

## Development of Framework to Evaluate Current State of Groundwater Governance under Urbanization and Climate Change

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### ABSTRACT

Groundwater, a shifting environmental resource below the earth's surface, exhibits both water and mineral resources characteristics and is the most dependable source of freshwater withdrawals among agricultural, domestic, and industrial sectors. As this resource is linked with the atmosphere and surface water resources, its safe yield mainly depends on the hydro-geologic environment and the area's physical and geographical factors. Furthermore, human-induced dynamics also play a vital role in its safe yield and sustainability. The exponential expansion of urban centres and increased demand for infrastructures have drastically altered the perviousness of land surfaces, impacting both the quantity and quality of groundwater resources. The rapid urbanisation, on the one hand, has increased the imperviousness of the cities reducing the city's infiltration capacity for groundwater recharge, while the increased demand for freshwater resources has raised its abstraction lowering existing groundwater level and making it more vulnerable to availability and contamination. Moreover, climate change and climate variability further exaggerate water demand and potential recharge. In addition to its vulnerability to availability and quality, the dual impact of urbanisation and climate change on groundwater resources have pressurised the common-pool resource in its effective management leading to unfair access to the resource and unequal representation in planning and decision-making of all related actors creating increased possibilities for sectoral and right based conflicts.

Thus, this study develops an indicator-based framework that consists of 4 dimensions and 30 indicators, and each of these indicators shall be rated from 0-3 based on two variables, namely "adequacy of provision" and "institutional capacity for implementation" (Fig. 1). The weights of the dimensions or indicators can be assumed contributing equally or allocated according to prioritised issues or statistically determined loads. The aggregation of the variables within each indicator (eq.1) and aggregation of the indicators within each dimension (eq.2) is done using,

$$I_{xy} = \frac{V_1 + V_2}{2} \quad (1)$$

$$D_x = \frac{\sum_{y=1}^n W_y * I_{xy}}{\sum_{k=1}^n W_y} \quad (2)$$

And finally, the GGI is calculated by using the formula,

$$GGI = \frac{\sum_{x=1}^n W_x * D_x}{\sum_{x=1}^n W_x} \quad (3)$$

where, D = Dimensions; I = Indicators; V = Variables; W = Weightage; and x, y represents number of dimensions and number of indicators within in each dimensions respectively.

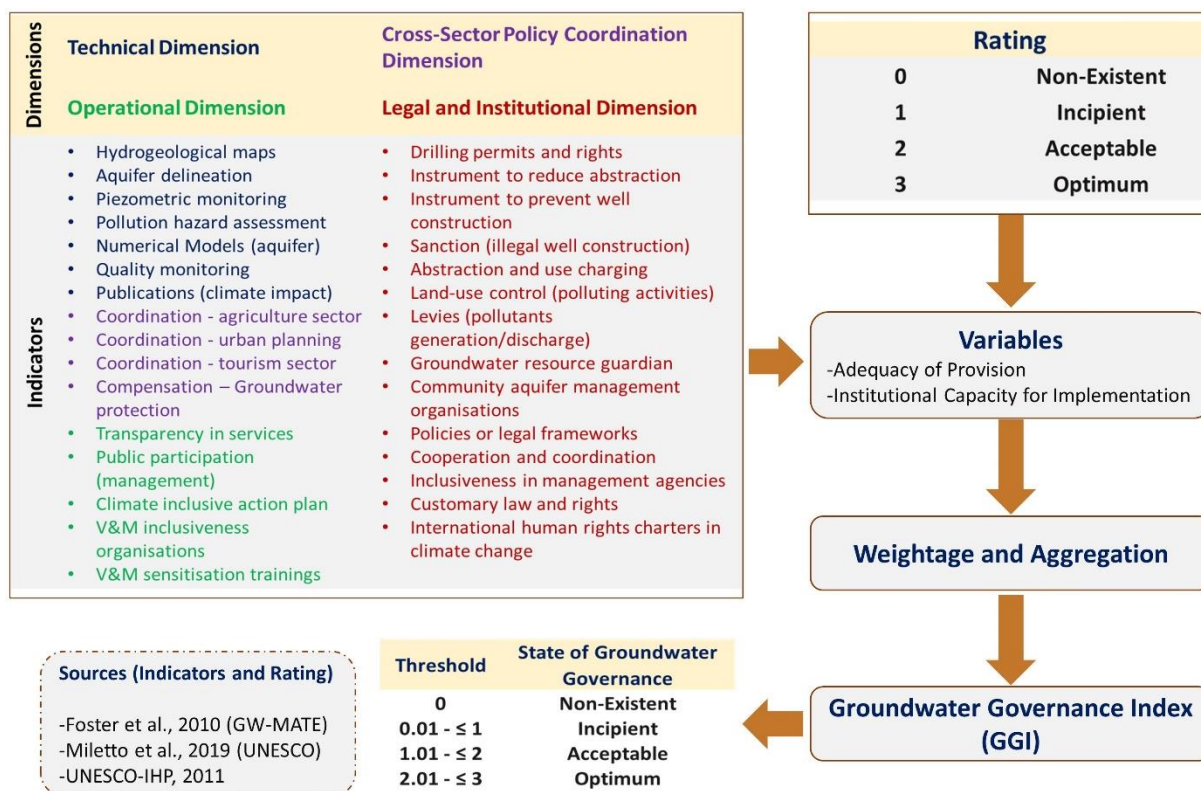


Fig. 1. Framework to evaluate groundwater governance

The aggregation of all the elements within the framework quantitatively indicates the existing state of groundwater governance known as the Groundwater Governance Index (GGI). The range of the GGI threshold (Fig. 1) denotes the baseline state ranging between non-existence to an optimal state of groundwater governance in the context of urbanisation and climate change. The results obtained from the assessment shall be validated qualitatively with the relevant actors and stakeholders for develop suitable recommendation strategies under multiple stresses. The individual and combined impact of climate change and urbanisation on groundwater resources have threatened the resource; thus, its assessment is a soft approach for sustainable management. The evaluation of the current state of its governance is the first step for the approach, and this developed framework shall be useful in appraising the current provisions and needs in groundwater governance in the study area. Furthermore, it shall be handy to policy, decision-makers, and related actors to visually understand and interpret the current state of groundwater governance in terms of extraction, quality, climate change, urbanisation, and inclusion of vulnerable and marginalised groups in the governance mechanism. Ultimately, this shall facilitate developing the right strategies for strengthening governance through equal access, opportunities, and the water right, leaving no one behind.

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