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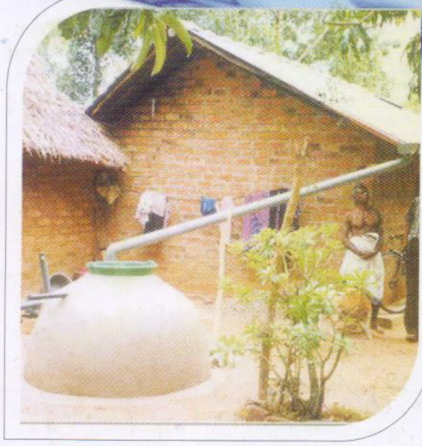

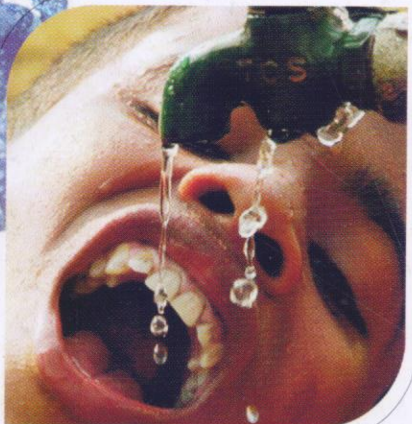

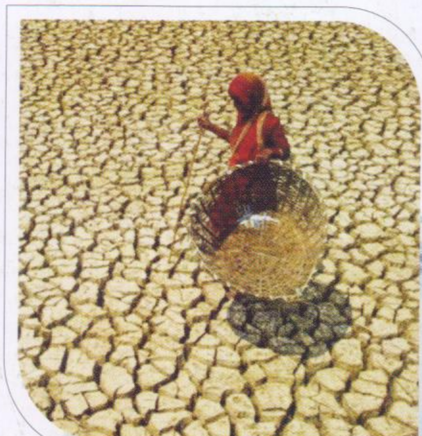

Water Conservation and Management: Towards a Societal and Technological Initiative for Sustainable Development

P. K. Singh, M. K. Nema and S. K. Jain
Water Resources Systems Division, National Institute of Hydrology Roorkee
S. K. Mishra
Department of Water Resources Development and Management
Indian Institute of Technology Roorkee
✉ *skm61fwt@iitr.ac.in*

Abstract

In many regions of India and the world as a whole, water has been considered a free resource. However, recent climatic vagaries, the hydrologic extreme events such as droughts, floods and dwindling water resources around the world have substantiated a need for a change in human perception about its uses, conservation and management practices. With this background the chapter presents the water situation at country and world level as a whole owing to the rapidly increasing population, agricultural, socio-economic and industrial developments. Based on Water Crowding Index (WCI) and Water Scarcity Index (WSI), Gosling and Arnell (2016) estimated that around 1.6 and 2.4 billion people, respectively, are currently living within watersheds exposed to water scarcity and by 2050 under A1B scenario it will be 0.5 to 3.1 billion people. The impacts of population, urbanization and industrialization on water resources are discussed in detail and based on the present per capita surface water availability and according to the Falkenmark Water Stress Indicator (FWSI), Jain (2011) found that the country will shortly enter the water stressed category and the stress will progressively become more severe. Lastly, this chapter suggests some of the required initiatives such as replacement of aging water infrastructure to prevent loss of Non-revenue Water (NRW) and water thefts, emphasis on water and environment education, need of Water-SMART campaigns/programs to the tune of SMART-Cities, and applications of precision farming techniques, plastics in agriculture, applications of GIS and remote sensing for efficient rainwater harvesting, and application of advanced micro-irrigation systems techniques to effectively tackle the problem of water scarcity in India.

Introduction

Since the days of civilization, the water availability and accessibility have played their key role in determining the locations of cities, towns, and villages in most of the regions around the world. With a rapidly increasing population, agricultural, socio-economic and industrial development, the water scarcity is becoming a common problem in many countries of the world (Kalra et al., 2012). The water scarcity is also inducing other problems, such as water pollution, food shortage, and ecological deterioration (Puri et al., 2011) as well as national and international conflicts caused by the water disputes (Duda and El-Ashry, 2000). The observational data and climate projections show that in many regions of the world the freshwater resources are highly vulnerable and will be strongly impacted by climate change (Bates et al., 2008; Kalra and Ahmad, 2011 and Kalra et al., 2013). The developing world is undergoing a major demographic transition from a rural, agrarian society to an urban, industrial one and by 2050, 70% of the global population will inhabit urban areas, up from about half today (United Nations, 2001). Almost all of this increase in urban population will occur in the developing world and more than half the growth will occur in just two countries, India and China (Cohen, 2004).

Among India's population of more than one billion people, about 68% are directly or indirectly involved in the agricultural sector. This sector is particularly vulnerable to present-day climate variability, including multiple years of low and erratic rainfall. Scenarios generated by Global Circulation Models (GCMs) show that India could experience warmer and wetter conditions as a result of climate change, particularly if the summer monsoon becomes more intense (Mitra et al., 2002; Kumar et al., 2002; McLean et al., 1998). However, the increased rates of evapo-transpiration due to the higher temperatures may offset the increased precipitation, leading to negative impacts on soil moisture (Keshta et al., 2012). Inter-Governmental Panel on Climate Change (IPCC) Assessment Report-5 (AR5) (2014) has shown that the earth temperature has increased by 0.85 (0.65-1.06)0C over the period 1880 to 2012 and due to increase in anthropogenic emissions of greenhouse gases the temperature increase is likely to be 1.8-4.00C by the end of 21st century (2081-2100). This would lead to more frequent hot extremes, floods, droughts, cyclones and gradual recession of glaciers, which in turn would result in greater instability in food production.

The competition among agriculture, industry and cities for limited water supplies is already constraining development efforts in many countries (FAO, 2005). About 80% of the world's population already suffers serious threats to its water security, as measured by indicators including water availability- water demand, water vulnerability and pollution (Vörösmarty et al., 2010). As populations expand and economies grow, competition for limited supplies will intensify and so will conflicts among water users. The extent to which a region or country is vulnerable to water depends on the quantity of water, temporal distribution, quality, and the extent of its use and requirements. While the hydro-climatological factors are the principal factor in water quantity and its inter-temporal distribution, the population and economic development are the main influences on quality and demand. Despite water shortages, misuse of water is widespread as small communities and large cities, farmers and industries, developing countries and industrialized economies - all are mismanaging water resources. Surface water quality is deteriorating in key basins due to urban and industrial wastes. Groundwater is polluted from surface sources and irreversibly damaged by the intrusion of salt water. Overexploited aquifers are losing their capacity to hold water and land is subsiding. Cities are unable to provide adequate drinking-water and sanitation facilities. Decreasing water flows due to catchment area degradation are reducing hydro-electric power generation, pollution assimilation and fish and wildlife habitats.

Global Water Situation

Water is not distributed evenly over the globe. Fewer than 10 countries possess 60% of the world's available fresh water supply: Brazil, Russia, China, Canada, Indonesia, U.S., India, Columbia and the Democratic Republic of Congo. However, local variations within countries can be highly significant (World Business Council for Sustainable Development, 2006). It has become one of the emerging environmental issues which our ecosystems are facing today. The three major concerned issues of water quantity, quality and availability are vital to the quality of the life on earth. Water issues have been included under the agenda 21 of the United Nations Environment Program (UNEP) for that water crises are the challenges to the global environment communities. Freshwater resources are being depleted very fast. On a global scale, total quantity of water available is about 1600 million cubic km. 97.5% of all water on earth is saline water. Out of remaining 2.5% fresh water, most of which lies deep and frozen in Antarctica and Greenland, only 0.26% flows in rivers, lakes and in the soils and shallow aquifers which can be readily used. The available freshwater resources are unevenly distributed and of which many resources are located far from human population. There are 263 major international river basins in the world which cover about 45% of the earth's land surface area. Among the available freshwater, 90% is available through groundwater resources and it serves the drinking water requirement of about 1.5 billion people around the world. Agricultural sector is the largest consumer of available water which consumes about 75% of the available global water and 20% of the water is consumed by industrial activities and 5% by domestic sector. **Figure 1** shows the comparison between competing water uses at world, high income group and low-and-middle income group of countries. It can be observed from **Figure 1** that the high income group of countries uses almost 1/4th of the water for agricultural purposes than the low and middle income group of countries (UNWWDR, 2003).

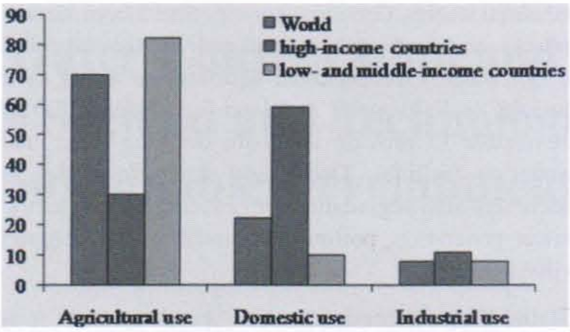

Fig. 1 : Competing water uses for main income groups of countries

Estimates show that as water scarcity increases, two-third of the world's population will be forced to live under water stressed conditions by the end of the next two decades. Global warming, due to the enhanced greenhouse effect, is likely to have significant adverse effects on the hydrological cycle (IPCC, 1996; Arnell, 1999). The hydrological cycle will be intensified, with more evaporation and more precipitation, but the extra precipitation will be unequally distributed around the globe. Some parts of the world may see significant reductions in precipitation, or major alterations in the timing of wet and dry seasons. Assuming different rates of economic growth and technological improvements and the same rate of population growth, the mid-range, high and low-case projections were produced by Arnell (1999) as shown in **Figure 2**. It can be seen from these projections that by 2025, the global water use will increase under the mid-range scenario by 35% over 1995 (with a range from 23 to 50% under the low and high projections), and by 67% by 2050.

Portmann et al. (2013) estimated that for each degree of global mean temperature rise, an additional 4% of

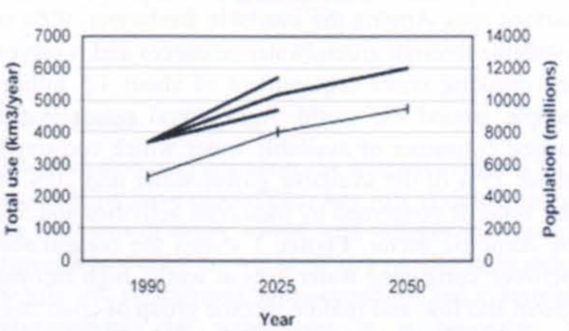

Fig. 2 : Global water resource withdrawals, 1990-2050. The thick lines show total withdrawals, under the mid-range, low and high (to 2025 only) Conventional Development Scenarios (CDS). The thin line shows the total population

the global land area will suffer a groundwater resource decrease of more than 30%. Schewe et al. (2013) also investigated the potential magnitude of the impact of climate change on water resources and estimated that about 8% of the global population would see a severe reduction in water resources (a reduction in runoff either greater than 20% or more than the standard deviation of current annual runoff) with a 1°C rise in global mean temperature (compared to the 1990s). Recently Gosling and Arnell (2016) applied 21 GCMs to 1339 watersheds across the globe under four SRES scenarios and Water Crowding Index (WCI) and Water Stress Index (WSI) were used to calculate exposure to increases and decreases in global water scarcity due to climate change. Where WCI represents a measure of the annual water resources per capita in a watershed) and WSI is a measure of the ratio of water withdrawals to resources. A WCI threshold of <1,000 m^3/capita/year and a WSI of >0.4 were used to indicate exposure to water scarcity (Rockström et al., 2009). They found that 1.6 (WCI) and 2.4 (WSI) billion people are currently living within watersheds exposed to water scarcity and by 2050 under the A1B scenario, 0.5 to 3.1 billion people will be exposed to an increase in water scarcity due to climate change (**Table 1**). The global statistics indicate for an urgent need of specific campaigns to develop and propagate efficient technologies/methodologies world-wide for conservation and management of water resources for shaping an exciting future of the society.

Indian Water Situation

Water resources of a country constitute one of its vital assets. India receives annual precipitation of about 4000 BCM, including snowfall and out of which almost 75% is received during the monsoon season. The rainfall in India shows very high spatial and temporal variability and paradox of the situation is that Mousinram near Cherrapunji, which receives the highest rainfall in the world, also suffers from a shortage of water during the non-rainy season, almost every year. The total average annual flow per year for the Indian rivers is about 1869.37 BCM and the total annual replenishable groundwater resources is 431.02 BCM. The annual utilizable surface water and groundwater resources of India are 690 BCM and 431 BCM, respectively (Central Water Commission (CWC), 2013). With rapid growing population and improving living standards the pressure on our water resources is increasing and per capita availability of water resources is reducing day by day.

Table 1: Numbers of people exposed to water scarcity in the absence of climate change (i.e. due to population change only), using WCI and WSI for four time horizons under the A1B scenario (Gosling and Arnell, 2016)

	Millions				Percentage of population					Millions				Percentage of population			
	2000	2020	2050	2080	2000	2020	2050	2080		2000	2020	2050	2080	2000	2020	2050	2080
WCI (<1,000 m^3/capita/year)									WSI (>0.4)								
North Africa I2R	128	172	206	210	74	76	77	78	North Africa	98	182	230	234	56	80	86	87
West Africa	7	19	42	42	3	5	9	9	West Africa	0	3	5	6	0	1	1	1
Central Africa	0	0	5	6	0	0	3	3	Central Africa	0	0	0	0	0	0	0	0
East Africa	4	15	97	163	3	7	31	47	East Africa	0	12	5 7	69	0	5	18	20
Southern Africa	16	10	11	12	9	5	5	5	Southern Africa	0	0	0	0	0	0	0	0
South Asia	491	1273	1466	1292	34	69	70	67	South Asia	1004	1419	1684	1559	70	77	81	18
South East Asia	0	0	0	0	0	0	0	0	South East Asia	1	23	75	70	0	4	10	11
East Asia	660	722	673	487	44	45	44	38	East Asia	666	776	1231	1038	44	48	80	81
Central Asia	0	1	2	2	1	1	2	3	Central Asia	48	62	77	79	84	87	89	90
Australasia	0	0	0	0	0	0	0	0	Australasia	0	0	3	3	0	0	6	6
Western Europe	112	115	160	164	29	29	38	39	Western Europe	205	197	216	238	53	49	51	57
Central Europe	7	7	6	5	5	5	5	5	Central Europe	36	33	30	7	28	26	26	7
Eastern Europe	4	5	5	5	2	2	2	3	Eastern Europe	22	24	24	21	10	11	12	12
Arabian Peninsula	34	76	143	190	73	92	98	99	Arabian Peninsula	40	82	144	191	86	99	99	99
Mashriq	27	48	92	93	21	28	45	48	Mashriq	72	117	144	142	55	67	70	73
Canada	5	6	7	7	17	17	17	17	Canada	7	8	10	10	22	22	25	25
US	34	58	76	79	12	17	19	19	US	124	156	233	258	44	47	58	62
Central America	21	48	53	50	13	22	21	20	Central America	55	82	95	90	32	38	38	36
Brasil	0	0	0	0	0	0	0	0	Brazil	0	0	0	47	0	0	0	22
South America	4	5	18	19	2	2	7	7	South America	15	30	55	84	8	14	21	30
Global	1555	2579	3064	2828	25	35	37	36	Global	2393	3209	4314	4146	39	44	53	53

National Commission for Integrated Water Resources Development (NCIWRD) has shown that the per capita availability of water varies widely in different regions of the country. In Sabarmati river basin it varies around 300 cubic meters per person per year and in Brahmaputra river basin, with a national average of about 2,000 cubic meters per person per year. With the population already crossing the 1 billion mark, India's annual per capita water availability is not enough to satisfy per capita requirements. The water scarcity is already increasing in many regions of the country and is among the countries projected to fall into the water shortage category before 2025. Currently, the global developments are indicating a shift from economic water scarcity (occurring due to missing infrastructure to extract or purify water – e.g., in developing countries) towards physical water scarcity (due to aquifer depletion or persistent droughts occurring also in many developed countries) (Ziolkowska et al., 2016). As for as the India's water resources is concerned, there are 12 major river basins (having catchment area of 20,000 km^2) or more with the total catchment area of 25.3 lakh km^2 (India WRIS) and out of which the Ganga-Brahmaputra-Meghna is the largest one with the total catchment area of about 11.0 lakh km^2 (more than 43% of the catchment area of all the major rivers in the country). The other major river basins with catchment area more than 1.0 lakh km^2 are Indus, Mahanadi, Godavari and Krishna. There are 46 medium river basins having catchment area between 2,000 and 20,000 km^2 with the total catchment area of about 2.5 lakh km^2. All major river basins and many medium river basins are inter-state in nature which covers about 81% of the geographical area of the country.

The Ganga and Brahamputra-Barak river basins jointly accounts for 60% of the average annual water resources potential, however, due to topographical constraints and spatio-temporal variability of the availability of water only 48% of the total water potential in the Ganga basin and 4% of the total water potential in the Brahmaputra basin is utilized (Gaur and Amarsinghe, 2011). The NCIWRD has estimated that the 9 out of the 20 river basins (as per CWC classification: **Figure 3**) do not have sufficient water for industry or other uses. Based on the availability of water according to priority of use, river basins like Indus and Sabarmati did not have any residual water left for industrial and other uses even in 2010. The situation will be worse in

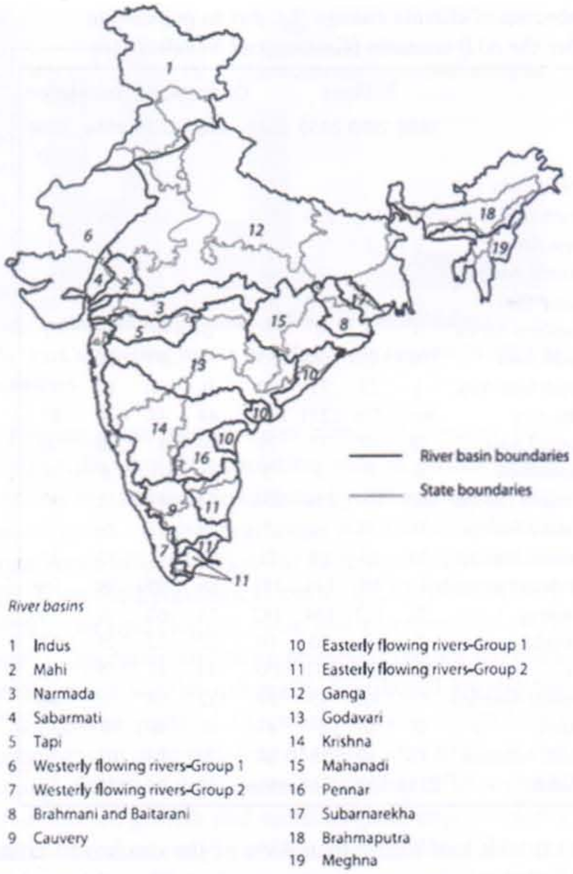

Figure 3 : The river basins of India as per Amarsinghe et al, 2004

2050 when Ganga and the basin fed by the east flowing rivers such as Mahanadi and Pennar will also face severe water availability problems.

Main Factors behind Water Scarcity

Water is critical for societies, not only for drinking and household uses, but also for agricultural/food production and industrial use. Demand for water increases with the population as water is needed to sustain life, for sanitation, agriculture, generate energy, run industries, etc (Jain, 2011). As discussed above, water consumption for food production is by far the biggest form of societal use of water, and agriculture is currently the largest user of water at the global level. Growing population, amplified urbanization and industrialization and changing climates are the major factors behind the present day water scarcity. This section, categorically discusses: (i) agricultural water use and impacts, (ii) population growth and impacts, (iii) urbanization and impacts, etc. to highlight the need of water conservation and management in India.

Agricultural Water Use and Impacts

Agriculture is an important sector of our socio-economic system which contributes approximately 14% of the nation's Gross Domestic Product (GDP). Among India's population of more than one billion people, about 68% are directly or indirectly involved in the agricultural sector. India has the second largest arable land base (159.7 million hectares) after USA and largest gross irrigated area (88 million hectares) in the world (India Water Portal www. indiawaterportal.org). This sector is also a relatively low-value, low-efficiency and highly subsidized water user group. About 40% of the irrigation water is supplied from groundwater and India is the world's largest groundwater user. The rates of depletion of groundwater in India are probably the highest in the world (Aeschbach-Hertig and Gleeson, 2012). Jain (2011) revised the estimates of future water requirements for irrigation to meet out the food grains demands of the projected population for years 2050 and 2065 as given in **Tables 2 & 3**. **Tables 2** present the projections of population for some selected years according to the UN medium variant. It can be observed from **Table 3** that annual irrigation water requirement for 2050 and 2065 would be 826.7 and 852.9 BCM, respectively, out of which approximately 40% has to be fulfilled through groundwater.

Table 2 also shows that agriculture sector is the largest consumer of water and hence it has the largest potential to save water with enhanced Water Use Efficiency (WUE). In the agriculture sector, enough possibilities exists to increase crop yield per drop of water (More Crop per Drop) as the crop yield per unit land area and water in India are low compared to other countries. Some existing techniques such as Precision forming, plastics in agriculture (to conserve soil moisture and reduce evaporation losses), and micro-irrigation systems such as use of drips and sprinkler (including micro-irrigation) have the potential to save large quantities of water. New farming techniques such as the system of rice intensification can save appreciable quantity of water from this water guzzling crop. Calculations show that about 20% savings in the

Table 2 : Projected population for a few selected years - UN medium variant (Jain, 2011)

Year	Population as per UN Medium Variant, million
2025	1459
2050	1692
2060	1718
2065	1718

Table 3 : Computation of future water requirement (BCM) for irrigation

Particulars	Unit	Year 2010*		Year 2050*		Revised Estimates	
		Low demand	High demand	Low demand	High demand	2050	2065
Foodgrain demand	Million tonnes	245.0	247.0	420.0	494.0	529.0	567.0
Net cultivable area	Million hectares	143.0	143.0	145.0	145.0	145.0	145.0
Cropping intensity	Percentage	135.0	135.0	150.0	160.0	158.0	163.0
Percentage of irrigated to gross cropped area	Percentage	40.0	41.0	52.0	63.0	65.0	65.0
Total cropped area	Million hectares	193.1	193.1	217.5	232.0	229.1	236.4
Total irrigated cropped area	Million hectares	77.2	79.2	113.1	146.2	148.9	153.6
Total unirrigated cropped area	Million hectares	115.8	113.9	104.4	85.8	eo.2	82.7
Foodcrop area as percentage of irrigated area	Percentage	70.0	70.0	70.0	70.0	70.0	70.0
Foodcrop area as percentage of un-irrigated area	Percentage	66.0	66.0	66.0	66.0	66.0	66.0
Foodcrop area - irrigated	Million hectares	54.1	55.4	79.2	102.3	104.2	107.5
Foodcrop area - un-irrigated	Million hectares	76.4	75.2	68.9	56.7	52.9	54.6
Average yield - irrigated food crop	Tonnes/hectare	3.0	3.0	4.0	4.0	4.25	4.40
Average yield - un-irrigated food crop	Tonnes/hectare	1.1	1.1	1.5	1.5	1.60	1.70
Foodgrain production from irrigated area	Million tonnes	162.2	166.2	316.7	409.2	443.0	473.2
Foodgrain production from un-irrigated area	Million tonnes	84.1	82.7	103.4	85.0	84.7	92.8
Total surrogate food production	Million tonnes	246.3	248.9	420.0	494.2	527.7	566.0
Assumed percentage of potential from surface water to total irrigation potential	Percentage	47.0	47.0	54.3	54.3	54.3	54.3
Irrigated area from surface water	Million hectares	36.3	37.2	61.4	79.4	80.9	83.4
Irrigated area from ground water	Million hectares	40.9	41.9	51.7	66.6	68.1	70.2
Assumed 'Delta' for surface water	Metre	0.91	0.91	0.61	0.61	0.61	0.61
Assumed 'Delta' for ground water	Metre	0.52	0.52	0.49	0.40	0.49	0.49
Surface water required for irrigation	BCM	330.3	338.5	374.6	484.1	493.3	508.9
Ground water required for irrigation	BCM	212.8	210.1	253.3	327.3	333.5	344.0
Total water required for irrigation	BCM	543.1	556.7	627.9	S11.4	826.7	852.9

irrigation and domestic water sector will yield about 170 BCM of water and this will make the demand nearly equal to the availability.

The concept of virtual water can also be employed to save water in areas with low rainfall. Crops that consume more water can be grown in areas with surplus water and transported to other areas. Subsidies should be available for the weaker sections of the society, but the policy of subsidizing on energy for extraction of ground water should be reviewed so that unsustainable withdrawals can be checked. A brief discussion on drip and sprinkler irrigation systems is also given here as follows.

National Mission on Micro Irrigation (NMMI): Drip and Sprinkler Irrigation Systems

Micro Irrigation (MI) scheme was launched in March 2005 and re-structured in the shape of National Mission on Micro Irrigation (NMMI) in June 2010. Drip and sprinkler systems were introduced for precise irrigations directly to the root zones of the crops for minimizing the irrigation water demand. MI has not only increased the water use efficiency but also the distribution of fertilizers and minerals in the form of fertigation. The government is promoting this system by providing subsidy directly to the farmers.

Drip irrigation refers to application of water in small quantity at the rate of mostly less than 12 litres per hour (LPH) as drops to the zone of the plants through a network of plastic pipes fitted with emitters. Drip irrigation is suitable for most of the Indian soils and has some specific advantages as: (i) increased water use efficiency (up to 85%); (ii) better crop yield; (iii) uniform and better quality of the crop produce; and (iv) minimum damage to the soil structure. In the sprinkler method of irrigation, water is sprayed into the air and allowed to fall on the ground surface somewhat resembling rainfall. The spray is developed by the

Table 4 : Response of different crops to sprinkler irrigation*

Crop	Water Saving, %	Yield Increase, %	Crop	Water Saving, %	Yield Increase, %
Bajra	56	19	Groundnut	20	40
Barley	56	16	Jowar	55	34
Bhindi	28	23	Lucerne	16	27
Cabbage	40	3	Maize	41	36
Cauliflower	35	12	Onion	33	23
Chillies	33	24	Potato	46	4
Cotton	36	50	Sunflower	33	20
Cowpea	19	3	Wheat	35	24
Fenugreek	29	35	Gram	69	57

*Source: INCID (1998)

flow of water under pressure through small orifices or nozzles.

The sprinkler irrigation is suitable for most of the cultivable land slopes, whether uniform or undulating. The water saving can be achieved to the extent of 34-40% as compared to the surface irrigation methods. The trials conducted in different parts of the country revealed water saving due to sprinkler system varies from 16 to 70 % (**Table 4**) over the traditional method with yield increase from 3 to 57 % in different crops and agro climatic conditions.

Population Growth and Impacts

Water resources are one of the main components of the infrastructure sector which will be facing increasing stress on account of growing population because the demand for water for various uses largely depends on the population. Based on UN medium variant as estimated by Jain (2011), the total population of India will reach to 1459, 1692 and 1718 Million with an increase of 9.21, 28.47 and 29.56% as compared to the 2011 census, respectively for year 2025, 2050 and 2065.

This increased population will require domestic water supplies to the tune of 66.90, 118.58 and 122.59 BCM, respectively for year 2025, 2050 and 2065 (**Table 5**). Out of which the rural demands alone will require approximately 89.67% of total domestic supplies by 2065. He found that the percentage of urban population will keep on increasing and will reach up to 65% by year 2065. Total food demands were also estimated by Jain (2011) as presented in **Table 6** and it was found that by year 2065 a total of 515 million tonnes of food will require to feed the total population of 1718 million.

Table 5 : Domestic water requirement in India for the years 2025, 2050 and 2065*

Item	Year 2025	Year 2050	Year 2065
Population, million	1333	1692	1718
Percentage urban	0.45	0.6	065
Percentage rural	0.55	0.4	035
Norm - urban area, Ipcd	220	220	220
Norm - rural area, Ipcd	70	150	150
Demand - urban, BCM	48.17	8152	89.67
Demand - rural, BCM	18.73	3705	32.92
Total, BCM	66.90	118.58	122.59

Table 6 : Food requirement for India for the years 2050 and 2065

Item	Year 2050	Year 2065
Population, million	1692	1718
Per capita food and feed demand, kg/annum	284	300
Total demand, MT	481	515
With addition of seed, feed, wastage, etc, MT	529	567

Table 7 : Per capita per year availability and utilizable surface water in India (Jain, 2011)

Year	Population, million	Per-capita Surface Water Availability, m^3/year	Per-capita Utilizable Surface Water, m^3/year
1951	361	5410	1911
2001	1027	1902	672
2011	1210	1614	570
2025	1459	1339	473
2050	1692	1154	408
2065	1718	1137	402

At present the surface water availability is about 1544.38 m^3 per year and the rise in population may reduce the per capita water availability to 1137 m^3 by 2065 as shown in **Table 7**. If this is true, then according to the Falkenmark Water Stress Indicator (FWSI) (Falkenmark et al., 1989) the country will shortly enter the water stressed category and the stress will progressively become more severe (Jain, 2011). According to FWSI water availability of more than 1700 m^3/capita/year is defined as the threshold above which water shortage occurs only irregularly or locally. Below this level, water scarcity arises in different levels of severity. Below 1700 m^3/capita/year water stress appears regularly, below 1,000m^3/capita/year water scarcity is a limitation to economic development and human health and well-being, and below 500m^3/capita/year water availability is a main constraint to life. It is estimated that if the population and waters of the north-east are subtracted from gross calculations, then the current per capita water availability for the remaining country will be about 1023.24 m^3/capita/year. It may be added here that currently there is no transfer of water from the north-eastern region to other parts of the country. Hence, from the management point-of-view, per-capita availability of 1023.24 m^3/capita/year appears to be more relevant which means that most of the country will soon enter in the 'chronic water scarcity' category according to FWSI.

Urbanization and Its Impacts

Urbanization is a worldwide trend, with more than 50% of the world's population currently living in cities, and over 500 cities now having more than 1 million inhabitants (UN Report 2010). India's urban population as per the 2011 census was 377.10 million, accounting for nearly 31% of the country's total population. Urbanization in India has been on an upward trend with more than 33% growth in urban population over the period 2001-11 (**Figure 4**) and it would reach up to 65% by year 2065. The absolute increase in urban population has surpassed the increase in rural population for the first time. It has been estimated that the urban population in India will reach to 600 million by 2030 and if it is true then some of the India's largest cities will be bigger than many countries of the world today.

Urbanization affects hydro-systems dramatically by altering hydrology, channel morphology, water quality and aquatic biota (Dunne and Leopold, 1978; Newall and Walsh, 2005). As discussed above, almost 70% of the global population will inhabit urban areas, up from about half today and almost all of this increase will occur in the developing world and more than half the growth will occur in just two developing countries, India and China (Cohen, 2004; Srinivasan et al., 2013). One of the major challenges arising from this amplified speed of urbanization, population and industrialization

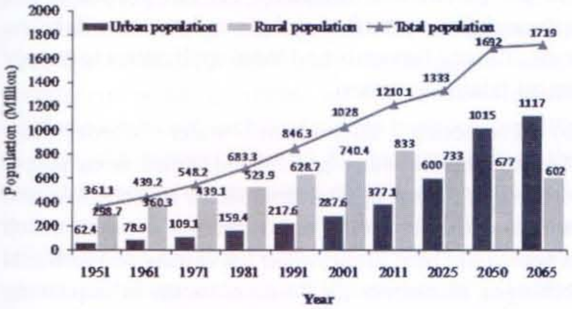

Fig. 4 : Urban and rural population growth trends in India

will be to supply water to fulfill their demands. There exists a bi-directional relationship between urbanization and environmental change (Seto and Satterthwaite, 2010; Seto et al., 2010). The creation of impervious areas and the simplification of the drainage network also result in much faster runoff response to rainfall, leading to shorter times of concentration and reduced recession times.

Due to rapid urbanization, cities are more at risk given the existing environmental, economic and social problems. Cities with large concentration of population, property and crucial economic assets and infrastructure are in highly vulnerable. With growing urban population size and density, additional water supply will have to be arranged from sources located outside the boundaries of the cities (Lundqvist et al., 2003) and more wastewater should be collected, treated and released safely into the environment at a pace and scale unprecedented in history.

Studies have shown that 3.1 billion urban dwellers will experience seasonal water shortages by 2050; almost a billion of these will experience perpetual shortages within their urban areas (McDonald et al., 2011) and this highlights the need of systematic and a well planned urbanization, industrialization and infra-structural developments. About 70-80% of the supply fresh water to a house hold retuned as a wastewater to the drains. As per census 2011 only 32.7% of the urban residents are connected with the waste water drains and the waste water treatment plants in majority of Indian cities are under capacity to handle the entire city load. Recently, the Government of India launched two big-ticket urban renewal projects, i.e., Smart City and Atal Mission for Rejuvenation and Urban Transformation (AMRUT) besides unveiling the Housing for All by 2022 with an emphasis to develop 100 Smart Cities and a renewal mission for 500 cities. These ambitious projects are going to be the greatest bench mark in India's urbanization sector, involving a huge socio-economic and infrastructural development. This urbanization would also boost up the industrial developments at a very large scale. However, one of the major challenges abstracting to the magnitude and speed of urbanization and industrialization would be to supply water to urban areas and efficiently meet out their supply-demand statistics rationally. There is an urgent need to promote the use of non-revenue water, conjunctive use of surface and groundwater, rainwater harvesting and use of recycled wastewater as new and renewable water resources.

Table 8 : Total water requirements (BCM) for the years 2050 and 2065 (Jain, 2011)

Uses	Year 2010*		Year 2050*		Revised Estimates	
	Low	High	Low	High	2050	2065
Irrigation	543	557	628	807	826.7	852.9
Domestic	42	43	90	111	118.6	122.6
Industries	37	37	81	81	90.0	90.0
Power	18	19	63	70	70.0	75.0
Inland navigation	7	7	15	15	15.0	15.0
Environment - afforestation	0	0	0	0	1.0	1.0
Environment - ecology	5	5	20	20	90.0	90.0
Evaporation losses	42	42	76	76	80.0	80.0
Total	694	710	973	1180	1291.0	1327.0
Population, million	1286	1333	1346	1581	1692.0	1718.0

*Estimates by NCIWRD

Others

There are two other main sectors which also need our due consideration, i.e, Water requirement for power generation and navigation and Water requirement for environment and ecology. The NCIWRD have estimated that a total water demand of 70 and 75 BCM would be required for power generation and navigation in 2050 and 2065, respectively. Similarly, to fulfill the demands for environment and ecology the at least 10% of the lean season flow should be set aside for environmental needs. It was found that an allocation of at least 5% of the total potential (surface water potential = 1869 BCM) or about 93.45 BCM of water by 2050 should be considered bare minimum for this purpose. Considering demands for various sectors as discussed above, Jain (2011) estimated the total water requirement for 2050 and 2065 as shown in **Table 8**. It can be observed from **Tables 7 & 8** that the demand for water will exceed the supply in the not too distant future unless sincere attempts are initiated quickly to tackle the problem.

Required Initiatives

Water conservation and management can be a powerful method for resolving the current water crisis and promoting sustainable development, and changes in water-conservation behavior should influence an individual's water-conservation awareness and actions. However, compared with technological innovation (e.g, designing water-conservation devices), behavioral innovations will likely present much greater challenge to water conservation (Xiong et al., 2016). Water is increasingly stressed by the demands of our society and adequate water supplies are essential for human survival, agricultural systems, ecosystem health, energy production, and economic sustainability. In order to secure and stretch water supplies for use by existing and future generations to benefit people, the economy, and the environment, it is the need of the time to address required initiatives for conservation and management of water resources from basin scale to the tap point of the distribution systems.

The long term economic development of every country and the health of its people and ecosystem depend on its ability to manage its natural resources. Recently, Lall (2016) suggested a Water Road Map for America's Water to effectively address the problem of water scarcity in the United States. The challenges of water-climate-energy-food-urban nexus and water risk can be effectively addressed through conservation and management of water resources. Following step can be taken up for future generations in the context of current climatic vagaries and unbounded urbanization and industrialization as :

(a) Advancing regional and national water information systems: Multi-resolution (in situ sensors, remote sensing, automatic weather stations, automated gauging stations, paleo-climatic proxies, archival sources) data platforms to enable access to water supply, quality and use parameters, including but not limited to the historical data on surface and groundwater availability, costs, climate forecasts and their application to supply chains related to water.

(b) Promoting inter-sector water transactions: Mechanisms for water and related transactions across sectors (i.e., from agricultural sector to domestic and industrial sectors during non irrigation periods, which in-turn could help in rainwater harvesting and artificial recharge), incentives for co-investments in improving water quality and quantity, aquifer recharge, rainwater harvesting on public private partnership mode.

(c) Integration of national and state water, agriculture, industrial and urban development agencies: A joint agency of the concerned departments for data collection, regulations and enforcements, infrastructure planning, development and management.

(d) Efforts for reducing water supply-demand imbalances in urban and rural areas for agricultural, domestic and industrial purposes: Improved storage infrastructure, improved water treatment and re-use, artificial groundwater recharge, rainwater harvesting, and increased water use efficiency.

(e) Improvements in the existing water infrastructure and development of new rationalized systems: Increased capital investment, technical expertise to execute and maintain large distribution systems (for domestic, industrial and agricultural applications), and replacement of age old infrastructure.

(f) Enhanced water research funding and implementation: Enhanced water research endeavors, dissemination of the results to the implementing agencies, advancements and optimization of rural, urban and industrial water infrastructures.

(g) Improved governance and financing for water infrastructure: increased transparency through better data information sharing, projections, regulated operational systems through automation technologies.

(h) Water education and social awareness and responsibilities: Provisions for water and environmental education in routine course curriculums, emphasis on behavioral innovations (societal awareness) through specific campaigns.

A well planned water conservation and management framework (say SMART-Water) program just to the tune of SMART-Cities is required to address future water supply and demand challenges for (urban & rural, agricultural and industrial) sectors, including degradation in water quality caused by pollution and land use practices, decreases in flow, declines in groundwater levels, and aging water infrastructure. Very low tariffs on water supply are the reason behind wastage of water in almost all the sectors. Ideally, tariff should be set such that people have an incentive to save, the money required for maintenance of the system is recovered, and some amount can be set aside to upgrade and expand the system. Similarly, the loss of Non-revenue Water (NRW) (domestic water supply) owing to leakage and/or theft in some cities is as high as 25–50%. Thus, a saving of 20% or even higher can be achieved through sincere efforts.

The recent advancements in Remote Sensing (RS) and Geographic Information System (GIS) can be applied for conservation and management of water resources at a very large spatial extent with ease of use. The moisture pattern can be defined using RS imageries. The satellite imageries can be used to quantify water resources and its areal extent and selection of subsets for detailed analyses. Water has distinctive spectral properties as it absorbs radiation – in infrared imagery. This property can be used to map the water bodies in a satellite image accurately. Water quality can also be adjudged from remote sensing – turbidity and/or depth. Remote sensing can be effectively useful for flood plain delineation, Inundation modeling, flood assessment, risk modeling and mitigation, monitoring changes in stream channels.

The GIS is a very strong analytical tool which can be used to analyze variety of problems for almost all spheres of the sciences. Information related to soil, yield and soil nutrient levels can be stored in GIS. The water distribution systems (domestic and industrial) can be very well managed using GIS. The GIS can be used to perform terrain, flow modeling (flow direction and accumulation determination, contributing area analysis, stream-ordering), watershed prioritization, multi-criteria modeling/ site selection for rainwater harvesting, construction of water conservation structures, erosion prone areas, etc. The Global Positioning System (GPS), Land Laser Leveler (LLL), plastics in agriculture and micro-processor based MI systems can be used to save and conserve water in agricultural fields.

Conclusion

Water conservation and management is the pressing need of the time and it is a powerful tool which can be applicable for sustainable development in the era of climate change, increased population, urbanization, industrialization and intensified agricultural practices. In this chapter, the water situation at country and world level as whole and the impacts of population, urbanization and industrialization on water resources based on the present per capita surface water availability for 2050 and 2065 was discussed in detail. The study also suggest some of the required measures for conservation and management of water resources in different sectors such as replacement of aging water infrastructure to prevent loss of NRW and water thefts, need of water and environment education, need of SMART-Water campaigns/programs similar to the SMART-Cities, and applications of recent geo-spatial techniques like GIS and remote sensing for rainwater harvesting, precision farming, use of plastics in agriculture, public-private partnership to meet out the supply demand statistics, and application of advanced micro-irrigation systems techniques to effectively tackle the problem of water scarcity.

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