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Determining Areas for Potential Groundwater Recharge in Industry Premises using GIS

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Abstract:- Groundwater is a vital resource that plays a significant role in sustaining many different industries. To ensure the long-term availability of this resource, it is essential to identify potential groundwater recharge points within industrial premises. This study focuses on the determination of optimal locations for groundwater recharge within industrial sites. Through a combination of geospatial analysis, hydrological modelling, and site-specific assessments, potential recharge points are identified based on factors such as land use/land cover, soil type, hydrogeological conditions, along with rainfall patterns. The methodology involves integrating geographic information system (GIS) data, hydrological modelling techniques, and field investigations. By identifying suitable areas for groundwater recharge, industries can implement sustainable water management practices that enhance groundwater availability, mitigate water scarcity, and contribute to the overall environmental sustainability of industrial operations. The findings of this study provide valuable insights for decision-makers and industrial stakeholders seeking to establish effective groundwater management strategies within their premises. In this study, a fruit processing/beverage industry situated in Narimogaru a village in Puttur Taluk, DakshinaKannada District, Karnataka is the area of study within the extent, 12° 45.69’- 12° 45.54’N, left: 75° 15.06’-75° 15.24’E and of area 63155.5 sq. km. It was determined to have 4 main classifications of land use/land cover, namely barren, buildings, greenery and paved. The soil group was identified as HSG-C and possible runoff of 105246000 million litres during the wet season of the year was calculated from the daily rainfall data for the wet season of the previous year.

Keywords:- *GIS; Ground Water Recharge; SCS-CN Curve Number; Geospatial Analysis.*

I. INTRODUCTION

Water has been one of the most significant natural resources for the foundation of life on earth. Surface water consumption increased, and there were shortages due to high population density, unequal water resource distribution, demand over space and time, economic development, and climatic change. Because the surface water resources are insufficient to supply all the water needed for drinking, irrigation, and industrialization, there is a growing need for groundwater (Krishnamurthy et al., 1996). Groundwater, a vital and finite natural resource, serves as a lifeline for various sectors, including industrial activities. With industries being major water consumers, the sustainable management of groundwater resources within their premises is paramount. As global water scarcity intensifies, identifying and establishing potential groundwater recharge points within industrial sites becomes crucial. Groundwater recharge, the refilling of underground aquifers by channeling surface water into the subsurface, emerges as a sustainable solution to counterbalance over-pumping and ensure the resilience of hydrological systems.Bouwer in 2002,thoroughly analyzes the idea and application of artificial recharge. Because it can act as a buffer against climatic variability and related floods and droughts, as anArtificial recharge using treated wastewater and stormwater has been successful in reversing groundwater decreases. Better infiltration and recharge methods must apply more frequently to maximize the capture of runoff and treated wastewater (Konikow& Kennedy, 2005).

Identifying suitable areas for groundwater recharge in industrial premises necessitates a holistic approach that combines geospatial analysis, hydrological modeling, and on-site evaluations. Factors such as land use patterns, soil characteristics, hydrogeological settings, and local precipitation regimes collectively influence the recharge potential of a given area. By strategically pinpointing these recharge zones, industries can actively contribute to responsible water stewardship, mitigate the risk of aquifer depletion, and foster the prolonged availability of groundwater resources.Numerous studies either directly or indirectly address methods for calculating groundwater recharge. With advancements in technology and analysis, remote sensing science has made significant strides during the past century.Jackson (2002) discusses how soil moisture monitoring and water balance modeling can be used to measure groundwater recharge on a broad scale remotely.To predict recharge rates, soil hydraulic characteristics have also been determined via microwave remote sensing of soil moisture (Jackson, 2002). A GIS cross-overlay approach combines various component maps and weight data about controls on recharge processes (Lubczynski and Gurwin 2005). The mapping of relative recharge rates has been used in DRASTIC-based investigations of aquifer vulnerability (Fritch et al. 2000; Al-Adamat et al. 2003) and as input data for numerical modeling (Salama et al. 1999; Lubczynski and Gurwin 2005).The groundwater recharge potentiality study using remote sensing (RS) and geographic information systems (GIS) addresses indicative surface elements like lineaments and drainage frequency and density, lithologic character, land cover/land use, etc., reflecting hidden hydrogeologic characteristics. The recharge potential is better estimated and qualitatively evaluated as a result. According to Adham et al. (2010), contours, surface and subsurface lithological characteristics, and land cover/land use, all play significant roles in the recharge process of groundwater. The drainage number (frequency) has the most substantial relationship with the recharge property.Krishnamurthy et.al., 1996 used ArcGIS for a case study in Ottapidaram taluk, Tuticorin district,where RS and GIS have been used to integrate various thematic maps such as lithology, slope, land use, contour, drainage, soil, and rainfall, which play an essential role in the study of occurrence, quality and movement of groundwater in the area under consideration. The various thematic maps were assigned with different weightage of numerical values to derive groundwater potential area.

Rain and runoff are the main water sources for recharging groundwater in the watershed. To estimate the runoff volume from the land surface that enters rivers or streams, utilize the SCS-CN approach(Satheeshkumar et al., 2017).AshishPandey et.al.,2003 applied the Soil Conservation Service (SCS) model for a study to estimate runoff in the Karso watershed using GIS and the Soil Conservation Service (SCS) model. The research, which covered a 2793hectare area in the Damodar Barakar catchment in the Jharkhand province of Hazaribagh, India, included information on hydrologic soil group, land use, and antecedent moisture conditions.The potential for using the SCS model modified for Indian conditions, highlighting the use of GIS in hydrological applications, and predicting runoff.In another study by Cantik etal.,2022 GIS was comprehensively used wherethe study focused on determining surface runoff in the SummareconSerpong area, an integrated development region in Tangerang Regency, Indonesia.

Changes in land use/land cover (LULC), urbanization, population increase, and climate change are all important threats to natural resources around the world. Water scarcity and steadily depleting surface and groundwater supplies are major drivers of societal vulnerability in emerging countries(Verma et al., 2019).The primary causes of groundwater depletion are rapid urban growth and extensive groundwater exploration for agriculture and other domestic uses. As a result, appropriate techniques for the sustainable management of natural resources and environmental monitoring are needed. The physical terrain has changed along with the demographic features due to human-induced processes. According to numerous studies (Yan et al. 2016; Battista and de Lieto Vollaro 2017; Chaudhuri et al. 2017; Somvanshi et al. 2018), increased urbanization can adversely affect environmental elements like water, land, and air.Groundwater recharge varies depending on the type of LULC (Owuor et al., 2016). Increased groundwater recharge results from the conversion of forest land/native vegetation to managed LULC systems. The impact of LULC on groundwater recharge is primarily determined by the vegetation rooting system, canopy interception capacity, and transpiration rates (Taniguchi 1997, Wang et al. 2004).

Since soil is the medium through which water must penetrate to reach the water table, it considerably influences groundwater recharge and runoff (Murthy, 2000). Depending on the soil type, the water-holding capacity and permeability of the soil become associated characteristics. In agricultural settings, soil types are a more essential factor in groundwater recharge. Soils, on the other hand, have an essential role in supporting or preventing groundwater recharge and measuring groundwater quality (Lillesand and Kiefer, 1987; Chotpantarat et al., 2011; Baghapour et al., 2014; Masipan et al., 2016; Selvam et al., 2016). Soil types play an important role in the amount of water that can infiltrate into the subsurface formations, hence infuence groundwater recharge(Ibrahim-Bathis& Ahmed, 2016), (Das, 2017). The soil texture and hydraulic characteristics are the mainfactors considered for estimation of rate of infltration.

This study embarks on a comprehensive assessment to identify potential groundwater recharge points within industrial facilities. By leveraging diverse geographic information system (GIS) datasets, sophisticated hydrological modeling methodologies, and meticulous field investigations, this research attempts to formulate a systematic framework for locating optimal recharge sites. Through this exploration, the research intends to provide valuable insights for industrial stakeholders, water resource managers, and policymakers, facilitating well-informed decisions in devising effective groundwater management strategies. These strategies are essential for ensuring consistent water supply to industries and upholding the broader environmental equilibrium of the regions in which they operate.

II. METHODOLOGY

The methodology adopted for identifying potential groundwater recharge areas within industrial premises encompasses a series of sequential steps, integrating geospatial analysis, hydrological modeling, and empirical data collection. This approach provides a comprehensive knowledge of the hydrological mechanisms regulating groundwater recharge and allows for strategically selecting optimal recharge sites.

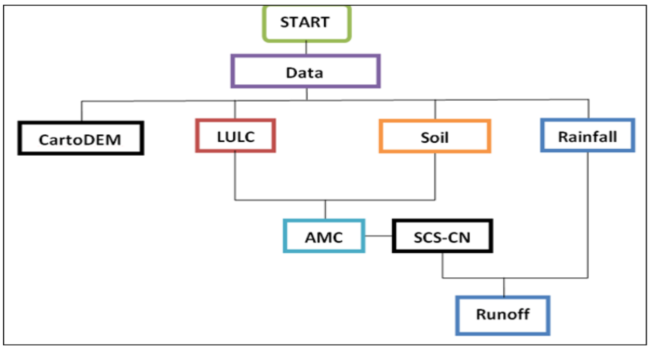

Fig 1 Process Flowchart

- *Determining Suitable Regions:*

The study used a Digital Elevation Model (DEM) from the Bhuvan Open Data Archive, a CartoDEM captured by Cartosat, to identify the area of interest. A polygon layer was created using QGIS 3.26.3 software, and contours were generated using the regular points tool. The DEM was color-coded according to elevation levels to identify areas with the lowest elevation. This method was necessary due to the area's small size, which posed challenges for accurate river network and watershed delineation. The color-coded DEM helped determine the most suitable sites within the zones of lowest elevation, refining the selection process for optimal groundwater recharge locations.

- *Land use Classification:*

Land use refers to human activities like agriculture, transport, forestry, and building construction that alter land surface processes, including hydrology. A meticulous digitization process was conducted using Google Hybrid imagery to classify different land use types within the study area, which served as the foundation for subsequent analyses.

- *Soil Classification and Curve Number Determination:*

Soil types play a critical role in groundwater recharge. Soil data was acquired from the Global Hydrologic Soil Groups (HYSOGs250m) database. By leveraging the raster attribute table, soil classes were assigned to corresponding areas within the study region. The Soil Conservation Service Curve Number (SCS-CN) method was then applied using the assigned soil classes to calculate curve numbers that quantify runoff potential.

- *Rainfall and Cumulative Rainfall Calculation:*

Historical daily rainfall data from the previous wet season was obtained. Cumulative rainfall, a key determinant of infiltration, was computed by summing the daily rainfall values. This cumulative approach provided insights into the overall wetness condition of the area over time, which in turn influences the antecedent moisture condition (AMC) for runoff calculations.

Table 1 Antecedent Moisture Condition (AMC)

AMC	Cumulative precipitation
1	<35.6 mm
2	between 35.6 mm to 53.4 mm
3	>35.6 mm

- *Runoff Calculation:*

Building upon the calculated cumulative rainfall and AMC, the Curve Numbers (CN 1, 2, and 3) were assigned based on the calculated SCS-CN values.Then thecurve numbers is used to derive the potential runoff depth for each land use and soil combination. The product of the area and runoff depth yielded the total runoff for the given combination.

$$CN2 = \frac{\sum(CN.Area)}{\sum Area}$$

$$CN1 = \frac{CN2}{[2.281 - 0.01281(CN2)]}$$

$$CN3 = \frac{CN2}{[0.427 + 0.00573(CN2)]}$$

$$S,(mm) = \frac{25400}{CN(as\ per\ AMC)} - 254$$

$$Q = \frac{(P - 03S)^2}{(P + 0.7S)}$$

- *Field Verification and Validation:*

Field visits were conducted to ensure the accuracy of the selected recharge points. Soil tests, infiltration rate measurements, and visual assessments of hydrogeological conditions were performed on-site to validate the suitability of the identified recharge areas.

- *Integration and Final Selection:*

Combining the results from the cumulative rainfall analysis, runoff calculations, and field validation, the final groundwater recharge points were identified. The convergence of empirical data and modeled insights facilitated the selection of sites that exhibited optimal infiltration and groundwater recharge conditions.

The methodology encapsulates a comprehensive approach that amalgamates data-driven analysis with empirical validation. By leveraging land use, soil characteristics, cumulative rainfall, and hydrological modelling, the methodology serves as a robust framework for identifying and prioritizing potential groundwater recharge points within industrial premises.

III. RESULTS AND DISCUSSIONS

- *Determining Suitable Regions:*

The extent of the industrial area is, 12° 45.69'-12° 45.54'N, left: 75° 15.06'-75° 15.24'E. The simple lines in white represent the contours. The symbology shows the highest elevation in dark green, lowest elevation in deep blue, and intermediate elevations in shades of brown. The suitable region was identified within which 2 most suitable regions (higher priority) and 2 next suitable regions (high priority) and the remaining regions (least priority) were determined and shown in varying shades of blue.

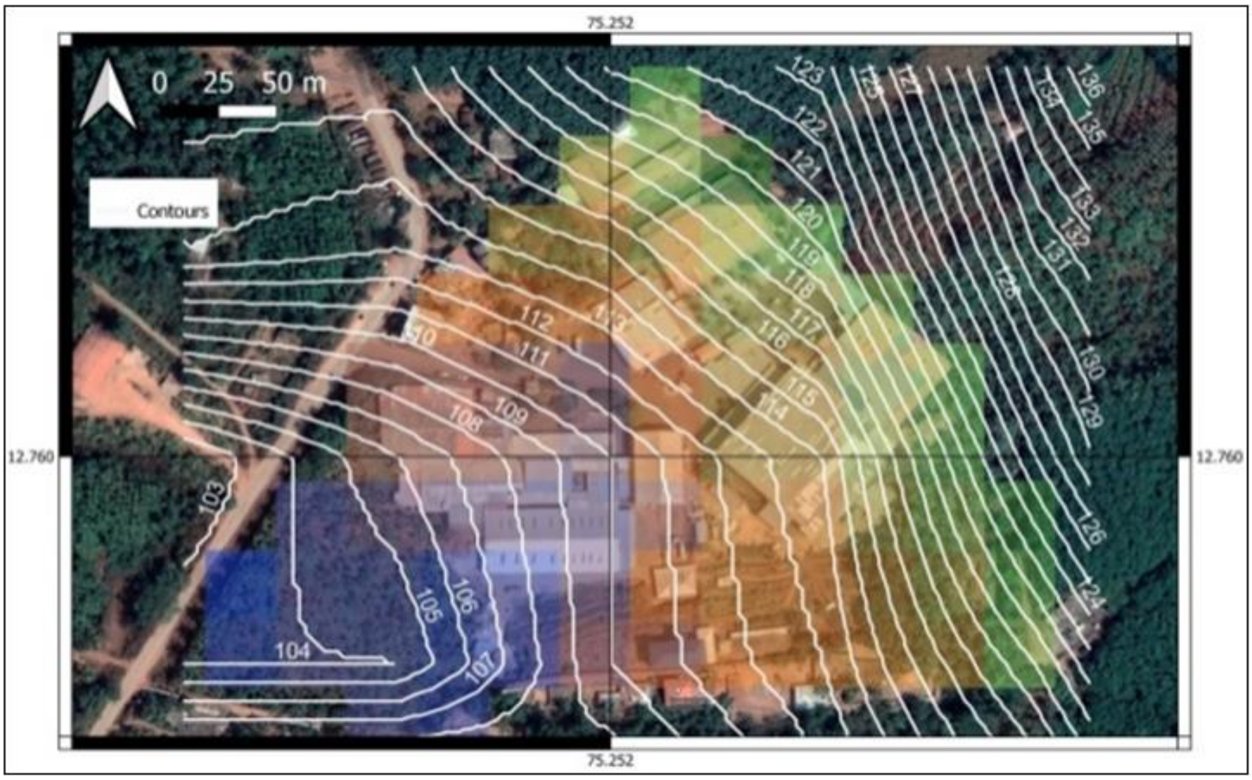

Fig 2 Contour Map Generated from DEM

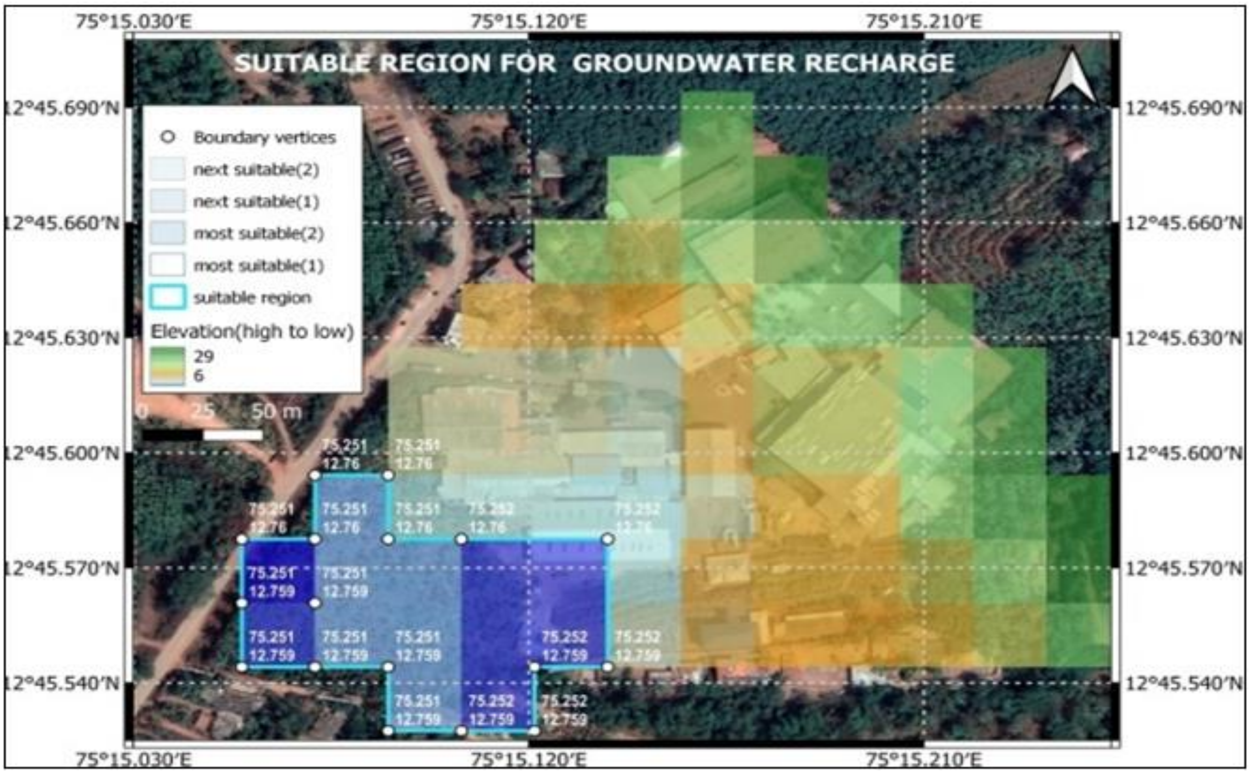

Fig 3 Suitable Region for Groundwater Recharge

- *Land use Classification:*

The area of study contains 4 main classes of land use/land cover, namely barren, buildings, greenery and paved which were manually digitized and paved.

- *Soil Classification and Curve Number Determination:*

The Soil type layer clipped to the study area showed only one class ID, i.e. 3, which correspond to soil group HSG-C: moderately high runoff potential (<50% sand and 20-40% clay). The respective CN values referring to SCS TR-55 Table 2-2a– Runoff curve numbers for urban areas were logged.

- *Runoff Calculation:*

The total runoff calculated was 105246000 million litres possible during the wet seasonof the year, based on the daily rainfall data for the wet season of the previous year (01-Jun-2022 to 31-Aug-2022).

IV. CONCLUSION

The study focuses on identifying potential groundwater recharge points in the beverage industry, especially in response to changing weather patterns. It highlights the importance of groundwater recharge as a resilient water management strategy. The project uses geospatial analyses, hydrological modelling, and empirical validation to identify optimal recharge sites. The integration of GIS in the industry helps navigate weather dynamics and informs recharge strategies. The research also emphasizes adaptive water management, as groundwater recharge can mitigate extreme events, support ecosystems, and enhance sustainability. This research contributes to sustainable water management discourse and cultivates resilience amidst dynamic weather conditions.

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- *Conflict of Interest*

There are no conflicts to declare.

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