Indian Farming 75 (11): 20-22; November 2025

Remote sensing applications in monitoring

and management of soil and water pollution

Krishan Kanahiya*, Parul Sundha and D. S. Bundela

ICAR-Central Soil Salinity Research Institute, Karnal, Haryana 132 001

Pollution of soil and water is major problem all around the world that effects the condition of ecosystem, agricultural productivity and well-being of human lifestyles. Traditionally, tracking and managing these problems require a lotof fieldwork, which can be laborious, time consuming and has limited both spatial and geographical coverage. A useful alternative is remote sensing, offers a promising alternative by making it possible to gather data from multiple sensors on a large scale and frequently. This article addresses the newest developments, methods and data types in the field of remote sensing, which investigates how remote sensing can be used to track and control soil and water pollution.

Keywords: Ecosystem, Remote sensing, Soil and water pollution, Tracking

INDIA has achieved tremendous progress in remote sensing technology, with numerous centres and organization devoted towards the applications, research and policy creation in this area. The supreme institute for space organization for space research is Indian Space Research Organisation (ISRO). It runs a huge network of earth observation satellite, which include CartoSat, ResourseSat and RISAT series, offer useful information for tracking the soil and water pollution. Its subsidiary organisations like National remote sensing centre (NRSC), Hyderabad and Indian Institution of Remote Sensing (IIRS), Dehradun play a crucial role for development of satellites and carrying out capacity-building initiatives. The Northern Space Application centre (NESAC) covers the specific requirements of the northeast region, whereas the Ahmedabad based space application centre (SAC) emphasized on sensor development. Remote sensing technology also used in research institute and agricultural universities like Central Soil Salinity Research Institute (CSSRI), Karnal and Chaudhary Charan Singh Haryana Agricultural University (CCS HAU), Karnal to investigate the water quality and salinity parameters including estimation of areas under salt-affected soils. Organization such National Institute of Hydrology (NIH), Roorkee and Central Water Commission (CWC) utilize leverage satellite data for hydrological modelling and real-time pollution monitoring.

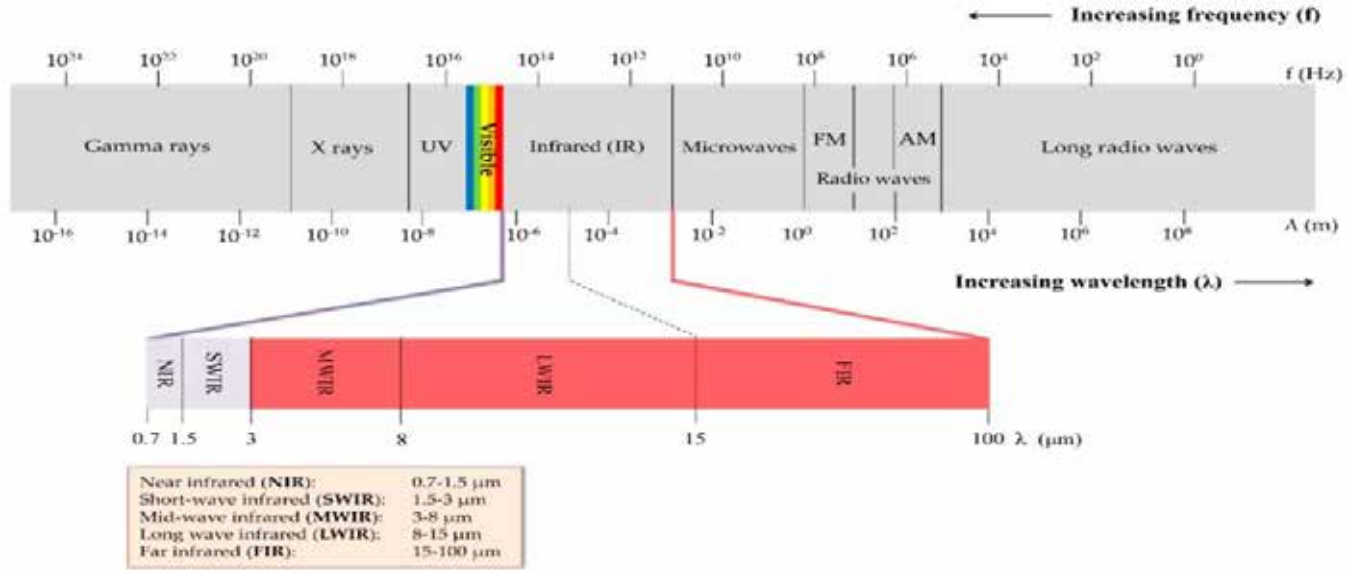
Principles of remote sensing in pollution monitoring

Remote sensing (RS) is a technique that collects data regarding the Earth's surface from afar, utilizing sensors affixed to satellites, airplanes and drones. It is based on detection and analysing electromagnetic energy that is absorbed or released by objects. Specific spectral patterns linked with pollutants or environmental changes may be helpful in the detection and quantification of soil and water contamination levels. Remote sensing collects hyperspectral, thermal and multi-spectral data that may be examined and processed for recognizing pollution anomalies.

Types of remote sensing data for pollution monitoring

Different data types are used in remote sensing applications for pollution monitoring, which have specific advantages to identify soil and water contaminations.

- ***Optical data:*** Visible and near infrared (VNIR) and shortwave infrared (SWIR) which have a wavelength (450—1350 nm) can be used to detect data for identifying vegetation indices, some soil contaminants and sedimentation. Amount of reflected sunlight captured by these sensors which changes according to the type and level of contaminants present.



Source: Image taken from: The basics of the electromagnetic spectrum: https://leadertechinc.com/basics-electromagnetic-spectrum/

This figure explain the electromagnetic spectrum with different wavelength and frequency, which are used in remote sensing applications for examining the surface characteristics of vegetation indices and thermal radiation.

- ***Thermal infrared (TIR) data:*** It detects temperature irregularities in water bodies that could be caused by thermal pollution or industrial effluent. When soil moisture or temperature characteristics changes, thermal infrared data identifies the organic pollution.
- ***Microwave and radar data:*** Synthetic Aperture Radar (SAR) and other microwave sensors can penetrate the cloud cover to gather information on soil moisture and structural changes in the terrain, which could point to chemical spills or other disruptions.

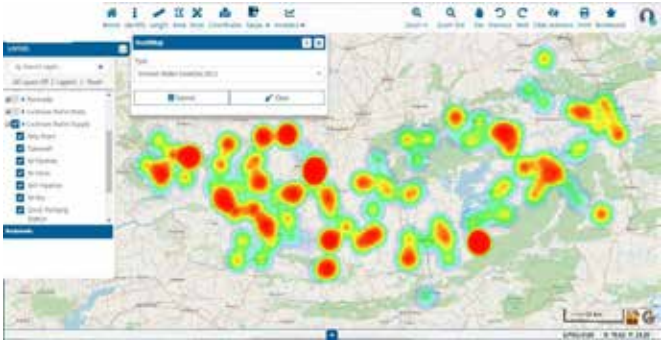
Applications of remote sensing in soil pollution monitoring and management

Remote sensing has numerous important applications that allows us for detection, tracking and manage soil pollution:

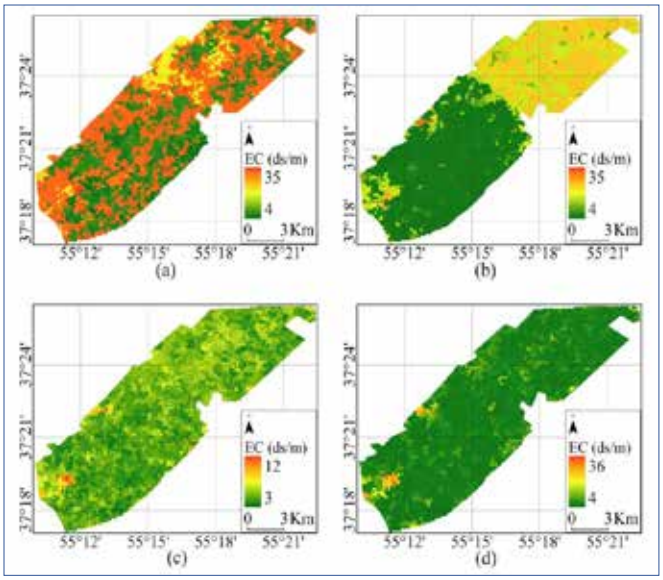
- ***Heavy metals and contaminants detection:*** Remote sensing can identify spectrum variations in soils that include heavy metals contaminants like cadmium, arsenic and lead. For this purpose, hyperspectral imaging work especially well because it can records wider spectrum of wavelengths. In particular, Sentinel-2 and Landsat imagery have been used to recognize unique spectral patterns of contaminated soils.

On the image, groundwater level monitoring using RS and GIS methods, red spots on the heatmap illustrates the critically low water levels, most likely as a result of pollution or over-extraction, while green spots denoting stable levels. These kind of visualizations are curtail for pinpointing the hotspot for groundwater stress and directing effective water resource management and pollution reduction strategies.

- ***Estimating the soil salinity:*** One common type of soil contamination that has a direct effect on agricultural productivity is soil salinity. Large-scale mapping and assessment of salinity levels are made with the help of remote sensing techniques, including those which evaluate reflectance pattern



Source: Image adopted from role of geo-spatial technology (GIS) in water resource management:https://www.sgligis.com/gis-for-water-resource/



Source: Image adopted from Scientific reports: A longitudinal analysis of soil salinity changes using remotely sensed imageries: https://www.nature.com/articles/s41598-024-60033-6

in visible and near infrared (VNIR) and shortwave infrared (SWIR) electromagnetic spectrum.

The figure represents the spatial distribution maps of soil electrical conductivity (ds/m). The colour gradient of map (a,b,c, and d) from green (low salinity), to red (high salinity) shows changes in the EC throughout the research area. These results illustrate how well satellite imagery helps to identify and monitor soil salinity at regional scales, supporting ecological management and precision farming.

- ***Monitoring agricultural runoff:*** Soil and water pollution can result in excessive use of fertilizer, pesticides and weedicides. By employing vegetation indices such as Normalised Difference Vegetation index (NDVI) to monitor the crop stress brought on by chemical usage or excessive nutrients, remote Sensing is able to track and detect the expansion of chemical contaminants from agricultural runoff.

Applications of remote sensing in water pollution monitoring and management

Remote sensing proposes numerous approaches to examine water quality, identify pollutants, and assess the ecological effects of water pollution:

- ***Observing suspended solids and turbidity:*** Higher level of suspended solids and turbidity often indicate water pollution from residue runoff, industrial discharges, or algal blooms. Remote sensors like MODIS and Landsat can monitor changes in water reflectance, helping perceive turbidity levels.
- ***Algal bloom detection:*** Harmful algal blooms (HABs) are a significant water pollution issue, often triggered by excessive nutrient runoff. Remote sensing can detect algal blooms and track their spread and severity by analyzing chlorophyll from satellite imagery.
- ***Revealing of organic and chemical pollutants:*** With the help of thermal and hyperspectral sensors certain pollutants can be identified due to their change in the thermal and spectral properties of water. Remote sensing not only track temperature anomalies but also indicates potential thermal pollution and water waste expulsion.
- ***Review of water quality parameters:*** Now a days, algorithms are developed to evaluate concentrations of turbidity, water quality indicators like chlorophyll-a, dissolved organic matter and many more of these parameters from satellite data, enabling real time monitoring

Advances in remote sensing technologies for pollution management

- ***Hyperspectral imaging:*** Advancement with time in hyperspectral sensors has provided high spectral resolution data, helping identification of precise pollutants and contamination types. With increase in spatial resolution the opportunity of hyperspectral imaging in distinguishing heavy metals and other pollutants is more precised.
- ***Unmanned aerial vehicles (UAVs):*** Drones equipped with high-resolution sensors are revolutionizing localized pollution monitoring by offering greater flexibility in data collection and enabling coverage of areas that satellites cannot reach.
- ***Machine learning in image processing:*** Introduction of artificial intelligence in remote sensing has significantly improved the accuracy of pollution detection in water. For instance, algorithms like Random Forest, Convolutional Neural Networks (CNNs) are being used to classify contaminated soils, map water quality, and assess pollution impacts.

SUMMARY

The monitoring and control of soil and water contamination through remote sensing, which provides an efficient and cost-effective method to access the environmental health on an extensive scale. Remote sensing is still developing and providing essential information for sustainable management and pollution control strategies from hyperspectral imaging to sophisticated machine learning algorithms. By combining remote sensing with field data and cutting-edge technologies, pollution problems can be managed more efficiently assisting with environmental protection and resource sustainability initiatives.

*Corresponding author email: krishantaneja24@gmail.com