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Benefits of Remote Sensing for Environmental Monitoring

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ABSTRACT

Remote sensing has emerged as a critical tool for environmental monitoring, providing comprehensive and timely data for various ecological and disaster-related applications. This review examines the diverse benefits of remote sensing in environmental observation, particularly in the domains of disaster monitoring, climate change assessment, forest area surveillance, and air quality management. The study highlights the role of remote sensing in tracking hydrometeorological disasters, global temperature variations, and extreme weather events, enabling proactive responses to climate-related challenges. Additionally, it explores its application in forest monitoring, including land and forest fire detection and biodiversity assessment. Furthermore, the review discusses how remote sensing contributes to air quality and health monitoring, specifically in detecting air pollution and identifying potential outbreaks of infectious diseases. By synthesizing recent advancements and case studies, this paper underscores the significance of remote sensing in supporting sustainable environmental management and disaster preparedness. Future research directions are proposed to enhance the accuracy, accessibility, and real-time application of remote sensing technologies

INTRODUCTION

Remote sensing is a method of analyzing an object by not directly touching the physical object, one of the ways is by using satellites. Systems in sensing generally use solar power as a source. This passive system can operate during the day if it uses a light beam, it can also operate during the day and at night if it is used thermal power. With image data, it will be easy to interpret and further analyze so that it is more effective, for example, the use of satellite imagery for temperature measurement, rainfall, pollutant particles in the atmosphere and regional mapping. Regarding area mapping, this can be a weakness of sensing in systems with low spatial resolution, where the required wavelength is also getting larger. The electromagnetic spectrum in the sensing system to arrive at the receiver sensor is affected by the atmosphere. Electromagnetic energy in sensing that is very effectively utilized is the visible (VIS) and infrared (IR) wave spectrum with a wavelength of 0.4 micrometres to 0.7 micrometres. The interaction between electromagnetic energy and the atmosphere affects the achievement of solar radiation that reaches the earth's surface, namely the source of energy, the atmosphere, the interaction between energy and objects, sensors and vehicles, data acquisition, and data users. For example, the benefits of sensing for life, namely the benefits of sensing in the field of meteorology and climatology for weather detection using weather satellites by utilizing visible and infrared waves to interpret cloud coverage, cloud type, cloud peak temperature, moisture in clouds, air pressure, and can also monitor rain from temperature/thermal power sensors, the water content in the air and further processed with colouring techniques.

LITERATURE REVIEW

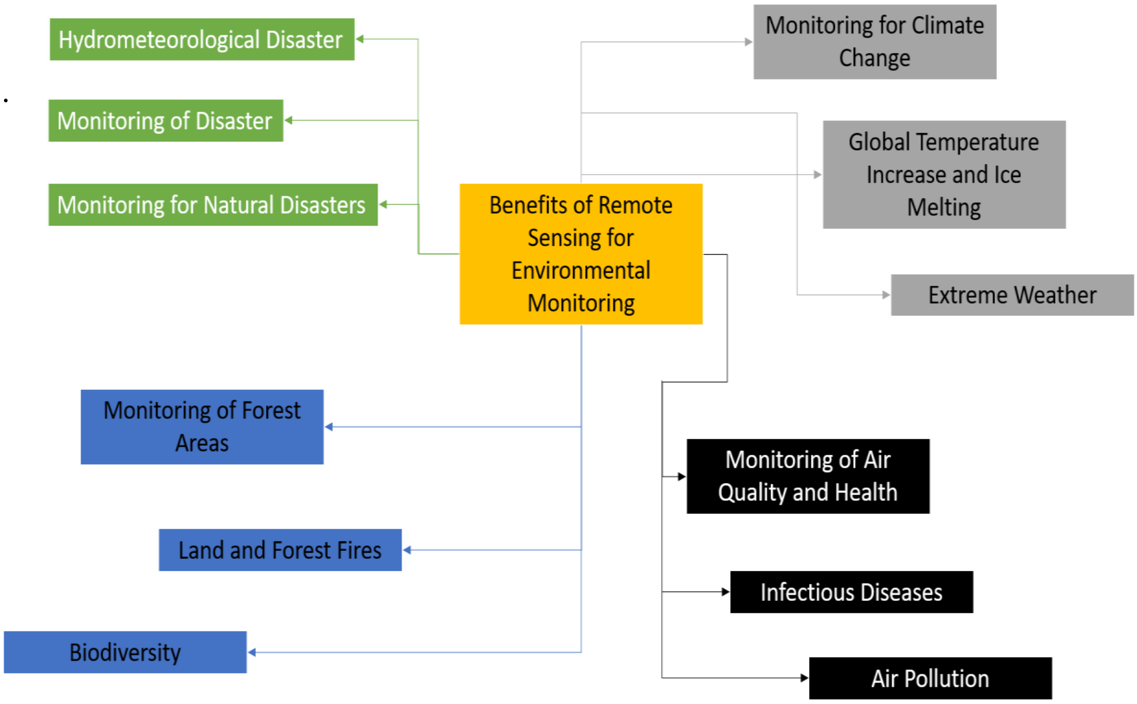
This research employs a literature review approach to examine the theme of the utilization of remote sensing for environmental monitoring. A literature review is conducted by collecting, analyzing, and synthesizing various scientific literature, research reports, and policy documents relevant to this theme to understand the development and application of remote sensing technologies in environmental observation. The sources used include academic journals, books, and publications from government agencies and international organizations, as well as technical studies related to remote sensing applications in disaster management, climate monitoring, forest conservation, and air quality assessment. Through this method, this research aims to identify key trends, challenges, and potential advancements in remote sensing, particularly in enhancing data-driven environmental monitoring and decision-making.

METHODOLOGY

This research employs a literature review approach to explore the utilization of remote sensing for environmental monitoring. The methodology involves systematically collecting, analyzing, and synthesizing scientific literature, research reports, and policy documents relevant to remote sensing applications in environmental observation. The literature review process begins with determining the research theme, followed by identifying and selecting previous studies, journal articles, government reports, and technical publications as data sources.

The selected literature is categorized into subthemes that align with key aspects of remote sensing for environmental monitoring, including disaster monitoring, climate change assessment, forest area surveillance, and air quality analysis. These subthemes serve as the foundation for data synthesis, allowing for a structured analysis of the latest advancements, challenges, and applications of remote sensing technologies in environmental management.

A thematic analysis is conducted to draw connections between different studies and identify patterns in remote sensing utilization. The findings are then synthesized to provide a comprehensive understanding of the role of remote sensing in supporting sustainable environmental monitoring and disaster preparedness. This approach ensures a thorough and structured examination of the topic, highlighting the significance of remote sensing in data-driven environmental decision-making.



Source: Processed by the Researcher
Figure1. Brainstorming Scheme of this Research

RESULTS AND DISCUSSION

1. Monitoring of Forest Areas

Through the development of current sensing technology, satellite scanning algorithms, both geostationary satellites and polar orbital satellites, have been widely used for various types of needs in various sectors of life, one of which is as an environmental monitor. Sensing using satellites, offers sensor tools intended for detecting forest and land fires by observing, detecting, managing, and analyzing observed objects. Hot spots or hotspots are obtained by the manifestations of the detection of heat, light and smoke plumes produced by fire. These hot spots can be obtained from observation using low-resolution or high-resolution image detectors. Hot spots detected using low-resolution imagery provide information in the form of coordinate points, object locations, spatial distribution, and fire temporal so that if it is set with a certain heat value limit, conclusions can be drawn whether the object is in the category of fire point or whether a fire or combustion has occurred. Then if the hot spots detected use high-resolution images, it can accurately and more comprehensively contain information other than the location of the fire point/burn area, it can also contain information about the type of land cover affected. The land cover map obtained from this sensing uses reflectance marks from various types of land cover. The heat emitted by an active fire can be detected with an infrared (IR) sensor where this procedure is called hotspot detection. It has been mentioned that satellites can be used for the manifestations of heat, light and plumes of smoke (Estes et al., 2007). The first manifestation is heat, starting with heat monitoring or heat emission where the amount of thermal radiation emitted by a black object on the surface with a certain wavelength where the wavelength depends on its temperature, the temperature seen or received by the satellite will be translated based on its brightness level and the spectral value of the emitted emission can be calculated using Planck's equation. Another type of monitoring manifestation is light, starting with light emission with DMSO-OLS imagery which can also be used to analyze fire points by scanning to form a time series of black objects which are then analyzed to produce a set of stable values in one location to see consistency, which means that it will show the fire point obtained from identifying if there are heat or light values that are outside the set of stable values.

Then the next manifestation of smoke plumes. This can be identified visually or can also be done by using the RGB technique or colouring, which is a technique of fusing primary colours, in the image as a line or tinge of white but slightly blurry and usually has a cone-like formation that fuses and leads to a point on the ground and is associated with the direction of the wind at the height of the smoke source. This information on the location of the fire point and wind direction can provide early warning or early action against the possibility of the spread of haze to the surrounding area. For example, in NOAA AVHRR satellite imagery, high-resolution satellite imagery, the location of the origin of the fire can be obtained from plumes of smoke that look very dense and spread far from the active fire point. The determination of the type of land cover affected can also be used as supporting information for anticipatory actions to extinguish fires after a fire occurs and to formulate short-term management of burning actions.

2. Monitoring for Climate Change

The next use of sensing for the environment is for climate change monitoring which manifests in global temperature increases and melting ice or glaciers as well as increasing the frequency of extreme weather events. Specifically, it will be discussed about the elements of melting ice or glaciers due to rising temperatures globally. Glaciers have been widely proposed by experts in the field of meteorology as one of the indicators of climate change with the phenomenon of increasing global temperature because glaciers contain almost 2/3 of the total area of fresh water in the world (Hamilton et al., 2020), so changes in the volume of glaciers are said to change the area of sea level. The most obvious change in glacier area is the shrinking of the glacier's mass balance from the retreat or advance of the glacier's front boundary. It can be seen with satellite imagery. Sensing using satellites on objects such as snow is obtained using visible (VIS) and infrared (IR) wavelengths. This electromagnetic wave spectrum has been used by sensors for a long time in applications of NOAA Advanced Very High-Resolution Radiometer (NOAA AVHRR) and Landsat Multispectral Scanning (MSS) satellites. The manifestations used in the detection of snow objects with optical wavelengths are surface reflectance, surface temperature, water/liquid content, and snow diameter. Optic sensing based on the manifestation of snow surface reflectance with air sensors as well as with space sensors relies on the sun as an energy source or source of radiation. With the mechanism of solar radiation emitted having passed through the atmosphere until it reaches the surface/snow, then some of it is reflected through the atmosphere and reaches the sensor, this back-and-forth radiation emission can be measured. Generally, snow is made up of several forming layers that metamorphose over time until homogeneous ice crystals are formed but depend on the meteorological conditions that form them. Sommerfeld and LaChapelle (1970) have proposed a classification of snow that is differentiated based on the basic type of metamorphosis, namely temperature gradient metamorphosis and temperature equilibrium metamorphosis. In the mechanism of a metamorphosis of temperature equilibrium, the thawing process causes a rapid change in the ice crystal crystals into clusters of wet grains and the ice freezing process causes the crystals to become more rounded. In general, ice crystals that tend to be drier and denser will appear darker in SAR satellite images, because the absence of surface melting and the small diameter of the snowdrops cause relatively low scattering values and show small volumes.

The homogeneous snow surface can be translated into homogeneous reflectivity, where the brightness level obtained in each pixel can be converted into a surface slope value, according to Bindschadler and Vornberger, (1994). Currently, research efforts are being intensively carried out to make maps of the slope and changes of the coast and glaciology on all surfaces in Antarctica using satellites, such as the Landsat satellite which is currently making this observation. It also uses SAR to examine changes in fluctuations or shifts in the front boundary of glaciers in Antarctica with a comparison of satellite imagery from different years. In addition, along with the rapid development of technology the manifestation of various advanced tools and the assistance of space instruments, multisensory sensing is used in the detection of terrain, for example, frozen rivers and lakes. This effort is considered to have a more significant contribution to the detection of water bodies in the Northern Hemisphere (BBU) and the impact of environmental change variability in the world.

3. Hydrometeorological Disaster

Environmental monitoring can also be detected by utilizing sensing, namely natural disaster mapping. The natural disasters discussed here are types of hydrometeorological disasters or disasters caused by weather factors such as floods (Gosset et al., 2023). Globally, floods are one of the disasters with the highest destructive contribution (Shakeel et al., 2021). If we talk about the scope of Indonesia's territory, Indonesia's maritime continent is the centre of atmospheric circulation activities as well as global ocean circulation. More than two-thirds of the maritime continent is an ocean that greatly influences climate patterns. Not only activities that directly come into contact with the sea, but also life on land. Currently, the world is facing a serious threat to the impact of global warming where the ocean plays an important role in other cases today we do not deny the strong influence of ENSO dynamics such as El Nino and La Nina on the climate of the maritime continent and concerns almost all aspects of life from agriculture, forest fires, water and energy resources, food security and so on (Chin Soo, 2001). Historically, Indonesia is a country that has a high potential for hydrometeorological disasters. The potential for disasters in Indonesia is relatively occurring throughout the year. These various threats make Indonesia a country that is very vulnerable to the threat of natural disasters. Therefore, adequate knowledge is needed to be able to see the impact and try to prepare mitigation measures where disaster risk reduction is the responsibility of all parties in Indonesia. From disaster data obtained from the National Disaster Management Agency (BNPB), the trend of disaster events from year to year (from 2011 to 2021) shows an upward graph which means the number of disaster events is increasing every year, where the largest contributors to disaster events come from the number of flood events, extreme weather, landslides, forest and land fires, drought and tidal waves/abrasion. Then as of June 4, 2022, the number of natural disasters that have occurred in Indonesia is quite large. A total of 87 incidents of forest and land fires, 1 drought incident, 681 floods, 317 landslides, 621 extreme weather events, and 8 tidal waves/abrasion, with a total of 1,726 incidents.

The occurrence of natural disasters or hydrometeorological disasters often has a significant impact on human life activities, where a total of 23,891 houses were damaged, a total of 638 facilities were damaged which included education, worship and health facilities, then a total of 70 offices were damaged and 86 bridges were damaged so that they could not operate again. Not a few property losses and loss of life occurred. And ironically, all regions of Indonesia are not spared from hydrometeorological disasters/natural disasters. Satellite data that is often used as a source of depiction of flood areas is optical data and Synthetic Aperture Radar (SAR). Optic data uses visible (VIS) and infrared (IR) wavelengths, but this type of observation uses sensors that require radiation/sunlight and are free from the presence of clouds because they will be an obstacle. Then SAR uses a sensor that sends microwave signals to the surface and measures the scattering of signals returning to the sensor, SAR can shoot through the clouds so that it is relevant for mapping flooded areas (Wilson et al., 2016). The weakness of this optical and SAR data is that if the flood event that occurs is relatively short, it may be missed because the monitoring carried out sometimes requires repeated scanning time to obtain one portrait/image result.

4. Monitoring of Air Quality and Health

Another interesting link related to the use of environmental sensing is air quality monitoring and its relationship with the health sector. Each country must place air quality observation devices tightly and determine healthy or normal air quality limits in their respective regions. Space satellites that are currently in operation have three main instrument manifestations, and each sensor has its own purpose. One sensor is for monitoring the behaviour of air mass flows, one sensor is for monitoring clouds and aerosols or particles floating in the atmosphere, and the other is for monitoring the main components of the Earth's atmosphere globally including aerosols and ozone. In an article written by Nizantri et al. in 2011, it was mentioned that MODIS satellite data has been able to utilize its sensor tools to analyze the relationship between the thickness of optical aerosols (AOT) and PM10 concentrations, which are commonly used as pollution indicators (Themistocleous et al., 2012). AOT uses a Moderate Imaging Resolution Spectroradiometer (MODIS) sensor where the image results show solar radiation that enters with aerosols in an atmospheric column and the vertical profile of the aerosol coefficient. Satellite sensing is a passive tool that can be used as a tool to monitor air pollution and its impacts both temporally and spatially (Bilal et al., 2020). To monitor pollutants, satellites are used for the detection of fairly subtle threats such as nitrogen dioxide (NO2) and fine particles (PM2.5) suspended near the earth's surface. The concentration of pollutants such as NO2 has significant indirect impact implications on public health even in the short term, this NO2 pollutant can harm health, and trigger various effects of respiratory disorders, then particulate pollutants such as PM2.5 are not spared from dangers that threaten public health where high levels of this substance can have an impact on the cardiovascular and respiratory systems and are average in the field Heart and lung health – Depat causes premature death (Seltenrich, 2014).

Talking about the benefits of sensing for the detection of poor and disruptive air quality, satellite data/sensing can also be utilized to predict infectious outbreaks such as malaria. Where the rain phenomenon is one of the main triggers for the spread of this disease outbreak because rain gives rise to a domino effect from the start of the mosquito life cycle by creating breeding grounds. In some regions in other hemispheres, the weather element of air temperature is also the main trigger in the spread of this disease outbreak, for example in Kenya, where the region is known as a cool area if there is a drastic increase in temperature or temperature, it can be associated with an increase in the risk of easy and fast transmission of the epidemic. By utilizing spatial satellite image data, it is possible to calculate the malaria epidemic forecast for the next 2 to 3 months with the calculation of the time series of temperature increase and rainfall distribution in each location. Pollutants such as Sox, Nox, and CO2 (Park et al., 2021) dissolved in rainwater produce acid rain. Air pollutants are also capable of triggering black crust and corrosion on rocks as well as on the walls of buildings, cultural heritage sites, and monuments. With spatial data or mapping of air pollutants in the atmosphere, it can be used as an early warning material or early action for local stakeholders in anticipating signs of further building damage caused by air pollutants on the surface.

CONCLUSION AND RECOMMENDATION

Along with the concept of balance, the more advanced technology develops, the more benefits can be taken and the development of technology provides implications for benefits not only for one specific sector but can contribute to all sectors of life, including its benefits as an early warning or early action. In the environmental sector, satellite data can be used a lot, one of which is to monitor air quality, forest and land fires, disasters, and climate change which are closely related to human activities. Take for example the use of satellite imagery to monitor hot spots with heat, light and smoke plume sensors. Then another use of sensing to map changes in glacier area as an indicator of climate change where there has been an increase in global temperature which has indirectly had a significant impact on ice melt in Antarctica. This can be observed with satellite imagery both temporal and spatially. These changes show the magnitude of the impact of climate change and trigger an increase in the frequency of extreme weather events. The domino effect also occurs from climate change in the number of natural disasters caused by climate and weather such as floods. Satellite data that is often used as a source of depiction of flood areas is optical data and Synthetic Aperture Radar (SAR). One type of space satellite has also been operated to monitor the movement of air masses, clouds and particles floating in the atmosphere, as well as major components of the Earth's atmosphere globally including aerosols and ozone. Air pollution can be observed specifically and later the data and information can help formulate a policy or decision in terms of early action or early intervention to prevent further infrastructure damage.

FUTHER STUDY

This research still has limitations, so it is necessary to conduct further research related to the topic of Benefits of Remote Sensing for Environmental Monitoring in order to improve this research and add insight for readers

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