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Irrigation and Groundwater Hazards in India

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Abstract

Today India is the top groundwater consumer (231bcm) in the world. With the spread of Green Revolution emphasis on irrigation source has slowly been shifted from canal to groundwater. In arid- semi arid regions of Punjab, Haryana, Rajasthan groundwater development is very high (>100%) followed by Gujarat and Tamil Nadu. Thus overextraction of groundwater in drier parts of the country has led to decline of groundwater table and consequent emergence of many critical blocks and overexploited blocks in those areas. It causes crisis of drinking water during summer, disfunctioning of shallow tubewells, local land subsidence and saline water intrusion to aquifer in coastal areas etc. To cope with lowering water table situation the big farmers replace shallow pumpsets by submersible pumps and small farmers who depend on them are exploited in groundwater market. Inland soil salinity and water logging in canal irrigated arid, semi-arid regions of Punjab, Haryana and Rajasthan are other environmental problems. Lowering of water table also causes degradation of groundwater quality like arsenic pollution, fluoride pollution etc. So it's high time to control groundwater irrigation by through dry crop cultivation, conjunctive use of surface water and groundwater irrigation and by strictly following the existing water laws of the country. Then only sustainable agricultural development is possible and hazards can be minimised.

Key Words: *Groundwater hazards, over extraction, water logging*

1. Introduction

One of the important natural resource of human civilization is water resource. The next world war is apprehended to be held due to crisis of water and right on water resources. With the expansion of agricultural, industrial and urban developmental activities demand of water increases. Today India has second largest population and she is the top consumer of groundwater in the world. Though world's highest rainfall occur in India, the rainfall is not equally distributed all over the country and there is uncertainty to the onset and withdrawn of monsoon. So farmers often have to depend on irrigation. It is to be mentioned that though India is rich in atmospheric water and surface water, about 90% of total groundwater extraction is used in irrigation purposes. Thick alluvial cover of Great Northern Plain in India is rich in groundwater resource. To the western part of this plain noticeable agricultural development and prevailing arid and semi-arid climatic condition demand much water and groundwater augments this need to a great extent. Groundwater has great agricultural importance in the semi-arid zones of peninsular India also. After Green Revolution demand of groundwater has increased as a whole in different parts of the country. All over the urban development altogether are responsible for declining groundwater resource and acute water crisis. With her huge population, rapid urbanization and developmental activities India is also facing the same problem of water crisis and inviting chain of environmental hazards in consequence. So it's necessary to analyse the problem and find out the escape route.

2. Objectives

Objectives of this paper are:

i) To study the scenario of irrigation development in India.

ii) To study the status of groundwater blocks in various states of India.

iii) To study the hazards related to overirrigation.

iv) To find out the possible remedies of the hazards caused by overirrigation.

3. Data Source and Methodology

Data has been collected from Groundwater Yearbook, India, 2011-12, published by Central Groundwater Board (CGWB), India. Source-wise irrigation in India after independence (1950-51 to 2002-03), state-wise status of groundwater blocks (2009) and state-wise groundwater development situation and groundwater budgets have been analysed. The entire study is based on secondary data analysis. To study the spatial impact of overirrigation and lowering of water table in various parts of the country the author has gone through literature survey.

4. Discussion

4.1 History of Irrigation in India after Independence

Agricultural development in India initially was based on rainfall and surface water irrigation sources like rivers, tanks and ponds. Role of canal irrigation became significant in Indian agricultural scenario after Independence and that of groundwater irrigation after Green Revolution. Uttar Pradesh, Madhya Pradesh, Andhra Pradesh, Punjab, Rajasthan and Haryana are major sharers of total canal irrigated area in the country. Canal irrigation is also wellknown in Bihar, Orissa, Karnataka, Tamil Nadu and West Bengal. Since Green Revolution demand of water in agricultural sector has largely been increased due to the use of HYV seeds and chemical fertilizers and thus expansion of groundwater irrigation has become inevitable both in the areas within and outside canal-command areas.

Table.1 : Source-wise Irrigation, India (1950-51—2002-03)

Year	Canal (m.ha)	Tank	GW (well & TW) in m.ha	Others	NIA	GIA
1950-1	8.30 (40.3%)	3.61	5.98 (29.04%)	2.97	20.58	22.56
1960-1	10.37 (42.05%)	4.56	7.29 (29.56%)	2.44	24.66	27.98
1970-1	12.84 (41.28%)	4.11	11.89 (38.22%)	2.27	31.10	38.20
1980-1	15.29 (39.49%)	3.18	17.70 (45.70%)	2.55	37.72	49.78
1990-1	17.45 (36.34%)	2.94	24.70 (51.42%)	2.93	48.02	63.02
2002-3	16.34 (29.25%)	2.29	34.50 (61.77%)	2.73	55.85	78.33

Source: A. Narayanamoorthy. Trends in Irrigated Area in India: 1950-51 to 2002-03

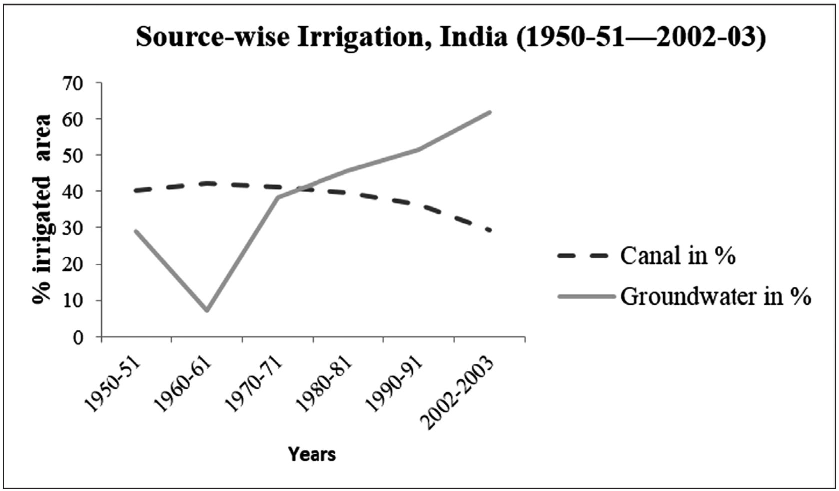

Fig. 1 : Source-wise Irrigation, India (1950-51—2002-03)

Table.1, (Fig. 1) shows that groundwater irrigation in India has increased from mere 5.98 mha in 1950-1 to 34.5 mha in 2002-3. The gap between net irrigated area and gross irrigated area has also been widened noticeably over last 50 years. Irrigation intensity has increased from 109.62% (1950-1) to 140.25% (2002-3). From 1950-1 to 2002-3 net canal irrigated area has become doubled, but its share has been decreased from 40.3% to 29.25%. Contrarily net groundwater irrigated area has increased nearly six times and its share has been doubled increasing from 29.04% to 61.77%. Tank and other surface water irrigation sources remain almost unchanged serving 5-6 mha throughout the time period and their share has decreased from 31% to 9%. Though groundwater irrigation is costlier, since last few decades it has been showing its growing importance in Indian agricultural scenario over canal irrigation. Canal irrigation is monsoon-dependent. It is available only along the lines of canals and is less effective at the tail ends of canals. Contrarily, groundwater irrigation is ubiquitous in nature and can be available at every piece of land throughout the year except in areas of crystalline rock. Therefore both small farmers and big farmers prefer groundwater irrigation to surface water irrigation.

4.2 Status of Groundwater Development in India

Today India is the top groundwater consumer in the world. The country receives an annual groundwater recharge of 431.03 bcm from rainfall and other sources like unlined canals, water bodies, irrigated fields etc. Of this 396.06 bcm is net available groundwater after the natural discharge, and the country annually withdraws 243.32 bcm groundwater for irrigation, domestic and industrial purposes. Thus at present the status of groundwater development in India (2009) is 61% and irrigation shares 90.9% of the total groundwater draft in the country. In 14 out of 18 major states of India irrigation shares 85%- 95% of the total groundwater extraction. Groundwater irrigation has less importance only in urbanized Delhi, Goa and Kerala and in the hilly terrains of North-Eastern India, Jammu & Kashmir, Himachal Pradesh and Jharkhand. In Punjab 98% of groundwater is shared by irrigation sector. The status of groundwater development (Table: 2, Fig. 2) in India is also highest in Punjab (170%), followed by Delhi (138%), Rajasthan (135%) and Haryana (127%). However groundwater in Delhi is used mainly in urban-and industrial sectors. The status of groundwater development in Tamil Nadu (80%), Gujarat (75%), Uttar Pradesh and Karnataka is also higher than national average (61%). Contrarily groundwater development status is low to very low (<40%) in Jharkhand (30%), Chhattisgarh (31%), Orissa and hilly states of North West and North East India. It's low to moderately developed (40%-60%) and also below the national average in rest of the country, e.g., rainfall rich Eastern India; Bihar (43%), West Bengal (40%), rocky Central and Southern India; Andhra Pradesh (46%), Madhya Pradesh (56%), Maharashtra (50%), Kerala (47%) and in hilly states of Himachal Pradesh (58%) and Uttarakhand (51%). Among these states however some districts of Andhra Pradesh (6), Madhya Pradesh (16), Maharashtra (9), Kerala (1), Himachal Pradesh (1) and West Bengal (2) experience >70% groundwater development (CGWB, 2012).

Table 2 : State-wise Groundwater Resource and its Development in India, 2008-09

Sl No.	States	Replenishable BCM	Available BCM	Draft irrigation BCM	Draft Total BCM	% GW Development
1	Punjab	22.56	20.35	33.97	34.66	170
2	Delhi	0.31	0.29	0.14	0.4	138
3	Rajasthan	11.86	10.79	12.86	14.52	135
4	Haryana	10.48	9.8	11.71	12.43	127
5	Tamil Nadu	22.94	20.65	14.71	16.56	80
6	Gujarat	18.43	17.35	11.93	12.99	75
7	Uttar Pradesh	75.25	68.57	46.00	49.48	72
8	Karnataka	16.81	14.81	9.01	10.01	68
	India	**431.03**	**396.06**	**221.42**	**241.66**	**61**
9	Himachal Pradesh	0.59	0.53	0.23	0.31	58
10	Madhya Pradesh	33.95	32.25	16.66	17.99	56
11	Uttarakhand	2.17	2.07	1.01	1.05	51
12	Maharashtra	35.73	33.8	15.91	16.95	50
13	Kerala	6.62	6.03	01.30	2.81	47
14	Andhra Pradesh	33.83	30.76	12.61	14.15	46
15	Bihar	28.63	26.21	9.79	11.36	43
16	West Bengal	30.50	27.58	10.11	10.91	40
17	Goa	0.221	0.133	0.014	0.082	33
18	Chhattisgarh	12.22	11.58	3.08	3.6	31
19	Jharkhand	5.96	5.41	1.17	1.61	30
20	Orissa	17.78	16.69	3.47	4.36	26
21	Assam	30.35	27.81	5.33	6.026	22
22	Jammu & Kashmir	3.7	3.33	0.15	0.73	22
23	Sikkim	-	0.046	0.003	0.010	21
24	Tripura	2.97	2.74	0.09	0.16	06
25	Nagaland	0.42	0.38	-	0.008	2.14
26	Manipur	0.44	0.4	0.0033	0.004	1
27	Mizoram	0.044	0.039	0000	0.0004	1
28	Meghalaya	1.2343	1.1109	0.0015	0.0017	0.15
29	Arunachal Pradesh	4.45	4.01	0.002	0.003	0.07

Source : Central Groundwater Board, Ground Water Year Book – India, 2011-12

Fig.-2

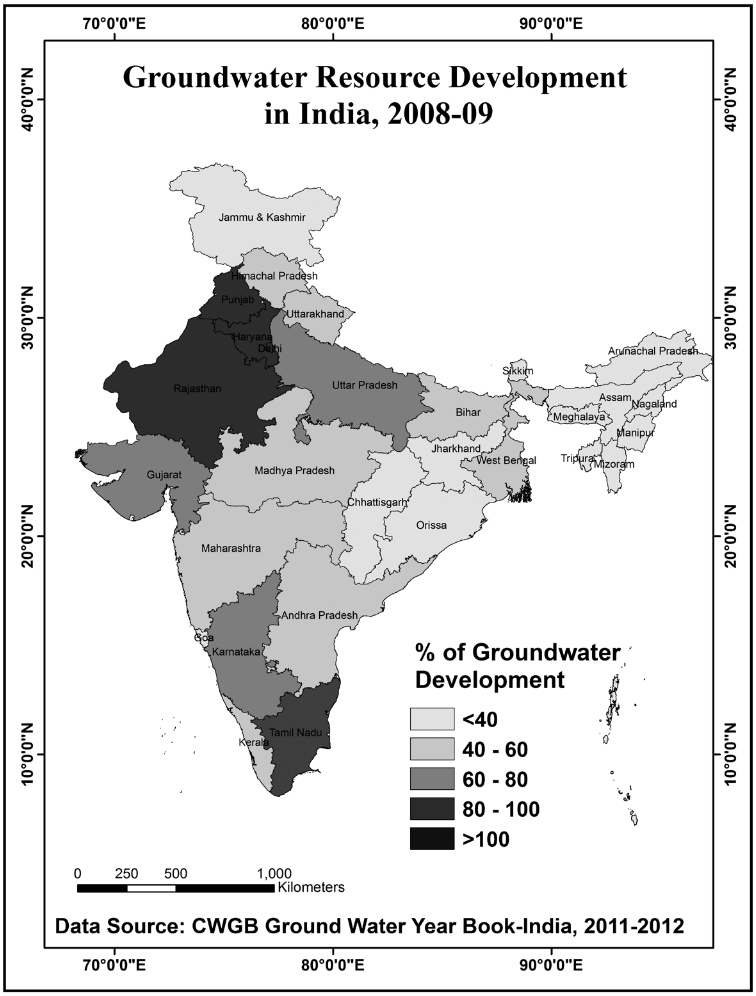

Fig. 2 : Groundwater Resource Development in India, 2008-09

4.3 Status of Groundwater Blocks in India

Overdevelopment of groundwater resource in Punjab, Rajasthan, Haryana and Delhi has led to depletion of groundwater resource in these states. According to CGWB (CGWB, 2012) all the districts of Punjab except Muktsar experience negative availability of groundwater for future irrigation use. Negative groundwater availability has also been experienced by 60% districts of Haryana and 25% districts of Tamil Nadu. In five districts of Rajasthan future groundwater irrigation availability has reached to zero level. Thus number of critical blocks and overexploited blocks are also higher in these states where 90% - 100% or >100% of annual groundwater recharge has been exhausted with continuous lowering of pre-monsoon and/or post monsoon water table (Table: 3). Overexploited blocks and critical blocks together hold 80% blocks of Punjab. Punjab is closely followed by Haryana, Rajasthan and Delhi (74%-79% blocks). Along with them percentages of critical and over exploited bocks to the state's assessed blocks are also above the national average (17%) in Tamil Nadu (45%), Karnataka (30%) and Himachal Pradesh (26%) only (Table. 4, Fig.3). Presence of critical blocks and overexploited blocks is much less (<20%) in Uttar Pradesh, Uttarakhand, Gujarat, Andhra Pradesh, Madhya Pradesh, Jharkhand, Maharashtra and Kerala, along with some semi-critical blocks (10%-15%) there. In India there are 71 salinity blocks found mainly in coastal areas.

Table 3 : Category of Groundwater Blocks in India, 2009

Stage of Ground Water Development	**Significant Long Term Water level Decline trend**		**Category***	**No. of blocks in India (5842)**	**% blocks**
	Pre-Monsoon	**Post-Monsoon**			
<=90%	No	No	Safe	4277	73.2
>70% and <=100%	Yes	No	Semi-critical	523	9
>70% and <=100%	No	Yes	Semi-critical		
>90% and <=100%	Yes	Yes	Critical	169	3
>100%	No	Yes	Over-Exploited	802	14
>100%	Yes	No	Over-Exploited		
>100%	Yes	Yes	Over-Exploited		

* Category criteria given by CGWB
Data Source: CGWB, Groundwater Yearbook, 2011-2012

Table 4 : Status of Groundwater Blocks in India, 2009

Sl No.	States	No. Assessed Blocks	Safe Blocks		Semi critical Blocks		Critical Blocks		Overexploited Blocks		Critical + Over exploited Blocks	
			No.	%	No.	%	No.	%	No.	%	No.	%
1	Punjab	138	23	17	2	1	3	2	110	80	113	82
2	Delhi	27	2	7	5	19			20	74	20	74
3	Rajasthan	239	31	13	16	7	25	10	166	69	191	79
4	Haryana	116	18	16	9	8	21	18	68	59	89	77
5	Tamil Nadu	386	136	35	67	17	33	9	139	36	172	45

6	Gujarat	233	156	70	20	9	6	3	27	12	33	15
7	Uttar Pradesh	820	605	74	107	13	32	4	76	9	108	13
8	Karnataka	270	154	57	34	13	11	4	71	26	82	30
	India	5792	4235	73	518	9	169	3	800	14	969	17
9	Himachal Pradesh	8	6	75			1	13	1	13	2	26
10	Madhya Pradesh	313	224	72	61	19	4	1	24	8	28	9
11	Uttarakhand	17	11	65	5	29	1	6			1	6
12	Maharashtra	353	324	92	19	5	1	0	9	3	10	3
13	Kerala	152	126	83	22	14	3	2	1	1	4	3
14	Andhra Pradesh	1108	867	78	93	8	26	2	84	8	110	10
15	Bihar	533	529	99	4	1						0
16	West Bengal	269	231	86	38	14						0
17	Goa	11	11	100								0
18	Chhattisgarh	146	132	90	14	10						0
19	Jharkhand	208	200	96	2	1	2	1	4	2	6	3
20	Orissa	314	308	98								0
21	Assam	23	23	100								0
22	Jammu & Kashmir	14	14	100								0
23	Sikkim	4	4	100								0
24	Tripura	39	39	100								0
25	Nagaland	8	8	100								0
26	Manipur	8	8	100								0
27	Mizoram	22	22	100								0
28	Meghalaya	7	7	100								0
29	Arunachal Pradesh	16	16	100								0

Source: CGWB, Groundwater Yearbook, 2011-2012

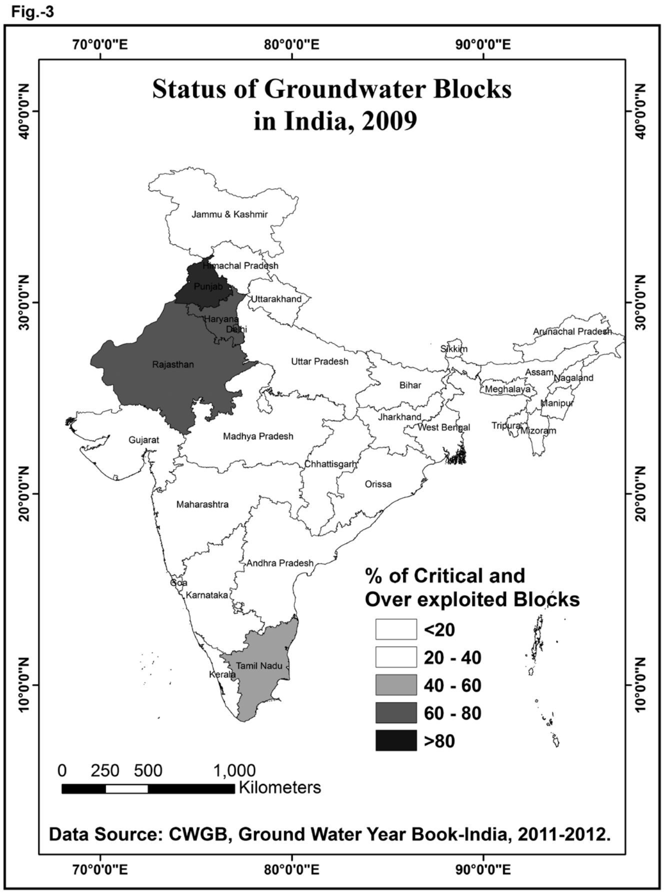

Fig. 3 : Status of Groundwater Blocks in India, 2009

Groundwater development is very low and 100% safe blocks are found in hilly terrains of North-Eastern states, Jammu & Kashmir, Sikkim and Goa. They are closely followed by the wet states of Eastern India where almost 100% blocks are safe in Orissa and Bihar. West Bengal has 86% safe groundwater blocks and 14% semi-critical blocks because of her better agricultural development. No critical or overexploited blocks are found in Eastern India. Like west Bengal in rocky terrains of Central India (Madhya Pradesh, Chhattisgarh) and Kerala also there are a large number of safe blocks (70%-90%) along with 10%-20% semi-critical blocks.

So low rainfall (50-75cm) and high agricultural development in arid and semi-arid parts of Western and North-Western India leads to high level of groundwater development. The Eastern India having more rainfall (>100cm) and surface water supply by the Ganga river system needs less groundwater irrigation and possesses a number of safe groundwater blocks. North-Eastern hilly region and rugged Himalayan mountainous region are not suitable for extracting groundwater resource. In Deccan Plateau region fractures in hard crystalline rocks increase the permeability to enrich groundwater resource. The coastal area gets more rainfall and has more potential groundwater reserve. Urbanization in National Capital Territory of Delhi in this tract of semi-arid India also suffers from water crisis.

4.4 Decline of Groundwater table

Overexploitation of groundwater and growing number of critical and overexploited blocks lead to substantial decline in groundwater level specially in north-western India. A study of Sheetal Sekhri (2012) from 1980 to 2010 shows that in most of the parts of Gujarat and Rajasthan groundwater level has fallen more than 16m and in central Punjab and Haryana it falls 12-16m during this period. Decline of water table is 8m to 12m in other pockets of Punjab, Haryana, Rajasthan, Gujarat, western Uttar Pradesh, and New Delhi. In a few districts of coastal Gujarat, central Rajasthan, Madhya Pradesh, Uttar Pradesh, West Bengal, Karnataka and Tamil Nadu the decline is 4m to 8m. About 1m to 4m decline of water table is widely observed in many parts of the country. A World Bank Report, 2010 says that, if current trends continue by 2025, about 60% of India's groundwater blocks will be in a critical condition. (www.worldbank.org.World)

4.5 Groundwater Hazards

Decline in groundwater level gives rise to several problems. However rising water table due to overirrigation has also caused hazardous situation.

i) Decline in water table has been observed since 1980s in northern, western and southern states of India as Green Revolution started there earlier (late 1960s and early 1970s) than Eastern India where Green Revolution took place in later phase (late 1970s). Though Eastern India is rich in ponds, rivers and canals, groundwater irrigation has also been adopted by the farmers for its reliability and availability at every piece of land. But lowering of water table beyond 7m depth causes disfunctioning of shallow pumps. The farmers try to avail groundwater by lowering their shallow pumps and that sometimes leads to small scale land subsidence, e.g., in many parts of Gujarat, in clay-rich parts of West Bengal (Laha, 2014). Again due to dwindling of water table pumping hours increases and therefore, cost of irrigation rises due to ever-rising diesel price since 2000s. Diesel price has risen from only Rs. 15/- per litre in 1995 to Rs. 61/- to 65/-per litre in 2017 in various parts of India.

ii) In low water table zones of Punjab-Haryana-Rajasthan-Gujarat region socio-economic disparity between the rich farmer and the poor farmer increases (Shiva, 1997). Big farmers are generally the sellers in groundwater market and they can avail groundwater by replacing the shallow pumps with costlier submersible pumps which is unaffordable to the small and marginal farmers. Small farmers who are often the buyers in groundwater market, get exploited by the big farmers or water sellers. It increases socio-economic disparity between the big farmer and small farmer. Farmers of Maharashtra in many cases escape this social rift by practising cooperative farming in sugarcane cultivation. In low water table areas of West Bengal (Bhatar, Barddhaman) also poor farmers cooperatively install submersible pump to stick to their occupation (Laha, 2014). Social disparity is comparatively less in Eastern India as agriculture is less mechanized here and a social nexus of exchanging irrigation water with agricultural labourer has been developed among the big farmers in one hand and the small and marginal farmers on the other.

iii) Declining water table leads to another problem in coastal region, i.e., saline water intrusion. In India there are 71 salinity blocks of which 70 are in coastal areas of Andhra Pradesh (38), Gujarat (14), Tamil Nadu (11) and Orissa (6). Saurashtra in Gujarat, Chennai in Tamil Nadu, Calicut in Kerala experience saline water intrusion. In eastern coast of India paddy dominating agriculture and in the western coast groundwater-dependent agriculture in semi-arid Gujarat are responsible for lowering of water table below the sea level and consequent ingress of saline water into the fresh water aquifer.

iv) Inland salinity is also a crucial problem in arid and semi-arid zones of Punjab-Haryana-Rajasthan, Gujarat, Uttar Pradesh, Delhi, Andhra Pradesh Maharashtra, and Karnataka. Due to low atmospheric rain salts don't leach out completely. As the water level rises due to seepage from water bodies or from irrigation fields, it's used by plant roots or lost due to evaporation leaving the salt behind. This affects the soil structure causing soil salinity and groundwater salinity as well. (Frazier, 1982; Karanth, 1987). Cultivation of water- intensive crops like rice and wheat in alluvial areas of India may have resulted the problem of soil salinity and soil alkalinity (Mitra, 1996). In India, it is estimated that about 8.5 million ha land is affected from different degrees of soil salinity. Of this about 5.5 million ha area lies in the irrigation canal command area and 2.5 million ha area lies in the coastal areas (Shakya and Singh, 2010).

v) In salt encrusted areas when further irrigation takes place, water can't penetrate and results into waterlogging situation. Heavy irrigation, poor drainage, infiltration from unlined canals, tanks and irrigated fields lead to rising up of water table specially in loose sandy soil (Todd, 2007). On the basis of the criteria given by the National Commission of Agriculture (1976) and Ministry of Water Resources, waterlogged/ critically waterlogged areas may be defined where water table is within 2m from the surface. Waterlogging occurs in Indira Gandhi Canal Command area of western Rajasthan (Sukhwal, 1993), Ukai- Kakrapara Canal Command area of Gujarat, in substantial parts of Punjab and Haryana and also in parts of Andhra Pradesh and Karnataka (Tyagi, et al, 2002). In high water table areas of Eastern India also overirrigation by canals causes waterlogging in some pockets. In India about 6.0 mha land is affected from various nature and orders of waterlogging (Shakya and Singh, 2010**).**

vi) Declining water table causes deterioration of groundwater quality, e.g, saline groundwater (Rajasthan), arsenic pollution (West Bengal), fluoride pollution etc. There are several places in Rajasthan and Haryana where EC values of ground water is greater than 1000 µmhos/cm.

vii) Arsenic pollution along the river Ganges in West Bengal of India is a great environmental issue today. Lowering of water table in paddy dominating Bengal Plain area causes oxidation of arseno-pyrites and arsenic thus gets released and dissolved in water as the water table rises in post monsoon season. Thus nine districts of West Bengal- Murshidabad, Maldah, Nadia, Barddhaman, Howrah, Hooghly, North and South 24 Parganas and Kolkata have been affected by arsenic pollution. In West Bengal arsenic content in groundwater is much higher (0.01ppm- 0.6ppm) than the permissible limit set by WHO (0.01ppm). Continuous consumption of arsenic contaminated water in long run results into skin irritation, blackening of skin (Melanosis), thickening of skin (Keratosis), hard nodules on palm and feet (Hyper-Keratosis), gangrene, skin cancer and ultimate death (Laha, 2013). About 50 millions of people are affected by arsenicosis in West Bengal (www.soesju.org/arsenic/wb.htm). Arsenic pollution in groundwater has also been found in Gangetic plain of Bihar and UP.

vii) Fluoride pollution, another geogenic groundwater pollution has also taken place due to groundwater mining (Gandhi and Bhamoriya, 2011). Long term consumption of fluoride rich water (>1.5mg/lit) causes dental fluorosis and skeletal fluorosis, and fluorosis also takes a longer period to be manifested on body (Sharma, 2003). In India nearly 90 million people including 6 million children in the country in 200 districts of 15 states are affected by fluorosis. The extent of fluoride contamination in groundwater in India varies from 1.0 to 48 mg/l. **(**www.nih.ernet.in/rbis/India). Rajasthan and Gujarat in North India and Andhra in South India are worst affected. Punjab, Haryana, Madhya Pradesh and Maharashtra are moderately affected states in India, while the states Tamil Nadu, West Bengal, Uttar Pradesh, Bihar and Assam are mildly affected by fluorosis (Arlappa, et.al. 2013).

4.6 Management

To combat various groundwater hazards generated from declining water table and problems of salinity and waterlogging the prime necessity is to reduce the use of groundwater and augment groundwater reserve situation through artificial groundwater recharge. Along with enactment of laws the local people should also play active role to conserve this valuable resource.

1. A balance should be maintained between annual groundwater recharge and annual abstraction of groundwater in

areas already having critical blocks and overexploited blocks. It is very much necessary to check further lowering of groundwater table in coastal areas of saline intrusion, in arsenic and fluoride affected areas and in arid and semi-arid parts of the country to assure potable drinking water supply and for a sustainable agricultural development in those areas.

2. To conserve water an efficient irrigation system with minimum wastage of water should be ensured. In arid and semi arid areas drip and sprinkler irrigation system should be adopted for judicial use of every drop of irrigation water.

3. In areas of sharp decline of water table a shift in cropping pattern from water-loving crops to dry crops is needed. Water-intensive paddy is cultivated commercially in semi-arid areas of Punjab and Haryana. Since the onset of Green Revolution HYV paddy is cultivated in Tamil Nadu also. These three states experience a large number of overexploited blocks. A diversified cropping pattern should be adopted there following their agro-climatic conditions. Emphasis should be given on dry crops like jowar, maize, bajra, gram, pulses, mustard, sunflower etc, in arid and semi- arid areas or in dry seasons of wet areas. Horticulture can also be adopted as low-cost, but remunerative crop-culture. Popularising horticulture is also an important agricultural policy now in India.

4. Rich farmers of arid and semi-arid areas of North-West India can invest their capital and technology to the irrigational development and overall agricultural development of Eastern India where most of the blocks are safe blocks and gap between potential and actual groundwater development is higher. It will help to increase the foodgrain or non-foodgrain production of the country. This may reduce regional disparity in agricultural development also. Big farmers of Punjab have already started investing in special type of potato cultivation employing the poor farmers of West Bengal for the growth of agro-based industry in Punjab.

5. In Eastern India there are many safe groundwater blocks. Despite, the year-round paddy culture is largely responsible for lowering of groundwater table and appearance of semi-critical blocks (15%) in West Bengal. With the advent of tubewell irrigation here minor surface water irrigation sources like tanks, ponds and bils have been neglected. To check overextraction of groundwater these surface water sources should be renovated and a conjunctive use of the both surface water and groundwater irrigation through integrated development of both the sources can be practised.

6. Inland soil salinity is a natural outcome of overirrigation in arid-semi arid areas. For food security in salinity affected areas scientific researches should be encouraged to invent salt-resistant varieties of seeds. Central Soil Salinity Research Institute, Karnal has already invented some salt-tolerant variety of

rice (CSR 10, CSR 13, CSR 23, CSR 27, CSR 30, CSR 36), Wheat (KRL 1-4, KRL 19, KRL 210, KRL 213), Mustard (CS 52, CS 54, CS 56) and Gram (Karnal Chana 1) (Gupta and Tripathi, 2010).

7. Reclamation of degraded saline and alkaline soils by ensuring better drainage and applying gypsum respectively can also bring more area under cultivation. To avoid cost of reclamation CSSRI has suggested alternative landuse of salt-affected lands like bio-saline agriculture, forestry etc. (Gupta and Tripathi, 2010). To identify and delineate degraded salt-affected areas satellite image analysis through GPS, Remote sensing and GIS would be helpful (Koshal, 2012).

8. Proper surface drainage in low-lying areas and building interceptor drain near the surface away from natural drainage to intercept seepage from canals and other water bodies may help to combat waterlogging. Construction of multi-tier interceptor drain of 10 cm diameter laid at a depth of 0.75 m from the surface during 1998 to 2000-01 has successfully reduced waterlogging and soil salinity situation in Karnataka (Tyagi, et.al. 2002).

9. Besides managing the demand side by reducing groundwater abstraction, the construction of recharge wells, dikes, check dams, artificial tanks etc, can help in artificial recharge of aquifers in the hard rock areas of Peninsular India. Further, mulching and composting can be used to conserve soil moisture in arid areas. Rainwater harvesting both in rural and urban areas should be practised to conserve groundwater resource. Community-based watershed development can be a good remedy as it largely focuses on land productivity, soil erosion and indirectly on developing micro-irrigation infrastructure. Bhalki watershed project in West Bengal, Sukhomajri in Haryana, Ralegaon Sidhi in Maharashtraare examples of successful community based watershed programme in india (Laha, 2011; Oza, 2007).

10. Along with demand and supply-side management of groundwater abstraction, firm legal steps should also be taken to check overdraft of groundwater. National Water Policy of India adopted in 1998 and amended in 2002, has no statutory status, and so the laws of this policy can't be legally enforced (Garduño, et. al, 2011). But it's high time to follow the existing laws strictly. The first and foremost necessity is to maintain the distance between tubewells, 200m for shallow tubewells and 600m for deep tubewells with submersible pumps. Regular monitoring of groundwater quality is also needed specially where groundwater quality has already been degraded. Controlled irrigation water supply to the fields may be practised by local authority and tax on groundwater abstraction can be imposed specially in areas of acute water crisis. These may reduce wastage of water.

11. Enactment of laws is not the ultimatum. Door to door campaigning and media attention can be the wayout to make the actual users aware about the environmental consequences of

overirrigation. The community should be trained by experts to conserve water resource and a blending of technology with the farmers' indigenous experiences would surely be helpful to the sustainable agricultural and irrigational development in respective regions.

5. Conclusion

India is agriculturally rich country from ancient time. Initially agriculture was rain-fed. Extension of canals after Independence geared up irrigation-based agricultural activities. After Green Revolution during late sixties and early seventies another thrust in irrigation development comes with the use of groundwater irrigation. Widespread use of groundwater irrigation has no doubt helped in the expansion of total cultivated land, cropping intensity and crop diversity in many parts of the country. But decline in groundwater table has taken place in arid and semi-arid parts of the country. Along with the declining water table land subsidence, inland and coastal soil salinity have also taken place in semi-arid Punjab-Haryana, Rajasthan region and coastal areas of Gujarat and Tamil Nadu. Overirrigation and seepage from canals has led to waterlogging also in arid and semi-arid parts of North-West India. Further, deterioration of groundwater quality in the forms of salinization, arsenic pollution and fluoride pollution as a result of lowering of water table has also taken place in different parts of the country. So to check overdraft of groundwater conjunctive use of surface water and groundwater irrigation, rainwater harvesting, changing cropping pattern, artificial groundwater recharge, enacting water laws and active community participation are necessary to save this valuable resource. Widespread campaigning and media attention to this vital issue of "save water" are also to be incorporated to spread environmental awareness among the commoners who are supposed to save this resource to stick to their occupation and to ensure their daily bread, otherwise the base of India's economy would be shaken up.

Bibliography

Arlappa, N., A. Qureshi and R. Srinivas, (2013): Fluorosis in India: an overview. *International Journal of Research and Development of Health*. April 2013., Vol. 1, No. 2: 97-102. www. ijrdh.com.

Central Ground Water Board, (2012): *Groundwater Yearbook 2011-2012*, Ministry of Water Resources, Government of India. Faridabad.

Frazier, J.W. (ed.). (1982): *Applied Geography, Selective Perspectives*. Prentice Hall Inc., London, New Delhi, Pp.139-169.

Gandhi, V. P. and V. Bhamoriya, (2011): Groundwater Irrigation in India: Growth, Challenges, and Risks. In *India Infrastructure Report, 2011, Water: Policy and Performance for Sustainable Development.* Infrastructure Development Finance Company. Oxford University Press, New Delhi.

Garduño, H., S. Romani, B. Sengupta, A. Tuinhof, and R. Davis. (2011): *India Groundwater Governance Case Study.* Water papers. Washington, DC: World Bank. http://documents.worldbank.org

Gupta, S.K and Dr. R.S .Tripathi, (2010): Central Soil Salinity Research Institute, Karnal.

Karanth, K.R. (1987): *Groundwater Assessment Development and Management*. Tata McGraw-Hill Publishing Co. Ltd., New Delhi.

Koshal, A.K. (2012): Spectral Characteristics of Soil Salinity Areas in Parts of South –West Punjab through Remote Sensing and GIS. *International Journal of Remote Sensing and GIS*, Vol. 1, No. 2: 84-89. www.rpublishing.org.

Laha, M. (2011): Spatio- social Impact of Mini-Watershed Project at Bhalki, Barddhaman District, West Bengal. *Wesleyan Journal of Research,* Bankura Christian College, Bankura. Vol. 4, No. 1: 10-20.

Laha, M. (2014): Groundwater Resource situation in Eastern Barddhaman, West Bengal. In *Managing Natural Resources.* Ed.H. N. Misra. PHI Learning Pvt. Ltd., New Delhi. Pp-263-275.

Laha, M. (2013): Social Implication of Arsenic Pollution in Eastern Barddhaman. *Transactions.* Vol. 35, No. 2: 173-184, IIG, Pune.

Mitra, A.K. (1996): Irrigation Sector Reforms: Issues and Approaches. In *Economic and Political Weekly*, March 30, Vol. XXXI, No. 13: A31-A37.

Oza, A. (2007): Irrigation: achievements and Challenges. In *India Infrastructure Report 2007*: *Irrigation and water resources*. Pp. 178-209. www.iitk.ac.in/reports/IIR2007/07-irrigation.

Sekhri, S. (2012): Sustaining Groundwater: Role of Policy Reforms in Promoting Conservation in India. In *India Policy Forum, 2012-13*. Vol. 9, Ed. S. Shah et.al. National Council of Applied Economic Research, New Delhi.

Shakya, S. K. and J. P. Singh, (2010): New Drainage Technologies for Salt-and Waterlogging areas of South-west Punjab. In *Current Science, Vol.99, No.2, 25 July, 2010.*

Sharma, S. K. (2003): *High Fluoride in Groundwater Cripples Life in Parts of India.* Diffuse Pollution Conference Dublin 2003. 7C Groundwater:

Shiva, V. (1997): *Violence of Green Revolution: Third World Agriculture Ecology and Politics*. The Other India Press, Research Foundation for Science Technology and Ecology, New Delhi.

Sukhwal, B.L. (1993): Water Resources and their management in the dry region: A case study of the Thar Desert, Rajasthan, India. In *Geographical Review of India*, Kolkata, Vol. 55, No. 3: 5-17.

Todd, D.K. (2007): Groundwater Hydrology. John Wiley & Sons, New Delhi.

Tyagi, N.K et.al. (2002): *Research on the Control of Waterlogging and Salinization in Irrigated Agricultural Land. Indo-Dutch Network Project (IDNP),* 2002. Central Soil Salinity Research Institute, Karnal (India) and Alterra- International Institute for Land Reclamation and Improvement, Wageningen (The Netherlands). Karnal, India.

http://www.iwmigiam.org/info/main/presentations/Day2-03-Narayanmurthi-Trends: A. Narayanamoorthy. Trends in Irrigated Area in India: 1950-51 to 2002-03.

http://www.nih.ernet.in/rbis/india_information/fluoride.htm. Fluoride Affected Areas.

http://www.soesju.org/arsenic/wb.htm. Groundwater arsenic contamination in West Bengal – India.

http://www.worldbank.org.World. World Bank Report, 5th March, 2010. Pragmatic action possible for addressing overexploitation of Groundwater in India.

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