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Remote sensing of water and soil environments

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Abstract
Water and soil resources mismanagement can create an adverse effect of escalating global poverty and also jeopardize the entire ecosystem. It can generate a significant cost to the environment. Even though not involved within certain 43,00 million hectares of geographic location, approximately 24% equivalent land surface of the earth is degraded land, also 1/3 global population, that is 2 billion people lack safe and affordable water for domestic purposes. Hence, taking the critical view to development of strategies is to identify the root causes of all the major problems. However, it requires a reliable and rapid information system that is indefinable due to the environmental complexity and the limited availability of the existing tools. Yet, the increased progress and availability of geographic data, remote sensing analysis tools can provide fresh possibilities to explore and monitor environmental inconsistency that influence key soil management and land use options. This review paper describes the prime constraints, explores the major concepts, the future remote sensing potential for mapping as well as to provide almost real-time features on water and soil quality in major land use context and practices deployed at the global level.

Keywords: Water quality, soil quality, remote sensing, mapping, sustainable resource management

Introduction

An Overview of remote sensing of water and soil environments

Sound assessment and reliable information methods concerning the ecosystem, mostly helps identify the correct indicators to assess changes that frequently occur in the ecosystem. Information regarding the available ecosystem can be gathered by ground based as well as remote sensing techniques. The data acquisition of ground-based method involves gathering in-situ data of field observations, while using remote sensing data collection method is based on the application of acquiring image data by different type of sensors. The technology of remote sensing is applied to gather data on unreachable or dangerous located sites, which are readily accessible by using ground methods. It is due to remote sensing helps collect data regarding the area at a distant location in the absence of direct contact with the location under investigation. Therefore, such information is usually acquired by interactive electromagnetic radiation measurements with the earth's locations, while the data are collected and maintained as images. This can be done by interpreting using GIS software. This is done by propagating Electromagnetic energy through space by means of waves, is featured by applying electrical along with magnetic fields. In several regions, remote sensing operates to provide by electromagnetic spectrum where, the spectrum, the UV portion provides the small wavelengths. The microwave and thermal regions have the larger wavelengths, which are practically used by remote sensing. Every spectrum band provides distinct information regarding the earth's characteristics (Kuenzer, *et al*., 2013) [13]. For example, thermal infrared provides microwaves and surface temperature to provide surface roughness information. The solar radiation, visible region is connected with various colors like green, red and blue spectra, which are known to be the principal visible spectrum colors.

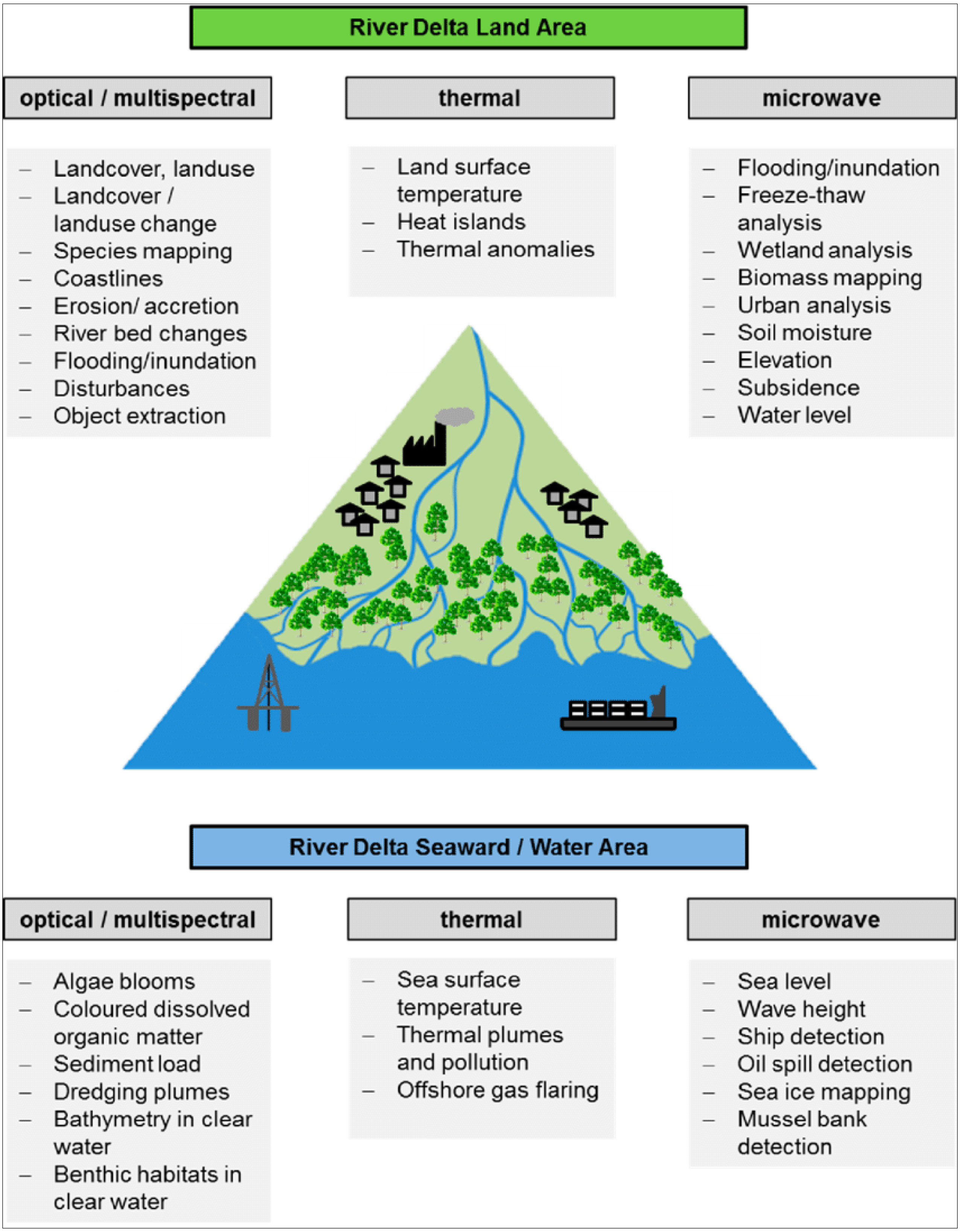

Fig 1: Remote Sensing of Land Surface Dynamics for the Large River Delta Region Quantification -- A Review (Kuenzer *et al*., 2019) [11].

Although, major advancements and innovation in this specific field have occurred recently, the earth observation from a distance was going on since long. The most noteworthy satellite-derived remote sensing started in 1972, when the NASA launched their initial civilian Landsat-1, remote sensing satellite, which cemented the process for the modern application of remote sensing in several disciplines. Presently, there is a requirement for sophisticated technologies in diverse areas like inventories, environmental monitoring, ecosystem management, biodiversity assessment and analysis of species-habitat suitability. Such technologies are based on different physical ecosystem parameters, social, economic positions in the community.

The recent climate trend and explicit impacts due to manifested transformations in sea level rise, temperatures and precipitations, have been compiled and categorized (Kuenzer & Renaud, 2012) [12].

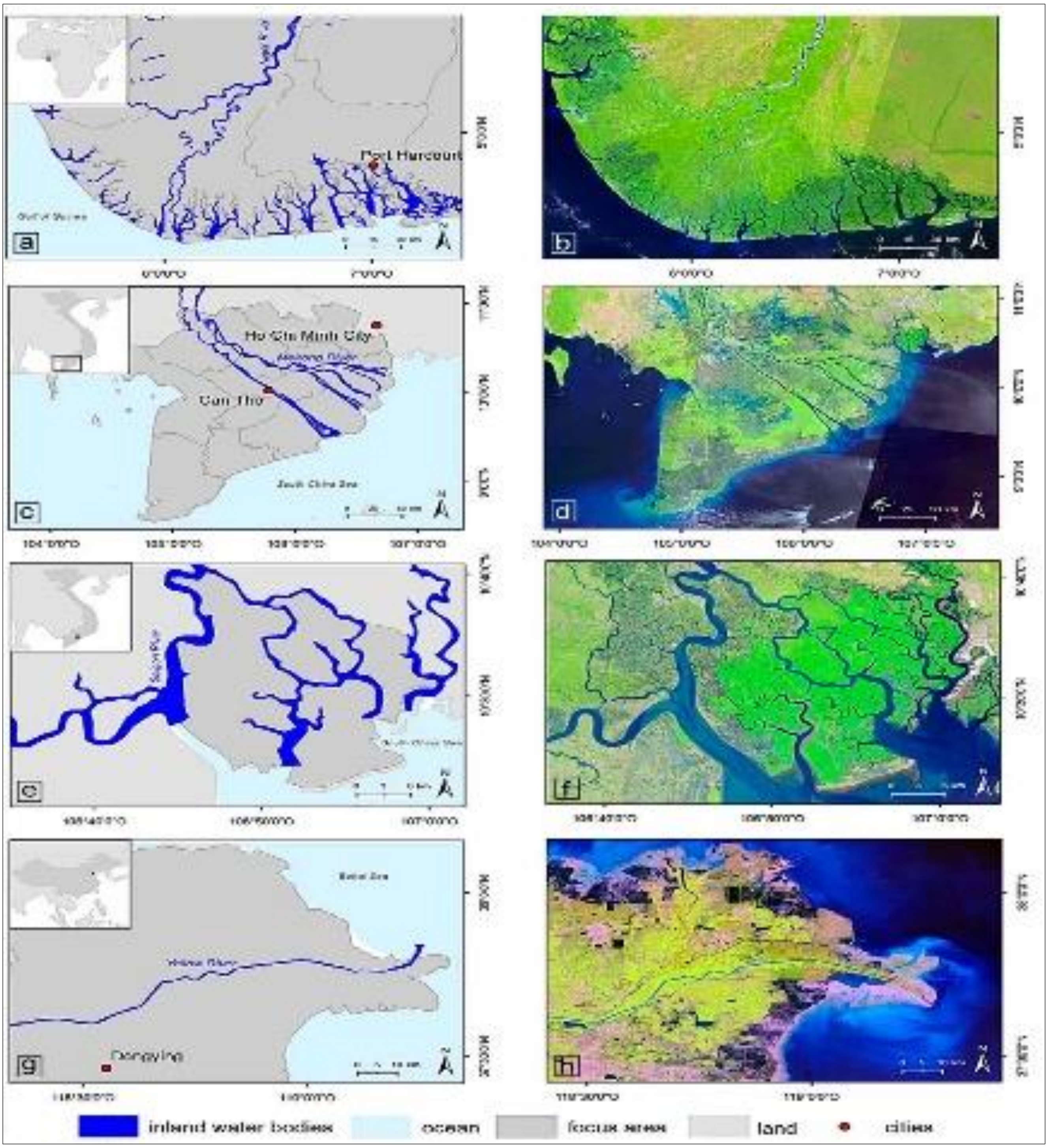

Fig 2: Large River Delta Region's Quantification of Remote Sensing, Land Surface Dynamics (Kuenzer, & Renaud, 2012) [12].

Hence, remote sensing is utilized to assess the ecosystem health in general by dynamically monitoring the earth's surface. NDVI- Normalized Difference Vegetative Index value is measured as a measured reflectivity ratio with the electromagnetic spectrum red and near infrared portions used to measure the vegetation covering of the earth. These bands of red and near infrared spectrum are selected because they are highly affected by the chlorophyll absorption and the green vegetation, surface (Kuenzer, *et al*., 2013) [13]. The investigation by ICARDA Scientists like Dr. Chandrashekhar Biradar showed the influence of food policies, cropping patterns and on the air quality and water over the past one decade. By Elsevier, they have published an open-access paper concerning the Global Environmental Changes. The remote sensing technological study was used in India, where country's one-fifth wheat is generated and paddy rice regions are increasing significantly (ICARDA Communication Team, 2021) [6].

From 2001 to 2018, depending on these observations made through multiple satellites, the scientists observed that the expansion of paddy rice enlarged groundwater depleted by almost 1.50 cm every year. The residue burning process was also amplified by 500%. These are main factors creating air pollution, which has augmented more than 32% in these areas (ICARDA Communication Team, 2021) [6].

Satellite observation indicated that groundwater protection policy enactment in the year 2009 considerably decelerated depletion of groundwater because of delayed harvest dates and rice planting (ICARDA Communication Team, 2021) [6].

Types of Sensors	Full Name	Manufacturer	Type	Scan System	Number of Bands	Spectral Range (μm)	Resolution (m)	Imaging Swath
AVIRIS	Airborne Visible Infrared Imaging Spectrometer	NASA Jet Propulsion Lab.	Hyperspectral	Whiskbroom	224	0.40–2.50	17	12 km and 614 pixels per scanline
HYDICE	Hyperspectral Digital Imagery Collection Experiment	Naval Research Lab.	Hyperspectral	Pushbroom	210	0.40–2.50	0.8 to 4	270 m at the lowest altitude
HyMap	in the U.S. known as PROBE-1	Earth Search Sciences Inc.	Hyperspectral	Whiskbroom	128	0.40–2.50	3 to 10	512 pixels
APEX	Airborne Prism Experiment	VITO (Belgium)	Hyperspectral	Pushbroom	Up to 300 VIS/NIR (114), SWIR (199)	VIS/NIR (0.38–0.97), SWIR1 (0.97–2.50)	2 to 5	2.5–5 km
CASI-1500	Compact Airborne Spectrographic Imager	ITRES Research Limited	Hyperspectral	Pushbroom	Up to 228	0.40–1.00	0.5 to 3	512 pixels per scanline
EPS-H	Environmental Protection System	Geophysical and Environmental Research Imaging Spectrometer	Hyperspectral	Whiskbroom	VIS/NIR (76), SWIR1 (32), SWIR2 (32), TIR (12)	VIS/NIR (0.43–1.05), SWIR1 (1.50–1.80), SWIR2 (2.00–2.50), TIR (8–12.50)	Dependent upon flight (minimum 1 m)	89°
DAIS 7915	Digital Airborne Imaging Spectrometer	GER Corporation	Hyperspectral	Whiskbroom	VIS/NIR (32), SWIR1 (8), SWIR2 (32), MIR (1), TIR (12)	VIS/NIR (0.43–1.05), SWIR1 (1.50–1.80), SWIR2 (2.00–2.50), MIR (3.00–5.00), TIR (8.70–12.30)	3 to 20 depending on altitude	512 pixels per scanline
AISA	Airborne Imaging Spectrometer	Spectral Imaging	Hyperspectral	Pushbroom	Up to 288	0.43–0.90	1	364 pixels per scanline
MIVIS	Multispectral Infrared and Visible Imaging Spectrometer	Daedalus Enterprise Inc., USA	Multispectral	Whiskbroom	102 VIS/NIR (28), MIR (64),TIR (10)	VIS (0.43–0.83), NIR (1.15–1.55), MIR (2.0–2.5) TIR (8.2–12.7)	3 to 8 depending on altitude	5.6 km at 4000 m altitude
Daedalus	Daedalus Multispectral Scanner (MSS)	Daedalus Enterprise Inc., USA	Multispectral	Pushbroom	12 VIS/NIR (8), SWIR (2), TIR (2)	0.42–14.00	25	714 pixels per scanline
HySpex ODIN-1024	HySpex hyperspectral cameras	Norsk Elektro Optikk (NEO)	Hyperspectral	Pushbroom	VIS/NIR1 (128), VIS/NIR2 (160), SWIR1 (160), SWIR2 (256)	0.40–2.50	0.5 m at 2000 m altitude	500 m

Chart: The commonly used specifications of airborne sensors to assess water quality (Gholizadeh, Haji *et al*. 2016) [5].

Introduction

The major twenty-first century global issues include fast population increase, insecurity and scarcity of food, water, and accelerated GHG- greenhouse gas emission (Kuenzer, *et al*., 2013) [13], while the global population is expected to reach 10.2 billion by 2045, and to 11.2 billion by 2100. (http://esa.un.org/wpp/AnalyticalFigures/htm/fig_1.htm; Lal 2001), The insecurity problems due to food and water can further escalate, particularly with the non-sustainable adoption solutions like land conversion and indiscriminate intensification of agricultural activities. Even though improved yield promising, the indiscriminate agricultural escalation dangers are based on excessive use of fertilizers, animal waste; pesticides, which eventually degrade the water resources and land to increase the chances of adverse weather and ecological conditions (Kolokoussis & Karathanassi, 2018) [10].

The degradation of land can decline the ecosystem functions, balance and productivity by various hurdles, hence, the land gets eroded unable to recover unaided (Kuenzer, *et al*., 2013) [13]. Further transport of solutes like phosphorus and nitrogen concentration to waterways from agricultural runoff following indiscriminate agricultural amplification pollutes most of the water resources (Jennerjahn, 2012) [9]. Around 2.8 billion people have no proper access to safe water. Further research is needed to reduce the indiscriminate agricultural growth repercussions with reliable techniques to assess water quality and soil changes in agricultural ecosystems (Jennerjahn, 2012) [9].

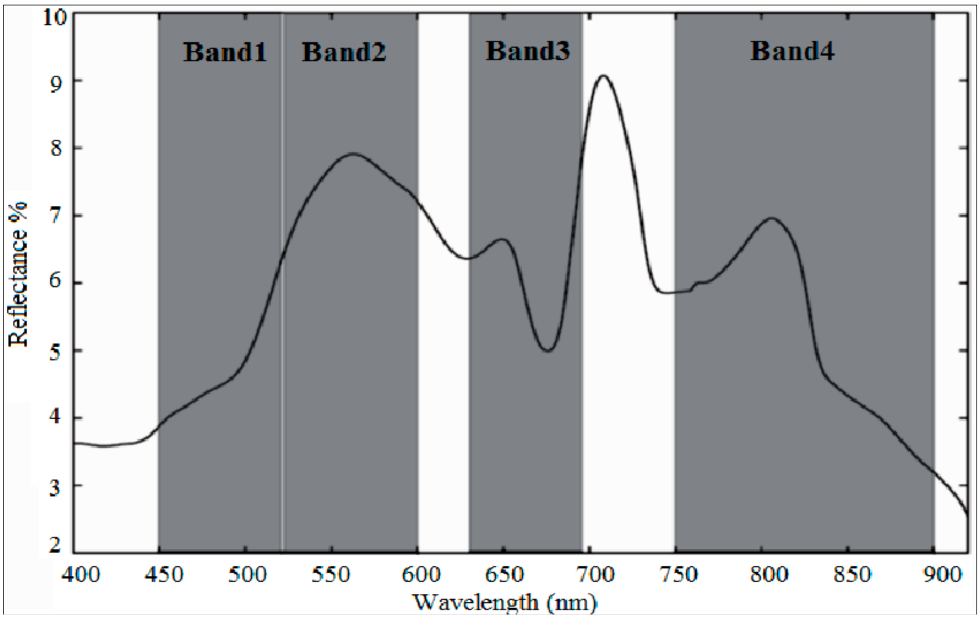

Fig 3: Positioning of Landsat7/ETM+ Spectral band on ASD, Spectroradiometer spectrum (El Saadi, & Jahin, 2014) [3]

2.1 Remote Sensing

The remote sensing procedure is the science and technique to acquire the correct information regarding the object property of a certain area or considered as phenomena without any physical contact with the area or objects under investigation (Dessalegn Ejigu, 2016) [1]. The instruments and tools utilized for such applications may employ several ranges of physical energy distribution. For example, Sonars operate on the optical instrument, acoustic wave distribution principles using a photographic camera with multi-spectral scanner for the distribution of electromagnetic energy. Hence, the electromagnetic radiation interaction with the surface of the earth is measured by space-borne or airborne sensors to gather data of interest regarding the given region and search data collected at the stipulated intervals to uncover the changes in the land-cover pattern and land use (Mironga, 2004) [19].

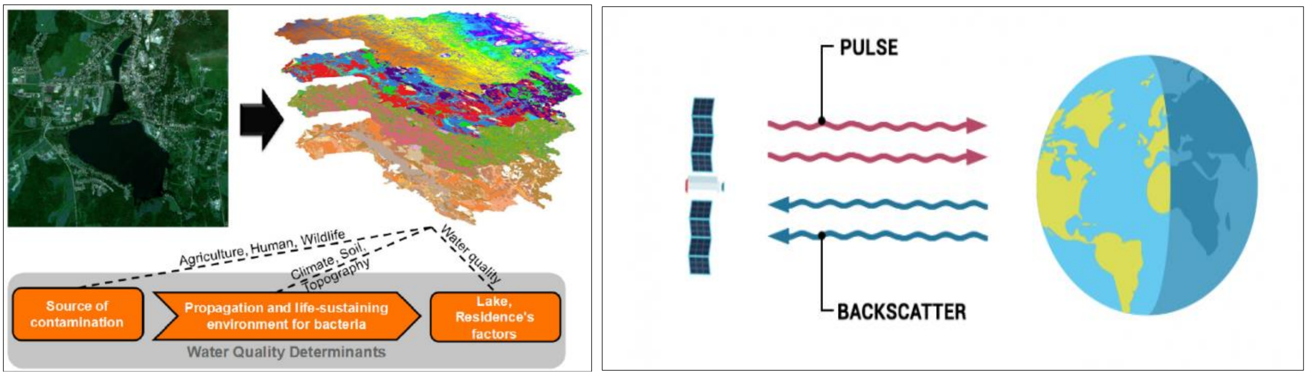

Fig 4: From the sun, the reflected energy emitted is measured by passive remote sensing, while active sensing remote work illuminates its target to measure its backscatter (GIS, Geography, 2021) [4].

Measurements taken and its analyses performed remotely is used to collect data, and they are stored as images in the data folders in the satellite images or aerial photograph form to be integrated to analyze using GIS and they represent the real features of the world. Although, the data of remote sensing can be interpreted and processed in the absence of other information, the actual result obtained by linking remote sensing to ground measurements or surface measurements with observations (Janssen, 2001) [7-8].

Airborne and Space borne Sensors to obtain Water Quality: The sensor tools for observation have bifurcated into two major categories depending on the proposal. Normally, within the Earth's atmosphere, Airborne sensors are placed on a secured platform like an aircraft, a balloon, a boat, a helicopter. While the space borne sensors are placed on a satellite or spacecraft to designated locations beyond the Earth's atmosphere. These sensor properties should be understood before application and it becomes imperative to select a proper sensor to fulfill the study objectives (Wang & Lin, 2011) [35].

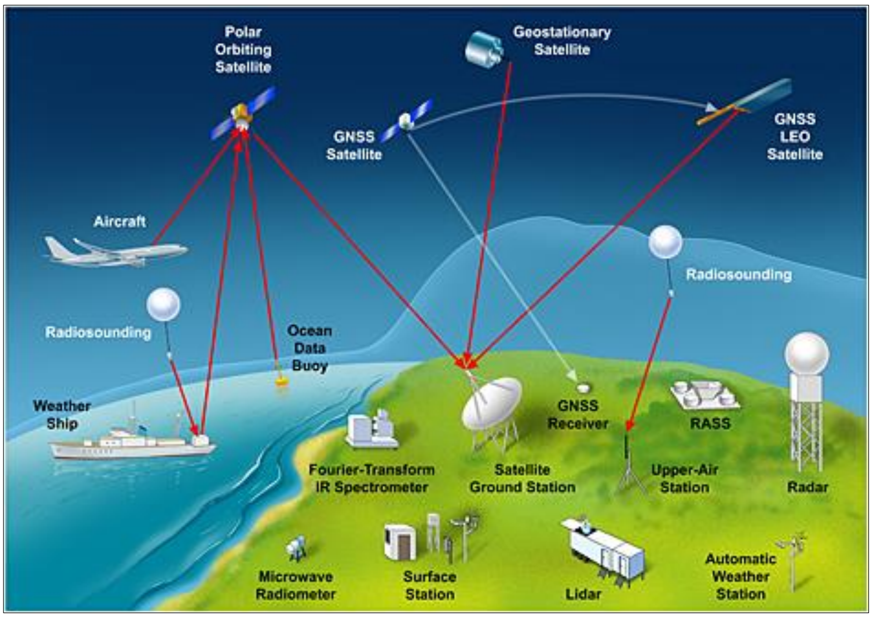

Fig 5: The remote sensing of lower Tropospheric Thermodynamic profile, a review of its indispensable role, the understanding and the simulation of energy and water cycles (Volker Wulfmeyer, *et al*., 2015).

Hence, several methods of satellite remote sensing and airborne systems are normally applied to assess water quality, together with the spectral properties, that includes spectral bands, spatial resolution, and revisiting time interval for presentation. The tabulated data help while designing and assessment planning of water quality studies, that can be applied with an appropriate sensor selection together with many varieties of sensors presently available in the market (Volker Wulfmeyer, *et al*., 2015).

Investigation of Water Quality through Remote Sensing Technology

The review of water quality is the evaluation of the physical, chemical, and biological process and water body characteristics, identifying the probable contamination sources that degrade and disintegrate the water quality (Pahlevan, Raqueno, & Schott, 2012) [20]. The quality degradation of water resources can happen for pesticides, waste discharges, heavy metals, sediment microorganisms, and nutrients. Various standards of water quality have been developed to assist in identifying the water pollution levels, and therefore to preserve these water quality standards (Minderhoud, *et al*., 2018) [17].

Passive and Active Remote Sensing

The remote sensing process utilizes various devices called as sensors to measure, assess, and record as evidence, the electromagnetic energy. The Active sensors like laser and radar have their own energy source and they emit a proscribed energy beam to the surface area. It can also measure the quantity of reflected energy. These Active sensors are utilized to measure and identify the emission and return time delay and can establish the speed, height, location, and an object's direction under investigation. Such active sensors can possibly emit the restricted and own controlled and managed signals, to operate during the day and night, irrespective of the external source energy availability. Whereas, on the contrary, Passive sensors can operate only by using the natural energy sources. Due to this, many passive sensors utilize the sun as a major energy source and can operate only during day time. Yet, passive sensors can measure more distance and the longer wavelengths concerning the earth's temperature, hence do not rely on the external illumination source and hence, can possibly operate at any time (Woldai, 2001) [31].

Limitations of Remote Sensing

Despite several invaluable and vital applications in various regions of interest, the remote sensing technology application to monitor and manage ecosystems and habitats can possibly face certain practical drawbacks. There are several practical limitations as well, which are normally engraved in the techniques applied because of restricted capability of light to penetrate and pass through the atmosphere and water levels. One other remote sensing limitation is the assessing suitability and in difficulties in certain sensors. For instance, remote sensing has the tendency to provide Geomorphological instead of reef structure, ecological information. This happens due to the limited spectral resolution and spatial motion caused by sensors in the presence of several external barriers like water depth and water turbidity. Apart from that, a highly vital remote sensing limitation is the cloud covering problem that can significantly decrease the quantity of proper images to be made available for every season (Mironga, 2004) [19].

Objectives

1. To identify and review the remote sensing sources, methods and applications.
2. To identify and review the Remote Sensing methods to problems related to Water and soil Environments.
3. To review various Remote Sensing tools to identify the probable water contamination sources.

Literature Review

The Review done by Melesse *et al*. (2007) [18], there exist eight prominent remote sensing regions; a few run parallel in time zone, but they are unique in technology terms, utilization of data concept, data characteristics, and applications. They are:

1. The era of airborne remote sensing: The era was evolved at the time of 1st and 2nd World War, when the remote sensing was specifically utilized for the surveying purposes, mapping and reconnaissance of military surveillance (Wang & Lin, 2011) [35].
2. The space-borne rudimentary remote sensing satellite era: Began after the 'test of concept' launch of rudimentary Sputnik 1 satellite by Russia and the US Explorer 1 at the 1950 end. It was followed by the meteorological satellite known as TIROS-1- Satellite-1 Television and Infrared Observation by the US (Volante, *et al*., 2012) [34].
3. The remote sensing Meteorological satellite sensor era: During this period, the initial sensors of meteorological satellite of GOES- Geosynchronous Operational Geostationary Environmental and NOAA- National Oceanic polar orbiting and Atmospheric Administration, AVHRR-Advanced Very High Resolution Radiometer were materialized. The data were generated in digital form, were assessed and analyzed by use of special computer software. Also, environmental applications and the global coverage became practical and realistic (Melesse *et al*. 2007) [18].
4. Landsat era: In 1972, it started with the Landsat-1 launch, called Resources Earth Technology Satellite carrying MSS- multi-spectral scanner and sensor. It followed by another satellite 2, called path-finding Landsat 3 carrying Landsat 4, MSS, and Landsat 5. They carried 2007, 7 3211 Sensors TM- Thematic Mapper. ETM+ Enhanced Thematic Mapper, the Landsat 7 carried the Landsat (Melesse *et al*. 2007) [18].

Conclusion and recommendations

This review paper assessed the limitations and potential strengths of a nondestructive remote sensing and rapid evaluation tool to detect, map, and monitor the agricultural impacts on water and soil quality and provide new data processing insights with options available to increase the validity of the information.

The review explains the tap water spectral reflectance i.e., purification) and it was observed to be considerably diverse from that lake water, which is not purified and observed in the wavelength range of 360 and 2,600. However, even though certain reflectance trends were identified for certain soils under explicit land management, such findings need further review. Because the reflectance of the soil pattern transforms sporadically when the wavelength is compared with water, mainly because of the soil material complexity and heterogeneity.

Ground data chosen after rigorous sampling designs, it is mainly for calibration validation. Regarding the heterogeneous land conditions, the technique of sub pixel mapping can decrease the imagery spectral ambiguity. A prime issue of remote sensing is based on various applications, providing a gap between complexities and understanding the environment, while the designers of sensors can critically observe and modify, if needed. More research is essential to identify the electromagnetic spectrum wavelengths to detect soil and water quality varies with the surface depths.

This can provide a useful building application for future sensors, due to their active sensors like RaDAR and LiDAR, which have explicit wave bands designed to initiate other resource mapping. Data integration and fusion of the sensor data can provide missing information to improve the monitoring outcome. In the future, the passive and active combination of sensors can prove useful to fill data gaps, and assesses water and soil quality at different spatial and temporal scales (Zhang *et al*., 2019) [32].

References

1. Dessalegn Ejigu. Application of Remote Sensing and Geographic Information System in Ecology: Review, Population ecology of mammals, and conservation biology, (PDF) Review paper: Application of remote sensing and GIS in ecology (researchgate.net), 2016.
2. Dr. Osama Asanousi Lamma. Study on groundwater analysis for drinking purpose in Mangalagiri Mandal regions, Andhra Pradesh, India, International Journal of Appl ied Research. 2020;6(1):148-153.
3. El Saadi M, Yousry H Jahin. Statistical estimation of Rosetta branch water quality using multi-spectral data, Environmental Science, Abstract this research aimed at assessing the approaching of Multi-Spectral Remote Sensing (MS-RS) data for estimating water quality (WQ) of the Rosetta branch (RB) using stepwise regression technique, 2014.
4. GIS Geography. Remote sensing technologies**,** what is Remote Sensing? The Definitive Guide, What is Remote Sensing? The Definitive Guide - GIS Geography, 2021.
5. Gholizadeh Mohammad Haji, *et al*. A Comprehensive Review on Water Quality Parameters Estimation Using Remote Sensing Techniques. Sensors (Basel, Switzerland), 2016, 16.
6. ICARDA Communication Team. How satellite observations help lessen the contribution of agriculture to climate change, how satellite observations help lessen the contribution of agriculture to climate change | ICARDA, 2021.
7. Janssen LLF. Introduction to remote sensing. In: Principles of Remote Sensing. An Introductory Text Book, (Janssen, LLF and Huurneman GC. Eds). International Institute for Aerospace Survey and Earth Sciences, Enschede, 2001, 25-49.
8. Janssen LLF, Bakker WH. Sensors and platforms. In: Principles of Remote Sensing. An Introductory Text Book, (Janssen, L. L. F. and Huurneman, G. C. Eds). International Institute for Aerospace Survey and Earth Sciences. Enschede, 2001, 84-109.
9. Jennerjahn T. Bio-geochemical Response of Tropical Coastal Systems to Present and Past Environmental Change. Earth-Sci. Rev. 2012;114:19-41. doi:10.1016/j.earscirev.2012.04.005.
10. Kolokoussis P, Karathanassi V. Oil Spill Detection and Mapping Using Sentinel 2 Imagery. J Mar. Sci. Eng. 2018, 6, 4, doi:10.3390/jmse6010004.
11. Kuenzer Claudia, Valentin Heimhuber, Juliane Huth, Stefan Dech. Remote Sensing for the Quantification of Land Surface Dynamics in Large River Delta Regions -- A Review, River deltas and estuaries belong to the most significant coastal land forms on our planet and are usually very densely populated, 2019.
12. Kuenzer C, Renaud F. Climate Change and Environmental Change in River Deltas Globally. In The Mekong Delta System Interdisciplinary Analyses of a River Delta; Kuenzer, C., Renaud, F., Eds.; Springer: Dordrecht, The Netherlands, 2012, 7-48. doi:10.1007/978-94-007-3962-8.
13. Kuenzer C, Guo Schlegel I, Tuan VQ, Li X, Dech S. Varying Scale and Capability of Envisat ASARWSM, TerraSAR-X Scansar and TerraSAR-X Stripmap Data to Assess Urban Flood Situations: A Case Study of the Mekong Delta in Can Tho Province. Remote Sens. 2013;5:5122-5142. doi:10.3390/rs5105122.
14. Moftah MA, Lamma OA. Analysis of heavy metals in tomato (*Solanum lycopersicum*) leaves, fruits and soil samples collected from industrial area, 2013.
15. Mohammad MJ, Krishna PV, Lamma OA, Khan, S. Analysis of water quality using limnological studies of Wyra reservoir, Khammam District, Telangana, India. Int. J Curr. Microbiol. App. Sci. 2015;4(2):880-895.
16. Lamma OA, Outhma AM. Research article, 2015. ISSN: 2321-7758.
17. Minderhoud PSJ, Coumou L, Erban LE, Middelkoop H, Stouthamer E, Addink EA. The Relation between Land Use and Subsidence in the Vietnamese Mekong Delta. Sci. Total Environ. 2018;634:715-726. doi:10.1016/j.scitotenv.2018.03.372.
18. Melesse AM, Weng O, Thenkabail PS, Senay GB. Remote sensing sensors and applications in environmental resources mapping and modelling. Sensors. 2007;7:3209-3241.
19. Mironga JM. GIS and remote sensing in the management of shallow tropical lakes. Appl. Ecol. Environ. Res. 2004;2:83-103.
20. Pahlevan N, Raqueno NG, Schott JR. Crosscalibration of Landsat-7's visible-near-infrared bands with terra-MODIS over dark waters. In W. W. Hou & R. Arnone (Eds.), Ocean sensing and monitoring IV. Bellingham: Spie-Int Soc Optical Engineering, 2012.
21. Lamma OA. Groundwater Problems Caused By Irrigation with Sewage Effluent. International Journal for Research in Applied Sciences and Biotechnology. 2021;8(3):64-70.
22. Lamma OA. The impact of recycling in preserving the environment. IJAR. 2021;7(11):297-302.
23. Lamma OA, Swamy AVVS, Subhashini V. Ground water quality in the vicinity of industrial locations in Guntur, AP, India.
24. Lamma, o. A., & krair, s. S. A. To study the relation between the environmental law and climate change.
25. Lamma OA, Swamy AVVS. Assessment of Ground Water Quality at Selected Industrial Areas of Guntur, AP, India. Int. J Pure App. Biosci. 2018;6(1):452-460.
26. Lamma OA. Discussing the waste management expectations of the future.
27. Outhman AM, Lamma OA. Investigate the contamination of tissue paper with heavy metals in the local market. IJCS. 2020;8(1):1264-1268.

28. Lamma OA, krair SSA. To study the relation between the environmental law and climate change.
29. Lamma OA. Waste disposal and landfill: Potential hazards and their impact on groundwater.
30. Lamm OA. Analysis of water quality (cha.), 2016.
31. Woldai T. Electromagnetic energy and remote sensing. In: Principles of Remote Sensing. An Introductory Textbook, (Janssen, L. L. F. and Huurneman, G. C. eds). International Institute for Aerospace Survey and Earth Sciences, Enschede, 2001, 49-72.
32. Zhang B, Wang R, Deng Y, Ma P, Lin H, Wang J. Mapping the Yellow River Delta Land Subsidence with Multitemporal SAR Interferometry by Exploiting Both Persistent and Distributed Scatterers. ISPRS J. Photogramm. Remote Sens. 2019;148:157-173. doi:10.1016/j.isprsjprs.2018.12.008.
33. Lamma O, Swamy AVVS. E-waste, and its future challenges in India. Int J Multidiscip Adv Res Trends. 2015;2(I):12-24.
34. Volante JN, Alcaraz-Segura D, Mosciaro MJ, Viglizzo EF, Paruelo JM. Ecosystem functional changes associated with land clearing in NW Argentina. Agriculture, Ecosystems & Environment. 2012;154:12-22.
35. Wang X, Lin Q. Effect of DEM mesh size on AnnAGNPS simulation and slope correction. Environmental Monitoring and Assessment. 2011;179:267-277.