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Remote Sensing in Water Quality and Water Resources Management

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ABSTRACT

The quality of water ascertains the 'integrity' of water for specific purposes. Tests and quality of examination of water can provide sufficient information about the waterway health. If tests are conducted over a span of time period, the water quality changes can be realized. There are several testing parameters like pH value, temperature, salinity, turbidity, phosphates and nitrates, which can help assess the water quality. Also, aquatic macro-invertebrates can give a proper water quality indication.

Surface water contaminated can pose a high risk to the entire human population and it remains a challenging task to investigate and resolve the problem for public health authority. Intensification of agricultural activities, change in climatic conditions, coastal area quick urban development, and resultant freshwater source declining have contributed considerably to the surface water contamination risk and the augmentation of waterborne disease incidences. The quality of surface water monitoring needs frequent problem detection to reduce any negative effect on public health. The epidemiology study applies geospatial and remote sensing technologies to distinguish the temporal and spatial environmental variability determinants to assess the epidemiology of certain diseases. By providing an integrated and systematic approach to risky water management for the public health and safety, a proper epidemiology method can be used and proved to be an efficient device to evaluate the quality of surface water and any related health risks.

SWRMS- Spatial water resource monitoring system provides important and beneficial information to support water management. Requisite innovative features involve the explicit water redistribution description and use of river water and groundwater systems, to achieve more spatial details like key irrigated area features and wetlands, to improve hydrometer observation accuracy and assimilating the observations. A review of research and operational applications reveals that satellite view can enhance spatial detail and accuracy in estimating hydrological model. Every operating system uses land cover classification, dynamic forcing, and a parameterization priory of vegetation dynamics, which is partially or completely based on remote sensing, while satellite observations are utilized in varying stages for data assimilation and model evaluation. The satellite observation, utility by data assimilation varies as a dominant hydrological function. This review paper identifies the spatial and temporal precipitation products, including the application of a higher remote sensing product range, along with operational challenges while research satellite mission continuity with data services, finding computationally-efficient data assimilation techniques. The entire observations critically relies on the detailed information availability and understanding the remotely-sensed spatial and temporal scaling.

Keywords- Remote Sensing, Earth observation, Water Resources, Water Quality.

I. AN OVERVIEW OF REMOTE SENSING IN WATER QUALITY AND WATER RESOURCES

Water Spectral Response as an Inorganic Constituent Function

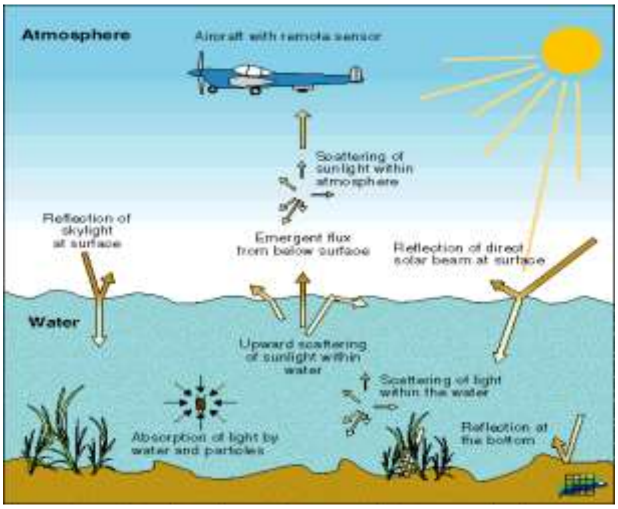

Figure: Mapping challenges of the submerged coastal area vegetation while using remote airborne sensing (National Environmental Research Institute, 2021).

Minerals like iron oxides, aluminum, and silicon, are observed in Water with Spectral Response as an Inorganic Constituent's Function of suspended in several natural water bodies (National Environmental Research Institute, 2021).

The particles observed were in the fine clay particle range of 4 to 5 µm diameter, sedimentary material of 6 to 44 µm, sand fine-grain 42 to 140 µm, and coarse grain sand 134 to 1350 µm.

Sediments arrive from several sources due to mountainous terrain weathering, agriculture and shore erosion, caused by water waves or boat regular traffic, and volcanic eruption producing ash.

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These suspended particles of mineral sediment come in concentrated form in the inland water and also towards water sea shore bodies.

Clear water, deep ocean water remains far away from shore and it hardly contains suspended particles of minerals, which are more than 1 µm diameter (Matthew Fisher, 2021).

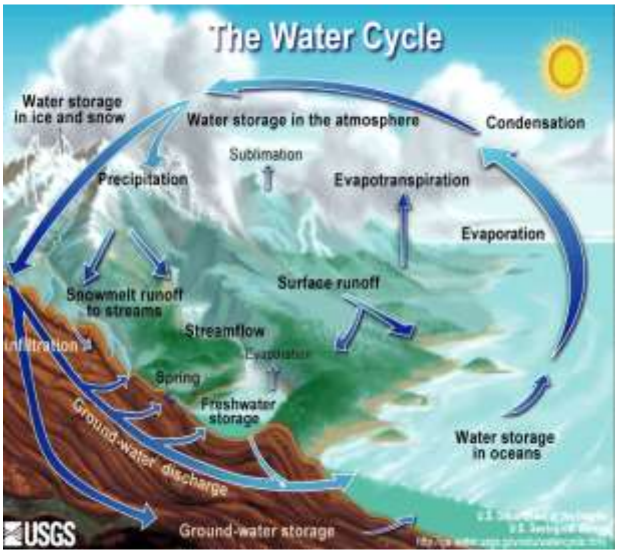

Figure: Water Cycle and Fresh Water Supply (Matthew Fisher, 2021).

II. INTRODUCTION

In small catchment areas such as the Mediterranean region, have high flash flood risk characteristics. The antecedent SM- soil moisture condition in such basins, are mainly observed by the given rainfall condition status to provide a flash flood alert. Hence, reliable and accurate SM estimates are prime factors to reduce flash flood uncertainties of early warning system (Garcia-Pineda, et al., 2017). In such situations, MW- microwave remote sensing provides a good opportunity for SM-synoptical monitoring. Recently, SM- Satellite-functional maps acquired from MW sensors featured by less spatial and high temporal resolution like Scatterometers and Radiometers were exploited to enhance hydrological model discharge predictions through DA- data assimilation techniques using SM and DA, for instance, (Auerbach et al., 2015). DA permits combined optimally diverse information sources that can be characterized by various accuracies of spatiotemporal resolution. By using DA techniques, SM approximation collected from hydrological modeling of satellite acquisition can be merged, so as to collect more reliable processing estimates and further to reduce the model forecast uncertainty (Higgins, et al., 2014). Such techniques can be used in an operating system to improve flash flood predictions.

Water Quality Parameter	Abbreviation	Units	Optical Activity
chlorophyll-*a*	CHL-*a*	mg/L	Active
Secchi Disk Depth	SDD	m	Active
Temperature	T	°C	Active
Colored Dissolved Organic Matters	CDOM	mg/L	Active
Total Organic Carbon	TOC	mg/L	Active
Dissolved Organic Carbon	DOC	mg/L	Inactive
Total Suspended Matters	TSM	mg/L	Active
Turbidity	TUR	NTU	Active
Sea Surface Salinity	SSS	PSU	Active
Total Phosphorus	TP	mg/L	Inactive
Ortho-Phosphate	PO_4	mg/L	Inactive
Chemical Oxygen Demand (COD)	COD	mg/L	Inactive
Biochemical Oxygen Demand	BOD	mg/L	Inactive
Electrical Conductivity	EC	µs/cm	Active
Ammonia Nitrogen	NH_3-N	mg/L	Inactive

Chart: The most frequent qualitative parameters of water measured by means of remote sensing (Gholizadeh, Haji et al. 2016).

2.1 Water as a Function provides an Organic Constituents Spectral Response of Organic Constituents - Plankton

The generic term Plankton is used to explain all the plant and animal living organisms survive in water bodies as unlike fish, they are unable to resist the water current. Water Spectral Response remains as an Organic Constituent Function of Plankton animals.ƒ Plankton can be bifurcated into phytoplankton- algal plant organisms, Zoolankton- animal organisms, bacteria called Bacteria-plankton, and algal fungi lower plant form. Small size single-celled plants called Phytoplankton are smaller than pinhead size, like plants on land composed of carbon substances. They further

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sink to meet ocean water-body floor as soon as they die. All water body Phytoplankton contain the Phhillotosynthetically active chlorophyll pigment. Two different phytoplankton are photosynthesizing agents called Phycobilins and Carotenoids. Bukata et al., 1995) explains the Chlorophyll can reasonably organic component surrogate of optically intricate natural waters.

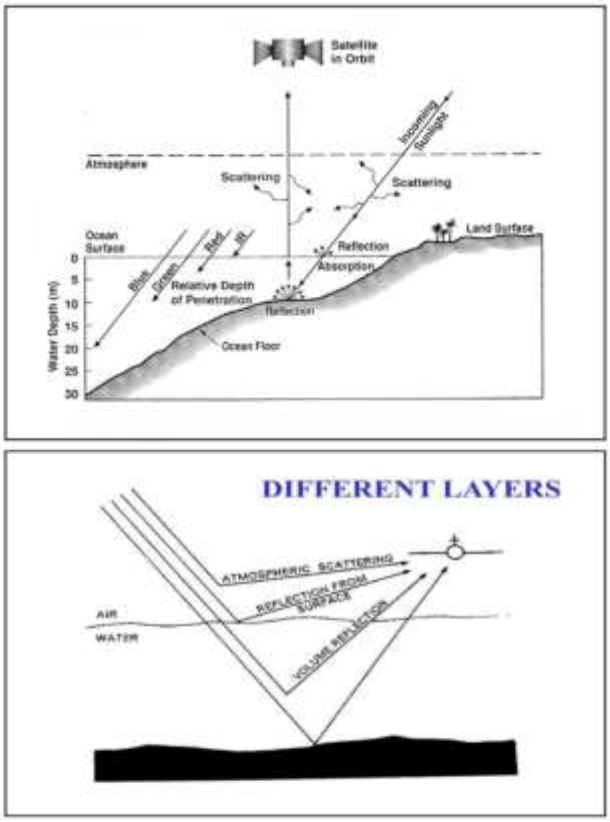

Figure: Water Spectral Response as a Dissolved Organic Constituent Function (John Jensen, 2007).

2.2 Water Spectral Response as a Dissolved Organic Constituent Function

The Sunlight can penetrate through the water body, the Photic zone depth of vertical distance of 1% Irradiance sending radiant light further to subsurface level from the surface of water:

- Phytoplankton remaining in the water column Photic depth consumes nutrients to convert into organic matter through photosynthesis. This is known as primary production,
- Zooplankton can eat Phytoplankton to generate organic matter,
- Bacteria-plankton further decomposes the organic matter (John Jensen, 2007).
- DOM- dissolved organic matter conversion enters the ocean water, near shore water, and also inland water body.
- In certain cases, in water, there enough dissolve organic matter to reduce the light penetration into the water column (Bukata et al., 1995).
- The phytoplankton cell decomposition gives away sulfur, inorganic nitrogen, carbon dioxide, and phosphorous compounds (ICARDA Communication Team, 2021).

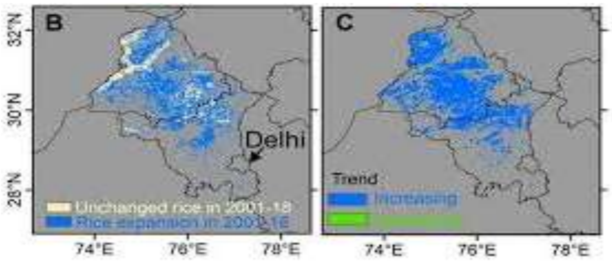

Figure: Observation through satellite helps reduce agriculture to climate change contribution (ICARDA Communication Team, 2021).

2.3 Water and soil quality investigation through remote sensing techniques

To find water turbidity and total suspended sediments, as well as soil soil quality, a technical Approach and proper methodology are needed (Obade, Lal & Chen, 2013).

The technical format. The original, natural, and appropriate soil quality and position assessments are performed through the analyses of laboratory-based tests (Munyati & Ratshibvumo, 2011). It can also be done by visual inspection of soil color by applying the Munsell color chart of soil (Gobin et al. 2000), wherein, the darker soils designate higher and better soil organic matters and hence, good quality of soil (Dieye, et al., 2012). But, in situ approaches can be taken to assess soil quality and that exercise may prove prohibitively expensive for some specific areas.

Table 2: SWAT water and soil assessment tool using inelastic NS neutron scattering method (Dieye, et al., 2012).

Table 2 Methods for assessing agricultural impact on soil and water quality

Method	Requirements and comments	References
Expert judgment	Subjective, particularly in the definition of quality and degradation classes: not degraded; slight, moderate, severe, and very severe Hardly reproducible Relatively low cost	Furby et al. (2010)

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In situ		
Field surveys	Costly, depending on the spatial extent, data requirements, because measure points samples, e.g., secchi disk INS for SOC determination and Wireless lysimeters Requires sampling strategy	Chatterjee et al. (2009), Kim et al. (2011), and Lobell (2010)
Ex situ		
Laboratory	Determination of chemical, physical, and biologic properties Expensive depending on the number of test	Chatterjee et al. (2009) and Wielopolski et al. (2011)
Remote sensing	Repetitive acquisition enables monitoring Cost depends on platform and sensor used Modeling performed based on relations between spectral reflectance of feature of interest and surrogate variables	Croft et al. (2012)
GIS modeling	Based on established models, e.g., SWAT Data integration possible, e.g., direct field measurements, remote sensing, and socioeconomic Future prediction possible Can be subjective, especially with over reliance on secondary data	He et al. (1993)

Above Table 2 gives an outline to approach for assessing the impact of land management on natural sources, providing the expert subjective judgment. PTF-pseudo-transfer function, a regression equation is obtained by clearly and easy comparing the soil properties along with complex measurement of soil properties to interpolate or predict various purposes seems to be the rapid assessment method for computing elaborate soil properties (Minasny and Hartemink 2011). PTF can be used for computing the missing inputs like SOC, soil bulk density, and soil moisture. They are used to assess natural resource threats by digital mapping (Minasny and Hartemink 2011). However, sometimes PTF proves to be inaccurate beyond the initial data range to construct proper PTF (Bouma and McBratney 2013). SOC concentration, a soil quality proxy can be evaluated by direct or indirect method. The Direct methods involve:

a) the method of Walkley-Black (Walkley & Black 1934),

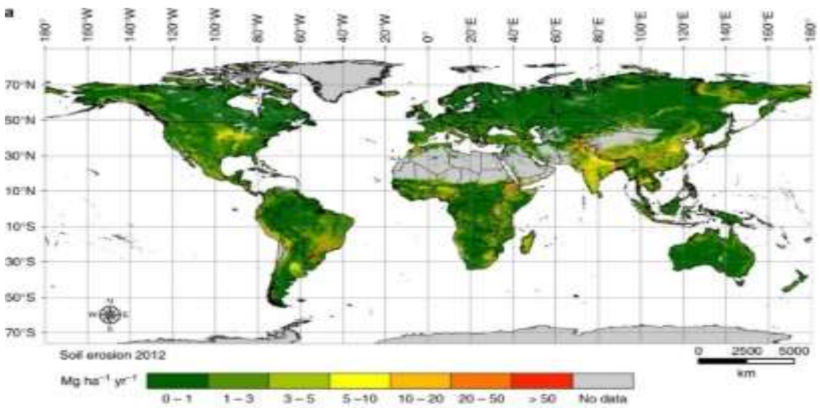
b) Method of dry combustion process (Nelson & Sommers 1996),

c) Neutron scattering inelastic method, and

d) The laser-induced portable breakdown method of spectroscopy (Wielopolski et al. 2011). The process of SOC is indirectly deciding the PTF or by different remote sensing method (Minasny & Hartemink 2011).

2.4) The Vegetation effects of Quality Assessment in Remote Sensing of Soil and Water

The effects of Vegetation were seen while Remote Sensing of water and soil Quality Assessment. That determined the difficulty in soil quality in high vegetated fields, because of soil, vegetation obstruction (Stockmann et al. 2013). A "quick fix" method can clearly mask the major portion of vegetation, so to remain simply with bare soil. However, this can produce data gaps regarding the soil information when vegetated areas are masked. In the case of heterogeneous landscape, there is considerable reflectance captured and thereafter merged by the sensor developing a blur entity that carries several images within the stated pixel size, that is mentioned as the mixed problem of pixel. Further, the sub pixel mapping process is applied to reduce the mixed pixel problems. The effect of adjacency can create pixels appearing from the reflectance of adjacent surfaces. The several spectral indices combinations are normally used to curtail the influence of vegetation on properties of soil by use of remote sensing (Bartholomeus et al. 2007).



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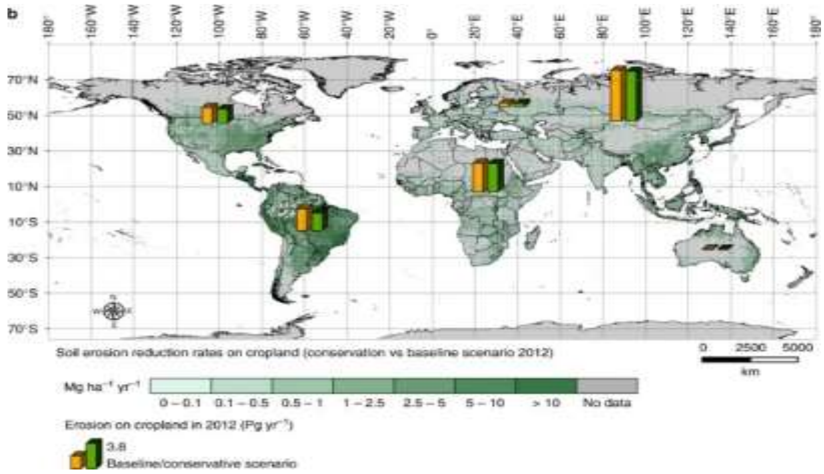

Figure: 21st century global impact assessment of the land use changes on soil erosion (Borrelli, P., Robinson, D.A., Fleischer, L.R., *et al.* 2017).

Evaluating the quality of soil mainly in high vegetated fields is complicated due to obstruction of the vegetation soil (Stockmann et al. 2013). A proper instant fixing method can help mask out vegetation, hence to remain with simpler bare soil (Roy, et al., 2010).

III. LIMITATIONS OF REMOTE SENSING IN ASSESSING SOIL AND WATER QUALITY

There are limitations of the remote sensing applications in quality assessment of soil and water and they arise out of:

a) Spectral confusions due to impure pixels, also from simultaneous reflectance signal detection at the sensors,
b) Trouble in distinguishing and identifying plant species,
c) Scaling problems and issues,
d) Less accuracy because of the heterogeneity of soil and water due to spectral complications of imperfect plant cover, and
e) Non availability of long-lasting satellite data, indicating data from the satellite was acquired after 1972 and also MODIS after 2000.

Models can be very simple or incomplete because of the variability of soil depth or identical soil observed everywhere, due to functionality of model design depending on the model developer professional background (Bouma and McBratney 2013). The PTF misuse in deriving physic-chemical properties of soil like texture, bulk density, available water capacity, soil moisture content, SOC, and so on, may develop erroneous results. Also, Soil characteristics like texture and bulk density are vital to assess soil quality and they are problematic to assess applying only remote sensing information and data (Jana and Mohanty 2011). Certain staff reported a large correlation between spectral reflectance and SOC concentration under restricted laboratory conditions (Bartholomeus et al. 2008), however, considering space and aerial derived platforms the less SNR attributed to scattering in the atmosphere, adjacency effects, bidirectional reflectance, geometric and topographic variation, and radiometric faults may reduce this accuracy. Moreover, the concentration or composition of heterogeneous soil or water mixtures like SOC, mineralogy, Fe_2O_3, chlorophyll, soil moisture, can considerably impact the reflectance signal characteristics detected by the sensors (Bartholomeus et al. 2011; Bartholomeus et al. 2008). The information, deciphered using remote sensors is complicated within such heterogeneous landscapes (Bai et al. 2008).

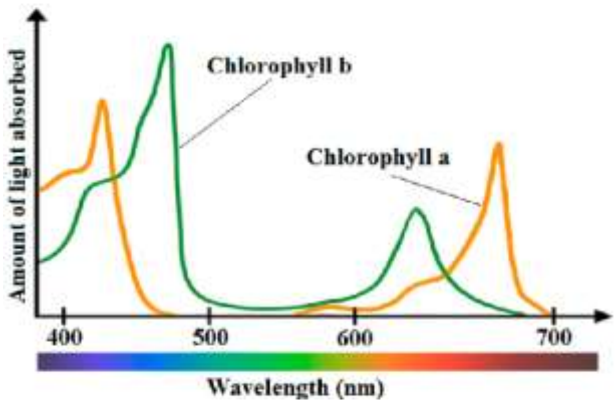

Figure: The Spectrum of absorption for pigments, chlorophyll-a and Chlorophyll-b (Gholizadeh, Haji et al. 2016).

IV. OBJECTIVES

4.1 To identify and review the remote sensing methods, sources, and applications.
4.2 To identify and review the Remote Sensing problems related to Water Quality and resources.
4.3 To identify Remote Sensing tools to evaluate water contamination sources.

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V. RESULTS AND DISCUSSION

It was observed that the tap water indicates the biggest spectral reflectance wavelength between 360 and 1,600 nm (nm), even though the lake is at 2000 nm. The water body Reflectance is impacted by absorbance of water cross-sections, suspended inorganic matters, plant pigments, DOC- dissolved organic carbon (Vertucci and Likens 1989), but the reverse tendency was seen at the larger wavelengths of about 2000 nm). Identical reports were found at 500 nm when suspended materials and plant pigments, DOC, were negatively linked with reflectance, however, positively linked at 700 nm. Moreover, the parameters were connected with alkalinity, aluminum concentration, lake water acidic value, pH, but poorly linked with reflectance. (Peltoniemi et al. 2009).

VI. CONCLUSION AND RECOMMENDATIONS

The extent of causes and related degradation degree of natural resource in one region may differ from all other, based on the practices or climate of land management. The ideal sensor must offer real time data and information for modeling as well as assessing directional changes (Stockmann et al. 2013). However, the natural environment, heterogeneity and complexity become a main hassle when collecting this information. The dynamic soil processes as a case in point occurs because of the soil organism biologic activities in search of food whereby they continuously transform the soil environment by redistributing process of soil nutrients (Dungait et al. 2012).

Clear water usually contains a high degree of pollutants in highly alkaline or acidic water, which is invisible to the human eye (Tuomisto et al. 2012). The optimum spectral range identification to identify water pollutants, like sediments chemicals, and chlorophyll requires further research (Arnold et al. 2012). Even though laboratory methods prevail to detect the water, chemical constituents like chlorides observed by using ion chromatography, ion selective electrodes, calorimetric methods.

These approaches remain rudimentary (Zhang et al. 2013). There are needs of very innovative techniques to enhance mapping accuracy to be embraced. For instance, “the whole to the part” principle is applied by geodetic surveyor like (Higgins, et al. 2014), hence the critical parameters act like a baseline, and they are measured with proper accuracy, by which, other measurements remain within the limits of accuracy. The remotely sensed data classification needs proper selection wit proper training data to get proper accuracies (Arnold et al. 2012). A main satellite data problem is classified as the loss of detailed information during the processing phases, as the cloud removal and atmospheric correction (Proud et al. 2010).

The Space Agency of Europe had a plan to launch five new satellites by 2013 known as Sentinels having LiDAR and RaDAR technology instruments, providing multi-spectral images capable of generating timely, accurate, and easily processing data map to correct all the atmospheric effects, along with monitoring ocean, land, by providing prevailing information to enhance environmental awareness (Erban, Gorelick & Zebker, 2014).

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