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GROUNDWATER DEVELOPMENT AND INSTITUTIONS IN NORTH INDIAN STATES: SOME POLICY OPTIONS

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Abstract: The groundwater has traditionally been dealt in north Indian states with in a laissez-faire mode without attention to the sustainability of the resource. Groundwater institutions are in an evolutionary phase and no simple blueprints for management success are appropriate. Groundwater overexploitation is a major concern. In Punjab, the level of exploitation is already at the level of around 98 per cent and Haryana follows with 80 per cent. The situation is also precarious in state of Rajasthan where the level of exploitation is about 62 per cent. Several parts of north Indian states have seen a steep decline in water tables. The implications of this trend are serious. Artificial recharge has augmented groundwater supply and delayed the crisis. Significant policy efforts by respective state governments have occurred in recent past and have shown significant localized progress in key areas of groundwater governance, however, the major performance challenges and institutional issues continue to persist. Therefore, the correction of institutional and governance bottlenecks in the development of groundwater is very vital. The development of groundwater resources should be so regulated as not to exceed the recharging possibilities, as also to ensure social equity. The detrimental environmental consequences of over-exploitation of groundwater need to be effectively prevented by legislation and its enforcement by local government bodies. Groundwater recharge projects should be developed and implemented with community participation for augmenting the available supplies.

Keywords: Groundwater; institutions; regulation; recharge; North Indian states; policy

JEL Codes: Q01, Q15, Q25, Q28, Q53

1. INTRODUCTION

Following Commons (1934), North (1990) and Ostrom (1990), groundwater institutions can be defined as rules that define action situations, delineate action sets, provide incentives, and determine outcomes both in individual and collective decision setting in the context of groundwater governance,

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which can be broadly categorized as legal rules, policy rules, and organizational rules (Saleth and Dinar 2004). Groundwater institutions also share the same features characterizing all other institutions such as subjective in origin and operation but objective in manifestation and impact (Hodgson 1998), path-dependent in the sense that their present status and future direction are dependent on their earlier course and past history (North 1990), stable and durable (Adelman *et al*. 1992; Hodgson 1998), hierarchic and nested both structurally (North 1990; Ostrom 1990) and spatially (Boyer and Hollingsworth 1997) and embedded and complementary not only with each other but also with their environment defined by the cultural, social, economic and, political milieu (North 1990). Institutional arrangements for groundwater governance play an important role in allocating, managing and sustaining scarce groundwater resources, which have long been a vital legal, constitutional, and social issue (Marothia 2003). Undoubtedly, institutional arrangements for groundwater governance largely influence the welfare outcomes; however, groundwater governance in India is confronted by several institutional challenges and grappling with poor performance, deterioration of infrastructure, high levels of extraction and related economic and environmental problems (Shah, *et al*. 2004). At the same time, there is little agreement about appropriate institutional arrangements for groundwater governance and criteria for successful institutional design (Olson 1965; Hardin 1968; Uphoff 1986; Wade 1987; Ostrom 1990, 1992, 1993; Ostrom and Gardiner 1994; Hanna *et al*. 1995; Balland and Platteau 1996; Hussain and Bhattacharya 2004; McCay and Acheson 1987; Mollinga 2001; McCay 2002). Thus, redefining groundwater institutions remains the top priority in the water policy arena.

In India, the spread of green revolution and development of drilling technology allowed the spreading of intensive groundwater abstraction in agriculture since mid 1960s, however, this was not accompanied simultaneously by the evolution of institutional arrangements. Therefore, the groundwater has traditionally been dealt in north Indian states with in a laissez-faire mode. The groundwater has been used to irrigate crops typically without attention to the sustainability of the resource, which has twofold effects: (a) the unregulated groundwater use has permitted spectacular expansion of agricultural growth and lifted millions of people out of poverty, and (b) many aquifers are now under severe stress and groundwater cannot wholly sustain the production. Introducing aquifer management is a time-consuming and politically challenging endeavour in overexploited areas. The north Indian states of India have started to proactively manage their groundwater resources; however, it is still in infancy stage and there are as yet few well-established examples of good practices and effective groundwater management. As compared to surface water management, groundwater institutions in north Indian states are in an evolutionary phase and no simple blueprints for management success are appropriate. With the above backdrop, the main objectives of the paper are to examine the groundwater scenario and the institutional arrangements and instruments available for groundwater governance in selected north Indian states and to highlight some key policy options regarding the way forward in groundwater management for the future.

2. GROUNDWATER SCENARIO

Groundwater is being used in India since the Vedic times, for over 6,000 years. Today, India has 16 per cent of world's population and only 6 per cent of world's water resources and 2.5 per cent of world's land. The annual precipitation in India is estimated to be 4000Bm^3, the southwest monsoon being the major contributor (3000Bm^3). The major and medium river basins contribute over 90 per cent of the total runoff in the country (CGWB 2017). The Indo-Gangetic planes have enormous amount of water, but the current method of utilization is not appropriate (Serageldin 1998). In 2015, the water resource potential of India in terms of natural runoff (flow) in rivers was 1869Bm^3, of which only 1122Bm^3 can be put to beneficial use. Out of this, 690Bm^3 is surface water and 432Bm^3 is replenishable groundwater. Currently, total water use (including ground water) is 634 Bm^3, of which 83 per cent is for irrigation (CWC 2015). The demand for water is projected to grow to 813 Bm^3 by 2010, 1093 Bm^3 by 2025 and 1447 Bm^3 by 2050, against utilizable quantum of 1123 Bm^3. Clearly, there will be a considerable gap between the water need and availability in next few decades (Ministry of Water Resources 1998).

The Central Ground Water Board (CGWB) has released its Report on Dynamic Ground Water Resources of India in 2017, which gives a broader groundwater development scenarios in selected north Indian States. In Haryana, the annual replenishable groundwater resource has been estimated at 11.36 Bm^3 and net annual groundwater availability at 10.30 Bm^3 in 2013. The annual groundwater draft was 13.92 Bm^3 and stage of groundwater development was 135% in 2013. Out of total 119 assessed blocks, 64 have been categorized as 'Over-exploited', 14 as 'Critical', 11 as 'Semi Critical' and 30 as 'Safe'. Groundwater recharge from other sources has increased from 6.12 Bm^3 to 6.70 Bm^3 during 2011-13 which is attributed to the contribution from return flow component by surface and groundwater irrigation. At the same time, annual groundwater draft has also increased from 13.05 Bm^3 to 13.92 Bm^3 due to increase in total number of tube wells from 741062 to 785894 during 2011-13. In Himachal Pradesh, the annual replenishable groundwater resource has been estimated at 0.56 Bm^3 and net annual groundwater availability at 0.53 Bm^3 in 2013. The annual groundwater draft was 0.27 Bm^3 and stage of groundwater development was 51%. Out of the 8 assessment units, one each has been categorized as 'Overexploited' and 'Critical', and 6 as 'Safe'. There are no significant changes in the annual replenishable groundwater resource and net ground water availability during 2011-13. However, the annual groundwater draft for irrigation has decreased from 0.25 Bm^3 in 2011 to 0.16 Bm^3 in 2013, which is due to refinement in the number of abstraction structures and draft parameters (CGWB 2017).

In Jammu and Kashmir, the annual replenishable groundwater resource has been estimated at 5.25 Bm^3 and net annual groundwater availability at 4.82 Bm^3 in 2013. The annual groundwater draft was 1.18 Bm^3 and the stage of groundwater development was 24%. It is significant to note that all the groundwater assessment units in Jammu and Kashmir have been categorized as 'Safe'. The annual replenishable groundwater resource and net ground water availability respectively have increased from 4.25 Bm^3 in 2011 to 5.25 Bm^3 in 2013 and 3.83 Bm^3 in 2011 to 4.82 Bm^3 in 2013, which is attributed to increased rainfall and recharge from other sources. During the same period, the annual groundwater draft has increased from 0.81 Bm^3 to 1.18 Bm^3 due to increase in groundwater structures for domestic and industrial purposes. In Punjab, the annual replenishable groundwater resource has been estimated at 25.91 Bm^3 and net annual groundwater availability at 23.39 Bm^3 in 2013. The annual groundwater draft was 34.81 Bm^3 and stage of groundwater development was 149%. Out of the 138 assessed blocks, 105 blocks has been categorized as 'Over-exploited', 4 as 'Critical', 3 as 'Semi-Critical', and 26 as 'Safe' and there is no saline area in the state. The annual replenishable groundwater resources has increased from 22.53 Bm^3 in 2011 to 25.91 Bm^3 in 2013 and similarly, net groundwater availability increased from 20.32 Bm^3 in 2011 to 23.39 Bm^3 to 2013, which is due to change in recharge factors of return flow and also reflected in the reduction of stage of groundwater development from 172% to 149%. In Rajasthan, the annual replenishable groundwater resource has been estimated as 12.51 Bm^3 and net groundwater availability at 11.26 Bm^3 in 2013. The annual groundwater draft was 15.71 bcm and the stage of ground water development was 140%. Out of the 248 assessed blocks, 164 blocks has been categorized as 'Over-exploited', 9 as 'Critical', 28 as 'Semi-critical', 44 blocks as 'Safe' and 3 as 'Saline'. During 2011-13, the annual replenishable groundwater resource, net annual groundwater availability has increased from 11.94 Bm^3 to 12.51 Bm^3 and 10.83 Bm^3 to 11.26 Bm^3 respectively, which is attributed to relatively good rainfall (CGWB 2017).

What really needs to be addressed is the demand-supply imbalance at the local level, which has already acquired serious proportion in north Indian states, as manifested by declining water tables. The increased use of and access to groundwater is often considered as instrumental behind the spread of the new agricultural technology in Punjab and Haryana. The pattern of development of groundwater in north Indian states has created a number of sustainability, equity and efficiency concerns. At national level, groundwater overexploitation may not be considered to be a major problem as India exploits only about 30 per cent of annual utilizable potential. However, groundwater overexploitation is a major concern in north Indian states. For example, in Punjab, the level of exploitation is already at the level of around 98 per cent and Haryana follows with 80 per cent. The situation is also precarious in states such as Rajasthan where the level of exploitation is about 62 per cent (CGWB 2006). Among the selected north Indian states, Punjab and Haryana have more groundwater resources from unconsolidated rocks. Several parts of north Indian states have seen a steep decline in water tables, often implying that water is being 'mined', or extracted at unsustainable rates. The implications of this trend are serious as these states of India that are witnessing the phenomenon of falling water tables, are also India's agriculturally important states with a heavy dependence on groundwater. The area irrigated by groundwater in the states of Punjab and Haryana is over 61 per cent and 48 per cent respectively (Bhatia *et al*. 1995).

The groundwater utilization is very high in the states of Punjab, Haryana, and Rajasthan. However, states like Himachal Pradesh and Jammu and Kashmir utilize only a small proportion of their groundwater potentials. If the present trend in groundwater utilization in Punjab and Haryana continues, the demands for water would need more supplies and such situation will be detrimental to development and can cause social upheaval and disruptions. The degree of groundwater exploitation has varied widely across north Indian states (CGWB 2017). In agriculture, water is mainly used for irrigation because of spatio-temporal variability in rainfall. The large tracts of north Indian states are deficient in rainfall and are drought prone. Hence, it is difficult to practice agriculture without assured irrigation during dry seasons. Water need of certain crops also makes irrigation necessary. For instance, water requirement of rice and sugarcane is very high, which can be met only through irrigation. The provision of irrigation makes multiple cropping possible and irrigated lands have higher agricultural productivity than unirrigated land. Further, the high yielding varieties (HYVs) of crops need regular moisture supply, which is made possible only by a well developed irrigation systems. In fact, this is why that green revolution has largely been successful in Punjab and Haryana.

In these states of north India, more than 85 per cent of their net sown area is under irrigation, where wheat and rice are grown. Of the total net irrigated area, 76.1 per cent and 51.3 per cent are irrigated through wells and tube wells respectively in Punjab and Haryana (CGWB 2006), which shows that these states have utilized large proportion of their groundwater potential and has resulted in groundwater depletion. Besides, the share of area irrigated through wells and tube wells is also very high in these states. In most parts of the over-exploited areas, the prime cause of over-exploitation is the rising demand for groundwater from agriculture. Further, in groundwater irrigated areas, decisions on cropping pattern and cropping intensity, which are the predominant determinants of agricultural demand for groundwater, are being taken largely independent of the ease of groundwater availability. Thus, water intensive crops have tended to be grown even in the face of scarcity of groundwater, if these crops are perceived to be relatively remunerative. Such distortions occur partly due to the legal/ regulatory regime governing groundwater and partly to the minimum support price policy and agricultural trade policy currently being followed. The problem has been compounded by the availability of cheap/ subsidized or even free power (for example in Punjab), since power is a main component of the cost of groundwater. Moreover in other states, electric supply is not metered and a flat tariff is charged depending on the horsepower of the pump. This makes the marginal cost of power zero and provides farmers with little incentive to use power or water more efficiently. Power subsidy has undoubtedly encouraged greater use of groundwater. In most of the districts of these states the concentration of dark blocks is more due to overexploitation of groundwater resources for agriculture.

Since 1954, CGWB has been carrying out exploratory drilling for identification of aquifer system, demarcation of potential aquifer zones and evaluation of aquifer characteristics. In Punjab, CGWB has drilled 142 exploratory wells, 154 observation wells, 22 slim holes and 75 piezometers till March 2004 (CGWB 2006). About 80 per cent of the hydrograph stations fall in all the command areas of various canal systems. The areas falling out of the command are major portions of districts of Hoshiarpur and Ropar, parts of districts of Gurdaspur, Kapurthala, Jalandhar, Ludhiana and Patiala. Water table elevation contours have a maximum value of 476.8 m amsl rising in the northeast along the Himalayas while the minimum value of 173.3 m amsl is in the Punjab plains (Muktsar district). General groundwater flow direction follows the natural slope. There is not much change in the groundwater flow direction which still remains northeast-southwest, but the groundwater gradient between contour level 190m and 180m in Muktsar and Ferozepur districts has become gentle indicating slowing of groundwater movement resulting in spreading of water logged areas to other districts (IDFC 2013).

The depth to water level lies between 0.97 m bgl in Muktsar district and more than 33.16 m bgl in the northeast in Hoshiarpur district. Deep water levels are observed in the central, eastern and southern parts of the state in parts of Ludhiana, Hoshiarpur, Sangrur, Bhatinda, Ropar, Fatehgarh districts. Deepest water levels (>20m) in about only 4 per cent of wells are prevalent along the kandi areas in the northeastern parts of the state. Very shallow water levels (<2m) in about 3 per cent of wells have been observed in a patch south of Satluj river in Ferozepur and Faridkot districts, which are mainly canal command areas and are water logged. Otherwise about 35 per cent of wells fall in 5-10m and 34 per cent of wells fall in 10-20 m category. Rise in water levels have been reported from south-western parts of the state mainly in Bathinda, Muktsar and Ferozepur districts. The decline in water levels have been reported from central and southern parts of the state mainly in parts of Sangrur, Patiala, Ludhiana, Jalandhar, Moga, and Amritsar districts. In Haryana also, the CGWB has been carrying out similar exploratory drilling since 1954. CGWB has drilled 341 exploratory wells, 233 observation wells, 21 slim holes and 141 piezometers till March 2003 (CGWB 2006). The exploratory drilling in Upper Yamuna basin has revealed existence of three major aquifer systems down to depth of 450m. The first aquifer system extends from ground surface to maximum of 167m, the second aquifer system occurs between 197m and 346m and the third aquifer system occurs below 346m and its downward extend has yet to be deciphered by deep drilling. The Upper Yamuna basin and Ghaggar basin have been investigated in detail under the two different water balance projects (CGWB 2006).

Groundwater occurs in alluvium as well as in hard rocks. In alluvium, sand, silt and gravel beds constitute potential water bearing zones. Groundwater at shallow depths occurs under unconfined conditions, whereas at deeper levels, confined/semi-confined conditions prevail. In hard rocks, weathered/fractured quartzites and cavernous limestone constitute potential aquifers. The flow of groundwater is generally towards southwest. In the north-eastern and eastern parts of the state falling in Ghaggar and Yamuna basins respectively, fairly thick and regionally extensive confined/unconfined aquifers exist down to a depth of 300m to 400m with yield potential of 150-300m3/hr except in Ambala city where the yield is about 40 to 100m3/hr. In Hissar-Sirsa belt, potential aquifers exist within 270m depth with yield potential ranging between 100m3/hr to 200m3/hr for low to moderate drawdown. Shallow aquifers down to 60m to 100m depth occur in the alluvial deposit of Faridabad, Gurgaon and

Mahendragarh districts. Wells in these areas yield 30 to 50m3/hr for moderate drawdown. In the parts of southern districts of Mahendragarh, Rewari, Gurgoan and Faridabad, aquifers in the fractured quartzites and cavernous limestone have yield potential of 5 to 50m3/hr for moderate to high drawdown (CGWB 2006).

3. GROUNDWATER INSTITUTIONS

An important ingredient in the groundwater institutional framework is the organizational form for groundwater governance. The groundwater is formally managed by government agencies, often at the central and sometimes at a lower administrative level. With increasing groundwater scarcity problems, however, aquifer management organizations, which consist of local stakeholders, have started to develop. This tends to coincide with changes in the laws governing groundwater management, but can also happen spontaneously. Figure 1 illustrates schematically how all of the above constitute the institutional framework that conditions groundwater governance, with the different institutional arrangements, instruments and organizational forms influencing each other.

Looking at the legal framework for management of groundwater in India, there are no *de jure* rights in groundwater; but *de facto*, all landowners having the right to groundwater underlying their land. This is the product

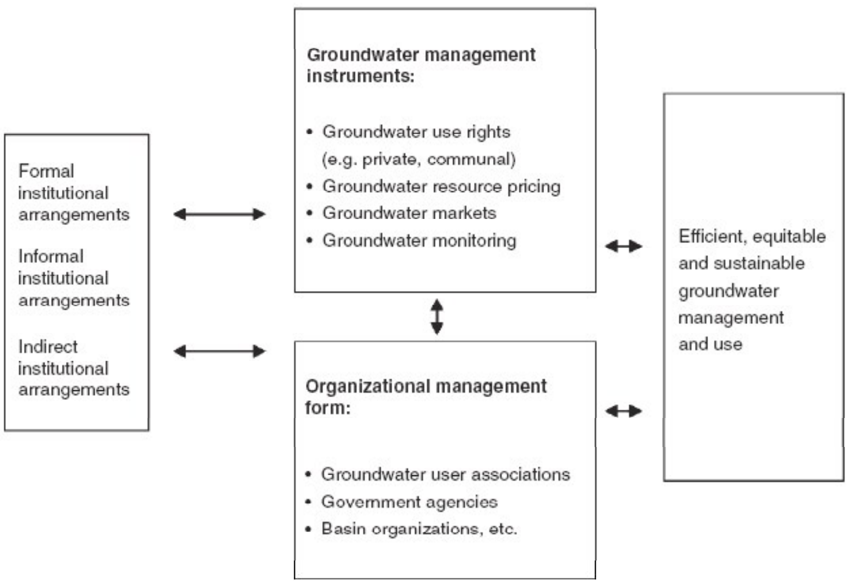

Figure 1: Schematic of Institutional Framework for Groundwater Governance

Source: Kemper (2007)

of a set of colonial legislation, the Easement Act (1882), which allows private usufructuary rights in groundwater by viewing it as an easement inseparably connected to land. The Transfer of Property Act 1882 provides that easements (groundwater) can be given to one only if the dominant heritage (land) is also transferred. Conversely, the Land Acquisition Act asserts that if someone is interested in getting rights over the groundwater, he would have to be interested in the land. Thus, groundwater is viewed essentially as a chattel attached to land. There exists, at the same time, no limit to how much water a landowner may draw, in contrast to a legal structure that specifies well-defined property rights setting absolute limits to collective and individual withdrawals.

India is a federal republic and its constitution distributes the legislative power over some subject matters to the States, some to Centre and for some to both Centre and States. The constitutional provisions in respect of allocation of responsibilities between the States and the Centre fall into three categories: (i) The Union List (List I in the Seventh Schedule); (ii) The State List (List II in the Seventh Schedule); and (iii) The Concurrent List (List III in the Seventh Schedule). Under the Constitution, "Water" is a matter included in Entry 17 of List II in the Seventh Schedule i.e. in the State List. "Water" as such is a State subject and that States have jurisdiction to regulate and control groundwater … as Entry 17 of the State List, clearly states "Water, that is to say, water supplies…" … where "water supplies" can be argued to include groundwater. The roles that the Government is expected to play in groundwater development and management are outlined in two important policy statements: National Environment Policy and National Water Policy.

The National Environment Policy has suggested the following action points in relation to groundwater: (a) take explicit account of impacts on groundwater tables of electricity tariffs and pricing of diesel; (b) promote efficient water use techniques, such as sprinkler or drip irrigation among farmers and provide necessary pricing, inputs and extension support to feasible and remunerative alternative crops for efficient water use; (c) support practices of contour bunding and revival of traditional methods for enhancing groundwater recharge; (d) mandate water harvesting in all new constructions in relevant urban areas as well as design techniques for road surfaces and infrastructure to enhance groundwater recharge; and (e) support R&D in most effective techniques suitable for rural water projects for removal of arsenic and mainstream their adoption in rural drinking water schemes in relevant areas.

The National Water Policy (2002) has the following recommendations relating to groundwater: (i) exploitation of groundwater resources should be so regulated as not to exceed the recharging possibilities, as also to ensure social equity; (ii) groundwater recharge projects should be developed and implemented for improving both the quality and availability of groundwater resource; (iii) integrated and coordinated development of surface water and groundwater resources and their conjunctive use should be envisaged right from the project planning stage and should form an integral part of the project implementation; and (iv) over exploitation of groundwater should be avoided especially near the coast to prevent ingress of sea water into sweet water aquifers.

The Model Ground Water Bills have also been framed to form a template for the states in their own regulations of rain water harvesting, notification of areas, requirements for applications for permits prior to digging and drilling of new wells, registration of existing wells and all existing water users. The salient features of the Model Bill are: (i) states to establish a Ground Water Authority; (ii) authority to have powers to notify areas for control and regulation of groundwater development; (iii) authority to grant permit for extraction and use of ground water in notified areas; (iv) existing users in notified areas and new users in non-notified areas to register with the Authority; (v) penalties prescribed for offences; (vi) states to implement rain water harvesting for groundwater recharge. However, once again, the provisions seek only to regulate the creation of water extraction mechanisms, rather than the quantum of water withdrawn. Besides, there has been opposition to the bills on the grounds that like the past record with the system of licensing, they would tend to breed corruption and inequity. Besides, it is felt that such an approach ignores the possibility of successes through localized, participative approaches and adopts a simplistic, centralized approach that fails to consider the wide array of management options suited to diverse sociological as well as hydro-geological contexts. The box 1 summarizes the institutional arrangements and responses for groundwater governance in India.

4. GROUNDWATER REGULATION

Some North Indian State governments have enacted groundwater legislation. An attempt has been made in the following paragraphs to examine the approach to and experience with groundwater regulation in case of Punjab, Himachal Pradesh and Rajasthan. Punjab is a predominantly agrarian state having 85 per cent of its geographical area under cultivation with an average cropping intensity of 188 per cent. The water demand for the kind of agricultural practices followed in the state is very high and a large part of it is for groundwater. Out of the 137 blocks in the state, only 25 are safe; 103 are over exploited, 5 critical and 4 semi-critical. Punjab is not in favour of groundwater legislation as it apprehends that such a step will cause hardship to farmers. Instead, to tackle groundwater over exploitation, the State is in favour of the following initiatives: (i) crop diversification by extending minimum support price to other crops to wean away farmers from paddy cultivation, which is water intensive and contract farming for sowing alternative crop of chick-pea has been successfully tried; (ii) large scale artificial recharge through construction of check dams, use of drainage water and roof top rain water harvesting; (iii) electricity supply to be controlled, regulated and metered supply in critical areas; (iv) micro irrigation for promotion of drip and sprinkler to conserve water; and (v) alteration in crop calendar by encouraging late sowing of paddy after 16th June to decrease evapotranspiration. The state is also contemplating complete ban on new tube wells and restricting horse power to 10 HP so that the deeper aquifers are not tapped. The pumps need to be replaced with energy efficient pumps. Conjunctive use of saline and fresh water will also help in bringing down the demand for fresh water.

Box 1: Institutional arrangements and responses for groundwater governance

Institutional arrangements	*Institutional responses*
Groundwater institutions	• Cooperative tube well organizations • Emergence of groundwater markets • Groundwater extraction and water trading • Pricing arrangements for groundwater transactions • Check-dams • Common property institutional arrangements • Primarily used for groundwater recharge • Surface irrigation, livestock, and domestic needs • Beneficiary contribute to construction and maintenance

Source: Author's compilation based on available literature

Box 2: Groundwater institutions in Rajasthan

Institutional aspects	*Mechanisms*
Groundwater development	• Regulation of exploitation of groundwater resources as not to exceed recharging possibilities and also to ensure social equity • Periodical reassessment on a scientific basis of groundwater potentials • Amending existing laws/new legislation be enacted· Controlling deep drilling through licensing and control on private operators • Public awareness for self-control in groundwater exploitation from WUAs

contd Box 2

- Developing a sense of water scarcity and need to conserve
- Improving data collection
- Preventing detrimental environmental consequences of over exploitation of groundwater
- Review and charging rationalistic and realistic water rates
- Volumetric measurement of water consumption in all sectors

Source: Author's compilation based on available literature

Himachal Pradesh Ground Water (Regulation and Control of Development and Management) Act, 2005 stipulates for establishment of "The Himachal Pradesh Ground Water Authority" with power to notify areas to regulate and control the development and management of groundwater, maintain database on groundwater, grant permit to extract and use groundwater, register the existing groundwater users and drilling agencies, alter, amend or vary the terms of the permit or certificate of registration, cancel permit or certificate of registration, and collect royalty in respect of use of groundwater. Every user of groundwater in a notified area shall install water measuring device on ground water abstraction structure. Emphasis should be made on rainwater harvesting for conservation and groundwater recharge. The provisions have also been stipulated for cognizance and trial of offences and penalties.

In the context of most driest state of Rajasthan, it has been propagated that the groundwater institutions need to be evolved and strengthened for optimal economic development and social well-being, which calls for an integrated and multi-disciplinary approach to planning, evaluation, approval and implementation of irrigation and drainage projects, including river basin management, of surface and groundwater. There is need for optimisation of groundwater resources exploitation and raising the level of reliability of supplies through conjunctive use of surface and groundwater. Besides, judicious and economically sound allocation of water resources to different sectors has also been called for. The institutional aspects and mechanisms for groundwater governance in Rajasthan are presented in box 2 and groundwater institutions in comparative perspective are presented in box 3.

In sum, the ownership of the groundwater should be governed by the ownership of the land to the extent the uses (exploitation) of groundwater is not causing depletion in the groundwater levels so the similar rights of the adjoining land owners and public at large are not encroached upon as this natural resource is meant for public use and it should not be allowed to be exploited beyond replenishable level. Therefore, there is a need of an "Act" at the State level to monitor the groundwater levels through scientific methods by piezometers under the advisory guidance of CGWB.

Box 3: Groundwater Institutions in North Indian States: A Comparison

Institutional aspects	*Haryana*	*HP*	*J&K*	*Punjab*	*Rajasthan*
Ownership of tubewells	Private	Private	Private	Private	Private
Ownership of pumps	Private	Private	Private	Private	Private
Overlapping tubewell command area	Yes	Uncertain	Uncertain	Yes	Yes
Competition among pump owners for water sales	Yes	No	No	Yes	Yes
Existence of laissez faire water markets	Yes	No	No	Yes	Yes
Role of village authorities in water regulation	No	No	No	No	No
Registration of GW structures	No	No	No	No	No
Licensing of GW structures	No	No	No	No	No
Conjuctive use	Yes	Limited	Limited	Yes	Uncertain
Social equity	No	Limited	Limited	No	Uncertain
Prevalence of water rates	Yes	No	No	Yes	Yes
Farmers' participation	Limited	Small	Small	Limited	Poor
Monitoring of GW quality	Absent	Absent	Absent	Absent	Absent
Institutionalized incentives	No	No	No	No	No
System of artificial recharge	Yes	Yes	Yes	Yes	Limited
Volumetric allocation	No	No	No	No	No
Pricing of electricity	Subsi-dized	Subsi-dized	Subsi-dized	Nil	Subsi-dized
Private participation	Small	Poor	Poor	Small	Small

Source: Author's compilation based on available literature

The State Government should also ensure that groundwater levels should not fall below the replenishable level and accordingly take necessary measures for regulation/restriction of the groundwater uses in the area. The enforcement for the regulation/reduction/restriction in the groundwater usage should be made effective by the State Government through the users' group/community participation/ involvement of Panchayat. The users group should be responsible for regulating the groundwater usage among various sectors i.e. irrigation, drinking and industrial. Such regulations by the user group will be made effective on the advice of State Ground Water Board (SGWB).

CGWB along with SGWB should assist the State Government in controlling the over exploitation through negative and positive incentives such as restricting institutional loans, limiting electricity supply, strengthening the oversight of the community specially that by the user group. The positive incentives can be supported for rain water harvesting and watershed development. Also the CGWB and SGWB should prepare suitable guidelines for aquifer water management based planning for use of groundwater. The efforts should be made to merge the schemes for watershed development, rain water harvesting etc. along with the involvement of panchayat in critical and semi-critical areas.

5. GROUNDWATER RECHARGE

In view of the increasing thrust on development of groundwater resources, several attempts have been made to recharge these depleting resources in the active recharge zone through natural or artificial recharge. Rainfall is the main source of both types of recharge. The rainfall occurrence in different parts of north Indian states is limited to a period ranging from about 10 to 100 days. The natural recharge to groundwater reservoir is restricted to this period only and is not enough to keep pace with the excessive continued exploitation. Since large volumes of rainfall flows out into the sea or get evaporated, artificial recharge has been advocated to supplement the natural recharge. Artificial Recharge is the process by which the groundwater reservoir is augmented through increased infiltration by using artificial structures. It may be noted, however, that to the extent artificial recharge reduces water flowing into existing lakes/ponds/reservoirs lower down the catchment, and it is not a net addition to available groundwater but only a re-distribution across different areas, which might be socially desirable.

The dominant method of artificial recharge is through the use of civil structures (such as check dams, recharge shafts etc) that arrest or slow down surface runoff, under suitable hydro-geological and hydrologic conditions. Some states such as Rajasthan, Himachal Pradesh and Jammu and Kashmir have implemented few schemes for construction of these structures at scattered locations. Artificial recharge through rain water harvesting is being practised in different parts of Himachal Pradesh and Jammu and Kashmir. However, it is seen that the selection of sites and type of recharge structures are not always compatible with hydrological and hydro-geological conditions. As a result, the desired benefits have not been realized.

The artificial recharging yields encouraging results in terms of arrest of rate of decline in groundwater levels, reduction of runoff, increased availability of groundwater especially in summer months (when the demand is more), increase in irrigation, and revival of springs, improvement of the environment through increase in soil moisture and improvement in groundwater quality. The efficacy of an artificial recharge scheme is not uniform and depends largely on the source of water availability, capability of groundwater reservoir to accommodate it, site selection and design of artificial recharge structure. The check dams, recharge shafts and sub-surface barriers are effective structures in hard rock areas of Jammu and Kashmir and Himachal Pradesh.

Water harvesting is an ancient art practiced in the past in many parts of North India. It is relevant to areas where the rainfall is reasonably distributed in time, but inadequate to balance potential evapotranspiration of crops. More precisely, water harvesting can be defined as the process of concentrating rainfall as runoff from a larger catchment area to be used in a smaller target area. This process may occur naturally or artificially. The collected runoff water is either directly applied to an adjacent field or stored in some type of on-farm storage facility for domestic use and as supplemental irrigation of crops. Water harvesting is generally feasible in areas with an average annual rainfall of at least 100 mm in winter rains and 250 mm in summer rains.

When the collected runoff water is diverted directly into the cropped area during the rainfall event, the technique is called runoff-farming water harvesting. Generally, the quantity of runoff exceeds the infiltration capacity of the soil. Therefore, ridges, borders or dikes are placed around the cropped area to retain the water on the soil surface. Surface storage based or supplemental irrigation water harvesting system is highly recommended when inter-seasonal rainfall distribution, or variability, or both are such that crop water requirements cannot be met. Surface storage structures range from an underground storage on-farm pond or tank to a small dam constructed across the flow. Storage capacity, storage location, type of storage structure and geometry of storage tank should be given due consideration in the design of surface storage facilities. The cost of the storage facility and hence the cost of water depends on the ratio of the storage volume and the volume of the excavated earth, known as the storage/excavation (S/E) ratio.

Besides these schemes, there are many examples of water harvesting and recharge projects reporting substantial improvement in groundwater availability and agricultural production. Yet even with full development of artificial recharge, groundwater availability would remain limited. If it is treated as an open access resource and its extraction continues as at present, pace over extraction would result in the end. It is, therefore, critical to find ways to limit the use of groundwater to keep it sustainable. Cooperative management by users to facilitate groundwater use in an equitable manner seems inescapable. While groundwater recharge schemes may not be the final answer, they do call for community efforts and create the spirit of cooperation needed to subsequently manage sustainably groundwater as a community resource.

6. CONCLUSION AND POLICY OPTIONS

The rate of extraction of groundwater is increasing in north Indian states and in many blocks exceeds the rate of recharge leading to lowered water tables and higher proportion of blocks are now semi-critical, critical or over exploited. The number of dark or over exploited critical is increasing rapidly. Since groundwater is an open access common property resource, the concept of tragedy of the commons is fully applicable. When groundwater gets lowered, it increases costs for all as they need to deepen their wells and require more powerful motors. Artificial recharge has augmented groundwater supply and delayed the crisis. An important gain from successful artificial recharge projects is that the community gets organised to behave in a cooperative manner. Such cooperation is critical for sustainable use of groundwater. The experience of north Indian states with groundwater governance shows that by itself it is not very effective and requires community cooperation.

Groundwater institutions in India remains legally weak, functionally disjoint, sectorally biased, and regionally uncoordinated. While physical stress and financial crisis have exposed the legal, policy, and administrative weakness of water sector, myopic political issues and administrative resistance have impeded institutional change. Similar is the situation of selected north Indian States. The drought of 1987 and the macro economic crisis of the late 1980s prompted a significant change in recent groundwater policies, which includes (i) National Water Policy (1987) advocating full cost pricing; (ii) Committee on Pricing Irrigation Water (1992) suggesting higher water charges and group-based volumetric distribution of canal water; (iii) austerity measures in groundwater investment with emphasis on improved cost recovery; (iv) Model Groundwater Bill (1992) advocating ideas like well permits, water metering, and withdrawal limits; and (v) promoting farmer's participation through water user associations (WUAs) by irrigation departments for water distribution, cost recovery, and system maintenance in early 1990s. In the selected north Indian states too significant policy efforts by respective state governments have occurred in recent past and have shown significant localized progress in key areas of groundwater governance, however, the major performance challenges and institutional issues continue to persist. Therefore, the correction of institutional and governance bottlenecks in the development of groundwater is very vital.

Since there is a declining availability of fresh water and increasing demand, the need has arisen to conserve and effectively manage this precious life giving resource for sustainable development. There is urgent need to take quick steps and make effective policies and laws and adopt effective measures for groundwater conservation. Besides developing water saving technologies and methods, concerted attempts need to be made to prevent the groundwater pollution. There is also need to encourage groundwater recharge through watershed development, rainwater harvesting, water recycling and reuse, and conjunctive use of water for sustaining groundwater supply in long run.

The development of groundwater resources should be so regulated as not to exceed the recharging possibilities, as also to ensure social equity. The detrimental environmental consequences of over-exploitation of groundwater need to be effectively prevented by legislation and its enforcement by local government bodies. To give teeth to their actions the Central and State governments should enact suitable legislation and notify the permissible water depths to which groundwater depletion will be permitted for each region/block/watershed after identifying the special problems of each area. Groundwater recharge projects should be developed and implemented with community participation for augmenting the available supplies.

The Government should transfer the authority for regulating groundwater use to the lowest level, the village panchayat. The Government should have the responsibility of laying down the rules and regulations and then monitoring the implementation. Effective groundwater governance requires (a) awareness of the status of groundwater, both its quality and the quantity available and monitoring is a prerequisite in order to identify whether problems are occurring or are likely to occur; (b) understanding of the aquifer sufficient to be able to identify options (and targets) to remedy a problem situation; (c) water laws and rights in place, widely accepted and clear, or in their absence a practicable system of incentives/disincentives; (d) surveillance, to monitor adherence to regulatory measures or response to incentives/disincentives; and (e) awareness in governmental planning and society at large of the importance of groundwater. Unfortunately these requirements are very rarely met in full. In particular, water rights and laws applied to groundwater can be ambiguous or uncertain in their interpretation. Realistically, changing the situation will take time, but long term goals need to include (a) increasing public and government awareness so that legislation on water issues (like ownership and rights) can be passed and enforcement accepted by society at large; (b) resourcing agencies to actively manage groundwater; (c) encouragement of community management; and (d) incentives (or disincentives) to reduce pollution load.

In brief, the groundwater policy for the future should have the following tenets for achieving sustainable development: economical and efficient use of the water pumped from the aquifers, watershed development and recharge augmentation, conjunctive use, prevention of pollution, more calories per cubic meter of irrigation water, creating a public awareness, pumpage control in overexploited watersheds, and promoting cooperative actions among various groundwater stakeholders.

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