sector [60] [61] [62]. The orderly application of earth observation satellites guarantees the delivery of images and geospatial information of an area affected by an occurrence of a natural disaster and a quick response by appropriate response teams [63] [64] [65].

Furthermore, Natural disasters can be categorized into volcanic eruptions, earthquakes, flooding and wind disasters. Discussions on the application of satellite communication in mitigating these categories are presented below.

2.3.1. Volcanic Eruptions

Nicola Pergola *et al.* [66] in their paper, Robust Satellite Techniques for monitoring volcanic eruptions were able to use a satellite-based method to detect and monitor atmospheric aerosol emitted by volcanic eruptions, while almost eliminating the problem of false alarms. The method proposed in their paper had the advantage of potency in identifying abnormalities in a field amidst highly variable surface background as well as its inherent exportability not only on various geographic areas but also on various satellite instrumental packages. Verity *et al.* [67] and Emiliano *et al.* [68] carried out similar research with similar results.

2.3.2. Earthquakes

Tramutoli *et al.* [69] in their paper, Robust Satellite Techniques for remote sensing of seismically active areas used a similar approach for detecting thermal abnormalities possibly associated to the seismic event under study and to monitor geophysical activities which could possibly lead to earthquakes. A minimal number of false alarms were also achieved using this approach. Bhardwaj *et al.* [70] reported abnormalities in the data on Land Surface Temperature (LST) before an earthquake derived from satellites but could not pinpoint this factor as a precursor for earthquakes as the data set varied greatly. Marchetti and Akhoondzadeh [71] worked towards inspecting the seismo-ionosperic abnormalities during the strong Mexico earthquake of 08 September 2017 using electric field instrument, absolute and vector field magnetometers on board each swarm satellite to show a clear anomaly so as to identify precursors to earthquakes.

Korepanov [72] in his research worked towards the possibility of detecting earthquake precursors using CubeSats, Ryu *et al.* [73] in their research carry out an investigation on the ionospheric data measured via the CHAMP and Demeter satellites for precursory signatures associated with large earthquakes. Feng *et al.* [74] used the Global Positioning System (GPS) and Synthetic Aperture Radar Interferometry (InSAR), RADARSAT-2, ALOS-2 and Sentinel-1A to model both co- and post- seismic faulting characteristics on the subduction interface of central Chile. Tazio *et al.* [75] worked on something similar. Kaku *et al.* [76] presented actions on the Japan Aerospace Exploration Agency (JAXA) and took, in collaboration with both home-based and foreign institutions accessing local post-earthquake conditions using Advanced land observing satellite (ALOS) with 3 remote sensors: the Panchromatic remote-sensing instrument, the Advanced visible and near infrared radiometer type 2 and the phased array type L-band synthetic aperture radar, to have satellite images engaged in disaster measures by users in cases of emergency.

2.3.3. Flooding

Although Ovando *et al.* [77] came to the conclusion that flood mapping would not be of much use in areas of dense vegetation, there have been headway breakthroughs in the use of satellite data for flood mapping in other regions. Amil *et al.* [78] worked on building up a geodatabase for natural disaster management, while channeling their focus on the river flood impact, using satellite data accessed by Remote Sensing integrated into Geographic Information Systems (GIS). This was achieved via a method of boundary definition and identification using ArcGIS software within the data processing of space images, with advancements in the GIS technology. Their work implies that data processing makes classifying boundaries with high accuracy achievable. The data cumulated show climate circumstances for the appropriate period of investigations to existing relationships between river flooding and the climatic parameters for the selected area. The developed database creates resources and opportunities for the prediction and reduction of the damaging impact of natural disasters due to the timely implementation of appropriate engineering and technological activities. Xueliang *et al.* [79] used a chain of flood phenomena maps between 1989 and 2014 generated via remote sensing technology in Landsat imagery to access recent flood patterns. Umar *et al.* [80] tried to accentuate the case study of the condition of the Watershed Kuranji River experiencing flash floods, via remote sensing satellite imagery and Geographic Information System (GIS) and try to figure out if the flood occurred due to extreme rain or collapse of existing natural dams in the upstream of the Kuranji River. Rao *et al.* [81], Veerakachen and, Raksapatcharawong [82], Khan *et al.* [83], Monowar *et al.* [84], also showed that the data collected via remote sensing technology and geostationary meteorological satellites prove useful in flood monitoring. Sifan *et al.* [85] combine the use of SPI and TWI to develop spatially distributed scaled map for early flood warning.

2.3.4. Wind Disasters

Wind disasters occur in various forms, for example the wind associated with typhoon increases sedimentation of the suspended particle concentration [86], erosion can be caused by the tsunami wave [87]. Hereher [88] in his research used Remote sensing of images as data gathered from five meteorological stations to examine the drifting sand and dune activity, it was made clear that wind and topography are the major causes of sand drift in the north. Sand dunes can be clearly observed in the Landsat images, this would help in warning against sandstorms. Folmer *et al.* [89] presented that Polar-orbiting and geostationary satellites are essential for the monitoring and prediction of extratropical transitions and tropical cyclones. It is observed that satellites were used to monitor and predict hurricane sandy in 2012, Satellite observations enabled government officials and rescue agents to rescue and save as much life and property as possible.

Li *et al.* [90] gives insight on disaster assessment from a remote sensing orientation, via the use of google earth images over various dates, checking for variations at particular sites that were affected by hurricane Katrina. Landsat data showed that efforts have been undertaken by many civil engineers in the city of New Orleans to prevent future disasters. Han *et al.* [91] analyze storm surges in Florida, with the aid of satellite altimetry with tide-gauge data for storm surge predictions to minimize damages. Al-Amin *et al.* [92] in their study recommend the use of post-classification variation detection technique, via object-based image investigation using optical imagery up to 30 meters resolution for storm collision classification and recovery.

2.4. Waste Management

Waste is by products of a useful material that are no longer required or useful. There are numerous types of waste but the most common are industrial waste, municipal solid waste, liquid waste, and gaseous waste. Although, Waste generation can be harnessed for economic growth of the nation, if it is not checked can result in pollution of the environment.

Sureshkumar *et al.* [93] made use of (Geographical Information System) GIS, to create a spatial map for the study area and integrated (Global Positioning System) GPS to locate the waste bins (the bins' longitude and latitude) as well as to track waste vehicle movements. Sensors are installed in the waste bins and connected to GSM modems; these sensors alert the relevant authorities when the solid wastes in the bins have exceeded certain thresholds. These alerts contain the location of the bins and other necessary information. The authors were able to achieve easier waste management as well as prevention severe of environmental hazards. The paper should have a monitoring portal for these sensors to improve the reliability of the waste management system.

Zaman and Lehmann [94] aimed at reducing waste management system to a more efficient system termed "zero waste practice". A challenge the authors faced is the benefits the case studies (cities; Adelaide and Stockholm) accrued as a result of waste generation and consumption. The "zero waste practice" proffered by the authors requires that the entire citizenry (consumers and industries) have a change of behavior or attitude to waste; there should be educational programs to create the necessary awareness. They should realize the importance of waste. However, they still suggested that there are more areas that we need to know about, and researchers should pick interest in studying such as how human behaviors can affect urban waste management, or how cities can employ technologies towards become zero waste cities.

2.5. Climate Change and Weather Prediction

Einaudi *et al.* [95] studied and researched issues that exist today in the full usage of satellite information to enhance weather and climate conjectures and we propose recommendations to solve them. The technique for providing this progress was presented to them by the National Polar-Orbiting Operational Environmental Satellite system (NOPESS) Preparatory Project (NPP). Basically, the paper explained about the status and the problems of the satellite and clarified using graphs and recommendations how it could be used to its fullest to help enhance and improve weather forecast.

Carlos *et al.* [96] studied satellites as an important instrument in the present observation of environmental climate change as they give estimation of earth over decades with a significant high spatial resolution. Satellite estimations of ocean surface temperature are a crucial part in the examinations of global warming 1 and its effects. Altimeters and gravity missions, for example, GRACE are utilized to gauge sea level ascent at worldwide and provincial scales. A variety of satellite sensors (microwave and visible radiometers, scatterometers, SAR, gravity sensors, altimeters, etc.) are utilized for following the melting of sea ice and mainland ice over the polar areas and Greenland.

Jin *et al.* [97] researched satellite imagery as it gives distribution data of cloud in a large scope of spatial and temporal scales. The paper studied how to enhance the precision of climate forecasting and improving the adequacy of atmosphere monitoring.

Narayan *et al.* [98] researched on Potential inescapable effects of climate change and the regularly rising interest of water because of developing industrialization and urbanization have expanded drought incidence rate, recurrence, and seriousness as of late. It is obvious that drought monitoring and early alerts require vigorous precipitation assesses over space and time. Such information is difficult to acquire using just ground estimations, as it is difficult to introduce and keep up a system of rain measure stations giving constant high-resolutions rainfall information. Subsequently, rainfall gauges dependent on satellite estimations are turning into an exceptionally alluring alternative, as they give constant spatial estimations of the rainfall field. This paper therefore seeks for the improvement in the instruments used for rain measurement and rain predictions.

Petra *et al.* [99] based their paper on two topics: the possibilities of satellite-based automatic detection of overshooting convective cloud tops and the connection between the overshooting and occurrence of severe weather on the ground. Some part of this research is focused on proving whether the outlook of the overshooting top, a manifestation of a very powerful updraft in the sky, can be connected to an abrupt change of certain weather elements on the ground. For example, according to Ibiteye *et al.* Oil and natural gas generate about 97% of the Nigerian foreign exchange revenue as of today [100] which makes waste management system a beneficial one.

3. Conclusion

Satellite communication has positively impacted the world via its implementation in various aspects. Initially, satellite communication was employed for communication purposes but aside from meeting communication needs, it has proven to be proficient in remote health service delivery, e-learning, e-governance, environmental hazard control and many others. In this paper, we have presented valid convictions as to how satellite communication can be implemented in environmental hazard control, thereby contributing to the attainment of the AU Agenda 2063 aspirations. Environmental hazards were categorized into different sub-sections namely, pollution, waste management, natural disasters, and climate change. Furthermore, we made thorough reviews on the application of satellites in detecting, monitoring, and mitigating such hazards. The study highlighted various techniques and methods employed in environmental hazard control which Robust Satellite Technique and the Remote Sensing Technique proved to be the most efficient and commonly used. Finally, this study showed that continuous improvements in satellite capabilities would eventually lead to timely achievement of the AU Agenda aspirations.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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