Theme 13

PROTECTION OF GROUNDWATER DEPENDENT ECOSYSTEMS - RIVERS, WETLANDS, LAKES AND SPRINGS

A HOLISTIC APPROACH FOR IDENTIFYING ARTIFICIAL GROUNDWATER RECHARGE ZONES TO REJUVENATE UNGAUGED LAKES AFFECTED BY GROUNDWATER DROUGHT

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Surface water bodies such as lakes are vital sources of fresh water for many communities and are important for local ecology. Hence, it is necessary to identify whether they exhibit gaining or losing nature over time and become perennial or non-perennial, especially for ungauged lakes. It is crucial to determine natural and anthropogenic activities that enhance groundwater drought and cause changes in the lake's behaviour. Therefore, it is necessary to identify the causes that influence groundwater drought near lakes. If the groundwater storage anomaly occurred due to a precipitation, there exists a strong correlation between them. The correlation between the groundwater storage anomaly and precipitation is found to be weak due to anthropogenic activities. Artificial recharge structures (ARSs) play a vital role in managing groundwater reserves and rejuvenating lakes to reduce the vulnerability of groundwater drought caused by meteorological events. There are many studies related to prioritizing the zones suitable for ARS for managing groundwater resources. The novel aspect of this study is to identify the zones suitable for ARS to rejuvenate the lake during non-monsoon seasons by recharging water into the aquifer during monsoon season. The objectives of the study are (i) developing Satellite–Derived Bathymetry (SDB) models to estimate the depth of water at ungauged lakes, (ii) computation of the relationship between head difference (groundwater table (GWT) and water surface elevation (WSE) in lakes), standardized groundwater table index (SGWTI), and Standardized Precipitation Evapotranspiration Index (SPEI), (iii) identifying the suitable zones for ARSs for lake rejuvenation by integrating remote sensing, GIS, Multi Criteria Decision Analysis (MCDA) and hydrogeological techniques, (iv) proposing suitable methods in different types of ARSs for lake rejuvenation.

Optical-based SDB essentially relies on the principle that there is a statistical relationship between the amount of energy reflected from a water column that a sensor can detect and the depth of the water. The Landsat-5, 8 top-of-atmosphere (TOA) reflectance data at different time bands are initially employed to establish a correlation with the water column depth. The band values are extracted for multiple stream gauge stations operated by the CWC using the Google Earth Engine (GEE) platform. The temporal resolution of Landsat-5, 8 is 16 days, and a cloud filter of about 20% is applied while extracting pixel values between 2001 and 2018. The difference between the regular river WSE and the WSE at zero discharge (river bed elevation) helps to calculate the water depth (daily time series) in stream gauge stations located in the upper Godavari River stretch. For the present study, three stream gauge stations were chosen at Dhalegaon (76.3667E, 19.2037N), G.R. Bridge (76.7174E, 19.0191N), and Panchegaon (74.8786E, 19.5376N). The datasets are merged based on date, and splitting was performed to create training (75%) and testing (25%) datasets. Finally, various machine learning (ML) algorithms like decision trees, eXtreme gradient (XG) Boost, and Random Forest are applied to develop the relationship between the depth of water in the river (m) and

the reflectance values at various bands. The various evaluation metrics like coefficient of determination (R2), Mean Squared Error, Root Mean Square Error, and K–Fold Cross Validation (CV) are computed. Based on the evaluation metrics, the best performance model is identified. The best performance model is used to determine water depth in lakes.

For computation of SPEI, the daily precipitation (0.25°×0.25° resolution) and temperature data (1o×1o resolution) are downloaded for years 2008–2018 from the IMD website. The potential evapotranspiration is computed by the Hargreaves method. The daily disparity (in mm) is determined by taking the difference between daily precipitation and evapotranspiration. The daily disparity is then transformed to a 3-month disparity. The transformed disparity is fitted by using Pearson-3 distribution by using the Kolmogorov–Smirnov test (KS test) at 5% significance level. The parameters of the Pearson-3 distribution are estimated by using the maximum likelihood method. The SPEI is estimated by using the method proposed by. For computation of SGWTI, the groundwater levels for the years 2008–2018 (seasonal data) are obtained from the CGWB. The groundwater levels at various observation wells are fitted by using various continuous distributions like gamma, normal, Pearson-3, exponential, Gumbel, Pareto, and generalized extreme value distributions by using the Kolmogorov–Smirnov test (KS test) at 5% significance level. The parameters of the distributions are computed by using the method of moments. The SGWTI is computed by standardizing CDF obtained from the best-fitted distribution. Finally, the relationship between head difference, SPEI, and SGWTI is quantified by plotting the Pearson correlation matrix. A strong correlation between SPEI and SGWTI signifies that stronger influence of meteorological parameters (precipitation and temperature) on groundwater levels, and a weak correlation implies some anthropogenic influence. A strong correlation between SGWTI and head difference signifies that groundwater drought impacts the lake water level and vice versa for a low correlation. The suitable zones for ARS for lake rejuvenation are identified by using considering various factors such as runoff–rainfall ratio, frequency of groundwater drought, frequency of waterlogging, soil type, land use & land cover, geology, lineament density, distance from lakes, lake density, transmissivity, the thickness of the aquifer, depth of the aquifer, average groundwater fluctuation, elevation, and slope. The entropy method is used to determine the weightage of each attribute, and the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) is used to determine the rank for suitable zones. The highly suitable zones are validated with the lakes, which are highly influenced by groundwater drought. The results reveal that strong correlation is achieved between SPEI and SGWTI at different lakes in the river basin. It implies that the precipitation deficit and elevated temperatures led to a groundwater drought in the upper Godavari Basin. The suitable zones for artificial groundwater recharge were identified using hydrogeological, remote sensing, and climatic data analysis. By employing artificial recharge strategies, targeted regions experience an increase in groundwater levels, which will then positively influence lake water levels, helping to mitigate the effects of drought. The study shed light on the interaction between meteorological drought, groundwater drought, and their combined effects on lake sustainability, particularly in areas lacking direct monitoring. This research identifies effective groundwater recharge zones to restore ungauged lakes that have been impacted by drought. It provides a replicable model for enhancing lake sustainability and supporting strategic water management decisions under drought conditions.

Keywords: *Artificial groundwater recharge, groundwater drought, satellite–derived bathymetry, remote sensing, machine learning, lake rejuvenation*

IDENTIFICATION OF MORPHOMETRICAL PARAMETERS USING GEOSPATIAL TECHNIQUES OF TROPICAL RIVER BASIN, KERALA, INDIA

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Morphometry is characterized as the quantitative assessment and mathematical evaluation of the Earth's surface configuration, alongside the geometrical attributes and magnitudes of its landforms. Morphometric assessment of a river basin yields a quantitative representation of the hydrological network, which constitutes a critical element in the characterization of drainage basins. The evolution of a drainage system across both spatial and temporal dimensions is modulated by a multitude of factors, including the geological framework, structural elements, geomorphological characteristics, as well as the soil and vegetative cover of the region through which it traverses. The quantification of geomorphometric parameters, including but not limited to basin area, perimeter, length, stream order, bifurcation ratio, stream length, stream frequency, drainage density, elongation ratio, circularity ratio, form factor ratio, and texture ratio, of any given basin provides comprehensive insights into the geological, physiological, and hydrological dynamics inherent to that basin. Numerous researchers have conducted investigations into the morphometric characteristics of drainage basins, utilizing them as indicators of structural influences on the evolution of drainage systems and neotectonic processes. The utilization of remote sensing and Geographical Information System (GIS) methodologies has also gained prominence on a global scale. The Kuttiyadi River basin, located in the state of Kerala, has been selected for a comprehensive analysis for the purpose of formulating effective watershed management strategies. The study area constitutes a segment of the Precambrian granulite terrain located in southern India. The basin area is predominantly occupied by hornblende gneiss, which has undergone granulite-grade metamorphism. The presence of charnockite is extensively observed in the northeastern vicinity of the Kuttiyadi basin. The study was undertaken using Survey of India (SOI) topographical maps (1:50,000) and Arc GIS 10.8 software. Various thematic layers were prepared and estimation of morphometric parameters was done. The Kuttiyadi river basin has been classified into six distinct sub watersheds of 6^{th} order, and were subsequently digitized utilizing a topographic map. The computation of basin parameters essential for morphometric analysis, including ordering, lengths, area, and so forth, was conducted within a GIS platform. The morphometric variables that were computed have been systematically categorized into linear parameters, relief parameters, areal parameters. These computed parameters were subsequently used to derive additional metrics such as stream length ratio (RL), bifurcation ratio (Rb), drainage density (Dd), stream frequency (Fs), drainage texture (T), form factor (Ff), circularity ratio (Rc), elongation ratio (Re), constant of channel maintenance (C), length of overland flow (Lo), relief ratio (Rr), gradient ratio (Gr), and ruggedness number (Rn) for each of the five sub-watersheds. The first order has 1672 streams totalling 861.424 km, with a mean length of 0.5152 km. The bifurcation ratio (Rb) for this order is 5.5919, and the stream length ratio (RL) is 0.2315. As the stream order increases, the number of streams decreases, and their mean length increases. The sixth order has a single stream of 41.2420 km. The values of bifurcation ratio and stream length ratio indicate the hierarchical structure and scaling patterns of the stream network within the basin. The hydrological characteristics of the study area, as determined using Strahler's method, reveal several key attributes that describe its drainage and stream network. The area of the basin is 664.584 km^2, with a perimeter of 153.2031 km and a basin length (Lb) of 42.78 km. The total stream length within the basin is 1341.5185 km, and there are 2081 streams of varying orders. The relief ratio (Rh) is 1900, indicating a steep and rugged landscape, reflected further by a ruggedness number (Rn) of 941.293. The drainage density (D) of the basin is 2.0185, suggesting a relatively high concentration of streams, while the stream frequency (Fs) is 3.1312, indicating the number of streams per unit area. The elongation ratio (Re) is 4.9474, and the form factor (Rf) is 15.5567, highlighting the shape of the basin and its tendency towards a more elongated form. The circularity ratio (Rc) is 0.3556, and the compactness coefficient (Cc) is 1.6758, both of which describe the basins compactness and its potential for efficient drainage. These parameters collectively provide a comprehensive overview of the basins hydrological and geomorphological features. In conclusion, the morphometric analysis of the Kuttiyadi River basin offers valuable insights into its hydrological and geomorphological characteristics. The study highlights the intricate relationship between stream network structure, basin shape, and landscape features. The high drainage density and steep relief indicate a dynamic and active drainage system, while the elongation and form factor suggest an elongated basin with potential for efficient water flow. The detailed parameters derived from this analysis provide essential information for effective watershed management and contribute to understanding the basin's response to both natural and anthropogenic influences.

Keywords: *Morphometry, geospatial techniques, Kuttiady, River basin*

TERRAIN MODELLING OF MANANTHAVADY RIVER BASIN, WAYANAD DISTRICT, KERALA, INDIA

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Morphometry, the quantitative study of landform shapes and dimensions, is a fundamental tool for understanding the geomorphological and hydrological characteristics of drainage basins. This field of study provides valuable insights into the structural and functional aspects of basins by analyzing parameters such as stream order, drainage density, stream frequency, basin elongation, and relief ratios. These metrics help evaluate the geometry of a basin, its runoff characteristics, flood susceptibility, erosion potential, and sediment transport dynamics. Such information is crucial for effective watershed management, land use planning, and environmental conservation. Morphometric analysis, conducted using Remote Sensing (RS) and GIS technologies reveals significant insights into the basin's geomorphological and hydrological behavior. Using Survey of India topo-sheets and ASTER GDEM data, the drainage network was delineated and analyzed based on Horton's stream ordering method. Morphometric parameters were calculated, including stream length, bifurcation ratio, drainage density, elongation ratio, circularity ratio, and form factor.

The Mananthavady River Basin (MRB), located in the northeastern part of Wayanad district, Kerala, is a tributary of the Kabani River and a significant component of the Western Ghats' hydrological network. Encompassing an area of 358.822 km², the basin lies within latitudes 11°40'00" N to 11°59'22" N and longitudes 75°46'38" E to 76°5'00" E, with elevations ranging from 720 m to 1860 m above mean sea level. The region features rugged terrain, including hill ranges, valleys, and alluvial plains, which provide a dynamic setting for studying drainage patterns and morphometric characteristics. The part of the MRB, originates near the Thondarmudi peak. The river merges with the Panamaram River at Koodalkadavu, where it becomes the Kabani River, eventually flowing into the Kaveri River in Karnataka. The stream order analysis of the MRB reveals a hierarchical distribution of streams, with the first-order streams dominating both in number and total length. There are 1051 first-order streams, totaling 366.34 km, with a mean length of 0.348 km. As the stream order increases, the number of streams decreases, while their mean length increases. Second-order streams number 523, spanning 173.23 km with an average length of 0.33 km. Higher-order streams, including the third (52 streams, 86.63 km), fourth (13 streams, 28.25 km), fifth (3 streams, 15.12 km), and sixth (1 stream, 27.11 km), show a progressive increase in stream length, reflecting the basin's typical fluvial hierarchy. The elongation ratio (0.325), circularity ratio (0.037), and form factor (0.293) suggest the basin has an elongated shape, leading to extended flow paths, slower peak discharges, and a reduced risk of flash floods. However, the high basin relief contributes to significant surface runoff and higher flow velocities during rainfall events, which can increase erosion risks. The ruggedness number, indicative of moderate erosion susceptibility, highlights the influence of steep slopes in shaping the basin's hydrology. Stream length is inversely proportional to stream order, indicating the homogeneity in geological and weathering processes. The basin is dominated by crystalline rocks, particularly those of the Wayanad Group and charnockites, which contribute to the predominance of lower-order streams and the dendritic drainage pattern. The mean bifurcation ratio (4.066) suggests minimal structural disturbances, reflecting a relatively

stable drainage network. Areal morphometric parameters like drainage density (1.941 km/km²) emphasize the influence of impermeable crystalline rocks and steep slopes, resulting in efficient surface runoff but limited groundwater recharge. Relief morphometric parameters, including high basin relief and moderate ruggedness, further underscore the basin’s susceptibility to erosion and high runoff potential. The MRB's geomorphology is largely defined by steep slopes, impermeable crystalline rocks, and a dense drainage network. These factors result in high surface runoff, limited groundwater recharge, and moderate susceptibility to soil erosion, particularly in steeper areas. Understanding these features is vital for developing sustainable water resource management practices and mitigating risks such as flooding and soil degradation. The MRB’s hydrological characteristics shows moderate to high stream discharge and elongated flow paths. These features, coupled with its high drainage density and rugged topography, require targeted watershed management strategies. Recommendations include afforestation to enhance infiltration, constructing check dams to regulate water flow, and implementing soil conservation measures to minimize erosion in vulnerable areas. Sustainable land use planning and monitoring human activities, such as deforestation and unplanned land use changes, are critical for maintaining the basin’s ecological balance. MRB exemplifies the interplay between geomorphology and hydrology in shaping drainage systems. Its elongated shape, dendritic drainage pattern, and high runoff potential emphasize the importance of morphometric analysis in guiding effective watershed management. By integrating geomorphological and hydrological insights with sustainable practices, this study offers valuable recommendations for preserving the basin’s ecological and hydrological integrity.

Keywords: *Morphometry, GIS, Remote sensing, Kabani River, ASTER GDEM*

PERMANENT SOLUTION FOR FLOOD AND DROUGHT CONDITIONS – A NEW SCIENTIFIC AND NATURE BASED WATER NETWORKING PROTOCOL TO NEUTRALIZE THE GLOBAL THREATS AND ENSURE WATER SECURITY FOR THE FUTURE GENERATIONS BY FOCUSING ON GROUNDWATER

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Water is essential to all life. Human species use water directly for domestic needs, growing food, generating power and for industrial processes. Ensuring sufficient water for people for these purposes is an important ethical question. Population growth, lifestyle changes, development, and agricultural practices will contribute to an increasing demand for water during the next 20 years. Global water use is likely to increase by 20 to 50 percent above current levels by 2050, with industrial and domestic sectors growing at the fastest pace. Urbanization and climate change are together exacerbating water scarcity where water demand exceeds availability for the world’s cities. Water and climate change are inextricably linked. Climate change is primarily a water crisis. We feel its impacts through worsening floods, rising sea levels, shrinking ice fields, wildfires and droughts. Drought and flood risks, and associated societal damages, are projected to further increase with every degree of global warming. By 2050, the number of people at risk of floods will increase from its current level of 1.2 billion to 1.6 billion. The impacts of disasters are exacerbated by urbanization and degradation of natural environments. Improving the resilience of water and sanitation services and protecting ecosystems will be key to surviving a climatically uncertain future.

India is highly vulnerable to floods. Out of the total geographical area of 329 million hectares (mha), more than 40 mha is flood prone. Floods are a recurrent phenomenon, which cause huge loss of lives and damage to livelihood systems, property, infrastructure and public utilities. It is a cause for concern that flood related damages show an increasing trend. This can be attributed to many reasons including a steep increase in population, rapid urbanization growing developmental and economic activities in flood plains coupled with global warming. Floods have also occurred in areas, which were earlier not considered flood prone. Continuing and large-scale loss of lives and damage to public and private property due to floods indicate that we are still to develop an effective response to floods. There has been an increasing trend of urban flood disasters in India over the past several years whereby major cities in India have been severely affected. The idea of a river as a living spiritual entity has no cognitive niche in Western materialism. By clarifying our values and ethical principles about water and nature, and about people and cultures, we will know better who we are, how we make sense of the world, and how our neighbours do the same. A robust field of water ethics, with room for divergent but ethically grounded views, can help us know ourselves and others more deeply, and find new and unexpected solutions to the challenges of the global water crisis.

The basics of groundwater was reviewed carefully and explained scientifically using few table-top experiments and technologies using few principles and techniques from biotechnology. Today on many newspapers, social media and networks, we can get the news that many volunteers had formed local groups and doing renovation activities of the available

water bodies to enhance the holdup volume and to minimize the water logging conditions in those areas which is a good sign of our community participation. This is one of the action plans of groundwater revolution mentioned in the earlier publication. The outcome of such community actions wherever happening throughout the globe is again an evidence-based proof for the New Hydrological basics for its acceptance and incorporation in the education system for our future generations. This temporary renovation actions alone are not enough to manage the flood and drought conditions. The Man-Made Mistakes happened in both the Surface visible water cycle and underground invisible water cycle needs to be rectified and corrected scientifically and technically by focusing on the Invisible Groundwater. The corrective measures will ensure water security for the future generations by neutralizing all the global water threats and scarcity projected for the next 30 years and provide a permanent solution for flood and drought conditions facing all these days throughout the globe.

Keywords: *Hydrological basics, water management, flood and drought, groundwater revolution, groundwater operation*

QUANTIFICATION OF FLOOD MITIGATION SERVICES BY GROUNDWATER-DEPENDENT WATER RESOURCES USING INVEST MODEL FOR THE WAINGANGA BASIN, INDIA

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Floods have been evident as a major point of concern globally, growing in frequency and intensity due to rapid urbanization, climate change and extreme weather events. Groundwater-Dependent Water Resources (GDWR) such as springs, lakes, wetlands, and peninsular rivers play a vital role in maintaining the ecological balance of urban watersheds by offering various ecosystem services (ES). Challenges such as growing population, rapid change in climatic conditions, unsustainable and uncontrollable human activities are disrupting the harmony and stability of these ES. Floods can drastically alter the river discharge, water level and quality of these resources, making them susceptible to pollution, erosion and decreased carrying capacity. The repercussions of floods extend beyond infrastructure damage and economic losses, affecting the daily lives of communities and essential ES provided by GDWR. However, the rapid transformation of urban landscapes, fuelled by increased development and advanced infrastructure, has led to impervious surfaces that interfere with deep percolation consequently increasing surface runoff and causing significant delay in the opportunity time for groundwater recharge. The benefits and services offered by the GDWR-based ecosystems need to be protected as they are crucial and very pertinent for the sustainable hydrological equilibrium of the environment and policymaking. The current study quantifies the urban flood mitigation (UFM) offered by the GDWR as an ecosystem service by the Wainganga Tributary of the Godavari Basin using the Urban Flood Risk Mitigation Module of the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) model. The model estimates the amount of the runoff retained per pixel for the GDWRs and also projects the potential economic damage. The Wainganga River is one of the major tributaries of the Godavari River, often referred to as the lifeline of Central Peninsular India due to its significant ecological, economic and cultural importance. The river holds a length of 580 km with a coverage area of 51,000 km^2, encompassing a diverse range of landscapes, from dense forests and grasslands to agricultural fields and urban centres. The basic concept of this module is based on the popular SCS-CN based method which is preferred and eminent for measuring runoff in a given area. The input data requires various spatial maps of the Wainganga basin such as LULC, soil hydrologic group map, built infrastructure accounting map of building footprints, and also depth of rainfall, damage loss table including potential damage loss data for each building type, biophysical table considering table of curve number data values for each LULC class. The output addresses runoff retention volume and runoff (mm) for each LULC class. The model estimates the amount of the runoff retained per pixel for the GDWRs and also projects the potential economic damage. Conclusively, the model measures the amount of precipitation retained by the GDWR for the watershed pixel by pixel. The measured value can also serve as a guide for the management planning for the protection of the GDWR ecosystem. The measured contribution by the GDWR concerning changes in the urban landscape has been addressed and respective planning and management for the conservation of GDWR has been suggested. The present study emphasizes the critical role of GDWR in urban flood mitigation and underscores the need to prioritize their conservation in policy frameworks to ensure sustainable basin management and resilience against future flood risks.

Keywords: *Wainganga basin, ecosystem services, flood risk, groundwater-dependent water resources, InVEST*

FLOATING TREATMENT WETLAND (FTWS): INNOVATIVE TOOL FOR REVIVAL OF KHAM RIVER IN CHHATRAPATI SAMBHAJINAGAR, INDIA

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Rivers are one of the most productive natural ecosystems as they provide numerous environmental, economic, and social benefits. Cities situated on the bank of rivers or with rivers flowing through them are uniquely positioned to enjoy these benefits. To achieve these benefits, people need to establish a harmonious relationship with rivers, ensuring that they take care of them, and in return, rivers provide them with all the benefits. The Kham River is a seasonal river in the Marathwada region of the Maharashtra state of India. It is a tributary of the Godavari River, which flows through the city of Chhatrapati Sambhajinagar (formerly known as Aurangabad) having latitude 19°53' N and longitude is 75°20' E. In its upper reaches, it crosses a distance of 65 km up to a distance of 8.8 km from the historic city of Chhatrapati Sambhajinagar, where it finally merged with the Jayakwadi Dam of the Godavari River.

Floating Treatment Wetlands (FTWs), often referred to as floating islands, are an innovative method for treating domestic wastewater. These compact artificial surfaces enable aquatic plants to grow in the water that is too deep for them to progress**.** In the field of restoring lakes and rivers, FTWs present a promising approach by combining natural processes with technological advances. Floating treatment wetlands have a natural ability to degrade a variety of pollutants especially organic pollutants which are present in the water body. They depend on microbial transformation, plant uptake, and sediment aggregation. Bacteria in the rhizosphere (near the roots) and endophytes (inside the roots and shoots) contribute to the overall pollutant removal process. Rhizospheric bacteria focus on removing pollutants near the roots, while endophytes target pollutants within the plant tissues. In addition to pollutant removal, rhizospheric and endophytic bacterial communities provide other benefits, such as stress reduction, increased environmental tolerance, and regulation of plant growth through various mechanisms. Furthermore, deliberate inoculation of plant roots with specific bacterial strains can further enhance the pollutant removal efficiency of the system. Floating treatment wetlands utilize this natural capacity by establishing an ecosystem in which aquatic emergent plants flourish. The specific ecosystem absorbs nutrients and converts specific pollutants into non-toxic by-products, helping lakes and rivers. FTWs serve multiple purposes, such as improving water quality in stormwater run-off, controlling nutrients in watersheds, and providing a sustainable method for improving freshwater ecosystems and protecting natural water resources.

Urban water bodies in India are facing severe pollution problems that are slowly killing them. The current estimated population of Chhatrapati Sambhajinagar Municipal Corporation in 2024 is approximately 16,67,000. The Kham Basin generates 240.67 MLD of Sewerage. Disposal of sewage into water bodies has increased the load of organic contaminants. Research suggests that Floating wetland systems are more cost-effective and energy-efficient

than effluent treatment plants or sewage treatment plants. Research shows that Floating Treatment Wetlands offer additional benefits to the river ecosystem in urban areas. To accomplish this, an integrated approach in between citizens and rivers need to engage in a coordinated effort, including cities and rivers that care for rivers that will provide many benefits to communities in the future.

To maintain healthy aquatic ecosystem; cities should maintain this mutually beneficial relationship with their rivers. The River Cities Alliance (RCA) was launched with 30 river communities in November 2021 and has now expanded to overall 145 cities. The National Institute of Urban Affairs (NIUA), a part of the Ministry of Housing and Urban Affairs, along with the National Mission for Clean Ganga (NMCG) under the Ministry of Jal Shakti, has now been entrusted with the responsibility of managing the RCA. The Kham River has become India's first seasonal river under this campaign. During the study we have also created a lab-based model of Floating Treatment Wetland (FTWs) and installed at S.B.E.S College of Science, Chhatrapati Sambhajinagar, Maharashtra. In this model the composite river water samples of Kham River were added. The findings of this model show good results. Plants absorbed the pollutants very well. The results of water quality parameters indicate that the FTW's will stands for an alternative treatment method. This is a very important factor in preparing an urban river management plan. If we adopt Floating Treatment Wetlands (FTWs) it is eco-friendly technology. FTWs will remain sustainable for the restoration of lakes and rivers in India in the future.

Keyword: *Eco-friendly technology, floating treatment wetland, pollutants, river cities alliance, river restoration*

REJUVENATING SMALL WATERBODIES: A CASE FOR SUSTAINABLE MANAGEMENT IN GAUTAM BUDDHA NAGAR, INDIA

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The systems of ponds, tanks and lakes are now increasingly under stress due to urbanization, inadequacies in the policy frameworks, and general apathy of the people. It centres on the initiatives of NbS carried out under the auspices of the HCL Foundation in Gautam Buddh Nagar District of Uttar Pradesh. This study evaluates the scope of NbS in saving water, assisting biodiversity generation, and thereby contributing to economic development. While it broadly focuses on NbS, the study still remains within its limitations to a certain extent, as it excludes mechanized water treatment systems and hydrological interventions. Besides this, it mainly concentrates on greywater-inflow ponds, while water bodies contaminated by industrial effluents and sewage are beyond the scope of its research. A mixed-method approach that integrates both quantitative and qualitative assessments has been adopted in order to evaluate the effectiveness of NbS in rejuvenation of ponds. The present research is based upon a stratified sampling. The four ponds have been selected for the study: Police Line Pond in Surajpur, Chauganpur Pond in Greater Noida, Milak Lachhi Pond in Greater Noida and Mahawad Pond in Dadri. The quality improvement of water was understood by measuring several vital parameters such as pH, TSS, BOD, DO and TDS. It is indicating that these aquatic environments are natural biodiversity hotspots that intrinsically have dynamic landscapes as a backdrop, thus interlacing human activities with natural functioning. Our strategies that have been implemented are holistic approaches to the management of water bodies, restoration of ecosystems, and promotion of biodiversity. The interventions selected at the site level fall under HCL Foundation's environment programme, ensuring sustainability. The water-quality assessments of all four ponds show trends as ecologically driven, thus indicating the positive effects of NbS interventions. Sedimentation and microbial decomposition up to replenishing oxygen are natural processes involving the ponds that enable improvement in water quality while encouraging biodiversity.

The results for these four ponds are presented as (i) Milak Lachhi Pond: pH ranges 7.02 to 8.67 signifies the water is generally neutral to slightly alkaline with support to aquatic life. TSS was significantly decreased from 391 mg/l at inlet to 23 mg/l inside the pond, which would be due to natural filtration that normally increases the clarity of water. Moderately high BOD levels -35.5–38.5 mg/l-suggest active microbial decomposition, which is the primary mechanism for nutrient cycling. In addition, the TDS level reduced from 402 mg/l to 304 mg/l, thereby indicating improved water quality favorable to aquatic organisms; (ii) Police Line Pond: pH value changed to a nearly neutral 7.2 in the pond with improved aquatic life conditions. TSS value reduced from inlet 104 mg/l to 44 mg/l, clarity improved, and photosynthesis occurred. BOD reduced from 38 mg/l to 17 mg/l, thereby resulting in less organic pollution. An elevation in dissolved oxygen levels from 3.8 mg/l to 5.1 mg/l results in more favorable conditions for aquatic organisms, while the reduction in total dissolved solids from 784 mg/l to 450 mg/l further denotes enhanced water quality; (iii) Chauganpur Pond: The broad stable pH range between 6.98 and 7.05 ensures aquatic stability. There is a marked TSS reduction from 100 mg/l to 30 mg/l, increasing light penetration, resulting in enhanced plant growth. Reduction of BOD from 70 mg/l to 25 mg/l indicates cleaner water.

The increase of DO from 2.6 mg/l to 4.5 mg/l would serve aquatic organisms, while the TDS values steady between 400–406 mg/l ensured a balanced mineral content; (iv) Mahawad Pond: The pH of water is found to be slightly alkaline (7.61). This supports biologically quite active. Low value of TSS -17 mg/l results in excellent transparency, which allows photosynthesis. Though a rather high BOD -65.5 mg/l exists, the decomposing action of microbes promotes nutrient cycle. DO level -3.5 mg/l is satisfactory for aquatic flora, and TDS -406 mg/l within the permissible range.

The matrix analysis revealed the ecosystem services of the ponds. The highest scores were achieved in the supporting services including habitat provision and biodiversity promotion, which stood at 64.09% indicating how the ponds support the ecosystem stability. The regulating services which include the improvement of water quality and climate regulation was scored to stand at 57.27%. Cultural services that include the recreation and aesthetic values of the sites were scored to stand at 35.76%, signifying the role the ponds played in facilitating conservation efforts. Livelihood support under socio-economic services secured 13.97%, while provisioning services-offerage of resources like food and water-scored the lowest at 10.77%, reflecting a shift in the community's interest from resource extraction toward obtaining ecological benefits. Community Perception was divided, however, when it came to concerns about pond maintenance in the community survey. Although 57.1% reported that no other agency had cleaned the ponds for over ten years, 98.5% recognized current efforts by outside organizations. In fact, 52.3% believed pond management should be the government's concern; 42%, the community's too, shared responsibility. It is worth mentioning that 76.1% participants were practicing cleanliness-related activities, a trend that indicates an increasing sense of community participation.

Gautam Buddh Nagar-based study shows pond water quality, biodiversity, and ecosystem resilience are significantly improved with NbS interventions, whereas sedimentation and the processes of microbial decomposition facilitate better clarity of water and ecological stability. Needless to say, supporting and regulating services are important to retain ecological balance; therefore, this matrix-based assessment emphasizes it is time to concentrate more on these components. Community engagement was an enabling tool to the achievements realised in pond rejuvenation, while shared responsibility among the stakeholders and government agencies becomes a necessity. Although provisioning services remain underutilized, their ecological and socio-economic benefits contribute to the value ponds hold in sustainable water management. To the end, it adds to the bulk of evidence proving NbS is a scalable and sustainable approach to water management. It therefore opens up the possibility of policymakers making decisions so much better informed by ecological resilience with community well-being. We acknowledge HCL Foundation's commitment to water conservation under their flagship environment program-Harit. The collaborative efforts of HCL Foundation in GBN have been instrumental in harvesting 34 billion liters of water through rejuvenation of 78 water bodies, spread over 214 acres, reviving local ecosystems. HCL Foundation increased its water retention capacity to 1,850 million litres in order to ensure water security for communities in Greater Noida. The local advantage of this lies in its ability to address the regional need for water conservation.

Keywords: *Biodiversity hotspots, climate resilience, groundwater extraction, nature-based solutions, water security*

ENCROACHING PLASTIC POLLUTION IN URBAN WETLANDS: A THREAT TO GROUNDWATER AND ECOSYSTEM HEALTH

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Urban lakes and wetlands are the blue spaces in urban ecosystems and they provide ecological, hydrological, and socio-economic benefits such as biodiversity conservation, flood regulation and water purification. However, these ecosystems are under severe stress due to urbanization and pollution. One significant but underexplored threat is, microplastics (MPs), i.e. plastic pollution which originates from the nearby landfills as leachate into wetlands, lakes, and adjacent groundwater systems. Our study focuses on Bhalswa Lake, an urban wetland in New Delhi, India, and its intricate connection to the nearby Bhalswa municipal solid waste landfill as well as the groundwater of the area. This work examines the potential of plastic pollution in creating a threat to the wetlands, especially the urban lakes, and their implications for environmental and groundwater health.

Landfills are part of urban waste management but have become major sources of pollution including microplastics. Microplastics in landfill leachate comes from the degradation of plastic waste and is a vector for toxic substances and antibiotic resistance genes. In regions like Delhi, where urban wetlands like Bhalswa Lake are in proximity to landfills, the risks of microplastic transport are amplified. These wetlands, intrinsically linked to their watersheds and surrounding groundwater systems, face compounded threats from leachate infiltration, urban runoff, and untreated sewage discharge. In our case study, the animal excreta from the nearby Bhalswa dairy, garbage dumping by local community, leachate from the nearby landfill and leftovers during gatherings cause the wetlands to engulf certain kinds of undesirable components injurious its health. Microplastic contamination in such systems poses a dual hazard. First, microplastics contribute to direct ecological disruptions by affecting aquatic biota and altering trophic interactions. Second, they act as carriers of pollutants, potentially contaminating groundwater. Despite these critical concerns, the interrelationship between landfill leachate, wetland pollution, and groundwater contamination remains inadequately studied.

Surface water samples from the lake were collected using a grab sampling approach, ensuring comprehensive representation of the lake's contamination profile. Approximately 30 liters of surface water were sampled and filtered in situ using stainless steel sieves (0.5 mm to 0.063 mm mesh). Residues were rinsed with distilled water into glass bottles and transported for laboratory analysis. Additionally, leachate samples from the landfill area were collected to investigate microplastics. Samples underwent wet peroxide oxidation (NOAA) to digest organic matter, followed by density separation using NaCl solution to isolate plastic debris. Filtered particles were analyzed using microscopy and FTIR spectroscopy for morphological characterization and polymer identification. Observations included microplastics of varying forms (fibers, fragments, films) and sizes, displaying diverse colors indicative of multiple sources and degradation stages (carbonyl index). FTIR analysis of microplastics from Bhalswa Lake revealed a dominance of polymers such as polyethylene (PE), polypropylene (PP), polystyrene (PS), nylon, and high-density polyethylene (HDPE) and PTFE. Morphological examination identified fibers, fragments, films, and foam, suggesting mixed

sources such as plastic waste from the landfill, urban runoff, waste disposal, and recreational activities. The diverse color spectrum of microplastics further indicated varying weathering processes and polymer types. The carbonyl index shows that polyethylene (PE) has higher degree of oxidation and degradation compared to polypropylene (PP). The higher carbonyl index of PE compared to PP could be due to the different chemical structure and environmental stability of these polymers. PE degrades faster under oxidative conditions because of its less crystalline and more amorphous structure which is more prone to oxidation. PP has more crystalline structure and presence of tertiary carbon atoms which has different degradation mechanism and slower oxidation rate compared to PE.

Leachate samples from Bhalswa landfill showed high microplastic contamination, the landfill is a persistent source. These particles can be transported through surface runoff or leachate seepage to the lake. Groundwater samples although not included in this study are at risk of contamination. Urban lakes like Bhalswa are ecological refuges, supporting biodiversity including migratory birds and ecosystem services like carbon sequestration and recreational spaces. But microplastic contamination disrupts these roles by degrading water quality, threatening aquatic life and bioaccumulation of pollutants in the food web. Microplastics in landfill leachate which is loaded with heavy metals and persistent organic pollutants are long term risk to groundwater quality. This interplay of pollution across interconnected systems underscores the pressing need for comprehensive management strategies. The transport of microplastics from landfill leachate to Bhalswa Lake and potentially to groundwater represents a critical environmental challenge. Groundwater dependent ecosystems are most vulnerable to this contamination which can alter hydro chemical characteristics, reduce water quality, and compromise their ecological functions. The connection between landfill leachate, urban wetlands and groundwater systems is a critical part of urban ecosystem health. Bhalswa Lake is an example of the complexity of microplastic pollution where leachate from a nearby landfill is a major source of contamination. This study highlights the need for integrated management approach including improving waste management practices, upgrading leachate treatment facilities, and conserving urban wetlands. Addressing these challenges is key to protecting groundwater dependent ecosystems and urban blue spaces. Bhalswa Lake may have been affected but still its ecological significance is supporting migratory birds and urban biodiversity. With proper interventions the lake's ecological integrity can be restored and reduce its vulnerability to microplastic pollution. This study highlights the broader implications of microplastic transport in connected systems and calls for collective action to mitigate its environmental impact.

Keywords: *Plastic pollution, urban wetlands, water quality, microplastics, landfill leachate*

SEDIMENT-WATER INTERACTION AND ITS IMPACT ON HYDRO-GEOCHEMISTRY IN THE SAJAMA NATIONAL PARK, VOLCANIC ZONE OF THE CENTRAL BOLIVIAN ALTIPLANO

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The Sajama National Park (SNP), surrounded by the Sajama, Parinacota, Pomerate, and Kunturiri glaciers, are important water reservoirs that provide ecosystem services and are highly sensitive to climate change. It is located in the central Bolivian Altiplano at an altitude of 3,860 to 4,184 m above mean sea level (amsl). The SNP is characterized by an average annual precipitation of approximately 320 mm. Previous geological studies carried out reveal that the area is completely covered by volcanic rocks of the dacitic-andesitic composition of Quaternary age (0.6 Ma) and remnants of rhyolitic pyroclastic flows of Pliocene age that cover the region, where these were eroded by past glacial activity and wind in the present, giving rise to fractured and eroded lava flows at the foot of the volcanoes and the sedimentation of sands and silts. This research focuses on evaluating the levels of natural contamination using contamination factors and geo-accumulation indexes and their impact on the hydrogeochemistry of groundwater and surface water systems within Sajama National Park, a volcanic zone in the Central Bolivian Altiplano.

A total of 59 samples were collected from various water sources (lakes, rivers, springs, thermal springs, wells) in the SNP, following Hydrochemistry laboratory protocols for water sampling. The geographic location of each sample point was recorded using a GARMIN portable global position system. Temperature (T), pH, Ox-Red Potential (ORP), electrical conductivity (EC), total dissolved solids (TDS) and dissolved oxygen (DO) were measured in the field using a HANNA multiparameter kit. Alkalinity was measured *in situ* by titration. Analyses of anions were carried out in the Environmental Chemistry laboratory of the Chemical Research Institute (IIQ), La Paz, Bolivia. The main anions, Cl^-, NO_3^-, and SO_4^{2-} were analyzed using a DIONEX model ICS 1100 ion chromatograph with an ion exchange column. The main cations, Na^+, K^+, Ca^{2+}, Mg^{2+}, total arsenic (As), and boron (B) were analyzed in the filtered acidified water samples using inductive coupled plasma emission spectrometry (ICP-OES) and mass spectroscopy methods (ICP-MS) at the University of Grenoble, France. A total of 30 sediment samples from rivers and profiles were digested with Suprapur HCl/HNO_3 solution, cold extractions were performed for 48 hours with constant agitation, and hot extractions were carried out using a Digiprep digester at 70°C for 24 hours. After cooling, the sample aliquots were diluted with 40 mL of ultrapure mQ H_2O, centrifuged for 20 minutes at 4000 rpm, and filtered using 0.45 µm filters into 15 mL Falcon tubes. Sediment extracts were analyzed with an ICP-OES, at the University of Grenoble, France.

The water sources within the Sajama National Park (SNP) exhibit considerable variability in their hydrochemical properties. Temperatures range from 5.1 to 31.5°C, with pH levels spanning from slightly acidic to alkaline (5.9–9.4). Salinity varies between 56 and 2330 µS/cm, with diverse redox conditions observed. Surface waters are predominantly of the Na-

Cl-HCO_3 type, while groundwaters are mainly Na-Ca-Mg-HCO_3 type, and hot springs display a Na-Mg-HCO_3-Cl composition. These water types are influenced by the dissolution of Na and Ca silicate minerals, dolomite, and calcite. The concentrations of dissolved elements in natural water sources show wide variation: arsenic (As) from 0.004 to 1900 μg/L, boron (B) from 28 to 11,792 μg/L, and lithium (Li) from 0.019 to 2810 μg/L. Along the Sajama River, where the Milluri, Junthuma, Taipypuchuni, and Taypyjawira rivers converge, there is notable accumulation of As, B, Li, and Fe. In river sediments, As ranges from 6.7 to 2006.6 mg/kg, B from 21.1 to 419.2 mg/kg, Li from 0.002 to 37 mg/kg, and Fe from 13,997 to 369,997 mg/kg. Lagoon sediments exhibit lower concentrations: As from 14.7 to 19.8 mg/kg, B from 27.2 to 33.5 mg/kg, Li from 5.1 to 6.1 mg/kg, and Fe from 11,759 to 29,353 mg/kg. Geothermal rocks contain As from 18 to 73.6 mg/kg and Fe from 1,885 to 137,667 mg/kg. High enrichment and geo-accumulation of As and B in river sediments along the Sajama River are primarily attributed to geothermal sources, with additional contributions from sedimentary and volcanic rocks and decomposing organic matter. Li and Fe concentrations in river sediments show low to moderate enrichment, with the highest accumulation in the Junthuma River, also linked to geothermal sources. The hydrogeochemistry of the Sajama National Park system reflects a complex interplay of geothermal activity, sediment interactions, and geological processes. Variations in volcanic rock composition, ranging from dacitic to rhyolitic and ignimbritic, significantly influence water chemistry by affecting mineral solubility. Enrichment and accumulation of As and B in river sediments within the Sajama basin appear to result from continuous input from geothermal waters. Additionally, fine-grained sediments and deposited organic matter contribute to this accumulation, underscoring the dynamic geochemical environment of the region.

Keywords: *Sajama National Park, hydrogeochemistry, sediment, enrichment factor, geo-accumulation index*

ECOSYSTEM HEALTH ASSESSMENT OF KOL WETLANDS, A RAMSAR SITE: TOWARDS ENVIRONMENTAL SUSTAINABILITY

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The Kol Wetlands, recognized as a Ramsar site in Kerala, India, are a distinctive and ecologically significant habitat. This research explores the ecological dynamics of the Kol Wetlands, with a particular focus on the ecological contributions of fish, birds, and mangrove species. Biodiversity assessments, based on the Shannon-Weiner Index (H') conducted to evaluate species richness. Findings reveal ecosystem stress in the Kol wetlands, marked by declining avifaunal diversity, low fish diversity, increasing invasive plant species, and mangrove degradation due to urbanization and land-use changes. Wetlands are “lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water”. The study has been carried out in Kol wetlands of Thrissur district, a Ramsar site in Kerala. The district includes an estimated wetland area of 13,285 ha, comprising 271 small wetlands that fall below the minimum size threshold. According to Kol Wetlands were also declared as a Ramsar Site in 2002 and form part of the Central Asian Flyway of migratory birds. The word "Kol," which is from the Malayalam language, translates to "bumper yield", this term is associated with an exceptional cultivation process performed within the backwaters during December to April. Kol Wetlands lie between 10°20' to 10°40' N latitude and 75°58' to 76°11' E longitude, these low-lying tracts, situated from 0.5 to 1 meter above mean sea level (amsl), are submerged for nearly six months in a year. The main objective of this study is to analyze the impact of changes in biodiversity (birds, fish, mangroves, and plants) on the functionality of the Kol wetland ecosystem.

Birds have vital significance in ecological processes such as pollination, control of pests, cycling of nutrients, and seed dispersal. Through their planktivorous diet, fish help maintain balance in phytoplankton populations, preventing harmful algal blooms that compromise water quality. Mangroves themselves provide essential ecosystem services, such as carbon sequestration, stabilize shorelines, thereby reducing erosion and shielding inland areas from floods. The H' is a diversity index used to assess species diversity of birds, fish, mangroves, and wetland plants in the Kol Wetlands, Ramsar site ecosystem taking into account species richness. Relative abundance (pi) was calculated for each species, which will help to identify trends and shifts in biodiversity. Total of 182 bird species were identified, spanning over 16 orders and 47 families. Among these, 24 species are newly recorded in this area, while 44 were transcontinental migrants. Habitat classification revealed that 24.86% of the birds relied on aquatic habitats, 21.55% were waders, and 53.59% were terrestrial, indicating that the Kol wetlands also support a significant number of passerine species. Shannon diversity of 3.11 for the whole wetland also indicates the high diversity of birds. According to (Jayson, 2018) total of 155 species of birds belonging to 15 Orders and 49 Families were recorded from the area. Among the 15 Orders, Passeriformes, Charadriiformes and Pelecaniformes dominated with 46, 30 and 25 species, respectively. The H' for the given bird population data is 2.13, indicating a moderate level of biodiversity among the species. As per the study it is observed that there is a reduction in Index value which denotes the pressure on avifauna in this region.

The study area recorded a total of 55 fish species distributed into 44 genera, 23 families and 10 orders. The most abundant species identified were *Amblypharyngodon melettinus* (2171 individuals) and *Systomus subnasutus*(1622 individuals). The estimated H′ for the two abundant *Amblypharyngodon melettinus* and *Systomus subna* species is 0.683 whereas the H′ calculated order-wise is 1.767. As per the estimated index, it is observed the aquafauna exhibit very low diversity. The Kol wetlands, Ramsar site host a total of 140 species, distributed across 23 families of dicotyledons, 11 families of monocotyledons, and 5 families of water ferns. The vegetation is characteristically unique with only aquatic and marshy varieties such as Hydrilla, Eichhornia, water ferns, and algae but also various types of small trees along the bunds that may endure long-term waterlogging. Recently *Cabomba furcata*, commonly known as Pink bloom has emerged as new threat to the Kol fields, along water hyacinth and *Salvinia molesta*. According to commonly found mangrove species are *Rhizophora mucronata* and *Excoecaria agallocha* similarly, rarely found mangrove species are *Avicennia officinalis*, *Bruguiera cylindrica*, *Aegiceras corniculatum*. Soil samples obtained from the Chettuva mangroves indicate that organic carbon content varies between 1.06% and 2.35%. The carbon stocks in these regions were 2,089.33 t CO_2 per hectare, with the mangroves mainly consisting of *Rhizophora mucronata* and *Bruguiera cylindrica*. According to the Shannon diversity corresponding to Kol wetlands is 3.309. The study noted that the Kol wetlands, Ramsar site are under significant pressure from habitat alteration, infestation of aquatic weeds, and changes in land use patterns. The Kol lands are being converted to coconut, areca nut, banana plantations and other cash crops at an alarming rate. However, mangrove destruction is underway, with ecotourism being one of the cited reasons for degradation in Chettuva, and real estate activities have already cleared out vast mangrove patches in Pulloot, Kodungallur. The evidence implies that human-induced reduction of mangrove cover could reduce these carbon sinks, making climate change even worse. Additionally, tourism activities were identified as potential hindrances to migratory birds, also reduction of mangrove cover could reduce these carbon sinks , suggesting a need for better management practices within Ramsar Sites.

Keywords: *Ramsar site, Kol wetland, Shannon-Weiner Index, Biodiversity, Ecosystem services*

ASSESSMENT OF RESERVOIR SEDIMENTATION USING GEOSPATIAL TECHNIQUE: A CASE STUDY OF SALERAN RESERVOIR IN SHIVALIK FOOT-HILLS OF NORTH-WEST INDIA

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Dams and reservoirs are important infrastructures to conserve soil and water, and saving downstream areas from floods and droughts. However, reservoir sedimentation has become an important issue all over the world as it reduces storage capacity and shorten the useful life. Soil erosion and reservoir sedimentation are interconnected processes that significantly affect the storage capacity and functionality of reservoirs. Runoff from sloped catchments carries eroded sediments into reservoirs, where the flow velocity decreases, leading to sediment deposition. This accumulation reduces the reservoir's storage capacity, shortens its lifespan, and negatively impacts downstream ecosystems, dam equipment, and water availability. Globally, reservoirs lose 0.1-1% of their capacity annually due to sedimentation, with India experiencing a slightly higher rate of 0.1-1.5% per year in north-wester parts of Shivalik hills locally known as the Kandi region. Sedimentation also distorts the elevation-area-capacity curve, leading to inaccurate water availability estimates. Conventional methods for estimating sedimentation, such as bathymetric surveys and stream flow analysis, are labour-intensive, costly, and time-consuming. In contrast, geospatial techniques using Remote Sensing and GIS offer a more efficient, cost-effective solution. These technologies allow for accurate calculation of reservoirs' water spread area and volume, aiding better reservoir management and planning. One such earthen dam was constructed at the outlet of Saleran watershed which is located between the coordinates of 31º 35' 58.56"N, 75º 59' 14.54" E and 31º 37'58.21" N, 76º 01' 47.87" E in Shivalik foot-hills in the year 1995. The reservoir of the dam is facing the problem of high siltation rate that is causing reduction in its storage capacity at a very fast rate. Hence, this study was planned with the specific objectives of determining capacity loss rate of the Saleran reservoir due to sedimentation and to update the elevation-area-capacity curve of the reservoir using geospatial technique. The Survey of India (SOI) toposheets have been used for preparing the reservoir catchment area. The digitization and georeferencing of traced area was carried out using ArcGIS software. The Landsat 8 OLI satellite sensor imageries with 30 m spatial resolution data was used in the present study. Satellite imageries of Saleran reservoir on different 18 dates, for the years 2016-2020 were downloaded from USGS Earth Explorer web portals. The layer stacking and image registration of downloaded satellite images were used to create subsets of the Area of Interest (AOI) using ERDAS Imagine 14.0 software. Modified Normalised Difference Water Index (MNDWI) was used to extract the water spread areas of the reservoir on different dates during the years 2016-2020 at different water elevations. The standard False Color Composition (FCC) of images were used for verifying the water pixels. Water spread areas of the Saleran reservoir at different water elevations between Full Reservoir Level (FRL) to Minimum Dead Level (MDL) on different months of the years 2016-2020 were used as an input in Prismoidal formula to calculate the reservoir incremental capacity. Field data collection and ground verification of Saleran reservoir features was conducted after geo-referencing of satellite imageries. The computed storage capacity and water surface areas (Geospatial 2020) and (Bathymetric 2021) have been compared with design storage capacity data and water surface area of the year 1995 of reservoir to analyze the reduction in the water surface area and the loss of reservoir storage capacity due to sedimentation and to update elevation-area-capacity curve. The loss in storage capacity-2020 estimated using geospatial technique and 2021 using bathymetric technique are compared to the design storage capacity of the Saleran reservoir in the year 1995 at different water elevations the loss in the storage capacity (2020) varies from 2.54 ha-m (93.27%) to 36.09 ha-m (18.03%) at the observed minimum and maximum reservoir water elevation of 389.67 m and 402.01 m, respectively in a period of 25 years (1995-2020). The total storage capacity of the Saleran reservoir was estimated to be 164.03 ha-m in the year 2020, against the design capacity of 200.12 ha-m at the highest elevation of 402 m in the year 1995. There was a loss of 36.09 ha-m of storage capacity due to deposition of sediments in 25 years (1995-2020). That means 18.03% of the storage capacity decreased by the year 2020. The results indicate that Saleran reservoir is losing its capacity at a rate of 0.721%, annually. As per bathymetric survey evident the loss in the storage capacity (2021) varies from 1.77 ha-m (65.00%) to 24.22 ha-m (12.10%) at the observed minimum and maximum reservoir water elevation of 389.50 m and 402.01 m, respectively in a period of 26 years (1995-2021). The total storage capacity of the Saleran reservoir was estimated 175.90 ha-m in the year 2021, against the design capacity of 200.12 ha-m at the higher elevation of 402.01 in the year of 1995. There was a loss of 24.22 ha-m of storage capacity due to deposition of sediments in 26 years (1995-2021). That means 12.10% of storage capacity decreased by the year 2021. As per bathymetric survey results indicate that Saleran reservoir is losing its capacity at a rate of 0.45% annually. There is an upward shift in the updated elevation-capacity curve compared to the design elevation-capacity curve-1995 indicating decrease in storage capacity of Saleran reservoir at different elevations and hence updated curve should be used for estimating water stored in the reservoir.

Keywords: *Reservoir, Sedimentation, Bathymetric, Remote Sensing and GIS, MNDWI*

SYSTEM DYNAMICS AND MODELING OF MICRO-WATERSHEDS

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Climate change has led to frequent and intensifying weather patterns that led farmers sought to groundwater resource for irrigation which substantially accelerated the decline of water tables in India. Sustainable management of water resources at micro-watersheds is critical for addressing long-term water security, particularly in regions reliant on groundwater for agriculture. Various government initiatives such as MGNREGA, Watershed Development under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) and Atal Bhujal Yojana (Atal Jal) have emphasized the development of surface water storage structures. However, understanding the intricate dynamics of climatic, hydrological, physiological, and socio-economic factors at the micro-watershed level presents a complex challenge for the rural communities to adopt and construct surface water storage structures. In this study, we leverage remote sensing data to model and analyze the dynamics of micro-watersheds, using which "what if" scenarios can be constructed to evaluate the impacts of various interventions like the creation of water bodies or the building of MGNREGA structures. These interventions aim to reduce groundwater stress and facilitate a transition toward rainwater-fed irrigation systems. Our simulations incorporate various climate-induced scenarios to assess the influence of prospective interventions on water availability and system sustainability. The simulations can help CSOs engage rural communities in exploring effective rainwater harvesting structures to support rain-fed agricultural systems and build community resilience against climate change.

We used different data sources for modelling the systems dynamics at micro-watershed level. These include Rainfall (GSMaP Operational: Global Satellite Mapping of Precipitation), Runoff, Temperature (from ECMWF ERA5-Hourly), Monsoon onset using CHIRPS Daily, Surface water bodies, cropping area, Area under different stream orders, Mild, moderate and severe weeks of drought based on Manual for Drought Management 2016 by Ministry of Agriculture and Farmers Welfare, Government of India, NREGA structures, Crop health, Stage of Groundwater Extraction using CGWB data and supplemental groundwater irrigation using evapotranspiration and soil moisture. The choice of remote sensing datasets was governed by their spatial coverage, spatial resolution, temporal resolution and whether they are operational. Using a socio-hydrological lens, we developed a systems model to model the dynamics at micro-watershed level. A micro-watershed is influenced by climatic factors that influence the supply-side of irrigation such as rainfall, temperature, drought and onset of monsoon. Depending upon the capacity of prevailing water bodies and MGNREGA water structures that harvest the generated runoff, total surface water storage of the micro-watershed is determined. Based on the field observations, the surface water storage in water bodies and MGNREGA structures are directly used for irrigation through horizontal siphoning (low impact zone of 200 m around the water body). The seepage from surface water bodies and MGNREGA structures has been observed to increase the soil moisture levels in surrounding farmlands, extending up to 1.5 km away (low impact zone). To irrigate farmlands within the low-impact zone and areas beyond both the low- and high-impact zones, farmers supplement irrigation by abstracting groundwater. Groundwater abstraction in a year

depends on the state of groundwater in the micro-watershed due to long-term abstraction along with the state of groundwater in the block, estimated annually by CGWB.

We intend to perform year on year projection of agricultural outcomes such as cropping area and crop health with continuous and discrete interventions of large surface water bodies and MGNREGA-funded water structures in the micro-watershed under various climate scenarios. The projection framework can be also used as simulation framework for what-if scenarios to maximize the climate resilience of the micro-watershed. What-if scenarios are hypothetical simulations used to predict outcomes of various interventions, for example, building ten check-dams and two ponds in the micro-watershed. What-if scenarios are essential to identify the most appropriate combination of interventions that are contextual and specific to the agro-ecology of the micro-watershed. The projection and simulation framework can provide critical evidence toward creating surface water storage structures through rainwater harvesting, ultimately reducing dependence on groundwater for irrigation. By demonstrating the potential benefits of these storage structures, CSOs can strengthen community engagement and mobilize local action in adopting rainwater harvesting methods that are sustainable and in line with national water conservation goals. The framework will provide evidence on the impact of increasing surface water storage using simulations enhancing cropping area, cropping intensity and crop health during drought years, demonstrating the farmer adaptation to groundwater scarcity by notable reduction in groundwater abstraction observed due to available surface water storage for a sustainable approach to alleviate groundwater dependence. Furthermore, we intend to identify the “tipping point” in groundwater usage, beyond which continued abstraction would lead to a sudden and unsustainable drop in groundwater levels, effectively eliminating access for many small farmers.

The projection and simulation framework aims to provide CSOs with evidence to initiate community discussions on the importance of supply-side and micro-watershed-based interventions for sustainable water management in irrigation. By demonstrating the positive impact of increased surface water storage and therefore reduced groundwater dependence to improve cropping area and crop health, the framework can help CSOs engage rural communities in exploring effective rainwater harvesting structures to support rain-fed agricultural systems and build community resilience against climate change. A key outcome of the above socio-hydrological systems approach is to model the complex feedback loops on demand side which are between natural and human systems, particularly illustrating how farmers’ crop choices prompted by increased water availability from surface water bodies for irrigation can amplify groundwater stress. For example, an increase in surface water availability has led farmers to transition from less water-intensive to more water-intensive crops in the past, thereby elevating groundwater demand. Another aspect to model within this framework is the equitable distribution of water bodies and MGNREGS structures among different social groups within the micro-watershed, ensuring fair access and promoting sustainable water management across diverse communities.

Keywords: *Climate change adaptation, groundwater stress, MGNREGA water structures, tipping point in groundwater usage, equitable irrigation*

VALIDATION OF CRAIG GORDON MODEL FOR EVAPORATION ESTIMATION IN THE GANGA YAMUNA DOAB REGION

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The research examines the application of stable water isotopes to assess evaporation (Craig-Gordon Model), illustrating isotopic enrichment along a running water body. A large number of studies has demonstrated isotopic enrichment as a component of evaporation from stagnant water bodies. However, there is a lack of knowledge regarding the evaporation and isotopic signature of ground level vapor (GLV) fluxes above running water bodies. The estimation of the water budget and the determination of vapor loss, particularly in natural river systems, can be challenging due to uncertainties in the monitoring of water flow. Nevertheless, it is somewhat simpler in canals/reservoirs where the inlet and outlet are fixed. The Upper Ganga Canal (UGC) evaporation characteristics are evaluated from September 2021 to August 2022, leaving out the wet season (June to July). Applying the model for evaporation investigations on running water bodies is made possible by the canal's controlled hydraulic environment. The UGC originates from the Ganga River at Bhimghoda Barrage in Haridwar, built in response to a severe famine in the Ganga-Yamuna Doab region of India caused by a lengthy monsoonal failure. The canal system has a principal canal extending 290 kilometers from the Bhimgoda barrage, Haridwar to Nanao, Aligarh, Uttar Pradesh. The canal discharges 300 m^3/sec of water, facilitating irrigation for the most densely populated areas of Uttar Pradesh and Uttarakhand, encompassing a fertile area of 9,000 km^2. Haridwar's climate is characterized by an average of 4.48 mm of precipitation per day and a maximum annual temperature range of 46.35°C to 1.83°C. Nanao exhibits a broader temperature range, spanning from 48.71°C to -1.03°C, and a reduced average annual precipitation of 0.26 mm/day.

Canal surface water and GLV samples were collected and analyzed for stable isotopic composition. GLV was collected utilizing a Cryogenic Trap where atmospheric air is constantly circulated at a flow rate of 250 ml/min by an air pump linked to a custom-built moisture trap submerged in -80° C ethanol-liquid nitrogen sludge. Moisture in the air is condensed in the trap, which is subsequently melted (Precautions are taken as the melting of the condensed phase may lead to fractionation) once a significant quantity of moisture has accumulated at ambient temperature. The results of canal surface water indicate distinct isotopic enrichments from the headwaters to the canal's terminus. There is a seasonal shift in the isotopic enrichment levels; higher enrichment is observed during the pre-monsoon season, intermediate enrichment values during the post-monsoon season, and lower enrichment during the winter season. The surface water evaporation in transit from Haridwar to Nanao is estimated using the revised Craig Gordon model. The seasonal variation in the evaporation by inflow (E/I) reveals less evaporative loss in the winter season (5.41 ±1.86%, standard error 0.93%), while the seasonal variation in the E/I indicate 15.49% ± 5.12% with standard error of 2.29% in the pre-monsoon season and intermediate values for the post-monsoon season (12.06% ± 1.43%, standard error 0.64%). The E/I ratio in the Upper Ganga Canal is inversely proportional to the slope of d-excess, meaning that a negative slope results in an intense evaporation while a slope that approaches zero results in a moderate evaporation. Prior studies suggest that the appropriateness of an estimation method for a

specific area can be assessed by examining the key climatic factors influencing evaporation in that region. Three climate zones are identified in the Ganga-Yamuna doab region according to the data collected using Normalized difference in vegetation index (NDVI), Standardized precipitation index (SPI), and Evaporative Stress Index (ESI), viz. The Northern humid zone, the Transition semi-humid zone, and the Southern semi-humid to semi-arid zone. The Craig-Gordon model evaporation estimates respond in a progressive order from the humid to the semi-arid climatic zone. For instance, the northern zone accounts for 20 ± 7% (standard error ~ 2%), the transition zone for 33 ± 5% (standard error ~ 1%), and the southern zone for 50 ± 10% (standard error ~ 3%). The sensitivity analysis highlights that relative humidity is the primary climatic variable in the Ganga-Yamuna doab region, surpassing temperature and ground-level vapor isotopes in its capacity to influence evaporation. An effort has been made to reduce the uncertainty in the evaporation estimation in comparison to previous studies by carefully designing year-long sampling, using canal surface water temperature, using GLV isotopic values and avoiding rainfall effects. Nevertheless, the estimated result could be improved by taking into account the flow velocity and turbulent mixing of water at check dams.

Keywords: *Stable water isotopes, ground level vapor, evaporation, Craig Gordon model, evaporative stress index*

APPLICABILITY OF KUMARASWAMY DISTRIBUTION TO DERIVE GEOMORPHOLOGICAL INSTANTANEOUS UNIT HYDROGRAPH (GIUH)

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Prediction of floods in ephemeral streams is very challenging due to the highly variable rainfall patterns and a lack of the historical time series data**.** Many of the researchers have utilized the Geomorphological Instantaneous Unit Hydrograph (GIUH) model to predict the discharge in un-gauged basins and the results were encouraging. The GIUH is a probabilistic model that is based on the drop's travel time distributions in the catchment. To determine the runoff from the catchment, various paths that a randomly selected raindrop would take in reaching the outlet known as the trapping state are calculated. The path probability functions are then convoluted to represent the unit hydrograph. The GIUH generated is the probability distribution function (PDF) of the travel times to the outlet. However, determining the probabilities for each path and convolution of various PDFs become very difficult. It is found that using PDFs to represent the GIUH can be a substitute for the conventional GIUH. An alternate proposal is to couple the GIUH with other models. Since the GIUH is represented using PDFs, it would be fitting to examine the suitability of various statistical distribution approaches to derive the GIUH. Over the years many PDFs have been employed with GIUH to produce reasonable runoff estimates. Some PDFs include gamma distribution, logistic distribution, Weibull distribution, and Nakagami-m distribution. In this study, an attempt has been made to derive a GIUH using the Kumaraswamy distribution. Keeping in mind the effectiveness of statistical distribution approaches, the present study aims to utilize the Kumaraswamy distribution to derive the GIUH and analyze its effectiveness in predicting floods in ephemeral streams. Simultaneously the effectiveness of existing GIUH models such as Nash-based model and travel time probability distribution model is also analyzed. Using the SRTM 1-arc-second data obtained from the USGS Earth Explorer, delineation of the channel network and basin is carried out in the QGIS 3.28.2 which is open-source software. The geomorphological characteristics are extracted and the GIUH models are developed in the Python programming language. Five events of heavy precipitation are selected to check the applicability. The results obtained from the simulation are compared with the observed data at the monitoring sites. Here, an approach has been made to utilize Kumaraswamy distribution to generate the GIUH from the known peak discharge and time to peak values. To generate the GIUH various geomorphological characteristics of the basin are required. The geomorphological features of various sub-basins of Banas River are extracted using the freely available SRTM Digital Elevation Models (DEMs) with the aid of open-source software QGIS. The channel network characteristics such as order of the basin, bifurcation ratio, stream length ratio, and stream area ratio are calculated from the extracted feature. These ratios are used to determine peak discharge values and time to peak. The parameters of the distribution are calculated using a heuristic search algorithm such as Harmony Search Algorithm. The validation of the proposed model is done by comparing it with the already published data. On comparison with other distribution approaches such as the Logistic, Gamma, Weibull distribution, and Nakagami- m distribution, it has been found that the

Kumaraswamy distribution outperforms other distribution approaches for the Myntdu-Leska catchment, while it significantly fails to regenerate the GIUH for Burhner catchment. However, beyond the peak discharge value, the shape of the GIUH is recaptured. It can be said that for catchments that require a longer time to attain. On comparison, the Root Mean Squared Error (RMSE) values for Logistic, Gamma, Weibull, Nakagami-m, and Kumaraswamy distributions come out to be 2.9, 1.5, 1.8, 1.7, and 1.3 respectively for Myntdu- Leska catchment and 15.8, 5.6, 4.3, 4.9 and 10.8 respectively for Burhner catchment. The R^2 error for the Kumaraswamy distribution for the Myntdu- Leska and Burhner catchment are 0.917 and 0.797 respectively. The RMSE values show that the Kumaraswamy distribution performs better for the Myntdu- Leska watershed than the other two approaches. After the peak discharge value, the Kumaraswamy distribution fits better than the other approaches while it fails to match the observed values in the rising limb part. It can be concluded that for rainfall events that produce peak discharge in a relatively shorter duration, the Kumaraswamy distribution can be a useful prospect for generating the shape of the hydrograph. This may be the case of the flash flood events when the high-intensity rainfall produces a quick runoff in a relatively short time. The validation with published data shows that Kumaraswamy distribution can be utilized as a PDF to produce the GIUH. The proposed approach has been extended to apply it to the Banas River basin which is a partially gauged basin of Rajasthan state of India. Various GIUHs have been developed for the sub-basins of the Banas River, which can be useful in predicting the flash flood events and in proposing the mitigation schemes.

Keywords: *GIUH, ungauged basins, Kumaraswamy distribution, probability distribution functions, flash floods*

WATER QUALITY AND GEOCHEMICAL ASSESSMENT OF TERRACOTTA DUG WELLS: AN IMPLICATION IN RESTORATION AND CONSERVATION OF ANCIENT CIVILIZATION

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The dug wells have been the source of drinking, domestic, and irrigation water since the inception of human civilization. We studied the geochemistry of fifteen dug wells constructed from the Stone Age to the Medieval period in the Mohani River basin with special reference to their archaeological significance and live status in delivering ecosystem services. These dug wells were located in the two ancient villages, Mangarh and Daihar, in the Chouparan Block of the Hazaribagh district in the Jharkhand State. Both villages are apostles of the ancient civilization that witnessed the evolution of Vedic culture in the form of Bhadrakali, Kamala Mata, and Maa Samohar Temples. The land use practices significantly impaired the archaeological evidence, including the density of ring-shaped dug wells in the Mangarh and Daihar villages. Ring wells were so named because of the lining with terracotta rings, which can be distinguished from other types of wells. The archaeological records classified the construction of such dug well as old as 2500 years ago. The shape, circumference, diameter, water table, and depth of all fifteen dug wells were almost identical in our study area. All were 1.9 meters in diameter with 35-40 ft depth. The base ring of the terracotta dug wells comprises the woods of the *Eugenia jambolana*, vernacularly known as Jamun, Jambul, or Java Plum. The Jamun wood does not degrade in water for a longer period. When placed in the dug wells, it prevents the formation of algal blooms in the water. It helps in the adsorption of organic pollutants, dyes, heavy metals, parasites, and toxins and minimizes the frequency of dug well cleaning.

The study area experiences three distinct seasons, namely summer (March-May), Monsoon (June-October), and winter (November –February), with annual average rainfall of 1347 mm. During peak summer, the maximum temperature goes up to 46 ^{0}C, and the minimum temperature drops to 4 ^{0}C. Geologically, the area is underlain by Chotanagpur granite gneiss and unconformably overlain by lower Gondwana formations consisting of sandstone, shales, and coal seams. Groundwater mainly occurs under water table conditions in weathered residuum and semi-confined conditions in deeper fractures. Granite rocks show maximum thickness of weathered mantle in favorable topographic and drainage conditions. The filed inventory of dug wells was carried out using handheld GPS and drone mapping in the monsoon month of September (2024). The water samples of the dug wells were collected by adopting standard protocols. Filed and laboratory analyses of the physicochemical parameters were carried out using standard methods. The results of dug well water quality data were analyzed to determine the geogenic and anthropogenic sources of the dissolved ions, decipher weathering patterns, and identify geochemical signatures of the groundwater.

The ionic balances were generally within ± 5-10 %. The pH, EC, TDS, and salinity varied from 7.29-8.80, 441-4080 µS/cm, 313-2890 mg/l, and 173-1730 mg/l, respectively. Dominating cations were of the following order: $Ca^{2+} > K^{+} > Na^{+} > Mg^{2+}$, and the dominating anions were of the order $HCO_3^{-} > Cl^{-} > NO_3 > {}^{-}SO_4^{2-} > F^{-} > PO_4^{3-}$. The Pearson correlation

showed a strong pairing between cations and anions, indicating their common sources in the dug well waters. However, the high dissolved concentration of K^+, NO_3^-, and Cl^- indicates a long history of farming practices and sewage disposal responsible for their enrichment. The PCA analysis revealed four principal components with 86.94 % of total variance having Eigen value > 1. The Gibbs' diagram suggests that rock weathering and dissolution of evaporites are the dominant mechanisms controlling the water chemistry of dug wells. Piper plot showed that the dug well water types are mostly characterized by Ca-Cl, Ca-HCO_3, Na-HCO3, and Na-Cl facies. The effective CO_2 pressure (logP_{CO2}) varied from -1.80 to -3.4, greater than the atmospheric value of -3.5. The dug well waters were supersaturated with calcite while saturated to supersaturated with aragonite. The high to very high salinity hazard can impact crop yield and land degradation. Interestingly, the low SAR (< 10) recorded in our study indicates water percolates through the soil more easily. The systematic and comprehensive geochemical assessment of the ancient fifteen terracotta dug wells indicates high concentrations of dissolved ions that make groundwater non potable. The total hardness of more than 50 % of dug well water samples exceeded the drinking water standard (IS10500). From the study, it is found that the restoration and conservation of historically important civilization pieces of evidence should be carried out and must be protected.

Keywords: *Ancient civilization, terracotta dug wells, geochemical assessment, ecosystem services, restoration and conservation*

MAPPING SPATIAL AND TEMPORAL DYNAMICS OF LAKES OF BELAGAVI TALUK, KANRATAKA USING GEO SPATIAL TECHNOLOGY

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Water bodies are vital to sustaining both human and ecological systems. They play an integral role in maintaining the balance of local and regional climates, providing water resources for agricultural, industrial, and domestic purposes, and supporting biodiversity. Identifying and monitoring changes in the extent and condition of water bodies is essential for effective water resource management and environmental protection. Remote sensing data has proven to be an invaluable tool for analyzing the spatial and temporal variations of lakes, helping to monitor hydrological changes and to study the impacts of urbanization, climate change, and land use on water bodies. One such study was conducted in Belagavi taluk, focusing on the long-term changes in the hydrological response of lakes in the region.

The study primarily utilized satellite data from various sources, including CartoSAT-1. Of 5.6m resolution and Corona space imagery, to evaluate changes in the number, size, and drainage networks of lakes in Belagavi taluk over a period of several decades. The study compared three significant time points: 1920, 1973, and 2017, using cadastral maps from 1920, Corona satellite data from 1973, and fused satellite imagery from CartoSAT and LISS IV from 2017. this study conducting analysis only for 1920, 1963 and 2017 as are identifying water bodies changes for century. Through these datasets, the study delineated the boundaries of lakes and drainage systems and assessed how these have transformed over the years, particularly focusing on urban expansion and its impact on water bodies.

The analysis showed that between 1920 and 1973, the number of lakes in Belagavi taluk declined by approximately 30.30%. However, there was a notable increase in newly formed lakes during the same period, with the number of lakes growing by 27.86%. This expansion could be attributed to changing land use patterns, possibly due to increased agricultural activities or natural processes such as flooding or changes in the region’s hydrology. In terms of surface area, the lakes in 1973 had expanded by 50%, reaching an area of 849.27 acres, compared to 563.18 acres in 1920. The average rate of expansion for the lakes during this period was about 5.63 acres per year, highlighting a gradual increase in their size.

However, the period from 1973 to 2017 witnessed a significant degradation of lakes in Belagavi taluk. During this time, a total of 49 lakes disappeared or were severely degraded, largely due to uncontrolled urban expansion, industrialization, and the impacts of climate change. Human activities, including the construction of buildings and infrastructure, resulted in the conversion of many lakes into built-up areas or other land uses. Other lakes that survived the urbanization process have experienced a reduction in size, and their water quality has deteriorated due to pollution, often becoming filled with algae and waste.

The study used remote sensing data to identify and measure these changes in a systematic manner. The satellite images from 1973 and 2017 provided a clear picture of the transformation of the region. In 1973, there were 160 lakes, while by 2017, only 124 lakes remained. Despite this decline in the number of lakes, the period from 1973 to 2017 saw the creation of 31 new lakes, although this number was significantly lower compared to the earlier period. This suggests that while new lakes were formed, their creation could not offset the losses experienced due to human interventions and environmental changes.

Urban growth was another critical factor contributing to the reduction in the number of lakes and their degradation. The study mapped urban expansion in the region by analyzing satellite images from 1973 and 2017. In 1973, the urban area was around 22 square kilometers. However, by 2017, this area had grown dramatically to 92.10 square kilometers, marking an increase of more than four times. This rapid urbanization resulted in the conversion of agricultural land, open spaces, and wetlands into residential, commercial, and industrial zones, significantly reducing the available space for lakes and drainage systems.

The consequences of this urban expansion are evident in the disappearance and degradation of lakes. A total of 49 lakes were either entirely filled in or converted into built-up areas or open land with scrub. The remaining lakes saw a reduction in their size and a decline in water quality due to pollution and the encroachment of urban developments. The shrinking of lakes and their pollution pose a significant threat to the local ecosystem, as these water bodies are crucial for maintaining biodiversity, supporting agriculture, and providing clean water.

The findings of this study emphasize the importance of monitoring and managing water bodies through advanced techniques such as remote sensing and geographic information systems (GIS). By conducting a systematic inventory and spatio-temporal analysis of lakes and drainage systems, it is possible to identify the factors contributing to the degradation of lakes and prioritize conservation efforts. The results of the study highlight that human activities, such as urban expansion, land use changes, and pollution, have had a profound impact on the health of lakes in Belagavi taluk. If these trends continue, the environmental consequences could be severe, leading to the loss of vital water resources and ecological functions.

The study concludes that effective lake conservation planning is essential for maintaining a healthy and sustainable environment. Through the use of scientific techniques and satellite data, authorities can identify critical lakes that require protection and develop strategies to safeguard these water bodies from further degradation. This could include implementing policies to control urban sprawl, reduce pollution, and restore damaged lakes. Furthermore, public awareness and community involvement in conservation efforts are crucial for ensuring the long-term preservation of lakes and their surrounding ecosystems.

In summary, the study on the lakes in Belagavi taluk demonstrates the significant changes in the number, size, and condition of lakes over a span of nearly a century. The combination of urban growth, land use changes, and environmental factors such as climate change has led to the loss of many lakes and the degradation of others. Through the use of remote sensing and GIS technologies, it is possible to track these changes, prioritize conservation efforts, and develop strategies to protect and restore the remaining lakes in the region.

Keywords: *Lakes, satio-temporal changes, drainage pattern, dynamics of lakes, Belagavi taluk, and remote sensing*

MORPHOMETRIC COMPARISON OF RIVER BASINS IN BARAMATI TEHSIL, MAHARASHTRA, INDIA

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A comparative investigation of areal, linear, and relief factors revealed that the Karha river basin is more developed than the Nira and Bhima basins. Watersheds, also known as drainage basins, are hydrological units defined by geographical characteristics that impact the flow and distribution of water. Morphology refers to the study of the size, shape, and organization of landforms. Morphometric analysis of watershed involves quantitative examination of land surface properties such as the dimensions, shape, and scale of landforms. Modern tools enable detailed analysis of the basin characteristics. Morphometric analysis is critical for the efficient use and management of natural resources within a watershed. Planners can find development prospects by analysing a basin's linear, areal, and relief parameters. Soil, vegetation, geology, and structure all have a role in shaping drainage networks, which contribute to landscape change.

Geospatial technologies have significantly enhanced the precision and ease of computing morphometric indicators, allowing for more accurate assessments of a basin's geometry, including aspects like geomorphology, geology, slope, and other structural constraints. Significant advances to geomorphology, particularly after 1945, have focused on the link between a drainage system's morphological features and hydrological factors. Initially it is necessary to investigate the relationship between stream order and numerous basin metrics, such as average stream length and drainage area. Geospatial techniques, aid in better understanding of these linkages and their implications in watershed management. The goal of this research is to improve knowledge of selected river basins' hydrological and geomorphological behaviour, laying the groundwork for long term and informed watershed management. Under this study morphometric analysis of the Nira, Karha, and Bhima River basins was conducted using topographic maps (1:50,000 scale, Survey of India, 47 J Series) and SRTMDEM data at a resolution of 30 meters. These river basins, which originate in western Maharashtra's Sahyadri highlands, are located in Baramati Tehsil, Pune District, Maharashtra, India.

Using ArcGIS 10.4 and the Arc Hydro tool, essential morphometric characteristics such stream lengths, watershed areas, and stream orders were calculated using Strahler's approach. The investigation also looked at areal, linear, and relief features with established formulae. The stream and basin networks were mapped in a regional coordinate system (WGS1984, UTM Zone 43N) to ensure uniformity and accuracy. The investigations yielded a number of notable results that help to better understand the region's hydrological and geomorphological aspects. The river basins were identified as 5^{th} to 7^{th} order streams. The investigation found that the Nira, Karha, and Bhima basins had 1603, 2543, and 750 streams, respectively, with total lengths of 1071.98 km, 1892.83 km, and 535.36 km. All the three basins are derived from the Deccan Traps, a volcanic plateau that has a considerable impact on the region's morphology and drainage patterns. These river basins feed left bank tributaries of the upper Krishna River, which is an important regional water system. Among the three basins, the

Karha River Basin is the longest and most developed, with evidence of considerable erosional processes shaping its current. form.

Each of the three river basins, has a dendritic drainage pattern, which is typical of locations where rivers follow the natural contours of the environment with no structural intervention. This pattern demonstrates that river systems have developed throughout time to accommodate the underlying Deccan Traps rock formations, which are usually homogenous and allow for unrestricted flow of water. However, the Karha basin has better developed characteristics than the other two. The Karha basin's areal, linear, and relief features, which include a bigger basin size, more convoluted stream networks, and steeper terrain, indicate that it is in the advanced phases of erosion. The use of GIS based morphometric analysis considerably improved the study's efficiency and accuracy when compared to traditional field methodologies. With tools like ArcGIS and ArcHydro, it was feasible to precisely map the basin borders, compute stream orders, and quantify numerous morphometric factors. This method sheds light on the hydrological, geological, topographical, and pedological interactions within basins, illustrating how these elements work together to determine river system behaviour. Previous research has shown that GIS based morphometric analysis is critical for successful watershed management and planning, especially for soil and water conservation initiatives. The findings of this study also emphasize the necessity of knowing these basins' hydrological, geomorphological, and hydrogeological properties in order to effectively manage watersheds and conserve natural resources. The findings of this study, in particular, highlight the importance of focused management in the Karha river basin, where erosion processes and geomorphic features require immediate attention to ensure long term environmental sustainability as the well-being of local communities depends on the river resources. The investigators suggest that planners may use GIS technology to make educated judgments on resource conservation, sustainable management techniques, and future development plans.

Keywords: *Areal aspect, linear aspect, relief aspect, GIS, GPS, morphometric analysis*

A MULTI-FACETED APPROACH FOR ASSESSING GROUNDWATER RECHARGE POTENTIAL IN THE BEGURU SUB-WATERSHED, KARNATAKA, INDIA

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The Beguru sub-watershed of Karnataka deals with severe groundwater decline that intensifies during prolonged years beyond drought seasons. Agricultural activities in the sub-watershed encompass paddy cultivation along with maize and are canut farms and additional field crops which demand efficient water management for agricultural sustainability and local living. The World Bank-assisted Rejuvenating Watersheds for Agricultural Resilience through Innovative Development (REWARD) program 1 implements contemporary watershed management approaches to build agricultural value chains and increase farmer resistance. The REWARD project uses a diverse assessment methodology to evaluate groundwater recharge capabilities throughout the sub-watershed. Effective science-based water management requires complete knowledge about how hydrogeology, land use activities particularly farming practices relate to water availability. This research combines evaluation of hydrogeological patterns together with geophysical techniques and examination of groundwater resources in detail. Hydrogeological data containing rainfall data (2015-2022) acquired from the Karnataka State Natural Disaster Monitoring Centre and LULC, soil, lithology, and geomorphology maps were provided by the Karnataka State Remote Sensing Applications Centre alongside groundwater level information. The LULC clearly mapped agricultural land distributions including diverse crop and plantation areas for evaluating their effects on water resource dynamics. The IISc established methodologies provided the basis to calculate Actual evapotranspiration (AET) from meteorological data. The groundwater potential zone map was generated using weighted overlay analysis of these thematic layers by integrating factors such as lithology, lineament density, soil type, LULC, drainage density, slope and geomorphology. ERT method was employed at 17 survey sites from GP1 to 17 as part of geophysical investigation for mapping sub-surface geological features and locating groundwater recharge areas. The ERT technology detects electrical conductivity variations beneath the surface that respond to the properties of geological materials along with their porosity and fluid content. Groundwater resource assessment was done to estimate the water balance (draft/excess) by considering the existing recharge and extraction of water from aquifer. The key properties of groundwater flow and storage were measured through pumping tests performed in four representative locations which determined both transmissivity and storativity values of the aquifer.

The hydrogeological study showed that the sub-watershed includes 57% of its land area used for agricultural production. Arecanut plantations take up a significant 8.16% share of the net cultivable land and stretch across the three regions of southern western and central parts of the sub-watershed as the irrigation demand is constantly throughout the year. A large concentration of this farming activity shapes the regional water flow patterns in ground waters. Rainfall analysis revealed an average annual rainfall of 917.7 mm with substantial inter-annual unevenness and the incidence of drought years, which pose significant challenges for primarily rain-fed agricultural practices. The regions with denser arecanut plantation in northwest and southwest sub-watershed showed lower groundwater levels was a result of continuous groundwater based irrigation. The weighted overlay analysis method generated a groundwater potential zone map that showed specific areas with maximum groundwater recharge abilities. The evaluation of subsurface characteristics at the 17 locations was conducted through geophysical investigations. A model based on geophysical measurements showed zones that possess resistivity signatures indicating saturated water-bearing zones and fractured units in the prevalent geologic formations. The geophysical survey at GP1 revealed low resistivity areas from shallow zones and from deeper zones which pointed toward potential recharge possibilities at various hydrology levels. The resultant high chargeability values in these zones further support the interpretation of water saturation. The other survey sites revealed alike spatial patterns with dissimilar depths and sizes which reflected the natural heterogeneity throughout the subsurface region. The geological areas detected during observations mark important zones for artificial recharge shaft deployment.

The estimated groundwater draft/excess amount stands at +2.07 MCM per year together with 1.87 MCM of yearly non-committed monsoon runoff establishes ample opportunities to develop artificial recharge systems for agricultural water needs. Four borehole tests across different locations showed variable transmissivity ranging from 11.97 to 97.61 m^2/day and storativity outcomes ranging between 3.37×10^{-9} and 0.0108. The low recovery rate in Pumping Test 1 indicated strong groundwater recharge potential within that area. The high transmissivity value measured during pumping test 2 confirmed that the aquifer possessed excellent connectivity properties. A total of 16 optimal recharge shafts were proposed based on the integrated analysis and their design parameters were set at depths between 20 and 35 m beneath ground level. The proposed shafts should allow for an annual recharge amount of 1.03 MCM. Hydrological analyses of the geophysical surveys alongside pumping tests produced a superior approach for location selection that prioritized appropriate areas for recharge shaft placement. This study successfully integrated multiple dataset types to accomplish complete groundwater recharge evaluation in the sub-watershed. This approach provides detailed solutions to address the critical water management requirements during heavy agricultural use. Through the integrated analysis of hydrogeological parameters and data from geophysical surveys and land use assessment, enabled the identification of precise locations with optimal characteristics for artificial recharge. Geophysical surveys delivered necessary knowledge about subsurface layers and their hydrological conditions to optimize the placement of recharge shafts. The conducted pumping tests produced vital aquifer characteristics that serve as essential inputs for designing the proposed recharge structures. This study yields essential data to establish sustainable groundwater management practices by showing how artificial recharge facilities should be situated to increase water accessibility for domestic and agricultural needs. Artificial recharge implementation will result in a significant contribution to water security durability while sustaining community livelihoods. Water resources from monsoon season can successfully be collected for artificial recharge purposes to support irrigation requirements during the essential and dry period between January-April when crops require immediate and crucial water support. The proposed recharge shaft network presents a sustainable approach to increase groundwater availability which results in enhanced water security and enables reliable agricultural practices in the study region.

Keywords: *Groundwater recharge, ERT, hydrogeology, artificial recharge*