International Journal of Marketing and Management Research
Vol. 12, Issue 10, October 2021, Impact Factor; 8.175, ISSN: (2229-6883)
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SUSTAINABLE GROUNDWATER MANAGEMENT AND PROTECTION THROUGH ECONOMIC INSTRUMENTS

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Introduction:
India is now the biggest user of groundwater for agriculture in the world. Groundwater irrigation has been expanding at a very rapid pace in India since the 1970s. The data from the minor irrigation census conducted in 2001 shows evidence of the growing numbers of groundwater irrigation structures in the country. Their number stood at around 18.5 million in 2001, of which tube wells accounted for 50%. There is no reason to believe that the growth in the number of these structures have slowed down since then. In all likelihood, the number of groundwater irrigation structures is now around 27 million with every fourth rural household owning at least one such irrigation structure. The share of groundwater in the net irrigated area has also been on the rise. Of the addition to net irrigated area of about 29.75 million hectares between 1970 and 2007, ground water a counted for 24.02 million hectares. On an average, between 2000/01 and 2006-07, about 61% of the irrigation in the country was sourced from groundwater. The share of surface water has declined from 60% in the 1950s to 30% in the first decade of the 21st Century.
The most dramatic change in the groundwater scenario in India is that the share of tube wells in irrigated areas rose from a mere 1% in 1960-61 to 40% in 2006-07. By now, tube wells have become the largest single source of irrigation water in India. Data from minor irrigation census 2001 showed that three states namely Punjab, Uttar Pradesh and Haryana accounted for 57% of the tube wells in India. On an average, there were 27 tube wells per square kilometre of net sown area in Punjab, 21.5 in Uttar Pradesh and 14.1 in Haryana in 2001. Interestingly, 68% of the households owning tube wells were of small and marginal farmers, indicating the growing dependence of these households on tube wells as a source of livelihoods and this despite the fact that India along with China and the United States has far outpaced the world in building large dams.
As a stern warning, the report of the expert group on groundwater management and government states that in 2004 some 28% of India’s blocks were showing dangerously high levels of groundwater development as compared to 4% in 1995. A more recent assessment by NASA showed that during 2002 to 2008, three states namely Punjab, Haryana and Rajasthan together lost about 109 km of water leading to a decline in water table to the extent of 0.33 meters per annum. The state-wise status of groundwater resources as on March, 2004, we can see that in many states, the net draft of ground water is either in excess of or close to the net available resource, implying that these states are facing a situation of dangerous over exploitation of their available groundwater resources.

Key Words: Groundwater, sustainable, management, instrument, agriculture, irrigation, vulnerability, development, economic, protection, value, abstraction, value etc.

Objectives:

The main intention of this present paper is to highlight the role of groundwater resources in ensuring livelihood security across the world, especially in economies that depend on agriculture.

Methodology:

This article is based on secondary data like reference books, various reports published by government and non-government organizations, research papers published in the various journals and information available on internet pertaining to groundwater resources and management.

Groundwater Vulnerability at District Level in India:

Though, groundwater overuse was recognized as a serious problem for quite some time conventional approaches to groundwater in India until the mid-1990s have involved a clear focus on the “development” of groundwater resources. The mid-1990s saw a slow and reluctant change in thinking, from a development to a management mode. The new thinking, which attempted to look at managing groundwater beyond sinking dug wells and drilling tube wells or bore wells, began to be backed by data from state and central groundwater agencies. Simultaneously, the methodology of groundwater estimation was also improved. We have district-level data sets on groundwater potential and use from the two recent assessments by the Central Groundwater Board, Government of India at two time points, 1995 and 2004. The comparability of these data sets is limited by two major factors: a) changing administrative boundaries of districts; and b) a slight change in the methodology of assessment in 2006. However, this data can be utilized to track the national scenario on groundwater use, over time. With these data sets, we now build a complete picture of quantitative and qualitative aspects of groundwater vulnerability in India. Vulnerability here implies potential danger to drinking water source, either in terms of the quantity of water available or the quality of available water or a combination of both. Available data shows that there has been a remarkable change in the groundwater scenario in the country even within a short span of nine years (1995-2004). On the basis of their stage of groundwater development, we classify districts as “safe” and “unsafe”.

Table: 1: State-wise Status of Groundwater Resources

State	**Billion Cubic Meters (BCM)**			**Stage of GW Development (Net Draft/Net Availabity*100)**
	Annual Replenishable Ground Water Resources	**Net Availability**	**Net Draft**	
Andhra Pradesh	36.50	32.95	14.90	45
Assam	27.23	24.89	5.44	22
Bihar	29.19	27.42	10.77	39
Chhattisgarh	14.93	13.68	2.80	20
Gujarat	15.81	15.02	11.49	76
Haryana	9.31	8.63	9.45	109
Jammu & Kashmir	2.70	2.43	0.33	14
Jharkhand	5.68	5.25	1.09	21
Karnataka	15.93	15.30	10.71	70
Kerala	6.84	6.23	2.92	47

Madhya Pradesh	37.19	35.33	17.12	48
Maharashtra	32.96	31.21	15.09	48
Orissa	23.09	21.01	3.85	18
Punjab	23.78	21.44	31.16	145
Rajasthan	11.56	10.38	12.99	125
Tamil Nadu	23.07	20.76	17.65	85
Uttar Pradesh	76.35	70.18	48.78	70
Uttarakhand	2.27	2.10	1.39	66
West Bengal	30.36	27.46	11.65	42
Other states	7.67	7.03	0.86	12
Total	432.42	398.70	230.44	58

(**Source:** Central Ground Water Board Report, 2006)

From the above Table we can see that the proportion of “unsafe” districts in India has grown from 9% in 1995 to 31% in 2004. The area under “unsafe” districts has risen from 5% to 33% and population affected from 7% to 35% within this short span of nine years.

Economic Consideration for Groundwater Management:
Economic deals with the allocation and use of scarce resources. As long as a resource is abundant, there is little need to take such decisions. As the resource becomes more scarce questions about how to utilize and protect it arise. Economic considerations can help the decision-making process and promote more efficient resource use.

While economic instruments to manage surface water and groundwater are similar, they are not the same as a result of certain peculiarities of the groundwater resource:

- Relatively high cost and complexity of assessing groundwater.
- Highly decentralized resource use, which increases management monitoring costs.
- Invisibility of groundwater to the general public, and time-lags with regard to resource impacts.
- Varying impacts of contaminant load depending on aquifer vulnerability.
- Long time-lags and near irreversibility of most aquifer contamination.

These peculiarities explain why groundwater management tools are generally less developed and applied than those for surface water. However, with increasing water scarcity the economic value of groundwater, and thus the benefit to investment in management, is increasing.

Groundwater tends to be undervalued, especially where its exploitation is uncontrolled. In this situation the exploiter of the resource receives all the benefits of groundwater use but pays only part of the costs usually the recurrent cost of pumping and the capital cost of well construction, but rarely the external and opportunity costs. This undervaluation often leads to economically inefficient resource use.

Determination of Economic Value of Groundwater:
The economic value of a resource depends on what one can do with it and on its relative scarcity compared to alternative resources. Thus the economic value of groundwater in a specific aquifer is derived from the use it can be put to, and from its local availability and quality compared to surface water. For instance, an aquifer in a region with abundant unpolluted surface water will generally have lower economic value than one in a region with

polluted surface water or one in an arid region without alternative resources. The economic value of groundwater originates from the benefits that it generates or the services that it provides. In many areas of the world, the economic value of groundwater is increasing, due to population growth and economic development, due to population of surface water basins and increasingly, due to climate variability and the necessity of having a drought-secure resource.

The economic value of a given groundwater economics often by its prospective use. In the absence of a market price for groundwater, economists often measure its value through user willingness to pay for a given quantity and quality of supply. For instance, an industry that needs water as an input for car production will be willing to pay more per unit volume than a fruit farmer. The economic value of groundwater in the area concerned is thus determined by the willingness of industry to pay-up to the point that their demand is met. The economic value of the nest volume used by the fruit farmer will be lower, but still higher than what a subsistence farmer would be willing to pay.

Values of Groundwater as Determined by Individual Stakeholders:

Type of value	Groundwater Service
1) Use value	Drinking water irrigation supply/industrial use recreational use.
2) Non-use value	Uncertain use potential existence for future generations.
3) Indirect value	Discharge to ecosystems discharge to rivers and takes.

When “willingness to pay” is not known, the residual value method can be used to value groundwater. This method values all inputs for the good produced at market price, except for the groundwater itself. The residual value of the good, after all other inputs are accounted for, is attributed to the water input.

Another method is hedonic pricing, where the behaviour of users and markets is observed. For instance, farm prices in an area with good groundwater availability are likely to be higher than in an area with scarce water resources. By comparing difference in farm prices across the region, the difference in price would lie in the value of groundwater access.

The above are selections of methods used by economists to determine the value of public goods such as groundwater and while none are perfect they do provide guidance to decision makers on the valuation of groundwater resources and on possible courses of action. An important consideration in this regard is the distinction between short and long term benefits expected from groundwater use.

Economic Instruments used to improve Groundwater Resource Management:

An economic instrument tries to stimulate an economic actor to voluntarily adopt certain behaviour. The underlying rationale is that human beings react to price incentives when prices are high less resource will be consumed. Moreover, while groundwater could be widely used in high value enterprises and create more income, jobs and wealth, too often it is still put to low value economic uses and thus is increasingly over abstracted, creating social tension between users.

Economic instruments can provide incentives to allocate and use groundwater more efficiently, thus helping to stabilize groundwater levels by reducing over abstraction, diminishing the risk of negative impacts and social conflict, and delaying the need for investment in alternative water resources. There are two categories relevant to groundwater namely those that focus upon:

- Changing Groundwater Abstraction Costs: by a) direct pricing through resource abstraction fees, b) indirect pricing through increasingly energy tariffs and c) the introduction of water markets.
- Positive Economic Incentives: for certain activities by a) modifications to agriculture and food trade policies and b) subsidies to encourage the use of more efficient irrigation technologies to achieve real water savings.

Direct Groundwater Pricing through Resource Abstraction Fees:
This is the most direct method, since users have to pay an abstraction fee based on volume preferably metered use to ensure that an incentive exists. Unfortunately, groundwater use by agriculture is rarely metered and thus controlling irrigation use is not straight forward. Alternative techniques to estimate actual agricultural water use include:

- Deriving volume pumped from electrical energy use.
- Assessing actual water consumption by remote sensing techniques.

Indirect Groundwater Pricing through Energy Tariffs:
The major cost in groundwater abstraction is the energy required to lift water. This cost will depend not only on water table depth, aquifer characteristics and well efficiency, but also on the unit cost of energy for pumping. Thus, energy pricing can be a powerful tool to influence groundwater pumping trends. Paradoxically, in many areas of the world, energy prices are used in the opposite way, with large subsidies in place to decrease farming costs. While it can be legitimate to subsidize poor farmers to improve their livelihood, subsidizing groundwater abstraction in general may not be the best vehicle to do so, because excessive groundwater abstraction can erode the same farmers' resource availability in the longer term. Other measures need to be defined which have a neutral effect on the resource, such as lump-sum payments to poor farmers at the beginning of the year to cover their estimated energy bill. In this way, they would have an incentive to use water more efficiently and consume less, maybe through a shift to higher value crops. Since they receive lump sum payments to offset their increased energy bills, they can actually gain twice by being more efficient and thus improve their livelihoods.

Economic Instruments to Control Groundwater Pollution:
This instrument usually prescribed to decrease water pollution is the polluter-pays-principle, by which an industry is charged for the amount of pollution it produces. The less it pollutes, the less it pays. This approach is not directly applicable to aquifer protection because of the special characteristics of groundwater, notably the time-lag of impacts, the persistence of some groundwater contaminants, and the potential cost of some pollution episodes. Instead economic incentives are required for industry and water utilities to invest in adequate wastewater treatment and recycling, especially where aquifer vulnerability assessments suggest high risk of groundwater pollution.
Another important issue is the control of non-point pollution from agricultural cultivation. Crop subsidies tend to lead to monocultures over large land areas, sustained by excessive use of fertilizers and pesticides, regardless of soil and climatic suitability. This can have a major negative impact on groundwater quality due to agro-chemical leaching, the cost of which is not initially taken into consideration. There is a pressing need to re-target such subsidies and thereby provide an incentive to reduce agrochemical leaching. There sometimes may be an

argument for going further and putting an environmental tax on fertilizers and pesticides to generate funding for water quality monitoring.

Conclusions:

Groundwater resources play a major role in ensuring livelihood security across the world, especially in economies that depend on agriculture. The socio-economic dependency on groundwater is explained over a range of factors by Burke and Moench. They explain the intricacy in managing groundwater resources. At the same time, groundwater systems have become the "lender of last resort" and depletion of renewable groundwater stocks is taken as the first indicator of water scarcity. Moreover, groundwater is considered to be less vulnerable than surface sources to climate fluctuations and can therefore help to stabilise agricultural populations and reduce the need for farmers to migrate when drought threaten agricultural livelihoods. In other words, groundwater resources provide a reliable drought buffer in large regions of the world. Groundwater is an open-access, common pool resource. Hence, protection of the resource is not possible unless the users agree to cooperate and manage the resource themselves in a sustainable manner. And also the various economic instruments for groundwater management must be used to attain sustainability.

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