



# **Participatory GIS Mode of Sustainable Surface and Groundwater Management Practices Involving NGOs in India**

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## **Authors' contributions**

*This work was carried out in collaboration among all authors. Author LMK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NK managed the analyses of the study. Author KCS managed the literature searches. All authors read and approved the final manuscript.*

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## **ABSTRACT**

Groundwater resources plays important role in agro-biodiversity and environmental conservation perspectives. Surface and groundwater have played a significant role in the agrarian economics in the developing economics particularly in India. At the same time, the tropical and sub-tropical India is the largest groundwater user in the world through unregulated construction and utilization of millions of private wells in the last five decades exploited groundwater availability and sustainable regeneration issues. Hence, in order to improve the surface and groundwater

conservation, regeneration, management and protection for sustainable utilization of Groundwater requires a participatory and coordinated action. Nationwide, many national and regional Non Government Organisations (NGOs) are functioning in the line of effective surface and ground water management the community. The recent Geographical Information Systems (GIS) based technologies also supports for drought mitigation and climate change adaptation. This study highlights the important NGOs led sustainable Groundwater management practices under various local hydro geological settings and agro economic realities for up scaling the community driven sustainable Groundwater management.

**Keywords:** *Agrarian economy; community driven; surface and groundwater management; Non Government Organisation (NGOs) GIS and climate change adaptation.*

## 1. INTRODUCTION

The rapid urbanization and economic expansion causes imbalance between natural supply and demand of the freshwater ecosystems that has already led to shortages and depletion of freshwater reserves. It automatically causes pressure on groundwater. In the last few decades, this pressure has been evident through rapidly increasing pumping of groundwater, accelerated by the energy subsidies, availability of cheap drilling and pumping technologies in some countries misleads the optimum utilization of natural groundwater resources. Altogether, the increased abstraction of fresh water is being accompanied by deterioration in the quality of available water due to pollution and environmental degradations affects the economy, environment, and standard of livings of the global masses [1].

In India, the rivers and lakes, tanks, ponds, canals and other surface water bodies play very important role in agriculture and allied sectors like fisheries and animal husbandries [2]. India is the largest groundwater user in the world. India has some of the largest river systems of Indo-Ganges- Brahmaputra for accessing the potential freshwater for agriculture and other economic development purposes. It also provides ecosystem services. India has a surface water potential of nearly 1,900 billion cubic metres (bcm) per year. But, only about 700 bcm water only effectively utilized and the unutilized water during monsoon rains' runoff water flow reaches oceans [3]. In India, over the last five decades of period, there has been a phenomenal growth in the exploitation of groundwater through construction of millions of private wells. Adoption of new high yielding crop varieties have led to an increase in water demand for irrigation, particularly during the dry season causes water scarcity. It leads a major constraint on increased food production. The rapid population growth also increased the per capita availability of fresh

water has declined sharply from 3,000 cubic metres to 1,123 cubic metres over the past 50 years in India [4].

### 1.1 Public System Governance for Effective Surface and Groundwater Management

The public system governance taken efforts to control water depletion and promote rain water harvesting / conservation through adoption of appropriate water conservation measures in an integrated manner to harvest and conserve the rain water in a scientifically planned manner through community participation. It also encouraged to stop the water bodies encroachment, diversion of water bodies and drainage channels. It also encourages the rain water harvesting practices for Artificial groundwater recharge in the country. It also encourages mass awareness programmes to people for promotion of rain water harvesting practices. Various public sector schemes like Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), Water Management (CAD&WM) and other programmes/schemes on water conservation and management, water harvesting, soil and moisture conservation, groundwater recharge, flood protection, land development, ridge area treatment, drainage line afforestation, soil and moisture conservation, rain water harvesting, horticulture, and pasture development etc for sustainable management of groundwater resources with community participation in water stressed regions of the country [5].

### 1.2 Issues in Public System Governance Based Surface and Groundwater Management

The Public System governance, due to the absence of a systematic registering of wells and poor knowledge level in farmers and other

people about the surface and groundwater utilization patterns affects the sustainable water utilization patterns. Though, the public investments were largely concentrated on surface water developments through major and medium scale irrigation projects in which water use efficiency is very low. Also, the public system has no direct control over the groundwater use of millions of private well owners, both in rural and urban areas. The Public System governance focus to increase the irrigation efficiency through micro irrigation practices such as drip and sprinklers through the micro irrigation subsidy schemes to avoid the inherent losses of water due to the traditional irrigation techniques like furrow and basin method of surface irrigation practices where, the conveyance efficiency is less than 60 % as a result of poor maintenance and increase the irrigated agricultural area in India. But, due to poor awareness and knowledge, still Indian farmers were not adopted the micro irrigation practices properly to improve the irrigation efficiency in agriculture [6].

The roles and responsibilities various public sector surface and groundwater institutions, water sharing rules for regulations, water bodies development for conservation and management has several issues for effective convergence for effective utilization and regeneration of surface and groundwater resources. At the village level, strengthening community participation also big issues for public institutions. Several waterbodies had been poorly maintained for effective water management under several watershed programs. To strengthen the existing, the people participatory community driven and ICTs based GIS monitoring may be the suitable solution through NGOs and other civil societies based organizations for efficient alternative with regard to the management of hydraulic structures [4].

### **1.3 Importance of National Water Policy**

India has 18 % of the world's population, but has only 4% of world's renewable water resources with 2.4% of world's land area. The groundwater meets nearly 40 per cent of the urban water needs in the country [6]. The water distribution also uneven in various regions with the impact of climate change and varying the water utilization patterns. Hence, strong water policies may address the emerging issues with appropriate water governance mechanisms. The GIS platform based hydrological data led information supports to find out the present status of water resources availabilities, utilization patterns, emerging water related issues. It also supports to

predict the future water demand in a transparent system [7].

The Climate change impacts may lead salinity intrusion in groundwater aquifers and surface water bodies. To address the climate change impacts, special focus suggested at micro level for enhancing the capabilities of community to adopt climate resilient technological options. The policy also suggests to scientifically recommended water utilization patterns. The policy also gives preference in preparedness for flood / drought with coping mechanisms as an option [8]. Also it emphasised on rehabilitation of natural drainage system and improved water supply in rural areas with proper sewerage facilities. It also suggests that, the Water resources should be managed in the context of the environment, ecology, sustainability, social justice, conservation with the community participation. The policy also avoided the over-abstraction of groundwater in both surface water and groundwater management with the support of appropriate land use pattern for agriculture and other needs, regulation of sand and gravel mining, etc [9].

### **1.4 Urgent Need for Sustainable Surface and Groundwater Management in India**

India is the largest user of surface and groundwater for human needs in the world. Agriculture is the largest user of groundwater in the country, and well irrigation accounts for nearly 2/3<sup>rd</sup> of the agriculture production from irrigated area. The monsoon and rainfall pattern seasonal variations leads the floods and droughts in various regions of the country. The drought affected southern and western regions highlighted the growing risk of groundwater over exploitation. Also, in some areas, the groundwater resources were over exploited by the farmers from accessing both superficial water tables and deep aquifers. The Indian decentralized governance process highlighted the lack of competence and the limited financial resources in the gross root level governance [10]. The recent ICTs based NGO's based community mobilization and GIS based information system provides a suitable platform for sustainable surface and Groundwater Management in India. The social capital based community organizations support effective water conservation and regenerations also has the potential to generate agricultural and other allied livelihood activities [11].

### **1.5 NGOs led sustainable Surface and Groundwater Management Practices**

India has 31 lakhs number of Non-Government organizations (NGOs) and civil society organizations for building people and institution for development of community action In India, hundreds of Non-Government organizations and individuals are working to conserve the water and improve soil health and restore land quality for sustainable food production for food security. It also saves the poor people livelihoods and poverty alleviation purposes. In India, some of the regions suffered by repeated droughts for a long time. In that time, relief works, water and fodder supplies and other emergency programs also unable to deliver in time. At the same time, the NGO's has greater community participation for sustainable development works in the vulnerable sections of people. The NGOs also involved in the community based water conservation works on the basis of watershed approaches through construction of hydraulic structures to distribute the water and the control of access with the support of the respective locations' community water user groups. It also provides financial support (Community sharing) and the supervision of civil engineering works. However, addressing the issue of the efficiency of water use requires recognizing the urgent necessity for the benefit of the farmers in order to define local irrigation management standards to improve the efficiency of water use. The NGOs focuses its action in their adopted villages, to improve water availability to secure agriculture yields and increase household incomes. The NGO' also support to maximize the catchments of surface water flows and to reduce the imbalances of water accessibility. The NGO's works towards social development of women empowerment, leadership development and social capital based value oriented consortium formation, etc. The community and civil society organizations also ensure the maintenance of hydraulic infrastructures in long-term perspectives [12].

The NGOs led community based watershed groups, federation and other water user associations already supporting for conservation through groundwater recharge systems, effective utilization of water for irrigation, river basin management through watershed management with construction and maintenance of 1,000 check dams and irrigation tanks in various land use patterns. Though they are doing well. But, the précised utilization and conservation is

missing. In this juncture, the GIS based soil-water resource mapping clearly displaying the soil-water resources in three dimensional digital platforms. This soil-water- ecosystem based village or local level data base clearly giving the importance of involving socio-economic perspectives of the local community for effective and sustainable mapping through Participatory Rural Appraisal tools (PRA) of resource mapping, social mapping and others [13]. No discussion of the results of findings no diagrams, maps or Tables to justified the results of finding, no sampling points or map showing the sampling points.

### **1.6 Participatory GIS (PGIS) for Sustainable Surface and Groundwater Management Practices**

The recent satellite sensor based geospatial information systems on surface and groundwater based natural resources subsystems can support location specific community oriented participatory water conservation and regulatory activities for compatible, effective utilization and conservation of natural resources to target agricultural and other economic policies for better governance. The potential of participatory geographic information systems (participatory GIS) tools and processes results a combination of people participatory approaches, spatial information and communication management for effective management of water and natural resources (forests, land) as a basis for formulating effective public sector policies for better governance.

The application of GIS in water resource management has been covered extensively since the creation of the first GIS in Canada in 1960. The GIS plays very important tool in integrated water resource management (IWRM) for promotion, development and management of water, land and related resources to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. The NGOs functioning in surface and groundwater conservation strategies are highly interested to adopt the Satellite / GIS based techniques with the support of local community. The activities may include farmers' participation efforts to conserve water and restore soils through artificial soil water conservation watershed development structures and other eco-friendly water conservation measures such as recommending cover crops, low water consuming crops such as sorghum, sunflower, Maintenance of social

forestry in the degraded farm lands, Conservation tillage, Mulching practices, Treatment of land slip areas with vegetative barriers and other practices [14]. It also safeguards biodiversity and act against climate change impacts. Hence, along with NGOs and GIS technology, the local people need based planning, designing, and implementation strategies may support to restore the sustainable ecosystem services, gender vulnerable people and social inclusion in a balanced way.

Participatory GIS (PGIS) based practices focus on appropriate need based technical “solutions” for effective utilization of surface and groundwater management perspectives. It also provides community empowerment for getting greater emphasis to facilitate surface and groundwater conservation and local economic development. It also ensures the effective delivery of water in rural communities [15].

### **1.7 Significance of Participatory GIS Based NGOs led Sustainable Surface and Groundwater Management Practices**

1. The location specific decision-making processes for Sustainable land and water Management could be feasible.
2. Water harvesting, soil-water conservation initiatives, optimum utilization of water and its conveyance to avoid the over exploitation of water resources could be enabled.
3. It also gives awareness and education to farmers for adoption and promotion of modern irrigation practices and techniques such as drip irrigation, eco-friendly water utilization patterns, etc
4. The water use efficiency of water in agricultural purposes could be increased.
5. Leads to increasing coordination between the different public sector services in a decentralized management perspective.
6. It could also support micro level water soil and water conservation practices with the convergence of people, various development and institutional stakeholders
7. The NGOs and people institutional also supports sustainable development practices, sustainable livelihoods and social entrepreneurship opportunities.
8. The NGOs led GIS based participatory water conservation strategies’ various technologies adoption strategy, communication, demonstration impact,

farmer’s motivation on adoption of groundwater management practices also create larger impacts to strengthen the community participation with effective surface and groundwater management practices and effective utilization for agricultural and allied activities in other areas.

9. It could act as a suitable option for drought mitigation in the major drought affected regions and climate change adaptation in the climate affected vulnerable regions.
10. The assessment of information and impacts may support for formulation of physical, socio- economical and institutional policy guidelines at macro level for NGO’s led participatory GIS based surface and groundwater development and management purposes.
11. These policy guidelines support the NGOs for raising awareness at community level. it also acts as an effective communication platform between researchers and decision makers. Effective communication can enable community participation.
12. It solves relevant surface and groundwater quality related problems and supports economic viability vis à vis environmental sustainability.

## **2. CONCLUSION**

In India, the Non-Government Organizations (NGOs) play very important role in water management with community participation since 1990s. They promoted participatory approaches aimed, organized local water user groups and gained influence to formation of public sector policies [16]. The participatory GIS mapping empower people and support for participatory action and good local governance, the PRA mapping also help to assess the socio- economic inequalities to suggest need based water conservation strategies for their development and livelihood needs. It also stops migration and respect people and their indigenous knowledge.

The climate change mitigation and adaption rely on effective utilization of surface and groundwater storage capacities. The participatory- GIS based community action integrate information with people friendly appropriate new technologies, market-based incentives to address the challenge of sustaining biodiversity, energy and food and nutritional priorities [17]. The GIS information

based participatory community decision making pattern supports collective action in the common property water conservation structures such as tanks, ponds rivers and other resources. It also enhances the accountability, legitimacy, social equity, gender empowerment and effectiveness of the local community. It acts as an effective local governance tool for sustainable surface and groundwater conservation and livelihood development strategies.

The economic efficiency of water utilization pattern improves through recognition of water user groups for involving them in to the field level actions on surface and groundwater management approaches such as water harvesting and recharge to regulate the water withdrawal. It also supports the integration of soil and water conservation engineering, economic and legal & policy based approaches in an effective way under various physical and socio-economic people participatory situations.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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