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Geo-Spatial Technology (GST) For Assessing Groundwater Management and Modeling and Its Role in Food Security

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Abstract–Geo-spatial technology refers to a set of tools and techniques used to collect, analyze, and visualize spatial data related to the Earth's surface. It plays a crucial role in almost all the fields including Groundwater studies. The combination of satellite and remote detecting information gives data about the different impact components of groundwater occurrence and its movement corresponding to the geology, geomorphology, soils, land use and land cover, drainage and lineaments density. Groundwater plays a major role in the Indian agriculture as over 60% of the irrigated land uses groundwater for agriculture. This study also includes the overuse of groundwater and its setback for the future food security in the country.

Key words: Remote sensing &GIS, Multi-Criteria Decision Making (MCDM), Analytical Hierarchal Process (AHP), Gravity Recovery and Climate Experiment (GRACE) Sensors and Total Water Storage (TWS).

1. INTRODUCTION

Groundwater is an essential component of the Earth's freshwater system and plays a critical role in sustaining life, agriculture, and economic development. In many parts of the world, it serves as the primary source of drinking water and irrigation, especially in arid and semi-arid regions where surface water availability is limited. Over the past few decades, dependence on groundwater has significantly increased due to rapid population growth, agricultural intensification, industrial expansion, and urbanization. This rising pressure has resulted in aquifer depletion, declining groundwater tables, deteriorating water quality, and reduced recharge capacity. Consequently, long-term water security and food production systems face substantial risks. In this context, the need for advanced, accurate, and sustainable approaches to assess and manage groundwater resources has become more urgent than ever.

Geo-spatial Technology (GST), which includes Remote Sensing (RS), Geographic Information Systems (GIS), Global Navigation Satellite Systems (GNSS), and spatial modeling tools, provides a modern and powerful framework to analyze, monitor, and manage groundwater resources efficiently. GST enables the integration and visualization of multi-layer datasets that explain the complex interactions among hydrological, geological, climatic, and land-use factors. Through satellite imagery, researchers can observe land surface changes, vegetation health, soil moisture variations, and terrain characteristics that influence groundwater recharge and extraction. GIS supports the compilation, management, and spatial analysis of these datasets, enabling the creation of detailed maps, models, and decision-support tools that help water managers understand the distribution and status of groundwater resources.

2. LITERATURE REVIEW

[1] The paper entitled "GIS-Based Groundwater Potential Mapping Using Remote Sensing and Multi-Criteria Analysis" by S. Magesh, N. Chandrasekar et al. (2012) discussed the integration of satellite imagery, geological layers, and soil characteristics for identifying groundwater potential zones. The authors highlighted that weighted overlay techniques combined with GIS enhance accuracy in recognizing recharge areas, especially in semi-arid regions. Their study provided a systematic approach for classifying high, moderate, and low groundwater zones, supporting scientific groundwater resource planning.

[2].The paper entitled "Groundwater Recharge Assessment Using GIS and Remote Sensing Techniques" by K. Machiwal and M.K. Jha (2014) proposed the use of thematic layers such as rainfall, slope, soil texture, and land use to determine groundwater recharge zones. Their study emphasized that RS-based mapping improves understanding of spatial hydrological variations. The model developed was able to simulate recharge behaviour under different climatic and land-use scenarios, making it suitable for long-term water management.

[3]. The paper entitled "Impact of Land Use and Land Cover Changes on Groundwater Resources Using GIS" by P. Singh, A. Panda et al. (2020) examined how rapid urbanization and agricultural expansion affect groundwater levels. The authors used multi-temporal satellite images to detect LULC changes, concluding that built-up areas significantly reduce infiltration, causing groundwater table decline. Their findings demonstrated the importance of continuous GIS monitoring for sustainable urban groundwater planning.

[4]. The research paper entitled "Evaluation of Groundwater Quality for Drinking and Irrigation Using Water Quality Index (WQI) and GIS" by R. Ravikumar et al. (2013) introduced GIS-based WQI mapping for analysing groundwater suitability. The study incorporated parameters like pH, EC, hardness, TDS, nitrates, and chlorides to compute composite WQI values. Results indicated spatial variations in contamination levels, and the model helped identify regions needing immediate water-treatment interventions.

3.OBJECTIVES

Gathering the information about Land use & Environmental parameters (Water table depth, Aquifer characteristics, Soil permeability and porosity etc.)
Collecting hydrological parameters (Recharge rates, Rainfall infiltration rate, Evapotranspiration etc.)
Characteristics of ground water, extracted through bore well from study area (Industrial and urban Area).
Impact of deforestation and urbanization using LULC.

4.MATERIALS AND METHODOLOGY

EDTA Solution

Buffer (ammonia), Potassium chloride, Sulfuric acid, Sodium hydroxide, Indicator phenolphthalein, Methyl orange, silver nitrate, Potassium chromite, Barium chloride , Magnesium Sulphate, Sodium Thiosulphate, Potassium Hydroxide

The methodology adopted for this study consists of three major components:
1. Physical Parameters
2. Chemical Parameters
3. Hydrological Parameters

5.PHYSICAL PARAMETERS

Physical parameters indicate the appearance, smell, clarity, and temperature of groundwater. These factors help identify visible impurities, organic pollutants, suspended matter, and thermal conditions affecting chemical reactions.

6.Colour

Colour represents the visual appearance of water due to dissolved minerals, organic matter (humic & fulvic acids), algae, industrial wastewater, or rust from pipes.
Procedure:

- Pour the water sample into a colour-comparison tube.
- Compare it against the standard colour scale (Pt-Co method).
- Identify if the colour is clear, pale yellow, or brownish.
- Significance:
- Brownish/yellow colour → suggests iron, manganese, turbidity, or decaying organic matter.
- Greenish colour → algae presence.
- Colour is important for domestic usability and identifying early contamination.

7. Odour

Odour indicates the presence of dissolved organic compounds, biological activity, industrial pollutants, hydrogen sulfide gas, chlorination, or chemical contamination.
Procedure:

- Gently shake the sample in a closed container.

Open the lid and smell immediately.
Compare with odour intensity scale (Agreeable, Odourless, Unpleasant, Rotten-egg smell, Chemical smell).
Significance:
Rotten-egg smell → Hydrogen Sulphide (H_2S)
Fishy/earthy smell → Organic decay or algae
Chemical smell → Industrial or solvent contamination
Odour assessment helps determine domestic safety and pollution levels.

8.Turbidity

Turbidity is the measure of suspended solids, clay particles, silt, microorganisms, rust, or organic matter that make water appear cloudy. Measured using a Nephelometric Turbidity Meter (NTU).
Procedure:
1. Calibrate the turbidity meter using 0, 20, 40, 100 NTU standard solutions.
2. Fill the sample tube without bubbles.
3. Insert into the meter and record NTU value.

Significance:
•High turbidity blocks sunlight → affects aquatic life.
•Indicates contamination from sewage, erosion, runoff, construction waste.
•High turbidity reduces disinfection efficiency.
•Essential for irrigation and drinking suitability.

Temperature

Temperature represents the thermal condition of water. It directly affects gas solubility, reaction rates, and biological activity.
Procedure:
•Measure using a digital thermometer.
•Record at the site immediately to avoid changes.
Significance:
•High temperature → lower dissolved oxygen → poor water quality.
•Affects metabolic rate of aquatic organisms.
•Influences EC, pH, and chemical reaction speed.

CHEMICAL PARAMETERS

Chemical parameters provide information about acidity, ions, pollutants, metals, salts, nutrients, and contamination levels. These determine groundwater suitability for drinking, agriculture, and industrial use.

pH (Acidity / Alkalinity)

pH is a water-testing parameter that measures how acidic or alkaline water is, on a scale of 0 to 14. A pH indicates hydrogen ion concentration, showing whether water is acidic (<7), neutral (=7), or alkaline (>7).Testing pH is crucial for assessing drinking water safety, its impact on aquatic life, and the efficiency of industrial processes.
What pH Measures
Hydrogen ion concentration: pH indicates the concentration of hydrogen ions (H^+) in a solution.
Acidity/Alkalinity: A higher concentration of hydrogen ions makes water acidic (pH below 7), while a higher concentration of hydroxide ions (OH^-) makes it alkaline (pH above 7).
Importance of pH Testing
Human health: The recommended pH for drinking water is between 6.5 and 8.5. Values outside this range may cause a bitter or metallic taste and can lead to skin or gastrointestinal irritation.
Environmental impact: Aquatic life thrives within a specific

pH range (typically 6.5 to 9). Deviations can harm ecosystems and reduce biodiversity.
Industrial applications: Industries such as pharmaceuticals and food and beverage production require precise pH control for optimal processes.
Toxicity: pH affects the solubility of toxic substances. For example, lower pH can increase the solubility of metals like aluminum, lead, and copper, making them more toxic.
Procedure:
•Calibrate pH meter.
•Dip electrode in the sample.
•Record the stable reading.
Significance:
•Low pH → corrosion of pipes
•High pH → scaling, reduced disinfection
•Ideal range: 6.5–8.5 (BIS standard)

Agriculture and hydroponics: EC is used to assess the concentration of nutrients in irrigation water and growing media.

Fertilizer management: It enables proper fertilizer application, ensuring plants receive adequate nutrients without the risk of toxicity from over-fertilization.

• ***Irrigation management***

By monitoring EC levels, growers can adjust their irrigation practices. High EC may require additional water to leach excess salts from the root zone.
This helps maintain healthy soil and optimal growing conditions for plants.
Procedure:
•Calibrate EC meter using KCl solution.
•Dip probe in the water sample.
•Read value in µS/cm or mS/cm.

Significance:
•High EC → salinity → unsuitable for crops.
•Low EC → good groundwater quality.
•Used to calculate TDS.

Total Dissolved Solids (TDS) measures the concentration of all organic and inorganic substances dissolved in a given volume of water, including minerals, salts, and metals. High TDS can affect the taste of water. While the Bureau of Indian Standards (BIS) sets the acceptable limit at **500 mg/L**, a range of **50–150 ppm** is considered excellent for drinking due to its balanced taste and mineral content.TDS represents dissolved inorganic salts (Ca, Mg, Na, Cl, SO_4, HCO_3).

A measure of dissolved substances: TDS represents the combined amount of all dissolved organic and inorganic substances in water, including calcium, magnesium, potassium, and trace amounts of other compounds from natural and human sources.

- **Measured in ppm:** TDS concentration is measured in parts per million (ppm), which is equivalent to milligrams per liter (mg/L) in water.
- **Impacts water quality:** It influences water taste and can indicate the presence of beneficial minerals or harmful contaminants.

Hardness is a measure of the total concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, expressed as equivalent milligrams of calcium carbonate ($CaCO_3$) per liter (mg/L) or parts per million (ppm). Water is classified as soft (0–60 mg/L), moderately hard (61–120 mg/L), hard (121–180 mg/L), or very hard (>180 mg/L). High hardness can cause scale buildup in pipes and appliances and reduce soap lathering, but it is not considered a health risk and can even contribute to essential mineral intake. It indicates dissolved calcium & magnesium ions.

- **Taste:** Water hardness can influence the taste of drinking water and beverages such as coffee and beer.
- **Mineral intake:** Hard water can be a useful source of dietary calcium and magnesium, while very soft water may lack these essential minerals.
- **Health effects:** Although generally safe, long-term consumption of extremely hard or very soft water has been associated with certain health concerns, but more research is needed.

- Hardness influences the types of aquatic organisms that can thrive in a water body, such as freshwater snails and certain fish species.

- Hard water can affect the texture of baked goods, making dough tougher and influencing yeast fermentation.
- It can also increase the stickiness of pasta during cooking.

Chlorides are salts formed when chlorine combines with a metal. Common examples include sodium chloride ($NaCl$) and magnesium chloride ($MgCl_2$). Chlorine in its elemental form (Cl_2) is highly toxic and is often used as a disinfectant, but when combined with metals such as sodium, it becomes essential for life. Small amounts of chlorides are required for normal cellular functions in plants and animals.

Chlorides are generally not harmful to humans; however, the sodium component of table salt has been linked to heart and kidney disease. Sodium chloride may impart a salty taste to water at concentrations around **250 mg/L**, whereas calcium or

magnesium chlorides usually become detectable by taste only at levels above **1000 mg/L**.
Chlorides may enter surface water from several sources, including chloride-containing rocks, agricultural runoff, industrial wastewater, oil well waste, effluents from wastewater treatment plants, and road salting. High chloride levels can corrode metals and affect the taste of food products. Therefore, industries and processed water systems have recommended maximum chloride limits. Excess chloride can also contaminate freshwater streams and lakes.
•Source: sewage, fertilizers, industrial waste.
•High Cl → salty taste.

Nitrates

Agricultural fields are the main diffuse source of nitrate (NO_3^-) leaching into groundwater. Nitrates can also come from point sources such as animal exercise yards and manure storage facilities. Groundwater contamination by nitrates has been increasing toward the end of the 20th century.
Elevated nitrate concentrations (greater than **2 mg/L**) in drinking water have been linked to adverse health effects. In infants, nitrate ingestion can lead to low oxygen levels in the blood, causing *methemoglobinemia*, a potentially fatal condition. High levels of nitrate and nitrite can also cause methemoglobinemia in livestock and wildlife.

Excessive inputs of nitrates and phosphorus into water bodies promote excessive growth of algae and aquatic plants. When these organisms die, bacteria decompose them and consume dissolved oxygen, leading to *eutrophication*. Oxygen levels can drop to the point where fish cannot survive, resulting in fish kills.

Fluoride

The major sources of fluoride in groundwater include fluoride-bearing rocks such as fluorspar, cryolite, fluorapatite, and hydroxylapatite. Fluoride levels in groundwater depend on several factors, including the availability and solubility of fluoride minerals, water flow velocity, temperature, pH, and concentrations of calcium and bicarbonate ions.
Although fluoride enters the body through food, water, industrial exposure, drugs, and cosmetics, **drinking water contributes 75–90% of daily intake**. Due to its strong electronegativity, fluoride is attracted to positively charged calcium in teeth and bones. Excess fluoride intake can lead to **dental and skeletal fluorosis**, along with other non-skeletal health issues.

HYDROLOGICAL PARAMETERS

Hydrological parameters help analyze groundwater recharge, movement, evapotranspiration, and aquifer interaction.

Recharge & Discharge Rates

Recharge

Amount of water entering the groundwater system through rainfall, infiltration, and seepage.

Discharge

Water leaving through pumping, springs, wells, rivers.

Purpose:

To understand aquifer sustainability and safe yield.
Rainfall Infiltration Rate
Percentage of rainfall that actually infiltrates through soil and reaches aquifer.
Procedure:
•Calculated using double-ring infiltrometer.

•Record drop-in water level over time.

Significance:

•High infiltration → good recharge

•Clay soil → very low infiltration (1–5 mm/hr)

Evapotranspiration (ET)
Combined loss of water from soil evaporation + plant transpiration.

Methods:
•Penman–Monteith equation
•Remote sensing NDVI-based ET mapping
Significance:
•High ET in Dharwad (1600–1700 mm/year) → requires more groundwater for crops.

5.3 Baseflow Contribution to Surface Water:

Groundwater naturally flowing into rivers, lakes, or streams. Importance: Shows groundwater–surface water connection. Reduces during dry season → indicator of aquifer health.

CONCLUSION

The study demonstrates that Geo-spatial Technology is a powerful, accurate, and sustainable tool for analyzing groundwater resources. Dharwad district exhibits diverse soil properties, variable recharge rates, and mixed groundwater quality influenced by urbanization and agriculture.

Sl no	Quality	Site pre msn
Dharwad msn		
1	Excellent	1,2,3,4,5,8,9,10,11,12,14, 16,17,18,19.
2	Good	6,7,13,20.
3	Poor	-

SL NO	Quality	Site pre msn
Belur msn		
1	Excellent	1,2,3,5,6,7,8.
2	Good	4,9
3	Poor	10.

SL NO	Quality	Site pre msn
Tarihal msn		
1	Excellent	1,3,5,6,7,8.
2	Good	2,4,9.
3	Poor	10.

Sl no	Quality	Site post msn
Dharwad msn		
1	Excellent	1,3,6,7,8,11,12,13,19,20.
2	Good	2,4,5,9,10,14,15,16,17
3	Poor	18.

SL NO	Quality	Site post msn
Belur msn		
1	Excellent	1,6.
2	Good	2,3,7,8,9,10.
3	Poor	4,5.

SL NO	Quality	Site post msn
Tarihal msn		
1	Excellent	2,4,5,6,7,10.
2	Good	1,8.
3	Poor	3,9.

Highest Total hardness of sampels:

	pre manson	post manson
1. Dharwad Location	(S.no 13)-32.5	(S.no 2)-25.2
2. Belur Location	(S.no 1)-13.6	(S.no 5)-8.5
3. Tarihal Location	(S.no 3)-35	(S.no 3)-500

Lowest Total hardness reading of sampels:

	pre manson	post manson
1. Dharwad Location	(S.no 16)-11.5	(S.no 10)-14.8
2. Belur Location	(S.no 6)-5.9	(S.no 10)-1.75
3. Tarihal Location	(S.no 4)-10.2	(S.no 8)-275

High levels of calcium and magnesium in groundwater can harm crops because they affect both the soil and irrigation systems. Too much magnesium can make the soil more alkaline and cause the soil particles to separate, reducing water movement into the soil. Hard water can also clog irrigation pipes, which leads to poor water flow and uneven watering in the field. All of this can reduce crop growth and yield. Excellent quality water is suitable for use and good or poor is not suitable for use.

Many industries release waste water and chemicals into the ground. This pollutes the groundwater and makes it unsafe to drink. People who use this polluted water may suffer from health problems like skin diseases and stomach issues,and not suitable for yielding purpose.
Overall, industrial use of groundwater harms people, agriculture, and the environment.

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