ADDRESSING GROUNDWATER DEPLETION IN KOLKATA, INDIA: SUSTAINABLE STRATEGIES FOR URBAN GROUNDWATER MANAGEMENT

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Groundwater is a vital resource for sustaining life, supporting economic development, and meeting the urban water demands of Kolkata. However, rapid urbanization, population growth, and unregulated groundwater extraction have led to significant challenges including declining groundwater levels, land subsidence, water quality degradation, and loss of natural recharge zones. These issues are further exacerbated by climate change, which impacts recharge rates, increases evapotranspiration, and poses risks of saltwater intrusion in coastal areas. This research aims to develop sustainable and climate-resilient strategies for groundwater management in Kolkata. The primary objectives include assessing the spatial and temporal changes in groundwater levels, analyzing the effects of urbanization on groundwater resources. Additionally, the study proposes effective strategies for sustainable groundwater usage and recommends policies to regulate extraction in critical zones, protect recharge areas, and integrate blue-green infrastructure into urban planning frameworks.

The study adopts a macro-level approach to provide comprehensive insights into groundwater challenges across the Kolkata Municipal Corporation (KMC) area. The macro-level study spans all 144 wards of KMC, utilizing secondary data sources such as groundwater monitoring well records, borewell data, and land use maps to evaluate overall extraction rates, impacts on the piezometric surface, and critical zones of depletion. Cluster analysis is applied to group the wards based on groundwater challenges. Secondary data is used to evaluate overall extraction rates and the impact on the piezometric surface, while primary data is collected through field surveys, stakeholder interviews, and observations to understand groundwater usage patterns, local impacts, and the feasibility of proposed interventions. Remote sensing and GIS are employed for spatial analysis, including mapping groundwater extraction patterns, recharge zones, identifying critical areas, and the impacts of urban land use on groundwater resources. Key techniques used include: (1) Multi-Criteria Decision-Making (MCDM): To evaluate and rank areas based on their susceptibility to groundwater depletion, considering criteria such as land use, groundwater extraction rates, groundwater levels, population, and recharge potential. (2) Groundwater Water Resource Carrying Capacity (WRCC): To evaluate the sustainable limits of groundwater extraction in critical zones. This method provides insights into the balance between groundwater availability and urban water demand. (3) Cluster Analysis: To group wards with similar groundwater characteristics, enabling the identification of specific zones for targeted interventions and the prioritization of policy actions. This integrated methodology ensures a data-driven understanding of Kolkata's groundwater issues, providing a basis for formulating actionable policies aimed at groundwater regulation. The study's initial findings highlight several critical issues driving the depletion of groundwater in Kolkata.

Excessive reliance on groundwater accounts for nearly one-fourth of Kolkata's total water consumption, amounting to approximately 310,000 m^3 daily. A large portion of this water is drawn from private motorized wells and municipal sources, surpassing the sustainable recharge capacity of aquifers. Overextraction has resulted in land subsidence, with an average annual rate of 13.53 mm. This subsidence poses serious risks to urban infrastructure and increases vulnerability to flooding. Persistent cones of depression in the eastern, western, and northern parts of the city highlight severe pressure troughs. These zones show inadequate groundwater recovery, even after seasonal rainfall. Rapid urbanization, characterized by the expansion of impermeable surfaces and the encroachment on natural wetlands, has drastically reduced natural recharge zones. Critical areas facing severe depletion include locations such as Science City, Garden Reach, and Tollygunge. The analysis identifies critical zones of groundwater depletion and calls for immediate policy-driven interventions to regulate extraction and protect recharge areas. The study emphasizes prioritizing targeted policies in these zones, including implementing extraction limits, promoting the use of alternative water sources, and encouraging sustainable practices to reduce groundwater dependency. Proposed strategies include enforcing policies to protect recharge zones and integrating blue-green infrastructure to enhance recharge capacity. The research also highlights the need for a conjunctive use approach, recommending increased reliance on surface water sources, such as the Hooghly River, to alleviate groundwater stress. This research underscores the urgent need for sustainable groundwater management strategies to address the challenges posed by overextraction, urbanization, land subsidence, and the loss of natural recharge zones in Kolkata. Through comprehensive spatial analysis techniques, the study identifies high-priority zones severely affected by groundwater depletion and in need of immediate intervention. These findings contribute to developing a comprehensive framework that integrates policy interventions, artificial recharge strategies, and urban planning practices to ensure long-term water security. Implementing large-scale rainwater harvesting systems, protecting natural recharge zones, and promoting green infrastructure tailored to the city’s dense urban fabric to support infiltration and groundwater recharge. Establishing stricter controls on groundwater abstraction through licensing and monitoring, particularly in critical and overexploited zones, to ensure sustainable usage. Optimizing the combined use of surface and groundwater resources to balance demand and ensure sustainable utilization. Raising awareness and involving local stakeholders in groundwater conservation efforts to ensure the success of proposed strategies and encourage sustainable practices. The implications of this study extend beyond Kolkata, offering replicable strategies for urban groundwater management in other rapidly urbanizing cities facing similar groundwater challenges. By integrating scientific analysis, innovative techniques, policy frameworks and participatory approaches, this research contributes to climate-resilient urban water planning and sustainable development.

Keywords: *Groundwater depletion, sustainable groundwater management, urban water security, groundwater regulation, recharge zones, MCDM, cluster analysis, Kolkata*

REGULATORY FRAMEWORK AND POLICY IMPLICATIONS FOR SUSTAINABLE GROUNDWATER MANAGEMENT THROUGH ADVANCED SCIENTIFIC INNOVATION FOR VIKSIT BHARAT@ 2047

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The study focuses on water management specifically regarding groundwater practice emerges as a critical necessity for India because its groundwater infrastructure remains the main water supply foundation that sustains diverse sector operations. Groundwater as a sub-surface water source is increasingly subject to severe damage from pollution and over-extraction which underscores the pressing necessity for improved management systems to support sustainable development. The journey to achieve Viksit Bharat@2047 in India demands a union of scientific innovation and effective legal protections when managing groundwater. This research first examines how technological solutions work for sustainable groundwater management, then establishes a legal structure to promote this practice. On track with the Viksit Bharat@2047 vision, India will solve its acute water resource dilemmas and bring an end to water scarcity. The research combines documentary analysis with survey data for studying India's groundwater management practices and legal structures. The analysis studied successful scientific innovation implementations through case studies across various territories to discover best practices. A thorough examination of international groundwater management policies was performed to help understand efficient global approaches. The analysis used stakeholder mapping techniques to determine how individual communities, policymakers, and scientific bodies participate in hydrological system and groundwater management operations. The analysis received additional depth through twenty-five semi-structured interviews performed with environmental scientists alongside water management experts and civil servants to assess policy and technological situations. India faces a dual challenge in groundwater management. The combination of agricultural water use inefficiency and inadequate water management strategies exists nationwide. The agricultural practice of flood irrigation combined with water overuse continues to deplete groundwater resources. Natural evolution in technology includes remote sensing alongside GIS, Artificial Intelligence (AI) and Machine Learning (ML) that create powerful possibilities. Water-related technologies facilitate precise measurement of water availability and assessment of climate change impacts and over-extraction effects. The combined wealth of data from these technologies enables informed decisions for groundwater recharging projects together with resource management strategies. The National Water Policy (2012) and the Groundwater Management and Regulation Bill need stronger scientific and technological foundations within their detailed implementation plans to establish effective governance.

The study explores essential function of technology emerges as a cornerstone in present-day groundwater management networks. An immediate requirement is the development of an online warning system which monitors groundwater in real-time. Levelled advancements in GIS applications and satellite data together with AI and ML create systems that enable

quantitative groundwater determinations while revealing hydrological deficits during procedure development for recharge operations. The effective implementation of these technologies requires an established legal framework which both provides mechanisms for user accountability and increases public understanding of conservation. India needs an exhaustive nationwide groundwater operational legislation which should specify maximum extraction measures and minimum replenishment conditions together with effective consequences for excessive consumption. Water tariffs should adopt pricing structures which accurately represent borehole well extraction costs in order to motivate water preservation activities.

Long-term success in groundwater management depends fundamentally on active community involvement. Local involvement with scientific techniques works together for sustainable groundwater management resulting in more efficient resource development. The integration of surface management strategies together with groundwater management strategies should become part of strategic policy frameworks especially in areas affected by water depletion. Water-resilient design measures which include rainwater collection systems and artificial groundwater enhancement must find integration during infrastructure and construction development. Low-cost environmental management solutions should be taught to local stakeholders to enforce sustainable water use norms. India needs to make responsible groundwater utilization a nationwide priority if the nation wants to reach its Viksit Bharat@2047 aims. Groundwater management gets elevated by advanced technologies which include artificial intelligence and machine learning and remote sensing capabilities for obtaining precise up-to-date data. The success of advanced technologies depends on a regulatory infrastructure with both monitored controls and local public partnership support. India needs to develop legal infrastructure which combines scientific or technological progress with local governance obligations to establish effective groundwater control systems. Collaboration between government entities scientists and groundwater users will create pathways for India to become water secure. Scientists and governments must work together as a team to achieve scientific groundwater management which will result in sustainable resource preservation for future needs. The success of enhanced groundwater management practices depends on three key elements: strong policies along with technological advancement and engaged community involvement. Sustainable water management science that supports Viksit Bharat@2047 will emerge through India's combined conservation efforts.

Keywords: *Groundwater, water management, Viksit Bharat, AI, ML*

INTERSTATE WATER DISPUTES IN INDIA AND THE ROLE OF GROUNDWATER

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Water is a vital resource for socio-economic development of any country, including India. However, in the Indian context, its unequal distribution in space and time is many a times responsible for disputes among various states over sharing of river waters. With over 20 major river basins shared among multiple states, interstate water disputes are a recurring feature of India's federal structure. The demands from many competing sectors like agriculture, industry, domestic use, and ecological needs aggravate these conflicts. To add to the conflict situation, the heavy use of groundwater, accounting for almost 85% of drinking water and 70% of irrigation demands, has deepened the issues of water management and dispute. India's legal and institutional structures, while strong in areas, have yet to effectively cope with the emergent difficulties of sharing water. On the one hand, the Interstate River Water Disputes Act 1956 offers a procedural mechanism that can be used for resolution; but tribunal processes are drawn out and taking it to court raises difficulties; again, this process ignores ground water. Furthermore, the continued over-exploitation of groundwater in the country which is linked to surface water flows exacerbate these conflicts and requires urgent attention.

India's vast and diverse geography, combined with its complex socio-political landscape, has led to several inter-state water disputes. These conflicts primarily arise from competing claims over shared river waters, often exacerbated by regional disparities in water availability, population pressure, agricultural demands and increasing variability in the patterns of climate. Interstate water disputes are further complicated because of the federal system of Indian Governance whereby the states are allowed to hold rights over the waters falling within their jurisdictions. Major disputes include the Kaveri River dispute among the States of Karnataka, Tamil Nadu, Kerala and Puducherry rooted in the colonial era agreements and competing irrigation demands; the Ravi-Beas conflict involving Punjab, Haryana, and Rajasthan, again rooted in the reorganization of Punjab in 1966 highlighting the complexities of river linking through the Sutlej Yamuna Link (SYL) canal; and the Mahanadi River dispute primarily involving Odisha and Chhattisgarh which gained prominence in recent years when Chhattisgarh initiated several dam constructions and irrigation projects upstream, which Odisha claimed, is negatively impacting its water supply and agricultural activities. Each of these disputes highlights the challenges of equitable water sharing in a federal system, where state interests can clash, leading to prolonged legal battles and political tensions.

Groundwater, often considered as a cushion in times of surface water scarcity, remains an un-acknowledged aspect of interstate water disputes. India's position as the world's biggest consumer of groundwater testifies to its significance but also to its vulnerability to over-withdrawal. Therefore, groundwater plays a pivotal, yet unexplored role in inter-state water conflicts as: (i) groundwater as a cushion/unseen reservoir, (ii) inequity in groundwater availability, (iii) surface-groundwater interactions and (iv) lack of regulation. Given that groundwater plays a crucial role in sustaining agriculture and also supplies drinking water, with its governance being fragmented, the issue arises in various challenges such as: (i) Inadequate data regarding the availability of groundwater, recharge rates, and groundwater extraction hampers the design of effective policies, (ii) lack of an overall framework for managing both the surface and groundwater resources promotes inefficiency, (iii) declining rainfall, increasing temperatures, prolonged droughts, and over-extraction of groundwater have resulted in further depletion of aquifers, decreasing the reliance on groundwater as a potential source, (iv) interstate water disputes resolution in India will require a complete paradigm shift towards Integrated Water Resources Management (IWRM) which takes into account the surface water and groundwater as an inter-connected system various key strategies like: (a) IWRM: Basin-level planning that includes surface and groundwater dynamics can be the basis of equitable sharing of resources, (bi) Groundwater Mapping and Monitoring: Technological application, like advanced remote sensing data and GIS tools, may assist in the identification of overexploited aquifers at a finer resolution and monitor the groundwater usage on a regular basis, (c) Legal Reforms: A complete national groundwater policy that would be integrated with the policy related to surface water is the need of the hour. Provisions regarding interstate aquifer sharing and cooperative management should be incorporated, (d) Water-Use Efficiency: Shifting from water-intensive crops, promoting micro-irrigation techniques, and improving water-use practices can reduce stress on both surface and groundwater, (e) Institutional Reforms: River basin organizations that include stakeholders from all riparian states can facilitate cooperation and dialogue, while tribunals should explicitly account for groundwater's role in disputes, and (f) Community Engagement: Participatory approaches to groundwater management can foster sustainable practices and equitable resource allocation at the grassroots level.

Interstate water disputes in India represent a pertinent example of the challenges of managing shared natural resources in a large, populous and multi-cultural country. Addressing these disputes requires robust legal frameworks, inter-state agreements, and cooperative management strategies that prioritize sustainable water use and conflict resolution. The inter dependence of surface and groundwater systems calls for an integrated strategy of water management. Groundwater is very often overlooked, but it is significant in both aggravating and potentially easing the tensions. For effective water distribution, sustainable resource usage, and long-term water security, the right mix of legal, institutional, technological, and community-driven solutions is necessary. Overcoming the challenges of groundwater governance, in conjunction with surface water disputes, can take India a step closer to a more cooperative and resilient water management framework. This paper highlights the need for an interdisciplinary and cooperative approach to the management of water resources, with a special focus on the often-neglected role of groundwater. Sustainability in the governance of water resources is critical not only for resolving disputes but also to support the broader developmental goals of India in times of increasing water stress.

Keywords: *Water disputes, groundwater, governance, IWRM, India*

GROUND WATER VISION 2047: ENSURING WATER SECURITY IN A CHANGING CLIMATE THROUGH SUSTAINABLE MANAGEMENT PRACTICE FOR INDIA

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India's hydrological diversity, spanning the Himalayan mountains, Indo-Ganga-Brahmaputra floodplains, western aeolian-alluvial deposits, basalt flows, and coastal regions, presents both opportunities and challenges for groundwater management. As the world's largest extractor of groundwater, India relies on this resource for over 60% of irrigation and 85% of drinking water needs. However, rampant overexploitation, aquifer depletion, and deteriorating water quality have severely strained groundwater reserves. Climate change-induced variability in rainfall patterns, prolonged droughts, and extreme weather events further exacerbate these challenges, demanding a comprehensive and sustainable approach to groundwater management. This study introduces "Groundwater Vision 2047" a strategic framework aimed at ensuring long-term groundwater sustainability in India by integrating a multidisciplinary approach encompassing hydrological assessments, advanced monitoring technologies, policy reforms, and community participation.

The methodology includes a comprehensive assessment of India’s diverse hydrological regions, such as the Himalayan mountains, Indo-Gangetic plains, and coastal zones, to identify region-specific challenges like overexploitation, salinity intrusion, and geogenic contamination. The study highlights alarming trends in declining groundwater levels across India’s plateaus. For instance, in the Deccan Plateau, groundwater levels have declined by 0.5–1 m/year due to over-extraction for agriculture and urbanization. Similarly, in the Malwa Plateau, levels have dropped by 0.8–1.2 m/year, with arid regions like Rajasthan experiencing severe depletion. The Chota Nagpur Plateau faces declines of 0.3–0.7 m/year, primarily due to mining activities and reduced recharge. These trends underscore the urgent need for region-specific interventions to address groundwater depletion.

A key component of the vision is Managed Aquifer Recharge (MAR) and urban water harvesting, which leverage artificial recharge structures such as check dams, farm ponds, and percolation tanks to enhance groundwater replenishment. Additionally, sustainable agricultural practices, including drip irrigation, crop diversification, and the adoption of genetically modified drought-resistant crops, are explored to optimize water usage efficiency. The increasing reliance on groundwater demands efficient water allocation mechanisms, where technological advancements play a crucial role. The integration of artificial intelligence (AI), the Internet of Things (IoT), and GIS facilitates real-time monitoring of groundwater levels, improved water allocation, and early warning systems for drought and flood management. Furthermore, tools like MODFLOW aid in identifying sustainable pumping rates and recharge zones, helping to mitigate groundwater depletion. The adoption of these innovative technologies can transform groundwater governance, ensuring efficient utilization and conservation of this vital resource.

Climate resilience is a central focus of the framework, addressing region-specific vulnerabilities. In flood-prone areas like Assam and Bihar, floodwater harvesting mitigates runoff and enhances recharge, while drought-prone regions like Rajasthan benefit from adaptive conservation strategies. Ecological restoration, including afforestation and wetland conservation, boosts natural recharge and reduces water loss. Ensuring groundwater quality requires stringent pollution control, such as zero liquid discharge policies and decentralized wastewater treatment. Adaptive wastewater management, including reuse for agriculture, reduces freshwater dependency. Public awareness campaigns promote sustainable water use and behavioral shifts toward responsible groundwater consumption. These measures collectively enhance groundwater sustainability, ensuring resilience against climate variability and securing water resources for future generations.

Policy and governance reforms are critical for effective groundwater management. Strengthening regulations, enforcing extraction permits, and promoting participatory governance empower local communities in decision-making. Public engagement through water management boards and advocacy fosters collective responsibility. India's annual freshwater withdrawals surged from 380 Bm^3 in 1975 to 647.5 Bm^3 in 2020**,** driven by population growth, urbanization, and infrastructure expansion. Groundwater depletion is severe in the Indo-Gangetic plains and hard rock regions, with declining water tables and contamination by arsenic, fluoride, and nitrates. Coastal zones face salinity intrusion, while arid regions suffer acute water scarcity. Addressing these issues requires stringent monitoring, policy reinforcement, and investment in water-saving technologies. MAR efficient irrigation, and technological advancements have improved sustainability. Micro-irrigation has cut agricultural water use by up to 50%, and community-led watershed management has restored degraded aquifers. Industries must adopt water audits, recycling, and stricter regulations to reduce groundwater stress. Transboundary water management is also essential to prevent over-extraction and conflicts in shared river basins.

"Groundwater Vision 2047" offers a roadmap balancing economic growth, ecological conservation, and social equity. By leveraging advanced technologies, enforcing policies, and fostering community participation, it aims to achieve water security and resilience against future uncertainties. The study highlights the need for an integrated, region-specific approach combining scientific advancements with traditional knowledge for sustainable groundwater management. Strengthening institutional capacity and legal frameworks is crucial to address emerging challenges. Future research should explore adaptive governance, economic incentives for sustainable water use, and innovative conservation technologies. Additionally, understanding the socio-economic impacts of groundwater depletion and developing community-driven models are essential for holistic sustainability. The framework integrates scientific research, policy interventions, and public engagement to tackle India's groundwater crisis. By addressing socio-economic, environmental, and governance aspects, it aims to foster a resilient, water-secure future. Urgent action, combining innovation, policy support, and community involvement, India can successfully navigate its water challenges and secure its groundwater resources for future generations.

Keywords: *Sustainable water management, rainfall patterns, aquifer recharge, climate resilience, groundwater governance*

MULTI-STAKEHOLDER LED INITIATIVE ON RIVER-WETLAND CO-MANAGEMENT IN THE ARIL RIVER BASIN, UTTAR PRADESH, INDIA

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Ramganga and its tributaries are aquifer fed river systems that are being subjected to loss of connectivity and degradation of river health (flows, water quality, biodiversity) due to over-abstraction of groundwater, diversion of surface water, unsustainable agriculture practices, pollution, land use change), encroachment etc. To improve river health, maintaining its 3-dimensional connectivity viz lateral (floodplain), Longitudinal (Upstream to downstream) and vertical (river-groundwater) connectivity is essential to maintain. Wetlands are crucial in supporting base flows in the river system through groundwater replenishment apart from providing a myriad of ecosystem services to communities and biodiversity. To address some of these issues, WWF-India had adopted a unique approach of river-wetland co-management to demonstrate rejuvenation of an aquifer fed and degraded river Aril (right bank tributary of Ramganga river) through wetland restoration, emphasizing multi-stakeholder engagement.

Situational analysis of Ramganga basin and its tributaries were carried out by generating several layers of information including landuse changes, groundwater scenario, mapping of influent and effluent streams etc. were developed. WWF-India along with its technical partners, IIT-Kanpur, mapped all the wetlands (>2.5 ha) in the Ramganga basin and assessed their degradation status overs last 3 decades and analysed the connectivity with their catchments. Tributary catchments of Ramganga basin were scanned and Aril River basin (a right bank tributary) was selected to showcase river-wetland co-management work based on its degraded catchment, groundwater scenario and status of wetlands. Spatio-temporal mapping of Aril basin indicated that about 60% of wetlands were in a degraded state. Based on the wetland's status and connectivity to river floodplains, 20 plus wetlands were field surveyed to collect baseline information which indicated that there are several major threats to the wetlands including excess weed growth, siltation, choked inlets/outlets, sewage, fragmentation, intensive chemical usage in agriculture LULC changes, to ownerships. Using a prioritization matrix three wetlands were selected viz. Khangawa Shyam (10.6 hectares (ha), Lilaur Lake (42 ha), Bahoda Kheda (7.42 ha) in Bareilly district. Detailed scoping surveys were carried out for these wetlands and baseline data on connectivity, inlet/outlets, water quality, invasives, biodiversity, groundwater level etc were collected. Individual wetland restoration plan was developed for all four wetlands.

A multi-stakeholder-led collective action approach was adopted from baseline data collection to implementation and monitoring where the District Administration (Bareilly), various line departments (Revenue, Irrigation and Water Resource Department, Forest Department, Rural development etc), District Ganga Committee, Bareilly (U.P.), riparian community, farmers and WWF-India contributed to improve the ecological health of river through river-wetland co-management. Over 500 farmers and community members across five villages were enrolled as Aril River Mitras or friends of river (volunteer network of citizens) trained in various aspects of conservation including wetland health monitoring, better management practices in agriculture, generating organic inputs and several restoration activities

The conservation and restoration efforts involved a range of activities, including community mobilization, technical support, training, capacity building, and physical restoration measures such as channel rehabilitation, de-weeding, desilting, waste to compost etc. Synergies were established with government schemes like MNREGA to leverage resources and accelerate restoration. The collective action approach yielded significant positive impacts with significant improvement in hydrological health of wetlands, river and enhanced resilience of riparian communities. Post restoration, the three wetlands received additional inflows of 2.7 billion litres of additional water between 2022-2024 as compared to baseline condition. This not only improved the wetland health and local water security but also rejuvenated the Aril River. Aril river, through a connected outlet channel from Khangawa Shyam wetland was rejuvenated by over 200 million litres of water. The increased water availability in wetlands led to an increase in groundwater levels by 4-5 feet in vicinity of wetlands thereby improving aquifer health and water security for communities

To improve wetland health and promote organic farming in the wetland zone of influence, 2500 quintals of wet weed were removed and turned into 700 quintals of compost which is being used by farmers in their crops. Apart from this 500 plus farmers were trained on the preparation and adoption of biofertilizers and biopesticides (Amrit Paani and Amrit Khaad) and follow better management practices in agriculture through customized Package of Practices (PoP). Farmers reported an increase in the length of the wheat spike, improved plant health, 20-25% reduction in water requirement, and substantial reduction in chemical application, through the adoption of PoP. Synergies with government schemes like MNREGA were built and through leveraging funds, 8 new inlets were created and 4 inlet channels were rehabilitated which brought more surface water inflows into wetlands. WWF-India provided the technical and on ground research and monitoring support. The enhanced flows and removal of weeds in specific wetlands resulted in improved concentration of dissolve oxygen which increased by 50-100%. (from 4 mg/l to 6-8 mg/l). The Improvement in wetland health provided conducive habitats for aquatic species and avian fauna.

All wetlands are ecologically and hydrologically important for river basin health. This pilot initiative successfully demonstrated the concept of river-wetland co-management and how wetlands can play crucial role in rejuvenating rivers and improving groundwater levels to improve the baseflows. There are about 754 wetlands in Ramganga basin (>2.5 ha area) and 97 plus wetlands in Aril basin, 60 % of which are in degraded state. Restoration of these wetlands through similar approach and collective action will not only help improving 3-dimensional connectivity in rivers-wetlands but also enhance resilience of riparian community and provide conducive habitats for dependent biodiversity.

Keywords: *Wetland restoration, sustainable agriculture, groundwater recharge, biodiversity conservation, Ramganga River Basin, Aril River, river rejuvenation, wetland hydrology*

COMMUNITY BASED RESUSCITATION OF MINOR WATERWAYS IN UPPER GBM DELTA: CASE OF BURI GANGA, WEST BENGAL, INDIA

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In the Upper Ganga-Brahmaputra-Meghna (GBM) Delta, Minor Inland Waterways (MIW) form principal sources for groundwater-dependent ecosystems (GDEs). These GDEs are under increasing pressure from Anthropocene actions. The actions are modifying the temporal patterns of the groundwater levels in the area. They are also hampering the essential ecosystem services such as providing freshwater supply for fishing and agriculture, protection against urban flooding and arsenic contamination, and sustaining aesthetic, cultural, spiritual and educational values of the MIWs. The study tries to understand why few MIWs could be successfully resuscitated while others could not. At the same time, it tries to understand MIW's importance on local socio-economic, cultural and environmental condition and vice versa. To bridge this gap, the current study tries to examine one such successful example of resuscitation of an MIW named Buri Ganga, located at Chakdaha, West Bengal. The study argues that MIWs are extremely important for local socio-economic, cultural and environmental conditions. As it focuses on the interplay between context and actors to explain the outcome, it starts from a critical realist ontology. It assumes that context is complex and actors only partially influence the outcome, but their decisions reproduce or transform the context. It also argues that actions done by actors are governed by their past beliefs and present pressures. The study tries to comprehend the process of community-based resuscitation through above-mentioned ideas. At the same time, to understand the impact of resuscitation of a MIW, the study tests Elinor Ostrom's theory on environmental commons governance (ECG). According to Ostrom, ECG is easier to achieve if five prerequisite conditions are met. These conditions are if a) resources are monitored easily, b) there are moderate changes in resources, c) dense social networks are present d) outsiders can be easily excluded and e) users support the monitoring of resource. The study tries to understand, to what extent these conditions changed after the MIW was resuscitated. The study adopts mixed-method research that consists of a combination of qualitative (process tracing and anthropology) and qualitative research (interview) methods. The main rationale for using mixed-method is that it provides complementary answers to the question of governance challenges. The study uses case study method as it allows to work with small units and large variables. The five prerequisite conditions are operationalized and questionnaire are formed. The qualitative data was gathered via surveying residents living in appurtenant urban, peri-urban and rural areas. The qualitative data is collected via interviews done in a semi-structured way to allow wide range of topics to be discussed. This also helped in deepening the understanding of the outcomes from the quantitative data analysis. Finally, both data were triangulated by using process tracing and document analysis.

Results indicate that the process of community-based resuscitation of a MIW involves multiple streams like problem streams, solution stream, political stream, choice stream and their temporal intensity. These streams create the several opportune moments in the process. These moments snowball and move forward towards certain directions, which in turn develops into positive outcomes. Results also indicate that land records department, irrigation department, water resource department, fisheries department, district development committee

and district advisory committee for river, and Kolkata Port Trust are connected to Buri Ganga. However, institutional monitoring is absent. People especially whose livelihood are dependent on the river, monitor the day-to-day changes on the river. Systematic monitoring over time by CBOs helped in its successful rejuvenation. Buri Ganga, is relatively free from pressure of urbanization and legacy intervention. There is also distinct change in the livelihood opportunities due to influx of freshwater in the MIW. Current study finds that due to increasing education, past association with the MIW and support from local government is helping in increasing the social capital in the area. However, there is non-participation by the common people and therapy by the local government. It is found that, extent of social capital is very high in Buri Ganga. Qualitative results show that continuous monitoring and campaign for twenty years by CBOs, inclusion of stake-holders (fishermen and jute farmers) in the decision-making process, support from non-stakeholders, triggering of decision-making process via protest, and snowballing of decision-making across the entire stretch of MIW helped in successful rejuvenation of Buri Ganga. At the same time, recent intervention by irrigation department (in July 2023) finally resulted in successful rejuvenation of the MIW. This shows that presence and action of outsider is extremely important for ECG. Finally, the study shows that rising level of education, growing environment awareness, increasing public engagement, and political will are increasing for both the MIW. However, loss of association with the river, organizational rigidity, lack of technical financial capacity, lack of knowledge of rights and environmental laws, and pauperization are negatively affecting the same.

The study finds that natural resources are often too big with different biophysical conditions. These varying conditions forge different levels of association with the user groups. Also, the occupation of the user group plays significant role on the association with the natural resource. Heterogeneity of users makes ECG quite challenging. Hence, for successful rejuvenation of MIW, mapping of stakeholder, their level of awareness, understanding, association and dependency on MIW is important. As current research suggests that user support is highly dependent on occupation, social strata and past association with resource, it can be said that tailormade strategic plans targeted at specific communities/ stakeholders should be made for creating user support. The study also finds that MIWs are exploited systematically over a long time, but the effect was not significant due to fewer users. Since 2000, with sudden population explosion, the effect has suddenly become prominent. Therefore, MIWs should be researched in their own rights. Most of the MIWs are situated in fast growing peri-urban areas, hence they contribute to the local socio-economic, cultural and environmental conditions. At the same time, MIWs are often used as drainage channel. Therefore, their rejuvenation is necessary. For the successful rejuvenation, along with continuous thrust factor, continuous exposure, triggering and gaining momentum plays a major role in building social capital. This can be achieved by creating multi-stakeholder platforms, participatory workshops, evaluation, feedback loops, and incremental improvements based on feedback. Finally, according to the study, action of outsiders is extremely important for successful rejuvenation. A milieu of actor-institution integration in the form of public-CBO-private can result in very strong forward-looking decisions. This can be achieved by building rapport with local government organizations, updating them about the situation of MIWs, and finding legal grounds for the rejuvenation of MIWs.

Keywords: *Upper GBM Delta, minor inland waterway, community-based initiative*

Theme 10

POLICY, REGULATION AND GOVERNANCE FOR GROUNDWATER MANAGEMENT