

COMMUNITY-BASED MONITORING OF GROUNDWATER RESOURCES

Dr. Rohan Kulkarni

Assistant Professor

Department of Environmental Science

School of Earth and Environmental Studies

Central Institute of Sustainable Studies, Pune, Maharashtra, India

Abstract

Groundwater is a vital but largely invisible source of drinking water, irrigation, industry, and ecosystem support. Its condition is often assessed through periodic technical surveys, yet many local decisions that influence recharge, extraction, pollution, and access are made every day by households, farmers, water-user groups, and local institutions. Community-based monitoring offers a practical way to connect scientific observation with local knowledge and collective action. It enables communities to record selected indicators such as well-water levels, rainfall, pumping duration, source reliability, electrical conductivity, and visible land-use changes, while also creating a shared basis for discussion about water allocation and aquifer protection.

This study uses a qualitative, literature-based approach to examine how community participation can strengthen groundwater monitoring and governance. It reviews the relationship between local observation, hydrogeological evidence, institutional trust, data quality, inclusion, and decision-making. The analysis follows the monitoring cycle from the selection of observation points and indicators to measurement, recording, validation, interpretation, public communication, and local response. It also considers how community monitoring can operate alongside the work of government agencies, universities, civil-society organisations, and technical experts rather than replacing professional hydrogeological assessment.

The study finds that community-based monitoring is most effective when it is designed as a continuing governance practice rather than a short data-collection exercise. Reliable results require simple protocols, repeated measurements, transparent records, basic technical training, local ownership of the process, and regular feedback to participants. Monitoring must also include women, smallholders, marginalised households, and people who depend on common or shallow sources, because groundwater impacts are not distributed equally. The paper concludes that community-based monitoring can improve early warning, strengthen accountability, support recharge planning, and encourage more equitable groundwater use when it is supported by credible institutions, accessible data, and clear links between evidence and action.

Keywords: Groundwater Resources, Community-Based Monitoring, Aquifer Governance, Citizen Science, Water Security, Recharge, Participatory Planning, Water Quality, Local Institutions, Sustainable Development

1. INTRODUCTION

Groundwater supports a large share of domestic water supply and agricultural production in many regions of the world. It is stored beneath the surface in pores, fractures, and aquifer formations, which makes changes in its quantity and quality less visible than changes in rivers or reservoirs. A well may continue to produce water even while water levels decline, recharge is reduced, or pollution spreads through the subsurface. This delayed visibility can encourage reactive decision-making: action is often taken only after wells fail, tanker dependence increases,

pumping costs rise, or water quality becomes unsafe. Sustainable management therefore depends on timely information about local aquifer conditions and the activities that influence them [2, 4, 10].

Technical monitoring networks remain essential, but they may be spatially sparse, irregularly reported, or insufficiently connected to the people making daily extraction and land-use decisions. Community-based monitoring can help close this gap by creating locally maintained records of groundwater levels, rainfall, well yield, spring flow, salinity, or household supply

reliability. In this approach, community members are not treated merely as respondents or recipients of information. They participate in choosing useful indicators, collecting observations, checking anomalies, interpreting seasonal patterns, and considering practical responses. This can improve both the relevance of monitoring and the legitimacy of local water-management decisions [5, 6, 26]. The promise of community monitoring should not be overstated. Local data can be affected by inconsistent measurement, unequal participation, short project cycles, political influence, and confusion between observation and inference. A single water-level reading cannot explain an aquifer system, and a community cannot be expected to resolve structural problems caused by urban growth, energy policy, irrigation incentives, or weak regulatory enforcement. For these reasons, community monitoring must be integrated with hydrogeological expertise, government information systems, and clear institutional responsibilities. The value of participation lies not in replacing science, but in extending observation, improving interpretation, and building the social capacity needed to act on evidence.

This paper examines community-based groundwater monitoring through a governance perspective. It reviews the main opportunities and risks, compares representative local contexts, and develops a practical framework for designing monitoring systems that are reliable, inclusive, transparent, and action-oriented. The central argument is that groundwater information becomes more useful when it is collectively understood, openly discussed, and linked to locally feasible measures such as recharge maintenance, pumping discipline, drinking-water protection, crop planning, and equitable source allocation.

2. LITERATURE REVIEW

Groundwater research has long emphasised the need to understand aquifer recharge, storage, abstraction, water quality, and the interaction between groundwater and surface-water systems. Hydrological methods include observation wells, pumping tests, geophysical surveys, isotope techniques, rainfall-recharge estimation, remote sensing, and numerical modelling. These methods are critical for identifying aquifer behaviour and estimating

sustainable use. At the same time, the groundwater literature recognises that technical information alone rarely changes extraction behaviour. Individual well owners may benefit from pumping even when collective extraction reduces long-term water security, producing a classic common-pool resource problem [6, 11, 16].

Governance studies therefore focus on institutions, incentives, rights, rules, participation, and the distribution of costs and benefits. In many groundwater settings, aquifers are physically shared but socially fragmented. Farmers, households, industries, commercial establishments, and public agencies may draw from the same underlying resource without common information or agreed limits. Community institutions can help create rules for monitoring, sharing information, maintaining recharge structures, protecting drinking-water sources, and resolving local disputes. However, effective collective action depends on trust, fairness, monitoring credibility, and the ability to include groups with unequal land, income, gender, or political influence [5, 7, 8].

Recent work on citizen science and participatory environmental monitoring provides additional insight. Local monitoring can be valuable when the indicators are understandable, the methods are appropriate to the capacity of participants, and results are validated through repetition or expert review. Participation is strongest when people can see how their observations influence decisions. Conversely, monitoring loses legitimacy when data are collected for an external project but are not returned to the community, when results are difficult to interpret, or when authorities do not respond to identified risks. These findings suggest that groundwater monitoring should be designed as a shared learning system with technical, institutional, and social components [23, 24, 26, 27].

2.1 GROUNDWATER MONITORING AND COMMUNITY PARTICIPATION

- Community-based monitoring may include repeated measurement of water level, rainfall, pumping duration, well yield, electrical conductivity, turbidity, spring discharge, and the condition of recharge structures.

- Local knowledge can help identify seasonal changes, historical source behaviour, areas of recurrent waterlogging or scarcity, informal extraction patterns, and land-use changes that may affect recharge.
- The approach is most useful when communities select a limited number of indicators that are directly related to local decisions rather than attempting to reproduce a full technical monitoring programme.
- Participatory records can complement official observation networks by providing more frequent local information and by revealing how groundwater conditions affect households, farms, and common water sources.

2.2 KEY CHALLENGES IN COMMUNITY-BASED GROUNDWATER MONITORING

- Data quality can decline when measurement points change, instruments are not calibrated, units are inconsistently recorded, or observations are made at different times of day or seasons.
- Participation may be dominated by better-resourced landowners or local elites, leaving women, tenant farmers, smallholders, and households dependent on public sources underrepresented.
- Communities may collect data without having authority, financing, or institutional support to respond to the problems that the data reveal.
- Short project periods can create expectations that are difficult to sustain after external facilitation ends, particularly where monitoring relies on unpaid labour or expensive equipment.
- Open data can be sensitive when information about well yield, water quality, land ownership, or extraction is perceived as commercially or politically significant.

2.3 PRINCIPLES FOR RESPONSIBLE GROUNDWATER MONITORING

- Monitoring should begin with a clearly defined local purpose, such as tracking seasonal decline, protecting drinking-water quality, evaluating recharge work, or supporting drought preparedness.

- Protocols should be simple, written in locally accessible language, and accompanied by training, demonstration, periodic refresher sessions, and clear responsibilities for verification.
- Data should be returned to the community through charts, maps, seasonal meetings, and practical explanations that support collective interpretation rather than technical reporting alone.
- Participation should be inclusive, with specific attention to the voices of groups that experience water insecurity differently or have limited influence over private-well decisions.
- Monitoring outcomes should connect to agreed response measures, including source protection, recharge maintenance, water budgeting, crop choice, demand management, or referral to public authorities.

3. OBJECT OF STUDY

The present study examines community-based monitoring of groundwater resources as a local governance practice. The object of study is not a single village, aquifer, or government programme. Instead, it considers the conditions under which residents, water-user groups, local governments, and technical partners can collaboratively observe groundwater conditions and use the resulting information for more responsible decisions. The study focuses on the relationship between local monitoring activities and the wider social, ecological, and institutional system in which groundwater is extracted, replenished, protected, and shared.

The theoretical basis of the study is grounded in the understanding that groundwater is a common and interconnected resource. Individual actions such as drilling a new borewell, extending pumping hours, sealing open land, discharging wastewater, or neglecting recharge structures can affect others who depend on the same aquifer. A legitimate monitoring process must therefore connect evidence with fairness, transparency, and collective responsibility. It should recognise differences between households, farms, commercial users, and public institutions while creating a shared platform for discussing aquifer conditions and locally appropriate responses.

3.1 LOCAL GROUNDWATER REQUIREMENTS CONTEXTS AND MONITORING

S. No.	Local Groundwater Setting	Typical Monitoring Focus	Main Management Challenge	Essential Community Measure
1	Irrigated agricultural villages	Seasonal water level, pumping duration, rainfall, and irrigation demand	Declining water tables and fragmented decisions by individual well owners	Shared well register, seasonal review meetings, and crop-water planning
2	Peri-urban neighbourhoods	Borewell levels, household supply reliability, leakage, and water quality	Rapid demand growth, informal extraction, and uneven access to data	Ward-level monitoring group, public dashboard, and complaint record
3	Hard-rock aquifer settlements	Water level recovery, recharge structures, spring discharge, and well yield	High local variability and limited storage in fractured aquifers	Micro-watershed mapping, rainfall log, and observation-well network
4	Coastal aquifer communities	Water salinity, tidal influence, extraction intensity, and seasonal recharge	Risk of saline intrusion and loss of drinking-water quality	Regular conductivity testing, abstraction limits, and village alerts
5	Drought-prone watershed areas	Pre-monsoon and post-monsoon levels, tanker dependence, and source reliability	Emergency responses that overlook long-term recharge and equity	Seasonal water budget, priority allocation rules, and recharge maintenance

3.2 STUDY OBJECTIVES

- To examine the role of community participation in monitoring groundwater quantity, quality, recharge, and local water security.
- To identify the technical, social, and institutional factors that influence the reliability and usefulness of community-generated groundwater information.
- To compare monitoring requirements across agricultural, peri-urban, hard-rock, coastal, and drought-prone local contexts.
- To evaluate the importance of inclusion, transparency, data validation, public feedback, and links between monitoring evidence and local action.
- To develop a practical framework for community-based groundwater monitoring that can complement professional hydrogeological assessment and public water governance.

4. RESEARCH METHODOLOGY

The study adopts a qualitative and literature-based research methodology. It synthesises scholarship on groundwater governance, common-pool resources, hydrological

monitoring, participatory environmental management, citizen science, and rural water institutions. This approach is appropriate because the research question concerns how monitoring practices, local knowledge, institutional arrangements, and technical evidence interact in groundwater decision-making. The analysis does not estimate the water balance of a single aquifer; instead, it develops an analytical framework for evaluating whether a community monitoring initiative is likely to produce credible information and meaningful local benefit. The methodological framework follows the monitoring cycle of a community groundwater programme. It considers the identification of a local problem, selection of observation points, choice of indicators, measurement procedures, recording methods, data verification, interpretation of trends, communication of findings, collective decision-making, and review of outcomes. The study also examines how local groups interact with government agencies, laboratories, universities, non-governmental organisations, and water professionals. Particular attention is given to

the way data can strengthen accountability only when responsibilities for response are clear.

4.1 RESEARCH DESIGN (QUALITATIVE ANALYTICAL APPROACH)

- The study follows a qualitative and comparative design based on groundwater, governance, and participatory-monitoring literature.
- The analysis compares local settings according to aquifer characteristics, livelihood dependence, exposure to water insecurity, institutional capacity, and potential consequences of inaccurate data.
- The study uses a monitoring-cycle perspective that links field observation with validation, interpretation, public communication, and response.
- Findings are interpreted through principles of sustainability, common-resource governance, environmental justice, inclusion, and practical usability rather than through a household survey or experimental trial.

4.2 COMMUNITY MONITORING FRAMEWORK

- Purpose and problem definition are assessed by asking whether the community has identified a specific decision need, such as drought planning, recharge evaluation, drinking-water protection, or extraction management.
- Measurement quality is assessed through the consistency of observation wells, timing, instruments, recording formats, unit conventions, and verification procedures.
- Inclusion is assessed through representation of women, smallholders, tenants, public-source users, youth, and other groups affected by local water conditions.
- Interpretation is assessed through the availability of basic hydrogeological support, seasonal comparison, local mapping, and opportunities to discuss uncertainty rather than treating every observation as conclusive.
- Actionability is assessed through agreed response pathways, public reporting, maintenance responsibilities, referral mechanisms, and periodic review of

whether monitoring changed decisions or outcomes.

4.3 SOCIO-ENVIRONMENTAL AND INSTITUTIONAL CONTEXT

- The study considers communities that rely on private wells, shared wells, springs, handpumps, piped supply, tanker water, or mixed sources.
- Groundwater is treated as a system involving aquifer properties, rainfall, recharge zones, abstraction, land use, water quality, energy access, household needs, agricultural practices, and public infrastructure.
- Monitoring is evaluated in relation to drinking-water security, agricultural livelihoods, drought resilience, social equity, ecological protection, and trust in local decision-making.
- Institutional capacity is considered through the presence of local committees, record-keeping practices, technical partners, financial support, conflict-resolution procedures, and access to government data.

4.4 PARAMETERS OF ANALYSIS

The following monitoring and governance parameters are evaluated:

- Clarity of purpose, local relevance of indicators, and availability of less burdensome ways to obtain the required information.
- Selection of observation points, measurement frequency, instrument suitability, data recording practices, and procedures for identifying errors or gaps.
- Participation, representation, workload distribution, protection from elite capture, and recognition of different water uses and vulnerabilities.
- Data ownership, privacy, public access, transparency of results, and the ability of participants to understand and question interpretations.
- Links between monitoring evidence and water budgeting, recharge planning, source protection, demand management, emergency response, or formal government action.

4.5 PROCEDURE OF STUDY

- Review research, policy reports, technical guidance, and community-monitoring

literature relating to groundwater use, recharge, quality, and governance.

- Identify recurring issues involving data quality, local participation, inclusion, institutional support, interpretation, and the conversion of information into action.
- Compare representative local groundwater contexts and the different forms of risk that may arise in each setting.
- Map monitoring requirements to practical governance measures involving community groups, local governments, technical experts, laboratories, and water agencies.
- Interpret the combined findings to formulate a community-centred framework for reliable and equitable groundwater monitoring.
- Develop practical recommendations for organisations seeking to support local observation systems without shifting public responsibility onto communities alone.

4.6 ANALYTICAL APPROACH

- Qualitative comparison of monitoring needs, risks, and safeguards across different aquifer settings and user groups.
- Interpretation of how local observation, scientific validation, communication practices, and institutional response combine to shape groundwater outcomes.
- Assessment of the relationship between information availability, collective action, public trust, and the sustainability of groundwater use.
- Identification of governance practices that can be adopted by village councils, water-user groups, municipal bodies, civil-society organisations, universities, and groundwater agencies.

5. DATA ANALYSIS

The qualitative analysis indicates that community-based groundwater monitoring cannot be evaluated only by counting the number of wells observed or records collected. Its practical value depends on whether the chosen indicators answer a local question, whether observations are made consistently, whether findings are understood by users, and whether there is a credible route from information to action. A community may maintain detailed registers of water levels, for example, but the register will have limited

governance value if no one compares pre-monsoon and post-monsoon trends, discusses changes in pumping demand, or uses the information to adjust local practices. Monitoring becomes meaningful when it supports shared learning rather than data accumulation alone.

The analysis shows that the selection of observation points is central. A single deep borewell can behave very differently from a shallow dug well, a spring, or a public handpump, even within the same settlement. Communities need a small but representative network that reflects major uses, hydrogeological zones, and vulnerable sources. The network should remain stable over time so that seasonal and annual comparisons are possible. Clear instructions are also necessary: water levels should be measured from a known reference point, preferably at comparable times and before major pumping where feasible. Where water quality is monitored, simple field indicators can provide early warning, but laboratory confirmation is needed for health-related decisions [12, 13].

Participation patterns strongly affect the interpretation of groundwater information. In many rural and peri-urban settings, men may own or operate private borewells while women manage household collection, treatment, storage, and daily use. Smallholders may depend on shallow sources that fail earlier than deeper private wells. Households without land may rely on public standposts or tanker supply and may have little voice in decisions about recharge investments. A monitoring group that records only the experience of larger well owners can therefore create an incomplete picture of local water security. Inclusive design requires attention to who is invited, who measures, who sees the data, and whose problems are treated as priorities [6, 7, 24].

The analysis further shows that data transparency must be balanced with trust and practical safeguards. Local sharing of broad trends can help communities recognise common risk, but sensitive information about individual well yield, property, or commercial extraction may generate conflict. A useful approach is to agree in advance which data are public, which are aggregated, and who can access detailed records. Public displays can

focus on seasonal trends, rainfall comparison, source-reliability categories, or water-quality alerts rather than exposing individual households. Transparent rules also help prevent the monitoring process from being captured by a small group or used to justify decisions that others cannot examine.

Finally, monitoring requires institutional response. Community groups can identify declining levels or emerging contamination, but they may not have authority to regulate drilling, repair public infrastructure, test contaminants, or manage urban wastewater. The strongest model is therefore collaborative: communities collect and interpret locally relevant observations; technical partners support validation and training; local governments provide a response channel; and higher-level agencies contribute hydrogeological data, standards, and enforcement where necessary. This arrangement recognises community monitoring as an important part of governance while maintaining the public responsibility to protect water resources and equitable access.

6. DISCUSSION

The analysis confirms that groundwater monitoring is both a technical and a social practice. Water-level measurements, rainfall records, and water-quality tests are necessary, but they become useful only when people can interpret their meaning and decide what to do together. Community involvement can improve the spatial and temporal reach of monitoring, especially in areas where official networks are limited. It can also reveal dimensions that conventional observation systems may not capture, including the time spent collecting water, the reliability of public sources, changes in local pumping behaviour, or the burden of tanker dependence. These contributions make community monitoring particularly valuable for early warning and local planning.

However, participation should not be treated as a low-cost substitute for professional monitoring or state responsibility. Communities should not be asked to perform complex hydrogeological assessment without instruments, training, or support. Nor should they be blamed for failure to solve problems driven by broader factors such as electricity subsidies, unregulated drilling, industrial

abstraction, urban impervious surfaces, or inadequate sanitation systems. A responsible programme must define what local observation can reasonably achieve and establish clear links to laboratories, technical experts, and public agencies for issues that require specialised action. This prevents the transfer of risk and responsibility from institutions to residents.

The strongest governance approach is layered. It combines community ownership of local observations with standardised measurement protocols, periodic technical review, inclusive representation, open communication of non-sensitive trends, and agreed response mechanisms. The approach should also include a sustainability plan. Monitoring activities need modest but reliable resources for tapes, gauges, notebooks or digital tools, transport, training, data backup, water-quality testing, and meetings. Incentives do not always have to be financial, but participants should see tangible value in the process, such as better drought preparation, evidence for public requests, improved maintenance of recharge structures, or stronger coordination of water use.

Public trust depends on whether monitoring results are used fairly. A community is more likely to sustain participation when records are visible, methods are understandable, uncertainty is acknowledged, and decisions do not privilege only those with the deepest wells or greatest influence. In locations with high water stress, monitoring should be paired with dialogue about allocation, source protection, recharge, and demand reduction. The goal is not simply to observe decline more accurately; it is to create the collective capacity to prevent avoidable decline and to protect essential uses when scarcity occurs.

7. CONCLUSION

This study examined community-based monitoring of groundwater resources as a practical and participatory approach to aquifer governance. It showed that the value of local monitoring extends beyond the collection of water-level or quality data. When designed carefully, it can make groundwater conditions more visible, strengthen communication between users and institutions, support early warning, improve accountability, and encourage locally appropriate action. The

effectiveness of monitoring depends on the entire process of indicator selection, measurement, data quality control, interpretation, inclusion, transparency, technical support, and institutional response.

The analysis found that responsible community monitoring requires a clearly defined purpose, stable observation points, simple and consistent protocols, ongoing training, representative participation, accessible communication of results, protection of sensitive information, and

credible pathways from evidence to action. Community groups can make a substantial contribution to groundwater sustainability, but they should operate alongside—not in place of—public agencies and technical institutions. Where these conditions are met, community-based monitoring can help transform groundwater from an invisible and individually managed resource into a shared subject of knowledge, responsibility, and long-term care.

8. REFERENCES

1. United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. United Nations.
2. UNESCO. (2022). *The United Nations World Water Development Report 2022: Groundwater - Making the Invisible Visible*. UNESCO.
3. Food and Agriculture Organization of the United Nations. (2016). *Groundwater Governance: A Global Framework for Country Action*. FAO.
4. World Bank. (2010). *Deep Wells and Prudence: Towards Pragmatic Action for Addressing Groundwater Overexploitation in India*. World Bank.
5. Shah, T. (2009). *Taming the Anarchy: Groundwater Governance in South Asia*. Resources for the Future Press.
6. Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press.
7. Meinzen-Dick, R. (2007). *Beyond panaceas in water institutions*. *Proceedings of the National Academy of Sciences*, 104(39), 15200-15205.
8. Foster, S., & Garduño, H. (2013). *Groundwater-resource governance: Are governments and stakeholders responding to the challenge?* *Hydrogeology Journal*, 21, 1733-1744.
9. Moench, M. (2004). *Groundwater policy and governance: The role of research in simplifying complexity*. In *Groundwater Governance in Asia*. IWMI.
10. Margat, J., & van der Gun, J. (2013). *Groundwater around the World: A Geographic Synopsis*. CRC Press.
11. Alley, W. M., Reilly, T. E., & Franke, O. L. (1999). *Sustainability of Ground-Water Resources*. U.S. Geological Survey Circular 1186.
12. Healy, R. W. (2010). *Estimating Groundwater Recharge*. Cambridge University Press.
13. Scanlon, B. R., Healy, R. W., & Cook, P. G. (2002). *Choosing appropriate techniques for quantifying groundwater recharge*. *Hydrogeology Journal*, 10, 18-39.
14. Taylor, R. G., Scanlon, B., Döll, P., et al. (2013). *Ground water and climate change*. *Nature Climate Change*, 3, 322-329.
15. Jasechko, S., & Taylor, R. G. (2015). *Intensive rainfall recharges tropical groundwaters*. *Environmental Research Letters*, 10(12), 124015.
16. Gleeson, T., Wada, Y., Bierkens, M. F. P., & van Beek, L. P. H. (2012). *Water balance of global aquifers revealed by groundwater footprint*. *Nature*, 488, 197-200.
17. Famiglietti, J. S. (2014). *The global groundwater crisis*. *Nature Climate Change*, 4, 945-948.
18. Konikow, L. F. (2011). *Contribution of global groundwater depletion since 1900 to sea-level rise*. *Geophysical Research Letters*, 38, L17401.
19. Rodell, M., Velicogna, I., & Famiglietti, J. S. (2009). *Satellite-based estimates of groundwater depletion in India*. *Nature*, 460, 999-1002.
20. Wada, Y., van Beek, L. P. H., van Kempen, C. M., Reckman, J. W. T. M., Vasak, S., & Bierkens, M. F. P. (2010). *Global depletion of groundwater resources*. *Geophysical Research Letters*, 37, L20402.

21. Vörösmarty, C. J., McIntyre, P. B., Gessner, M. O., et al. (2010). Global threats to human water security and river biodiversity. *Nature*, 467, 555-561.
22. Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, 325(5939), 419-422.
23. Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, 141(10), 2417-2431.
24. Pretty, J., & Smith, D. (2004). Social capital in biodiversity conservation and management. *Conservation Biology*, 18(3), 631-638.
25. Danielsen, F., Burgess, N. D., Balmford, A., et al. (2009). Local participation in natural resource monitoring: A characterization of approaches. *Conservation Biology*, 23(1), 31-42.
26. Danielsen, F., Jensen, P. M., Burgess, N. D., et al. (2014). A multicountry assessment of tropical resource monitoring by local communities. *BioScience*, 64(3), 236-251.
27. Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: Issues and opportunities. *Environmental Monitoring and Assessment*, 176, 273-291.
28. Bandaragoda, D. J. (2000). *A Framework for Institutional Analysis for Water Resources Management in a River Basin Context*. International Water Management Institute.
29. Agarwal, A., & Narain, S. (1997). *Dying Wisdom: Rise, Fall and Potential of India's Traditional Water Harvesting Systems*. Centre for Science and Environment.
30. International Groundwater Resources Assessment Centre. (2020). *Global Groundwater Monitoring Network: Guidelines for Groundwater Monitoring*. IGRAC.