Mega Integration of Water Cycle and Socio-economics of India

G. N. Kathpalia[1], Rakesh Kapoor[2]

[1]Alternative Futures, B-177, East of Kailash, New Delhi – 110065, India
[2]Alternative Futures, B-177, East of Kailash, New Delhi – 110065, India
Email: gnkathpalia@gmail.com
Telephone: +91 11 41635188

Abstract

In India both land and water are critical natural assets to serve the purpose of socio-economic development. Land area as recorded is 305 mha which includes 195 mha as culturable area and 69 mha as forest area in 1995-96. The balance area is used for other purposes or is barren. The population was 361 million in 1951, increased to 1210 million in 2011 and is currently 1338 million. It may stabilize at approximately 1600 million by 2050. This huge increase in over half a century requires a serious relook at the way we have been planning for water and land till now. The assets related to water include visible water (glaciers, river water, ground water and sea water) and invisible water (soil moisture, vegetation and atmosphere). Each of these elements of water and the interaction between them plays a role to maintain ecosystems and provide water for humankind and animals. This water cycle starts from the sea and through clouds coming over the land with a precipitation of 4000 bcm flows through various rivers to the sea to complete the cycle, after being used for various purposes on land.

The first systematic study of water availability in India in different forms was done by the National Commission on Agriculture from 1972-75. Rainfall was considered for the past 100 years as recorded and its average annual availability was considered with regard to land use for various purposes. A flow chart along with revised precipitation and its flow and utilization upto the sea was made. The actual use in 1970s and projections for 2000 and 2025 were also given. There are shortages of water in various places, from the year 2000 onward because of additional population, urbanization, increased agriculture and industrial activities. Also, excessive pollution makes part of the available water unusable.

In recent decades there has been a decrease in the ground water recharge due to decrease in infiltration because of higher use of irrigated agriculture and mismanagement of forest area. However, in recent years new sources of water such as desalination of sea water have become available through research and reduction in costs. Waste treatment, using appropriate technologies, is another new source or means to produce water. Greater use of solar and wind power as against conventional power plants can also help in more land becoming available for infiltration and recharge of groundwater.

In order to keep groundwater-level sustainable and manageable, it would be necessary that wherever ground water recharge is hindered, it should be recharged through various means - natural and artificial. Climate change in the next few decades is another very important factor to consider. Our paper suggests various policy measures and methods to prevent decrease in groundwater recharge and use of newer sources of water based on modern technologies like desalination.

Keywords: *Groundwater, Socio-economics, Infiltration, Land-use, Recharge, Policy changes*

1. Introduction

Land and water are critical natural assets to serve the purpose of socio-economic development. With India’s population likely to increase to approximately 1600 million by 2050, we need to seriously relook at the way we have been planning for water and land till now. The assets related to water include visible water (glaciers, river water, ground water and sea water) and invisible water (soil moisture, vegetation and atmosphere). Each of these elements of water and the interaction between them plays a role to maintain ecosystems and provide water for humankind and animals.

In recent decades there has been a decrease in the ground water recharge due to decrease in infiltration because of greater prevalence of chemical use in irrigated agriculture, mismanagement of forest area and increase in urbanized area. However, at the same time new sources of water such as desalination of sea water have become available through research, innovation and reduction in costs. Waste treatment, using appropriate technologies, is another new source or means to produce water. Greater use of solar and wind power as against conventional power plants can also help in more land becoming available for infiltration and recharge of groundwater.

In this paper we argue that 'overuse of groundwater' is just one cause or aspect (the demand side) of groundwater loss in India. The other set of causes (the supply side) - and one that is usually not focused on - is the decrease in infiltration due to all kinds of destructive practices and policies. Also, there should be a greater focus on integrating India's water cycle with its socio-economic conditions in a bottom-up or community driven manner with effective monitoring mechanisms at the local as well as national level.

The policymakers have to focus on what the situation will be like in 2050, based on a thorough knowledge of the changes that have taken place and the problems that have cropped up during the last three decades. We conclude our paper by suggesting various policy measures and methods to prevent decrease in groundwater recharge and use of newer sources of water based on modern technologies like desalination. We suggest that by adopting these policy changes in earnest an undesirable 'business-as-usual' scenario can be avoided.

2. Causes of Decrease in Groundwater Recharge

The criticality of groundwater in the Indian subcontinent can be easily fathomed by the fact that it provides 60% of the total water used for irrigation and 80% for human and animal consumption. Over the years, there has been a steady decline in India's groundwater resources. In a span of one year from January 2015 to January 2016, the Central Groundwater Board recorded a decline of 2 metres in its monitoring wells (India Water Partnership, 2016). The Board also reported 64% of groundwater blocks in India as over-exploited. But over-use of groundwater has been well-documented and reported across academia and news media.

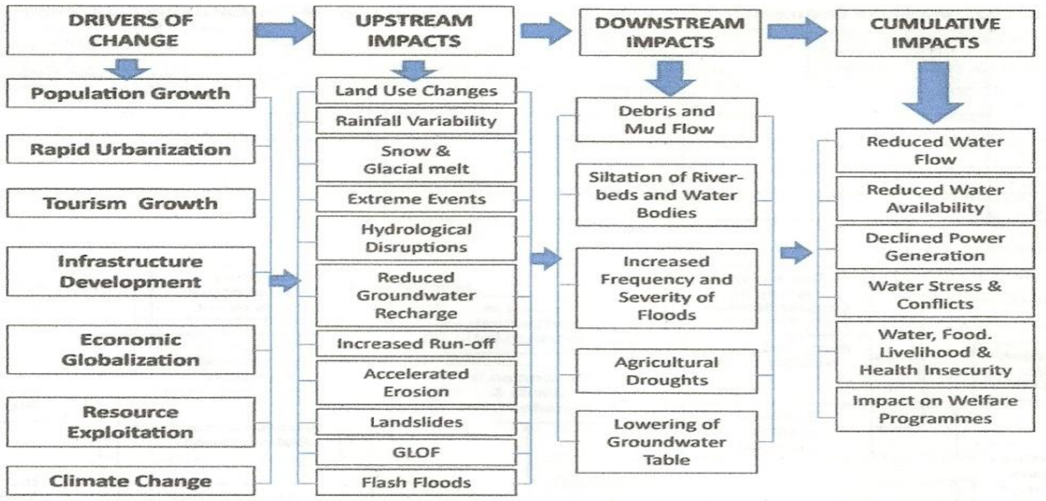
What is under-reported is the severity of the problems with natural groundwater recharge processes. About 65% of India's aquifers are hard rock aquifers lying in peninsular regions of the country. The hard rock formations are a natural hindrance for groundwater recharge owing to low permeability. Water level in these aquifers tends to drop rapidly once the water table falls more than 2-6 metres and low permeability means there is limited recharge through rainwater (Suhag, 2016). Over-exploitation may lead these aquifers to eventually dry out. The northern plains of the country have significantly better natural storage spaces owing to alluvial soil. But even there, excessive groundwater extraction and increasingly low recharge rates have put the aquifers at risk of drying out.

Notwithstanding the nature of the country's aquifers, some key changes over the years have drastically reduced natural groundwater infiltration across the country:

<u>Destructive practices in the Northern Hills</u>

A 2015 Kumaon University study on natural springs in Uttarakhand reported that 37% of natural springs in the state were drying up. These springs are part of a network of aquifers that contribute upto 90% of water to the Ganga (Chakravartty, 2015). In Almora district, over a span of 150 years the number of natural springs has gone from 360 to 60, with the rest now becoming seasonal. Tiwari and Joshi (2014) have discussed environmental degradation and its impact on rural water, food, livelihood and health in their study in the upper catchment of the Kosi River, one of the most densely populated regions of Uttarakhand. Their study reveals that land use changes over a period of 30 years have led to drastic changes in water generation from land to springs and streams with 33% of natural springs and a staggering 736 km length of streams now dried up. This has led to an overall negative impact not just on the availability of water, but also biomass and other resources for which the local population was traditionally dependent on forests in the region. The cumulative impact (see Figure 1 below) of these processes, as the study notes, has been a decrease in the overall quality of life of the people in the region in terms of livelihood, health, and food security which has exacerbated out-migration of enterprising youth to the plains.

Figure 1 - Environmental changes in Himalayas: Upstream and Downstream Impacts (Tiwari and Joshi, 2014)



One of the core reasons for such rapidly dying underground water resources, other than decreasing overall forest cover, is the spread of commercially important Chir pine throughout the lower Himalayas. Introduced by the British as its resin added significantly to the state revenue, the Chir pine spread like wild fire over the years and replaced the native Himalayan Oak or Banj. This was helped further by the forest department's policy of commercializing the forests for revenue, more so since the 1970s. Now covering up to 16% of the forested land in the state of Uttarakhand, the pine not only soaks up moisture from the ground but also contributes to the acidity of the soil (Sharma, 2016). Although it is a good source of wood and charcoal, pine combs and needles burn easily. Just in the year 2016, 4,000ha of forest area was destroyed from the burning of pines. On the other hand the broadleaf Oak, preferred by locals as it gives better firewood, prevents erosion, and enhances groundwater infiltration, is now shrinking in cover.

Rapid Urbanisation

Unregulated urbanisation across states has meant that there is high surface run-off and less recharge of groundwater. In states like Delhi, Haryana, Punjab, and Rajasthan, groundwater development is more than 100% (Suhag, 2016). This means that the annual groundwater consumption exceeds the annual groundwater recharge in all of these states. All of these states have rapidly developing urban agglomerations with large areas covered by paved roads, buildings, etc. and high rates of deforestation as the urban centres expand. Deforested land is devoid of forest litter which absorbs rainwater and restricts rapid runoff. It also has high rates of transpiration. Thus urban, deforested land has low rates of infiltration of rainwater into the ground. This gets coupled with high groundwater extraction rates as 50% of urban water requirements are met through groundwater extraction by borewells (Suhag, 2016). This, when there is greater utilizable surface water in India as compared to groundwater – the total annual utilizable surface water is 690 BCM while the total annual replenishable groundwater potential is 433BM (CWC, 2015). One issue is that in India the owner of a piece of land holds the right to the water under it which makes it more prone to overuse due to ease of access (Suhag, 2016). The destruction of wetlands is yet another problem in major Indian cities that is associated by various studies with rapid urbanisation. The destruction of wetlands directly affects the flood channels of a city and the recharge of underground aquifers. In Delhi, a 2011 study found that due to heavy encroachment 232 out of 629 identified water bodies are beyond the threshold of possible revival, meaning they are practically dead. A similar study by Indian Institute of Science in Bengaluru found that the number of water bodies in and around the city had reduced from 207 in 1973 to 93 in 2010 (Ahmad, 2017). One needs to note that the urban population in India is estimated to expand by the year 2031 to 600 million (and well over 800 million by the year 2050), which will by all means, lead to further encroachment of wetlands.

Ingress of sea water into ground due to overuse in coastal areas

There aren't many studies available on the overall impact of groundwater overuse in coastal areas. However, ingress of sea water increases into inland underground aquifers as more and more groundwater is pumped out along coastal areas which leads to contamination of underground freshwater aquifers by saline water and ultimately to the pollution of fresh water streams and wells. A 2017 report published in The Hindu claims that out of 152 block panchayats in the state of Kerala, 22 have been marked as 'semi-critical' in terms of groundwater development while 50 blocks have more than 70% groundwater development (Pillai, 2017). This indicates an increased annual groundwater consumption vis-à-vis the annual groundwater recharge. In areas with mangroves, like Sunderbans, the situation is even more alarming. A study by the School of Oceanographic studies at Jadavpur University reported that more than 124 km^2 of mangroves in the Sunderbans delta were eroded between 1986 and 2012 (Singh, 2017). Whether groundwater use had any role to play in this is certainly not something one can comment on as of now but the authors of the study did point out that there was less and less fresh water flow and supply of sediment in the Indian part of the delta. The point here is that a lack of fresh water flow near coastal areas can significantly alter the local ecosystem services available in these areas, in this case, those offered by the mangroves.

Dependence on groundwater for irrigation

Net sown area in 2011-12 was 140.8 million hectares (mha) out of which the rainfed area was 75.5 mha and the net irrigated area was 65.3 mha. Groundwater use for irrigation at present is 222 BCM against the groundwater resources of 431 BCM (Ambast, 2017). Since the 1950s, the use of groundwater for irrigation has been increasing (see Figure 2 below). The main thrust for use of groundwater for irrigation was after the big drought in North India in 1967-68 and import of wheat from USA. This encouraged research into improving wheat and mustard seeds. The second major thrust for more use of groundwater started in the 90s when subsidized electricity and water were given in the northern states of Punjab, Haryana and Western UP which led to double cropping of rice and wheat. This has continued over the years leading to increased use of groundwater even though groundwater recharge has decreased. Table 1 below, from Tyagi (2017) gives the status and projections for relative development of surface water versus groundwater development in India over the period 2000 to 2050.

Figure 2 - Increase in ground water utilization for irrigation (Suhag, 2016):

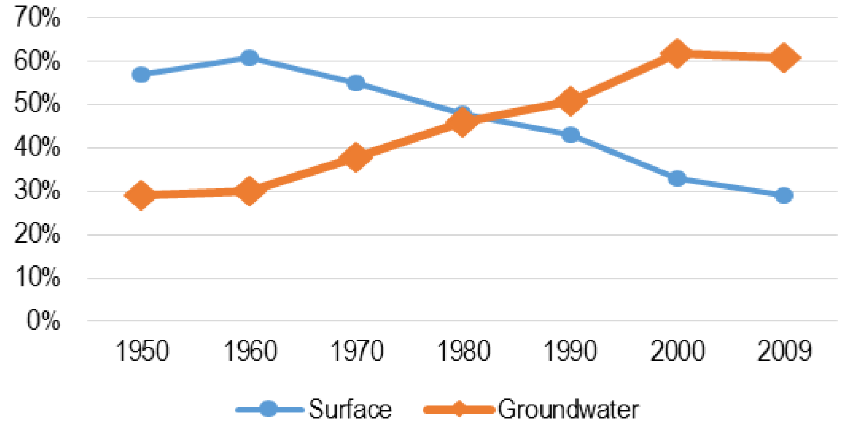


Table 1: Status and Projections for water resource development in India

Item	Level of development (BCM)		
	2000 (Ultimate)	2010	2050
Surface water	360 (690)	404	647
Groundwater	210 (396)	260	396

3. Groundwater Pollution

A 2015 CPCB report stated that the total sewage generated in Indian cities was 57233 MLD against a treatment capacity of 21478 MLD of the STPs currently in function (Mohan, 2015). The deficit thus goes into rivers and aquifers untreated. Improper waste disposal practices have thus led to increased groundwater contamination. The case of Bathinda and other towns in the Malwa belt of Punjab received much attention some years ago when the then union minister Jairam Ramesh confirmed the presence of Uranium and other heavy metals in the groundwater of this region (The Hindu, 2012). The story was accompanied by details of a cancer 'epidemic' and children being born with abnormalities in this region. The presence of such heavy metals was connected by some environmentalists with increased use of pesticides and agro-chemicals, while others blamed thermal power plants. One study claimed that about 37% of groundwater in South Asia contained Arsenic at toxic concentrations (MacDonald et al, 2016). Another issue which is related mostly to urban waste disposal is that due to increased population, the total solid waste generation has significantly increased. Delhi alone generates 7000 metric tons of municipal solid waste daily, 90% of which is disposed off at landfills. Studies carried out at landfill sites in different cities all reveal that groundwater in and around such areas is usually unfit for domestic purposes as the leachate from solid waste deposited in the landfills percolates through soil and renders the underground aquifers contaminated (Rajkumar et al, 2010; Gupta and Rani, 2014; Rajendra and Ramu, 2016).

4. Remedial Actions

(a) As discussed above in section 2, the infiltration rate in forest areas has decreased and the flow from springs for normal use has also stopped. This has happened due to poor watershed management, monitoring and maintenance upstream of the forest area and the forest area itself. The mechanisms for terracing and gully plugging along with other improved methods should be tried. This practice has been conventionally followed by farmers. Earlier, the forest department used to follow this method to conserve water for groundwater recharge but gave it up in the past two to three decades with change in the composition of forests. If the practice of terracing and bund-*ing* is restored, even during heavy rainfall run-off can be decreased, thus allowing infiltration for a longer period. This would slow down the surface flow and reduce the intensity of flooding to some extent apart from ensuring groundwater recharge.

(b) At present there is a great emphasis on generating hydel-power which is mostly exported down to the cities and industries. This damages the mountains and the forests, hinders the recharge of groundwater, and disturbs the flow of water in the rivers. To minimize ecological damage, it would be better to generate hydel-power in small quantities on tributaries, wherever possible, for local power supply. The emphasis should be more on solar power and wind power wherever possible.

(c) A comprehensive land-use policy, taking into account both natural and socio-economic parameters, is imperative for restoring ecological services and attaining community sustainability in the entire Himalayan region. There should be a proper plan for development of the Himalayas at various levels from J&K to Arunachal Pradesh. The major activities would be security for the border with China and their socio-economic development through tourism, people going for pilgrimage, growing medicinal plants, fruits and vegetables and their processing, while keeping in view the ecology, environment and means of livelihood. This would encourage the families to stay there rather than men migrating to plains for better jobs. This would require education, medical and health facilities, IT and all infrastructural facilities as available in a small town along with an effective public distribution system.

(d) There should be a regulatory and monitoring body for ecologically and geologically sensitive areas that should assess and plan for all land and water use in these areas. To achieve the safety and protection of ecology of the mountains, the number of people travelling should be limited and regulated. Also, it would be necessary to build more tunnels instead of more roads along the edge of the mountains to avoid landslides. This would also reduce the time for travel and save fuel, which would be very helpful in the long run and reduce fuel as well as maintenance costs.

(e) Similar plans would have to be made for the forest areas from Gujarat to Odisha and the North-east as well as for the Eastern and Western Ghats where mining is a major industry and a source of livelihood, but also contributes to groundwater contamination. Rat-hole coal mining in Meghalaya, though banned by the NGT in 2014, caused water and soil contamination through the Acid Mine Drainage that was pumped out of the mines (CPCB, 2015). Several other studies across the country also reveal the contamination of groundwater caused by mining. A study on opencast limestone mining in the Katni river watershed in Madhya Pradesh compared groundwater samples from the year 1995 and 2006 to reveal that the total hardness and calcium content of the water had significantly increased (Bhatnagar et al, 2014). Another study on Barite Mining in Andhra Pradesh revealed that drinking water wells in the mined areas had high sulphate concentrations (211-589 mg/L) as compared to the non-mined areas (25 mg/L), thus directly connecting groundwater contamination with mining (Suresh et al, 2007). In many such areas, tribal people are dependent on forests for their livelihood which are wiped out once mining operations start. Special efforts have to be made to ensure that tribals have alternative means of livelihood. They should also be allowed to continue to collect small products from the forest area and provided with better marketing facilities.

(f) The average water and energy foot prints of crops in India are given below in Table 2. It is required that the relevant crops and the water allocated should be on agricultural zone basis taking into account, rainfall, surface water and groundwater, so that they can economize on groundwater use besides improving the efficiency of water use and agronomic practices. As Tyagi (2017) writes, "The guiding principles for building resilience in water resources systems are based on limiting water as renewable supply, adaptive allocation, transparent water markets and maintenance of environmental flows" (Tyagi, 2017).

Table 2: Average water and energy foot prints of crops in India (Tyagi, 2017)

Crops	**Global average water foot prints, (m^3/t)**	**Average water foot print in India (m^3/t)**	**Average energy foot print in India (MJ/t)**
Paddy	1673	2070	6317
Wheat	1827	2100	5322
Maize	1222	2537	4847
Potatoes	287	291	1690
Sugarcane	3048	6026	888
Rapeseed	2271	3398	7574
Seed cotton	4029	9321	19785

(g) Another remedial action required is the consolidation of small holdings. There are comparatively small holdings which are difficult to manage for any major crop purposes. Some people give this land on lease to another person with a bigger land holding on sharing basis while they themselves work elsewhere. In some cases, enterprising people get together 30-40 land holders with adjoining land (about 40ha) to form a group of their own. They take decisions based on consensus with regards to cropping pattern, purchase or renting machinery required and other inputs. Since their operational holding now becomes above 40ha, they can bargain for cheaper inputs. These have come up in Punjab and Maharashtra due to local leadership. This also helps them to sell their product to a larger party at a higher price at their own fields. They can also integrate the water from rainfall, groundwater and surface water. Thus, they are able to save water and also decide on less water-intensive crops during drought. Such groups can also join together for a better deal with the buyers and sellers. They can be encouraged to use groundwater more efficiently with better water harvesting and better watershed management. The levels of groundwater are lowest in the month of May and highest in October, after the monsoon has withdrawn in North-West India. The gain in groundwater level can be measured by the Panchayats and checked through satellite, if necessary, for giving incentives. These dates may vary according to the location and other factors.

(h) Various types of waste are generated in urban and rural areas. Many types of machinery and methods are available at present to convert waste into useful products, to generate wealth, and save water and land. The objective is to deal with each type of waste, i.e. sewage, organic waste, electronic waste and industrial waste. In rural areas agriculture waste mainly consists of organic waste and the raw material left after harvesting. Each one has to be so treated that it can produce usable water for biogas, manure, electric power, etc. leaving no waste on the land. In the urban and industrial areas, this can be done by municipal or city organisations with a regular trained staff engaged at the time of construction or long term lease given to private contractors. In the rural areas, the Panchayat and Gram Sabhas can keep qualified and trained staff separately for this purpose which would take care of disposal and cleaning of septic tanks, etc.

(i) Desalinization with improved research and machinery has become cheaper which means that desalinized water can now be used for any purpose. Desalinization plants can be set up at all the ports along India's coasts. So far, at various places ingress of sea water used to pollute the groundwater. But now this can be stopped by desalinized water being used for industry and urban requirements, thus, saving the groundwater for upland use.

(j) A general policy should be to use water harvesting and solar/wind energy wherever possible for groundwater extraction and other purposes, especially in rural areas, so as to save the cost of transmission and distribution, and provide self sufficiency.

5. Artificial Groundwater Recharge in India

The Central Groundwater Board came out with a Master Plan for artificial recharge of groundwater back in 2013, as part of which 1.11 Crore artificial recharge structures were proposed to be constructed in urban as well rural areas at an estimated cost of INR 79,178 Crore in a phased manner over a period of 10 years (CGWB, 2013). The plan envisaged construction of 88 lakh recharge structures for utilizing roof top rain water and 23 lakh structures for conserving non-committed surplus run-off. It was based on assessment of groundwater in a 23 lakh km^2 area identified according to the level of groundwater development and water tables as safe, semi-critical, critical, over-exploited, and saline. The most over-exploited areas were found in regions of Punjab, Haryana, Delhi, Western Uttar Pradesh, Rajasthan, Gujarat, Karnataka, Andhra Pradesh, and Tamil Nadu. The Master Plan had two main predecessors,

a) The 1996 "National perspective plan for Recharge to Groundwater by utilizing Surplus Monsoon run-off" which served as a conceptual framework for utilization of surplus monsoon run-off. The plan estimated that a possible 21.4 million hectare metre of surplus monsoon run-off could be stored as groundwater reservoir.
b) The 2002 Master Plan for Artificial Recharge to Groundwater under which construction of 39 lakh artificial recharge structures was proposed at a cost of INR 24,500 Crore. Various state agencies took up construction of such structures as part of state and central schemes as proposed by the plan.

The Master Plan had proposed various types of artificial recharge structures such as, check dams, gabion structures, gully plugs, nala bunds, percolation tanks, sub-surface dykes, etc. to be constructed based on the specific need of a particular area.

The importance of implementing these plans can be judged by the fact that between 2009 and 2011, the number of over-exploited units mapped by the CGWB rose from 802 to 1071. The CGWB Master Plan 2013 stated clearly that

"Proliferation of ground water development by stakeholders of various sectors has resulted in water scarcity, quality deterioration and other related development problems in many areas of the country."

But three years later, in a report of a Parliamentary committee submitted in December 2016, it was revealed that only six states had taken up construction of such structures. Out of the six states, only three – Uttar Pradesh, Gujarat, and Karnataka – are the ones actually identified as having regions with over-exploited groundwater or what the CGWB calls the "dark units" (Mohan, 2017). Though fresh data on the number of such structures completed four years after the Master Plan is awaited, there are some case studies from past initiatives that point to the urgency with which artificial ground water recharge should be adopted in India.

Moti Rayan and Bhujpur Area, Kutch District, Gujarat
"A total of 18 Check dams, 3 percolation ponds, two recharge wells and one sub surface dam with four recharge wells were constructed in this area to augment groundwater recharge. During the year 1994, there were 34 rainy days from June 30th to September 15th. The daily rainfall varied from 1 mm to 175 mm. The number of rainy days in June, July, August and September were 1, 8, 6 and 9 days respectively. The water harvesting structures received around 2 fillings and total quantity infiltrated amounted to 344.664 m3. This indicates that even during low rainfall years, ground water can be recharged through water harvesting structures." (CGWB, 2000)

Gujra Sub-Watershed, Durg, Chhattisgarh
"A total of 23 masonry stop dams, 12 percolation tanks, 25 boulder check dams, and 13 nala bunds were constructed while 28 ponds were de-silted under the project. A set of 8 observation wells were established in the watershed to monitor the effect of the project. During the first three years (2001-2004), pre-monsoon water levels were in the range of 17 to 31m in all the observation wells, while for the next three years (2005-2008) they remained within 5 to 13m. For the post monsoon period, water levels recorded in the initial two years were in the range of 14 to 23m which improved in the last 3 years to be in the range of 2 to 6m. Due to rise in water levels, the dug wells in the area, which were rendered useless prior to the implementation of the project because of lowering water levels, got revived. This resulted in improvement of soil moisture conditions and agricultural production." (CGWB, 2011)

6. Priority Policy Changes Required

1. Conversion of all types of waste should be taken up with urgency. The different types of waste collected in rural and urban areas cause pollution of land, water and air. This not only affects the health of the population in general but also has an adverse impact on the economic empowerment of the underprivileged. It is of utmost importance to address this through the use of new technologies that can convert waste into various useful products including potable water, thereby generating income and saving land and water from contamination.

2. Removal of subsidies for use of energy and water for agriculture where most of the water (especially groundwater) and land is used. Such populist and tactical measures

worsen the over-exploitation of groundwater for agriculture. The export of sugar and normal rice should also be regulated, as it is virtual export of land and water.

3. Assessment of actual land use and water availability from 1975 to 2015 should be undertaken. Projections for land and water use with climate change possibilities should then be considered along with the incorporation of data on increase in actual requirements of various kinds for the next 30 years. New and cheaper technologies now available including desalination of brackish water on land should be utilized and invested in as part of immediate steps.

4. A separate monitoring organisation is required for managing the river and all its activities like: pollution, flow and velocity of water and its quantity, according to agreed contribution by each state. The information in these matters to be collected and distributed to various authorities dealing with it for their functional operations. The authority should also have the power to take action against the defaulters.

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