Progress Review and Future Directions for Remote Sensing in Planetary Health

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Abstract: *Planetary health focuses the link between human well-beings and the Earth's natural systems. As the environmental pressures intensify, remote sensing technologies have emerged as indispensable tools for monitoring ecological changes, supporting sustainable development, and informing public health strategies. This review synthesises recent advancements in remote sensing applications for planetary health, contextualises it within the broader global research landscape. These includes water resource management, climate action, biodiversity, and land use, and propose future directions to enhance planetary health monitoring through Earth observation.*

Keywords: *Planetary Health, Remote Sensing, Sustainable Development Goals, Earth Observation, Environmental Monitoring*

Introduction

The notion of planetary health (PH) has gained popularity all around the world as a result of the consequences that mankind is in the process of experiencing. These consequences include climate change, the loss of biodiversity, pollution, and the utilization of resources in a manner that is not sustainable. To have a complete grasp of the ways in which the deterioration of the environment has direct and indirect consequences on human health as well as the environment, it is vital to have this understanding. It is possible to observe, measure, and analyze environmental indicators at a variety of scales by utilizing remote sensing, which can be carried out by satellite, aircraft, and unmanned aerial vehicles. This makes it possible to view, measure, and analyze environmental indicators. Through the usage of these technologies, the Sustainable Development Goals (SDGs), notably those that pertain to clean water (SDG 6), climate action (SDG 13), life below water (SDG 14), and life on land (SDG 15), are being monitored more closely.

Despite the increasing utilization of remote sensing technologies and data sources, a deficiency in coherence persists regarding the integration of these elements into frameworks for PH. It is possible to encounter challenges in a wide variety of domains, such as the development of technological competence, the transformation of observations into policy that can be implemented, and the collecting of data with a high resolution. Additionally, developments in data fusion, artificial intelligence (AI), and real-time analytics are creating rapid changes in the state of the art in remote sensing. These developments are causing technological advancements. This is a consequence of the lightning-fast pace at which technological growth is occurring. While these advancements bring about new opportunities, they also bring about new obstacles for monitoring the health of the planet. Both realities are brought about simultaneously. This article provides a review of the progress has been reported in main indexed-publications regarding applications of remote sensing for planetary health. In addition, progress in Malaysian's context is also added.

2. Applications of Remote Sensing to SDGs and Planetary Health

The concept of planetary health places an emphasis on the interconnectedness that exists between human well-being and the natural systems of the Earth, which is closely aligned with the Sustainable Development Goals (SDGs). SDG 3 (Good Health and Well-being), SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land) are among the most important Sustainable Development Goals (SDGs). Each of these SDGs has a set of measurable indicators, such as mortality rates for children under the age of five, climate-related disaster impacts, levels of marine pollution, and changes in forest area (RSIS, 2025; Zhao et al., 2025).

One of the most important aspects of tracking these indicators is satellite remote sensing (RS), which provides data that is both scalable and real-time, allowing for the monitoring of environmental and health-related parameters. It has been demonstrated that remote sensing technologies can directly support Sustainable Development Goal indicator tracking and planetary health goals as summarised in Table 1 (Pham et al., 2024; TraceX, 2025). Hashim et al., (2023) has made significant contributions to remote sensing applications in tropical ecology, water resource mapping, greenhouse gas monitoring, and coastal habitat assessment.

Table 1. Major applications of Remote Sensing for Planetary Health and Sustainable Development Goals

RS applications	SDG Targets & indicators	Planetary Health relevance
Urban heat islands & land use	SDG 11.6.2: Annual mean levels of fine particulate matter (PM2.5)	Tracks urban stressors affecting respiratory and cardiovascular health
Forest loss & biodiversity	SDG 15.1.1: Forest area as proportion of total land area; SDG 15.5.1: Red List Index	Monitors habitat degradation and zoonotic disease emergence
Climate indicators (temp, CO_2)	SDG 13.1.2: Number of deaths, missing persons and directly affected persons from disasters	Models climate-health impacts like heat stress and displacement
Water quality & hydrology	SDG 6.3.2: Proportion of bodies of water with good ambient water quality	Detects pollution and scarcity affecting disease risk
Crop health & food security	SDG 2.4.1: Proportion of agricultural area under productive and sustainable agriculture	Forecasts malnutrition and agricultural resilience
Marine ecosystem monitoring	SDG 14.1.1: Index of coastal eutrophication and floating plastic debris density	Assesses ocean health and fisheries collapse
Disaster risk & resilience	SDG 13.1.1: Number of countries with disaster risk reduction strategies	Supports early warning systems and health response

2.1 Remote Sensing applications for planetary health in Malaysia

In Malaysia, the application of remote sensing in the administration of water resources has contributed significantly to the improvement of a huge number of aspects of the health of the planet. Through the utilization of multi-temporal satellite imagery, Hashim et al. (2023) and Baiya & Hashim (2020) were able to estimate the changes in land use and the consequences that these changes had on water output in the Johor River Basin, Malaysia. Facilitating data-driven planning for water resources is a step forward achieving Sustainable Development Goal 6 (SDG 6). Landsat, MODIS, and Sentinel are examples of satellite missions that have made it feasible to monitor water bodies, droughts, and flood dynamics on a global scale (McCarthy et al., 2025). Additionally, UAV-based sniffer sensors were utilized for the purpose of measuring greenhouse gas concentrations in industrial zones for the purpose of conducting climatic and atmospheric research (Hashim et al. 2023, Ng and Hashim, 2023). This was done in addition to satellite-based air quality monitoring (Hashim et al. 2023; Yap and Hashim, 2013).

Remote sensing has proven beneficial for the surveillance of biodiversity and coastal environments. Hashim et al. (2022, 2019) conducted research on mapping seagrass biomass and blue carbon reserves using Landsat imagery, which supports conservation planning. Remote sensing has been employed globally to assess coral reef health, mangrove coverage, and habitat fragmentation (Zhang et al., 2024). In land use and geological mapping, Hashim employed hyperspectral imaging and machine learning to categorize lithological features and enhance long-term mining exploitation (Hjaj et al., 2024). Remote sensing is frequently employed to observe deforestation, urbanization, and agricultural activities, along with their associated ecological impacts (Yeoh et al., 2017).

A notable domain where remote sensing could contribute is disaster risk mitigation. Pour and Hashim (2017) and Etim et al. (2023) utilize high-resolution satellite data for kinematic analysis of landslides, which corresponds with the emphasis of SDG 11 on early warning systems.

Methodology

In recent years, there have been significant advancements in methodologies that have significantly improved the accuracy and breadth of applications for remote sensing. Examples of common applications of machine learning and deep learning include the classification of images, the discovery of objects, and the search for changes (Ahmad & Jhara, 2025). By including data from ASTER, Sentinel-2, unmanned aerial vehicles (UAVs), and ground stations, multi-sensor integration brings about an increase in the reliability of the data as well as an improvement in the spatial and temporal resolution. In order to gain an understanding of how ecosystems function and how the climate is changing, it is vital to be able to observe seasonal and long-term changes in the environment. Time-series analysis makes it feasible to see these changes. In the present moment, researchers and policymakers are able to obtain and analyse data thanks to cloud-based tools such as

Google Earth Engine. Consequently, this opens up the field of remote sensing to wider applications .

3.1 Future directions of Remote Sensing applications in planetary health

Advances in technology and the pressing need for scalable environmental-health surveillance are putting the future of satellite remote sensing (RS) in planetary health is indispensable. RS application is expected to be a foundational tool for urban epidemiology, climate resilience, and precision public health, according to high-impact studies. To enable granular assessments of pollution-health links, next-generation RS platforms will merge atmospheric exposure research with urban morphology analytics, as highlighted by Tian et al. (2023). Xu et al. (2022) note that RS is becoming increasingly important in disease transmission, vector habitats, and climate-induced health hazards. The hyperspectral imaging, data fusion with artificial intelligence, and real-time worldwide monitoring systems are all contributing to these advancements, which are presented in Table 2 (Springer RSES, 2025). With the growing severity of global health issues including heat-related mortality and zoonotic spillovers, RS will transition from being a mere observer to a proactive decision-support system.

Table 2: Projected Remote Sensing Applications in Planetary Health

Future RS Capability	Future Applications	Impact to Planetary Health	Refs
Hyperspectral imaging	Detection of soil and water contamination	Early warning for toxic exposure and disease risk	Tian et al., 2023
AI-driven RS data fusion	Mapping and modelling of urban heat and air quality	Fine scale mapping of health vulnerability zones	Xu et al., 2022
Real-time epidemiological mapping	Vector-borne disease monitoring and tracking (e.g., dengue)	Rapid response to outbreaks and spatial forecasting	MDPI, 2022
Climate-health risk modeling	Predictions of heatwave, flood, and drought.	Supports SDG 13 and public health preparedness	Springer RSES, 2025
Coastal and marine RS surveillance	Monitoring and prediction of Harmful algal blooms and fisheries collapse	Protects food security and marine health (SDG 14)	Tian et al., 2023
Urban morphology analytics	Built environment and respiratory illness	Informs urban planning for healthier cities	Tian et al., 2023

The future of remote sensing for environmental health has a number of exciting possibilities. Predictive models powered by AI can foretell shifts in ecosystems and lend credence to preventative management approaches. By collecting data from the ground and encouraging participation from locals, citizen science programs can supplement the use of remote sensing. Improved reactivity to environmental dangers is possible with real-time monitoring systems that use cloud platforms and Internet of Things (IoT) sensors. New possibilities for data collecting in varied environments are opening up because to emerging technology like autonomous drones, submersible vehicles, and wearable sensors. We can build comprehensive monitoring systems for the planet's health by integrating these with conventional remote sensing platforms.

3.2 Challenges and Limitations

There are still many problems, despite these advancements. When it comes to developing countries, data accessibility is a major issue because high-resolution data restrictions and advanced processing equipment can be quite expensive. However, practical constraints often impede ground-truthing validation, despite its critical importance. Since many regions do not have the necessary infrastructure and trained personnel to effectively employ remote sensing technology, technical capability is another impediment. Integrating socioeconomic and remote sensing data for comprehensive SDG monitoring, as well as PH application is also still a challenge. In order to transform ideas into practical strategies, collaboration across sectors and disciplines is essential when policy integration is limited. Following instructions will have to be adopted by authors of articles when they submit it to the conference:

Conclusion and Recommendation

Remote sensing is a cornerstone of planetary health monitoring. The reviewed previous works amongst others demonstrates its potential to support both SDGs and planetary health implementation and environmental stewardship. Future efforts must focus on technological integration, capacity building, enhance open-based data sharing and policy alignment to fully realise the benefits of Earth observation for planetary health.

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