Understanding Groundwater for Proper Utilization and Management in Nepal

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Abstract

Groundwater resources occur in various natural settings in Nepal due to diversity in its geology, geomorphology and physiography. In the intra-mountain valleys such as Kathmandu, Dang and similar other valleys, groundwater is restricted to well-defined and sometimes isolated basins, whereas groundwater in the relatively flat plains south of the Himalayan mountain ranges, the Terai, forms a part of the larger system operating in the large Indo-Gangetic plains. Almost one half of the country's population is living in the Terai and they depend solely on groundwater for their domestic water needs. Although the available groundwater resource in the Terai has a potential to play a vital role in irrigation to ensure the country's food security and economic growth, its utilization level in irrigation has remained low so far. A contrasting scenario exists in Kathmandu valley, where the resource probably is already being over-exploited. Absence of adequate scientific data essential for proper understanding of the resource system is proving to be a serious set-back for the policy makers and planners in striking a balance between satisfying the water demand and the resource protection in the Kathmandu valley on one hand, and improving the access of the poor farmers, to the abundant groundwater resources in the Terai, on the other hand. Distinct approaches to resource utilization and management are, therefore, essential to address such diverse settings and dissimilar levels of uses. On top of it, discovery of natural arsenic contaminated groundwater in parts of the Indo-Gangetic alluvial plains have added a new challenge for the countries in this region. The socio-economic, infra-structural and policy environment for operation and development of groundwater irrigation in Nepal has some distinctive features, which are different from those of the neighboring countries. Some possible areas of new research and development for proper utilization and management of groundwater resources necessary for sustainable economic development are also discussed.

Introduction

Groundwater occurs in different natural settings in Nepal due to the diversity in geology, geomorphology and physiography. Intra-mountain valleys such as Kathmandu, Dang and other similar valleys have isolated groundwater basins whereas groundwater in the southern *Terai* plain is a part of the larger system in the Gangetic basin. The *Terai* constitutes 23 percent of the country's total area but it is home for over 48 percent of the population. It has abundant groundwater resources, and has fertile soils. This region is the main grain basket of Nepal and has great potential for further agricultural development, necessary for food security and poverty reduction in the country.

Groundwater is a very important water resource for the *Terai*. It is the main source for drinking water supply, and is also becoming increasingly important in the agriculture sector, particularly after the advent of tube well technology in the early 1970's. Since 1980, the Government of Nepal has launched groundwater irrigation development programs in the *Tera*i by providing subsidies in various forms. At the same time, manually operated shallow tube wells have always been the centerpiece of the government's rural water supply development programs. At present, there are already about 800,000 shallow drinking water tube wells in *Terai,* but similar growth has not occurred in the case of irrigation shallow tube wells even after 20 years of government subsidy programs from 1980 to 2000. Compared to a potential of irrigating 612,000 ha, only 206,000 ha of *Terai* land was irrigated with groundwater through about 60,000 shallow tube wells (STWs) and 1,050 deep tube wells (DTWs) in the year 2000. For practical reasons, a shallow tube well is defined in Nepal as a small diameter well (generally of 10 cm diameter) with less than 50 m depth, whereas wells more than 100 m deep are called deep tube wells. The latter has commonly a diameter of at least 15 cm or more.

There are 1,337,000 ha of irrigable agricultural land in the *Terai.* But, only 1,121,000 ha (84 percent) are under irrigation at present, out of this, only 206,000 ha (or 18 percent of the total irrigated area) are under irrigation by groundwater. Studies have shown that annual groundwater recharge in the *Terai* is sufficient to irrigate more than half of its irrigable land (APP, 1995; Kansakar, 1996). The Agricultural Perspective Plan (APP) has placed a high priority on groundwater irrigation, mainly through STWs, for agricultural development in the country. It has planned to irrigate 612,000 ha of *Terai* land by groundwater in a 20-year period (1995-2015). But, the STW growth rate has remained way below this target level. Heavy reliance on economic policy measures without due consideration for social factors is responsible for this failure.

Similar to other countries in this region (like India and Bangladesh), the challenge for Nepal is in increasing groundwater utilization in agriculture for poverty reduction and food security improvement on the one hand, while managing the resource properly on the other hand. Comparatively, Nepal still has a relatively large potential for expanding groundwater use and by proper management Nepal can avoid some of the social, economic and environmental impacts from uncontrolled growth in groundwater exploitation that the neighboring countries are already facing.

Groundwater Management

Groundwater management in Nepal must be viewed from two aspects. One is the resource conservation and protection aspect, and the other is the proper and controlled utilization of the resource.

Resource Conservation and Protection

Traditionally, groundwater resources have been considered as something that will naturally and always be available for human exploitation. The nature of its occurrence makes groundwater a 'common pool' resource, but it is being used commonly as a 'private resource', because it can be exploited independently and privately by anyone who is willing to do so. As a result, it is difficult to regulate or control the exploitation of groundwater. This is more so in the developing countries where law enforcement is generally always weak. Since groundwater occurs beneath the land surface, any harm done to this resource is not visible directly and immediately. Even among the policy makers and the planners, the mentality of 'out of sight – out of mind' works strongly in this case. It is generally too late when the damages become noticeable.

As elsewhere, groundwater in Nepal is also being exploited without any consideration for its management. All the efforts are focused on increasing the exploitation of this resource. Even the scientific investigations are meant for helping intensify this exploitation. Groundwater conservation and management has so far received a 'lip service' only recently, without any concrete programs or mechanisms in place, be it legal, institutional or policy measures. No program has addressed the conservation and sustainability of the resource. Some crucial areas for successful groundwater management in Nepal are discussed here.

Proper Understanding of the Resource

Groundwater resource exploitation will remain sustainable only if the resource utilization level remains in good agreement with resource replenishment, i.e. when conservation rules and measures protect the resource from over-exploitation. But resource conservation is possible only when the groundwater system is well understood.

The annual groundwater recharge or the dynamic reserve depends on the size and nature of the groundwater basin and the climatic conditions. Being a part of the larger Ganges basin and because of ample rainfall/snowmelt confluence, the *Terai* plain is in a good position with respect to renewable groundwater reserves, and has enough scope to expand its utilization. On the other hand, groundwater resources in the mountain valleys have limitations because they are in small and isolated basins. Again, one valley differs from another for their groundwater conditions due to their geologic, physiographic and climatic conditions. To be more specific, a relatively smaller river, the Bagmati, drains Kathmandu valley and it is filled with fine sediments of lacustrine and fluvial origin. Therefore, annual recharge is slow and small. Deep groundwater in the middle of the valley is about 28,000 years old (JICA, 1990). On the other hand, inner *Terai* valleys (e.g. Dang, Deukhuri, and Chitwan) are drained by larger rivers and have coarse fluvial sediment deposits, allowing quick aquifer recharge. But, in Surkhet valley, another valley in the inner *Terai*, has very little groundwater because it contains finer sediments. Therefore, a uniform approach for groundwater development cannot work for all areas. Failure to understand and act according to the specific groundwater conditions has already led to over-exploitation in the Kathmandu valley. It was estimated that 18 MCM of groundwater was being extracted annually against an estimated 5 MCM of annual recharge (CES, 1992). But, there has been no serious attempt to understand the groundwater system in this valley.

Protecting Recharge Areas

Protection of recharge areas has primary importance in groundwater quality and quantity management. The northern part of the *Terai*, known as the *Bhabar* zone, is a narrow belt of an average width of 5 km width along the foot of the Siwalik range. This Bhabar zone is the main recharge area for the multiple aquifer systems occurring in the *Terai*. The Bhabar zone is constituted of coarse grained colluvial and alluvial fan deposits whose sediment sizes decrease gradually towards the south and merges into the main *Terai.* Although direct rainfall recharge is significant all over *Terai*, lateral subsurface recharge from *Bhabar* is important for the deeper confined aquifers.

Earlier a densely forested area, the *Bhabar* zone is presently under rapid human encroachment for various social and economic reasons. The east-west highway, which more or less follows the southern limit of the Bhabar zone, has also contributed extensively to these processes of deforestation and human activity. New settlements and the associated agricultural activities have grown both legally and illegally. Increasingly, modern industrial establishments are also coming up because of the convenience of the highway. The main recharge zone for the *Terai* is thus facing increasing threat from industrial, agricultural and other human activities. Collectively, all of these have consequences on the groundwater recharge and the quality of recharge, which are ultimately important for the health and livelihood of the *Terai* population.

Rapid urbanization has already consumed much of the recharge areas in the Kathmandu valley. Because of its unique geologic construction, the recharge area is limited and groundwater movement is also slow in this basin. Diminishing capture zone and increased human activities in the recharge zone have implications on the groundwater recharge system, which has not received any attention yet.

Protecting Water Quality

Groundwater is the only source of drinking water for the people in the *Terai*. Much of the drinking water supply in Kathmandu valley also comes from this resource. But, quality of water is crucial for this purpose, and hence water quality management is an important aspect of groundwater management.

Shallow groundwater aquifers are mostly used for drinking purposes, but they are also easily polluted because their water originates from unconfined or semi-confined aquifers. Originating in the braided river deposits, the *Terai* aquifers are inter-connected, and hence pollution of one aquifer can contaminate the other easily. Besides anthropogenic contamination, groundwater may also contain natural pollutants. Arsenic is already known to be occurring in the Ganga - Bramaputra - Meghna basin (see Zahid et al., this volume). Shallow aquifers in some parts of the *Terai* have also been found to contain this pollutant (Shrestha et al., 2004, Khadka et al., 2004).

Geology and geomorphology have main control over the occurrence of arsenic in groundwater in the *Terai* (Kansakar, 2004). Shallow aquifers are more susceptible to arsenic contamination, whereas deep aquifers have been found to be generally free from arsenic. But deep tube wells may become contaminated if tube well construction practice is not proper. Arsenic-bearing shallow groundwater may get mixed up with the deep aquifer water in the multiple-screen tube wells and also through gravel pack material in the tube well annular spaces (Bisht et al., 2004). Thus, there is a clear need for groundwater quality management in order that the clean aquifers are protected from contamination and the known groundwater quality problems are adequately addressed in the development programs.

Proper Utilization

Utilization in the Drinking Water Sector

Universally, drinking water use receives precedence over all other uses of any water resource. The Water Resources Act (1992) of Nepal also provides the first priority for drinking water use. But, without suitable water quality, such legal provisions have little meaning, because people will not drink low quality water as long as they have an alternative. Therefore, proper utilization depends much on the quality management.

All of the *Terai* population meets its daily domestic water needs from groundwater. Dug wells have been replaced increasingly by small diameter shallow tube wells (4 cm diameter) since the 1970's. It is estimated that over 800,000 such domestic wells are currently in use in the *Terai* as a whole. In Kathmandu valley also, dug wells and pit basin water spouts (commonly known as *Dhuge Dhara* or *Stone water spouts* were the main sources of domestic water supply before the piped water supply system was introduced in the Kathmandu valley. Since early 1980's, domestic and industrial water demands in the Kathmandu valley are also being met from this resource to a great extent. Nearly 80 percent of groundwater extraction in Kathmandu valley is for domestic purposes and 33.8 MLD or 45 percent of the municipal water supply was supplied from groundwater source in 1987 (Acres International et al., 2002). Although deep aquifers are tapped for municipal water, individual common households generally use shallow aquifers, because it is easier and cheaper to exploit. In the *Terai*, according to Kansakar (1996), at least 165 MCM of groundwater is extracted annually for domestic purposes from an estimated 800,000 shallow tube wells, and this number is growing every year. But the same shallow aquifers are also being tapped for irrigation use, and the number of shallow irrigation tube wells is also increasing every year, albeit slowly. About 520 MCM is abstracted annually in the *Terai* for irrigation. Although the current level of groundwater abstraction in the *Terai* is small compared to the annual recharge (8,800 MCM), unmanaged growth in irrigation STWs and agricultural development may cause over-extraction (well interference) or pollution in the shallow aquifers. In such situations, the poorest of the poor will be affected the most, because safe and deeper aquifers are out of their reach.

Deep aquifers are generally safe from arsenic, even where the shallow aquifers are found to be contaminated (Bisht et al., 2004). But they are also more expensive to tap. People in arsenic-contaminated groundwater areas are already facing a major problem. No solution has been found that is socially, economically and technologically sustainable. Numerous household level arsenic removal techniques have been developed and tested, but such technologies cannot be the long-term solutions to the arsenic problem, because of low level of awareness, regular maintenance requirements and the recurring cost involved in using these technologies. Locating affordable alternate safe water sources could be the ultimate and long-term solution. The immediate groundwater management need is, therefore, the protection of the known safe aquifers from contamination for future uses and search for safe shallower aquifers in the *Terai.*

Utilization in Irrigation Sector

Irrigation is the other sector where groundwater can find equitable and economic utilization. With a large un-utilized renewable recharge, groundwater in the *Terai* has the potential for playing a central role in poverty reduction and agricultural growth in the country.

Agriculture is the source of livelihood for 86 percent of the population in Nepal. The vast majority of them are small-scale poor farmers. About 31 percent of the population lives below the poverty line. Although the landless population is very small (0.79 percent only), 74.15 percent population has landholding size smaller that 1.0 ha (CBS, 2001/02). Therefore, poverty in Nepal may be attributed mainly to the low agricultural productivity and the unsustainably small landholding sizes (CBS, 2004). Therefore, increasing agricultural productivity could be the key to poverty reduction. Groundwater irrigation can play a central role because it is available in most parts of the *Terai* region. Equitable access to this resource can be achieved through tube well technologies, which can be engineered to suit the farmer's economic capabilities. The main challenge for Nepal is how to improve poor farmers' access to tube well irrigation, without losing control over the groundwater resource exploitation.

Groundwater Management vis-à-vis Tube Well Development in Terai

Policy Environment

Subsidy policy, whether in the form of direct capital cost subsidy or in other indirect forms, plays a vital role not only in groundwater irrigation development but also in resource management. The policy of direct capital cost subsidy and credit facility for the past 20 years, from 1980-2000, was found to actually restrict the growth in STW installations primarily due to the Government's limited capacity to fund. This policy also had a number of undesirable social and economic effects. Studies have shown that the Government's subsidy was consumed mostly by the larger and influential farmers, majority of whom were absentee farmers and were not concerned much about increasing their farm productivity. On the other hand, the small and poor farmers were left out because they could not meet the collateral conditions of the loan program or because they could not afford initial down payment amount or run the tube well profitably due to small land holdings. However, this policy had one advantage; the tube well growth took place in government's full control and the STW growth was well recorded. Such record is highly essential for groundwater management and development planning.

After a policy shift in 2001, the government policy is now to support group-owned shallow tube wells through indirect subsidies like collateral-free group loan and agricultural support programs. But, tube well growth under this program is low, perhaps due to the 'shock effect' from previous years, but also due to the difficulty in forming groups and operating tube wells in groups. As the poor farmers have their lands scattered around, forming a tube well group of 4 ha is quite difficult, and thus this program is proving to be a 'hard nut to bite' for many of the willing small farmers. So, the participants in this program are only a few of the deserving poor and small farmers. According to the government records, only about 2000 STWs have been installed in the *Terai* after this new policy.

Interestingly, however there are no signs in the pump market that the demand has stagnated. The most likely explanation for this is that many farmers are now opting to install tube wells on their own, because the investment on private tube well is attractive enough to offset the 'cost' of having to 'operate in a group'. But, this also means that private STWs outside the government program are growing and will continue to grow faster in the coming years. This is surely going to be a problem for future management because groundwater abstraction data will no more be available.

Socio-economic Environment

The government policies for STW development in Nepal have always tried to address the social issues by technology and economics. A standard STW technology, good for irrigating a minimum of 4 ha plot to become economically viable is being pushed to the farmers, who in majority are small-scale farmers. In the Terai, 74 percent of the households own less than 1.0 ha and 47 percent have less than 0.5 ha of farmland (CBS, 2001/02). For economic viability, the government policy has been to push for group-owned tube wells. But, all small farmers do not have their lands together and moreover, maintaining group cohesion is very difficult. Social conflicts are the main problem in the community STWs, and also in the existing DTWs. It is indicative that 97 percent of the STWs installed during the earlier subsidy policy regime are individually owned, even though a much higher level of subsidy (even up to 85 percent, at one point) was provided for the group tube wells. This trend also is evident in the neighboring South Asian countries, where private STW operators have been the main driving force in bringing the groundwater irrigation development. Hence, utilizing groundwater to lift the numerous small-scale farmers out of poverty is not a straightforward task.

Appropriate Tube Well Technology

For the social conditions mentioned above, and as an alternative to STW, the treadle pump has gained popularity in a short time in Terai. It is a pro-poor and pro-small farmer technology. But, because it requires human labor (Figure 6), this technology places a serious limitation on the farmers' economic growth after a certain point. At present, the only other option available for a successful treadle pump farmer is the standard STW, which is not profitable for his plot size. There is a large section among the *Terai* farmers whose landholdings are between 0.5 ha and 2.0 ha for whom neither a treadle pump nor a standard STW is suitable. Thus, there is a technology gap, which needs to be closed in the benefit of millions of farmers in the *Terai* alone.

Energy for Mechanized Pumping

The electricity distribution network in Nepal serves only 15 percent of the population and 32 percent of the area. Even though the government provides 52 percent subsidy on electricity for irrigation use, very few STW operators have benefited from this policy and almost all STWs are run by diesel. Only 1,050 DTWs are run by electricity only because electrification was built into the project itself, but even those few wells are underutilized because DTW operation is not profitable due to the substantial 'minimum demand charge' on electricity tariff and a relatively much cheaper tariff in neighboring India, which makes their products expensive due to the open door policy between the two nations. Only 29 GWh of electricity was consumed in tube well pumping in the year 2001 (NEA, 2001). This is only 2 percent of the total power consumed (1407 GWh) in that year. The power distribution policy is highly biased towards domestic and industrial consumers, and therefore, STW irrigation does not receive any priority even in the rural electrification programs.

Studies have shown that STW electrification is economically attractive (GDC, 1994), but the initial cost of power connection (Rs. 76,000) is too high for the small farmers to invest. Government has been reluctant to promote STW electrification mainly due to power deficit in the past. Now, with the increased power generation capacity in the country, Nepal has surplus energy, which could be easily supplied to the tube well irrigators. Therefore, a sound national policy is required to utilize and manage both hydroelectricity and groundwater resources, without creating the problems that the neighboring countries are already facing today (see Mehta, this volume).

Water Saving Techniques

Groundwater requires one or another form of energy to be pumped out, and therefore it has a cost. On the other hand, farmers everywhere obtain surface water irrigation more or less free of cost. But ironically, irrigation method and the crops grown are the same whether the source is groundwater or surface water. Naturally, farmers find groundwater irrigation more expensive. However, there are numerous technologies for saving water, for example drip and sprinkler irrigation, but they are seldom used, because those technologies require change in the cropping pattern also. Farmers have been reluctant to bring changes in their irrigation methods and cropping pattern due to inadequate knowledge and limited market. This issue has not received due attention of the planners and the policy makers. Water saving techniques are necessary not only for making groundwater irrigation profitable, but also to minimize stress on the groundwater resource. Success in groundwater management depends on actualizing the slogans of 'more crop per drop' and 'more value from every drop'.

Conclusions

Groundwater development is still in the initial stages in Nepal. There are groundwater resources enough to irrigate nearly one-half of the agricultural land in *Terai*, but they remain largely unutilized. Tube well irrigation can play a central role in poverty alleviation and contribute to improving food security in the country. There are numerous challenges to its development, but even bigger challenges lie in guiding this development towards good groundwater governance. The present approach to groundwater development in Nepal is risky for sustainable groundwater resource management in the long run. Nepal has still time to learn lessons from other countries, especially from the experiences of India, Pakistan, Bangladesh and others, because of similarities in their social, economic and environmental conditions. The groundwater situation in the Kathmandu valley needs to be taken as a 'wake-up call' and should not be ignored.

Different approaches and tools are available for groundwater management, but their effectiveness depends on numerous factors. Solutions that have worked in the post-agrarian industrialized countries may not be suitable for developing countries, where the societies are mainly agrarian in nature. The Government of Nepal is already considering legal mechanisms for groundwater management, but enforcing groundwater regulation is expensive (as in the western countries), or difficult (as in India and China), or even politically impossible (as in India, Pakistan and Bangladesh). Alternatively, various policy measures such as economic incentives, water tariff systems, energy pricing and supply policies, water saving technologies, transparent groundwater monitoring, and so on, may be viable options, and are under discussion in other South Asian countries. But, a deep and thorough understanding of the groundwater socio-ecology is necessary before arriving at workable solutions. A collective effort to bring science into policy discussions by placing alternative approaches to good groundwater governance on the table can only bring this important but vulnerable 'out-of-sight' resource 'into the minds' of the public, the immediate stakeholder, the policy makers and the governments in this region.

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