Government of Karnataka

Environmental Management & Policy Research Institute (EMPRI)

State of Environment Report for Karnataka 2015

Water Resources and Irrigation Management

Prof. Krishna Raj and Prof M G Chandrakantha
Institute for Social and Economic Change, Bengaluru

Water Resources and Irrigation Management

1. Introduction:

Water is essential for human wellbeing and environmental sustainability. Water resources of the State continues to play a crucial role for the sustainable development of the State in the years to come. Water, as an ecosystem, serves as input for production of goods and services in the economy. Karnataka's economy is one of the fastest growing economies in India with on an average Gross State Domestic product (SGDP) of 7 per cent and Per Capita Income of Rs 1,59,893 during 2016-17 (GoK, 2017). As economy is fast advancing under the new economic policy of liberalization, the competing demand for water is also growing at a higher rate for irrigation, industry, domestic, and environmental needs. The scenario of water availability and demand is swiftly changing with the mounting total population from 61 million as per the 2011 Census to projected population of 75 million by 2021 with the demographic transition of rapid urbanization. The fresh water balance is fast dwindling with continuing impact of climate change as the State is facing severe droughts for the past several years. Regardless of water scarcity, water is continued to be treated as free good even though it is essential for sustaining all life forms. Continuous depletion of surface and ground water resources both in quality and quantity would seriously affect the economy, environment and wellbeing of the society. The State is already stressed with decline in per capita availability of water. Consequently, water conflicts have already emerged with inter and intra sectoral allocation and this shows the hallmark of inefficiency in water resource management. Therefore, the stark diagnosis of the causes and consequences resulted in the state of water resources vis-à-vis to economic development will serve as a benchmark for the policy of the State towards efficient management of water resources in a larger ecosystem perspective.

2. State Water Resources at a Glance:

2.1. Rain Fall

Rainfall plays a key role in creating the unique climates of certain areas by replenishing surface and groundwater resources. The rainfall dependability is erratic as the occurrence and distribution of rainfall in the State is uneven. About 2/3rd of the geographical area of the State receives less than 750 mm of rainfall. The annual normal rainfall is 1138 mm received over 55 rainy days. It varies from as low as 569 mm in the east to as high as 4029 mm in the west. About 2/3rd of the geographical area of the State receives less than 750 mm of rainfall. Karnataka receives 73 percent of its rainfall from south west monsoon from June to September and 16 percent of the rainfall from north east monsoon from October to December (Table 1 and Figure 1). The south west monsoon obviously is the determining factor for agriculture in the State. The study by Krishnan (1991) considering the definition of drought by the II Irrigation commission that drought occurs when annual rainfall is below 75 percent of the normal rainfall, considering the data for 80 years (from 1901), in North eastern dry zone and central dry zone, drought occurred in more than 25 percent of the years (or once in four years).

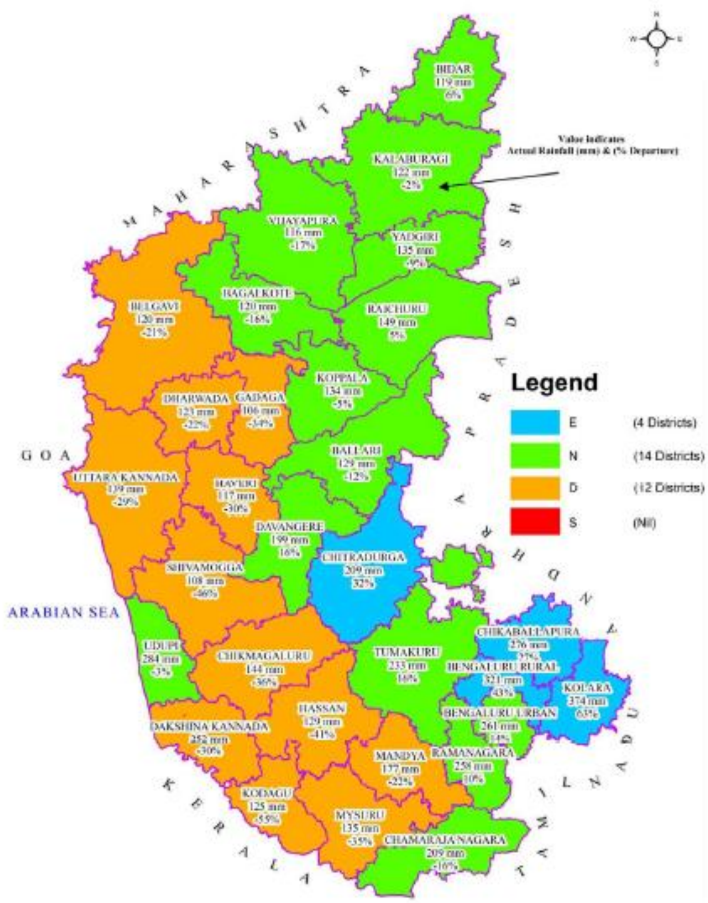
Table 1: Distribution of Rainfall in Karnataka across Seasons, Monsoons and Months

Season and Monsoon	Month	Average Rainfall Received (mm)
Kharif, South West monsoon	June - September	991.7 (73 %)
Rabi, North East monsoon	October - December	212.4 (16 %)
Cold season	January – February	8.3 (1%)
Summer season	March - May	142.3 (10%)
All seasons	June - May	1354.7 (100%)

Source: Perspective land use plan for Karnataka 2025, Karnataka state land use board, 2001, p. 565

This shows that even assured rainfall areas of the State experience scarcity of water in some years. The Karnataka is the second most drought prone region of India after Rajasthan State. The Monsoons are continuing to be erratic and deficient causing the severe droughts in more than 20 districts of the state for the last several years. The rainfall deficiency affected agriculture sector as 60 per cent of the total cultivable land is not irrigated in the State. The graphical rainfall information of all the districts is depicted in the Figure shows that is only 4 districts have Excess Rainfall (>20 per cent), 13 districts have normal rainfall (-19 to +19 per cent), 12 districts face deficient rainfall (-59 to 20 per cent) and no district falls in the scanty rainfall area (-99 to -60 per cent). This is reflected in the poor flow of rivers in the state (Fig 2)

Figure 1: District Wise Rainfall (mm) information (2015)



Source: Karnataka State Natural Disaster Monitoring Centre

The spatial and temporal variability of rainfall shows that the yield and productivity of water is fast declining with less dependability on rainwater due to the impact of climate change and this will worsen economic scarcity of fresh surface water for farming, industry, drinking and environmental water needs.

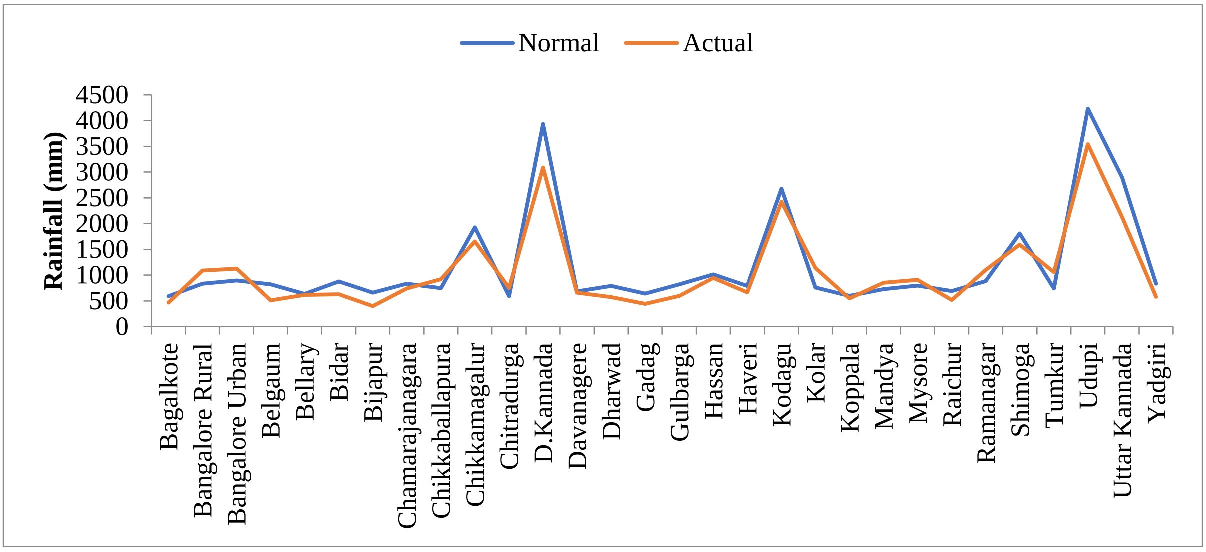
Figure 2: The Drought in Karnataka represents the poor flow of water in River Basin

Source: The Hindustan Times, 2017

2.2. Rivers:

Karnataka State is blessed with many rivers and rivulets originating mainly the Western Ghats. Even though the State has major 7 river basins viz., Krishna, Cauvery, Godavari, West Flowing Rivers, North Pennar, South Pennar and Palar with availability of 3475.2 TMC of water, hardly 1690.30 TMC of water is economically used at 50 per cent dependability for the developmental needs of the State (Table 2 and Figure 3). The River Cauvery and River Krishna together yield 93 per cent of water for the State. Economic use of water in the West Flowing Rivers is constrained as they flow in Ecological Sensitive Area of Western Ghats for the construction of dams. However, efforts are made in recent years particularly through Yattinahole Project to divert water from the West Flowing river to the Plains. The State is already reached the stage where it cannot further enhance the utilization of water through construction of storage facilities (Multipurpose Irrigation Dams) by taping surface water of the rivers as inter-state water disputes drag the developmental activities (Figure 4 and 5). This clearly shows that physical and economic scarcity of water results in insufficiency of water availability for the future developmental and environmental needs.

Figure 3: District-Wise Cumulative Rainfall in Karnataka during 2015-16



ARC Division DES

Table 2: Estimated Yield of Surface Water from River Basins of Karnataka

Sl. No.	River System	Catchment Area Sq. km	Catchment Area Percentage	Available Quantity in TMC	Percentage	Utilization in TMC	Percentage
1.	Godavari	4,405	2.30	49.97	1.44	22.37	1.32
2.	Krishna	1,13,271	59.10	969.44	27.90	1156.00	68.40
3.	Cauvery	34,273	17.80	425.00	12.23	408.62	24.17
4.	West Flowing Rivers	26,214	13.70	1998.83	57.51	0	0
5.	North Pennar	13,610	7.10	32.00	0.92	103.31	6.11
6.	South Pennar						
7.	Palar						
	Total	1,91,773	100	3475.2	100	1690.30	100

Source: Water Resources Department, Government of Karnataka

Figure 4: River Basins of Karnataka State

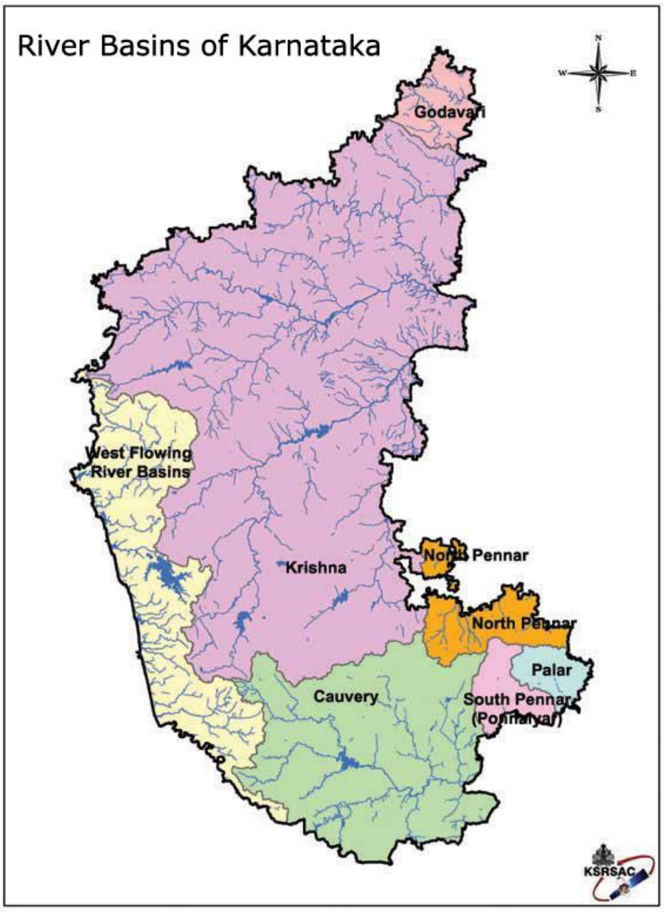


Figure 5: Tungabhadra Multipurpose Irrigation Dam in Karnataka

The comparative analysis of the water yield shows that the state yields very less water from system of 7 Rivers when compared to water yields in various basins of India. Further, the Central Water Commission estimates show that the per capita water availability is drastically dropping 15 per cent during 2001 and 2011 from 1816 to 1545 cubic meter respectively. It is projected further that this will be dropped the level of 1474 cubic meters during 2011-15 as a result the country is categorized as "Water Stressed" (Table 3). It is projected that the per capita water availability will drop further to the level of 1401 and 1191 cubic meters by 2025 and 2050 respectively. Water scarcity, water use inefficiency and inequity in water distribution have already resulted in prevalence of water poverty all over India. Karnataka less endowed with water resources is not excepted; the per capita availability of water would be less than the national average.

Table 3: Water Resources Potential of River Basins of India

Sl. No.	River Basin	Catchment Area (sq.km)	Average Water Resources Potential (BCM)	Utilizable Surface Water Resources
1	Indus	321289	73.3	46
2	Ganga-Brahmaputra-Meghna			
	(a) Ganga	861452	525	250
	(b) Brahmaputra	194413	537.2	24
	(c) Barak & others	41723	48.4	
3	Godavari	312812	110.5	76.3
4	Krishna	258948	78.1	58
5	Cauvery	81155	21.4	19
6	Subernarekha	29196	12.4	6.8
7	Brahmani-Baitarni	51822	28.5	18.3
8	Mahanadi	141589	66.9	50
9	Pennar	55213	6.3	6.9

10	Mahi	34842	11	3.1
11	Sabarmati	21674	3.8	1.9
12	Narmada	98796	45.6	34.5
13	Tapi	65145	14.9	14.5
14	West Flowing Rivers from Tapi to Tadri	55940	87.4	11.9
15	West Flowing Rivers from Tadri to Kanyakumari	56177	113.5	24.3
16	East Flowing Rivers between Mahanadi and Pennar	86643	22.5	13.1
17	East Flowing Rivers between Pennar & Kanyakumari	100139	16.5	16.5
18	West Flowing Rivers of Kutch and Saurashtra including Luni	321851	15.1	15
19	Area of Inland Drainage in Rajasthan	-	Negligible	-
20	Minor Rivers draining into Myanmar (Burma) and Bangladesh	36202	31	--
	Total		**1,869.4**	**690**

GoI, Central Water Commission, 2008

2.3. Lakes and Tanks:

Lakes and Tanks continues serve economic, recreational and ecosystem needs in rural areas and urban lakes almost not fit for productive uses due to pollution and rejuvenation has been undertaken by the Lake Development Authority. The State has about 37,000 and spread over 685000 hectares of command area. The highest number of lakes are in Hassan (5599), Kolar (4263) and Shivamogga (4890) Districts (Table 4 Figure 6). However, Belgaum district has highest hectares of land under net irrigation by the wells and tanks, followed by Bijapur and Bagalkote. The conservation of tanks and lakes is very important as more than 50 percent of irrigation tanks in the State are filled with silt and community management of tanks is completely missing and this has resulted in tragedy of common property resources.

Table 4: Lakes and Tanks Irrigated Area in Karnataka - 2014-15 (Area in Ha)

Sl. No.	District	Gross	Percentage	Net	Percentage
1	Bagalkote	298398	7.13	281220	7.69
2	Bangalore (urban)	12067	0.29	11146	0.30
3	Bangalore (Rural)	25581	0.61	22491	0.61
4	Belgaum	589508	14.08	530758	14.51
5	Bellary	290629	6.94	208501	5.70
6	Bidar	44359	1.06	39611	1.08
7	Bijapur	354472	8.47	309811	8.47
8	Chamarajanagar	62851	1.50	55022	1.50
9	Chikkaballapur	54787	1.31	46512	1.27
10	Chikkamagalur	62113	1.48	53912	1.47
11	Chitradurga	103686	2.48	88117	2.41
12	Dakshina Kannada	82309	1.97	80527	2.20
13	Davanagere	251002	6.00	203716	5.57
14	Dharwad	56120	1.34	43113	1.18
15	Gadag	103442	2.47	100004	2.73

16	Gulbarga	132803	3.17	119895	3.28
17	Hassan	116564	2.78	104128	2.85
18	Haveri	120828	2.89	98447	2.69
19	Kodagu	1637	0.04	1637	0.04
20	Kolar	26144	0.62	17135	0.47
21	Koppal	180882	4.32	158282	4.33
22	Mandya	154229	3.68	130584	3.57
23	Mysore	170538	4.07	153774	4.20
24	Raichur	258920	6.19	237381	6.49
25	Ramanagar	41302	0.99	37322	1.02
26	Shimoga	174515	4.17	143639	3.93
27	Tumkur	163908	3.92	146072	3.99
28	Udupi	33642	0.80	32870	0.90
29	Uttara kannada	40425	0.97	38778	1.06
30	Yadgir	178520	4.26	164302	4.49
Karnataka State		4186181	100.00	3658707	100.00

Source: Annual Season & Crop Statistics Report 2014-15 of DE&S, Bangalore.

Figure 6: Thonnur lake, Thonnuru in Pandavapura Taluk of Mandya District

2.4. Ground Water:

Ground water is another important source for meeting nearly half of the demand for Irrigation, industrial production, and municipal water needs of both rural and urban areas. The total replenishable ground water potential for the State is estimated at 17.03 Billion Cubic Meters (BCM) received from both monsoon and non-monsoon seasons (rainfall constitutes 9.48 BCM and recharge of 7.55 BCM from other sources. It is estimated that 2.2 BCM of water is naturally discharged during the non-monsoon period and net availability of ground water is 14.81 BCM. The total annual ground water draft (9.41 BCM) for irrigation and Domestic and Industrial use is estimated at 8.59 and 0.28 BCM respectively and the residual 5.4 BCM is available for economic use (Table 5). The State has already over drafted ground water by 64 per cent and 6.53 BCM is available for future use (GoI, 2014). Government of India assessed ground water status in 270 blocks of 26 districts and among them 34 blocks identified as semi critical, 21 as critical and 63 as over exploited.

Table 5: Ground Water Resources Availability and Utilization in Karnataka

Sl. No.	District	Annual Replenishable Ground Water*	Net Ground Water Availability#	Annual Ground Water Draft			Projected demand for Domestic and Industrial Use (2025)	Net Ground Water availability for future irrigation use
				Irrigation	Domestic & Industrial Use	Total		
1	Bagalkote	43208	39574	32904	3028	35932	3838	10795
2	Bangalore Rural	21391	20184	22376	3239	25616	3240	107
3	Bangalore Urban	13417	12746	12229	5749	17978	5749	0
4	Belgaum	114125	103436	73925	6337	80261	8000	31892
5	Bellary	72946	65966	24363	3072	27436	4871	37877
6	Bidar	32722	30680	15732	1766	17498	2348	13719
7	Bijapur	51446	47410	30634	5006	35640	6070	16071
8	Chamrajnagara	37785	34322	26170	1446	27616	1910	10017
9	Chikballapur	32703	29883	40612	2705	43318	2735	1591
10	Chikmagalur	68630	56402	22015	2235	24250	2604	32580
11	Chitradurga	54852	49677	47941	2941	50882	3557	5998
12	Dakshin Kannada	51579	32404	19414	2958	22373	3471	10614
13	Davangere	61215	55952	46814	2800	49613	4236	11840
14	Dharwad	27151	21745	11850	917	12767	1524	8549
15	Gadag	27127	24957	20613	1577	22190	2011	5581
16	Gulbarga	69295	63299	16699	3374	20073	4609	42025
17	Hassan	82020	73593	37804	2347	40151	3486	38414
18	Haveri	58188	53154	31214	2680	33894	3734	18465
19	Kodagu	32328	27441	5451	433	5884	617	21373
20	Kolar	33889	31828	57766	1757	59523	1757	0
21	Koppal	60093	54352	21625	1590	23215	2533	31181
22	Mandya	104395	94103	42432	2043	44476	3470	52536
23	Mysore	63391	57803	23075	2043	25118	3634	32178
24	Raichur	92116	83209	23232	2207	25439	3483	57628

25	Ramanagara	24087	22298	19527	4527	24054	4779	749
26	Shimoga	108216	92549	23330	1962	25292	2856	66378
27	Tumkur	85428	78424	73846	4488	78334	6596	15495
28	Udupi	53834	32775	9646	2393	12039	2888	20241
29	Uttar kannada	83421	52905	16869	2752	19621	3256	32780
30	Yadgir	41666	38050	9051	1607	10657	2499	26500
	State Total (bcm)	17.03	14.81	8.59	0.82	9.41	1.06	6.53

Note: *- Recharge from both rainfall and other source #- Net ground water availability after natural discharge during non-monsoon season Source: GoI, 2014

2.5. Water Balance:

The State's water resources are fast dwindling mainly due to vagaries and deviation of normal rainfall. Rivers experience low flow and less than 50 per cent dependency and consequent shortage water storage in Reservoirs (Table 6). Depletion of ground water table due to overdraft at 64 per cent is a serious cause for concern. As a result, the critical water flow in the rivers has affected the river ecosystem. While climate change is seriously impacted on the rainfall pattern in the state. Deforestation in Ecological Sensitive Areas of Western Ghats has limited the river flows in the basins and also cause silt accumulation in the Dams. The overdraft of ground water is drastically shortened the water replenishment. Lakes and tanks bunds are mercilessly encroached and diverted for agriculture and other development purposes allowing them for gradual demise.

Table 6: Major Reservoir Levels (Feet) in the State (2016)

Sl No	Name of the Reservoir	Reservoir level (As on 2016)	Deviation	Per cent Deviation
1	Linganamakki	1790	29	1.59
2	Supa	1787	63	3.41
3	Varahi	1915	34	1.74
4	Harangi	2818	41	1.43
5	Hemavathi	2865	57	1.95
6	Krishna Raja Sagara	79	46	36.80
7	Kabini	1160	1124	49.21
8	Bhadra	2116	42	1.95
9	Tungabhadra	1587	46	2.82
10	Ghataprabha	2144	31	1.43
11	Malaprabha	2050	29	1.39
12	Alamatti	1686	18	1.06
13	Narayanapura	1611	4	0.25

These structural changes in the economy and environment have seriously affected the water availability from both surface and ground water sources for meeting the current and future water requirement of the State. This clearly implies that water crisis due to deficit will continue in the State. Obviously, the State is highly constrained to meet future demands for agricultural, industrial, domestic water supply and ecological needs unless efforts are made on war footing to secure water catchment areas of rivers, integrated watershed management for replenishment of ground water, securing common property resources such as Lakes and Tanks and protecting River Banks. Apart from supply side management of water resources, the blatant inefficiency in water use in all the sectors is paramount and that calls for demand side management of water resources effecting change in the pattern of production and consumption of agricultural crops, industrial products, and drinking water. Combination of supply and demand side management of water resources will ensure long-term water resource balance (water supply equals water demand) in the state and in turn which will secure our common future.

3. Pressure Points:

3.1. Water Demand:

The accelerating demand for water exceeds supply in future making the State as "Water Deficit or Stress". This will limit the economic growth prospects of agriculture, industrial production and meeting essential drinking water needs in both rural and urban areas. Understanding of water in a globalized economy as economic good ensures devising various new market instruments towards achieving higher economic growth with limited use of water. This will also help efficient and equitable allocation of water among competing sectors of the economy. Efforts have been made to include Natural Capital such as Water in the Integrated Economic and Environmental Accounting or Green GDP and also to assess the Total Economic Value (TEV) of water contributing for economic growth. Already the growing scarcity of water is reflected in the emergence of formal and informal water market in agriculture, industry and domestic water use. The society has accepted the end of abundance of water or water is conditionally renewable good and no more it is merely a renewable good. Sever drinking water shortages due to droughts and depleting water tables all over the State has forced the Government to take policy measure for efficient and equitable allocation of water for all the sectors. Interstate water conflicts and public outcry or societal water struggles are showing up in more often in several places of the State in recent years. As a result, the property rights over water (allocation of interstate water) is defined, asserted, and imposed by the institutions due to growing water scarcity. Therefore, an assessment of water demand by the agriculture, industry and domestic sectors clearly accounts that to what extent the competing requirement of water exists with limited supply. Even though, water allocation is highly skewed for agriculture sector, recent economic growth and population explosion drive more allocation of water for Industrial and domestic water needs.

3.1.1. Water Demand for Agriculture Sector:

Agriculture sector continues to use 85 per cent of the total water in the state. However, at the same time the demand for agriculture sector is growing for both surface and ground water. However, the State has brought only 34 per cent of the total gross cultivated area under the gross irrigation. The trend will continue to due to State policy of bring more cultivated area under irrigation as the state faces severe droughts in the Hyderabad Karnataka regions (Tables 7 and 8, Figure 7).

Table 7: Land use & Irrigation for Karnataka State

Sl. No.	Classification	Year				
		2010-11	2011-12	2012-13	2013-14	2014-15
1	Total geographical area	190.5				
2	Net Area sown	105.23	99.41	97.93	99.23	101.34
3	Area sown more than once	25.4	21.18	19.55	23.44	21.13
4	Total cropped area	130.62	120.59	117.48	122.67	122.47

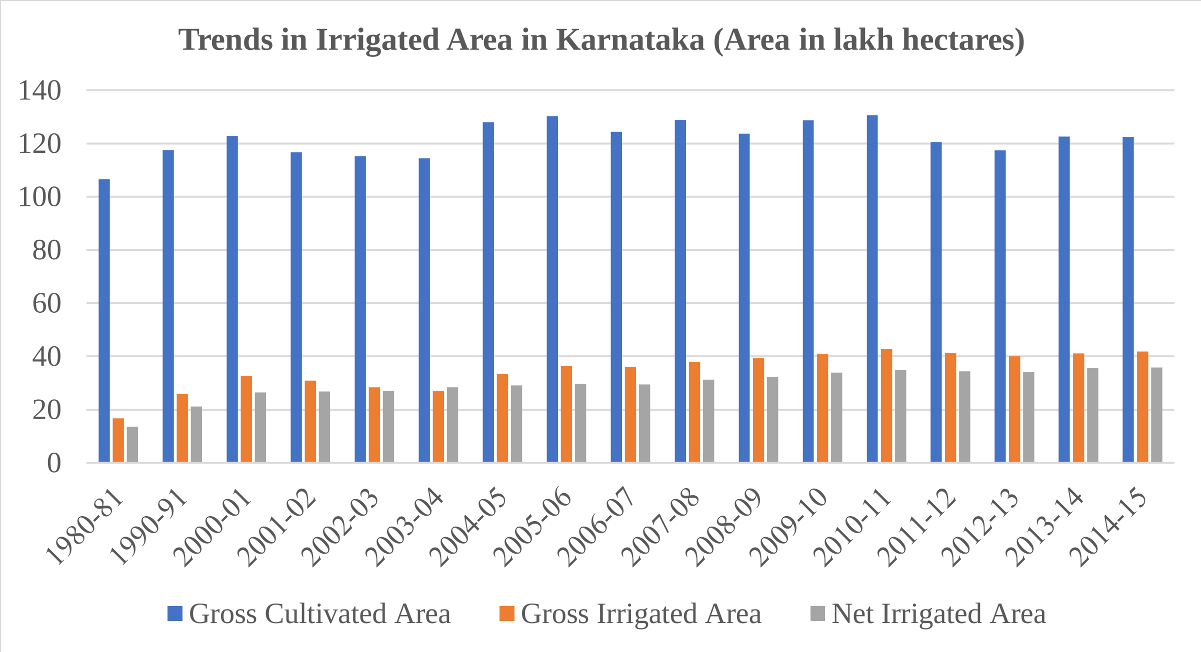
4A	Area under Agricultural Crops	111.62	101.23	98.74	103.94	102.26
5	Cropping intensity	124	121	120	124	121
6	Net irrigated area	34.9	34.4	34.21	35.56	36.59
7	Net irrigated area in %	33	35	35	36	36
8	Gross irrigated area	42.79	41.37	40.07	41.12	41.86
9	Gross irrigated area in %	33	34	34	34	34
10	Cropping intensity in Irrigated areas	123	120	117	116	114
11	Net rainfed area	70.33	65.01	63.73	63.68	64.75
12	Net rain fed area in %	66.83	65.39	65.07	64.17	63.9
13	Gross rain fed area	87.83	79.23	77.41	81.55	80.6
14	Gross rainfed area in %	67.24	65.7	65.89	66.48	65.82
15	Cropping Intensity in Non- Irrigated areas (rainfed areas)	125	122	121	128	124

Table 8: Trends in Irrigated Area in Karnataka (Area in Lakh Hectares)

Year	Gross Cultivated Area	Gross Irrigated Area	Net Irrigated Area	Growth rate of GIA (%)	Growth rate of NIA (%)	Gross Irrigated Area (%)
1980-81	106.6	16.76	13.62	-	-	16
1990-91	117.59	25.98	21.13	55.01	55.14	22
2000-01	122.84	32.71	26.43	25.90	25.08	27
2001-02	116.7	30.89	26.83	-5.56	1.51	26
2002-03	115.32	28.41	27.05	-8.03	0.82	25
2003-04	114.5	27.02	28.38	-4.89	4.92	24
2004-05	128.07	33.28	29.06	23.17	2.40	26
2005-06	130.27	36.32	29.7	9.13	2.20	28
2006-07	124.38	36.03	29.46	-0.80	-0.81	29
2007-08	128.93	37.89	31.32	5.16	6.31	29
2008-09	123.68	39.42	32.38	4.04	3.38	32
2009-10	128.73	40.96	33.91	3.91	4.73	32
2010-11	130.62	42.79	34.9	4.47	2.92	33
2011-12	120.59	41.37	34.4	-3.32	-1.43	34
2012-13	117.48	40.07	34.2	-3.14	-0.58	34
2013-14	122.67	41.12	35.56	2.62	3.98	33
2014-15	122.47	41.86	35.89	1.80	0.93	34

GoK, DES 2016-17

Figure 7: Trends in cultivated and Irrigated area (Lakhs Hectares) in Karnataka



3.1.1.1.Ground Water Demand:

Karnataka state depends on groundwater for irrigation to the extent of 51 percent. Thus, the State depends almost equally on groundwater and surface water for irrigation (Tables 9 and 10). Ground water resources have not been exploited uniformly throughout the state. Exploitation of ground water in the dry taluks of North and South interior Karnataka is higher as compared to Coastal, Malnad and irrigation command areas. There is deficiency of water for drinking, agricultural and industrial use in dry taluks of North and South interior Karnataka. Where adequate surface water is available, utilization of ground water resources is minimum. In about 43 taluks there is overexploitation of ground water resources. Further, groundwater exploitation has exceeded 50% of the available ground water resources in 29 taluks of the State. These 72 taluks are critical taluks from the point of view of the ground water exploitation. In the 72 critical taluks about 4 lakh wells irrigate an area of 7.5 lakh ha. Due to over exploitation of ground water resources, more than 3 lakh Dug-wells have dried. Shallow bore wells have failed and yield in deep bore wells are declining. Area irrigated by ground water extraction structures is decreasing. Consequently, more than Rs.2000 crores of investment made by the individual farmer on the construction of wells, pumping equipment, pipelines, development etc., have become infructuous.

Table 9: Groundwater supply in Karnataka

Groundwater structures	**Number**	Total gross irrigated area (ha)
1. Dug wells (or Open wells)	456463	483074
2. Tube wells	619099	1288639
All Wells	1075562	1771713
Total **S**urface and **G**roundwater irrigated area (ha)		3457231

Considering the total of 2180 TMC of water, 1695 TMC of surface water which forms 78 percent of the total irrigates fifty percent of the irrigated area of 16,85,548 ha. The remaining

485 TMC of groundwater forming 22 percent of the total volume of water irrigated the remaining 50 percent of the irrigated area. This shows the lopsided distribution of surface water compared to groundwater resources. Thus, groundwater farmers are relatively more efficient than the surface water farmers as the groundwater farmers use their scarce 22 percent of water on 50 percent of irrigated land, while the surface water farmers use 78 percent of state's water on 50 percent of irrigated land. Thus 1/4th of total water (=groundwater) is used on half the irrigated land and 3/4ths of total water (=surface water) is used on the other half of irrigated land in Karnataka (Table).

Table 10: State of Groundwater Development in Karnataka

Particulars	Volume in ha meters	Vol in TMC
1. Net groundwater availability (supply)	1529659 ha meters	540.19
2. Groundwater use for irrigation	974731 ha meters	344.22
3. Groundwater use for domestic & industrial purpose	96581 ha meters	34.10
4. Groundwater use for all purposes	1071312	378.33
5. Average crop water requirement	83 cms or 830 mm	
6. Balance groundwater potential available	781340 hectares	

1 TMC = 2831.7 ha meters; 1 ha meter = 10000 M^3

In order to increase access to groundwater for farmers, Government resorted to implementing schemes such as Million Wells Scheme (MWS) in 1988. In addition, soft loans were provided to dig /drill wells, rural electrification schemes were introduced for pump energization. Since 1980, the energy supplied for pumping groundwater for irrigation has also been provided free of cost to farmers to encourage groundwater extraction and use in irrigated agriculture. These schemes unfortunately lacked environmental focus. Even though there were restrictions such as maintenance of isolation distance between irrigation wells, this applied only to those wells for which institutional credit was to be disbursed. Even this rule was seldom followed in letter and spirit. There was also no limit on the number of functioning wells a farmer could possess. Even to this day, there is no restriction on this parameter. Thus, due to encouragement to dig and drill wells through different schemes, there was a gradual leap in the depth to groundwater through change in water extraction structures (from dug well to dug cum bore well, onto shallow and deep bore wells. Private capital formation in agriculture now largely refers to investment by farmers on irrigation wells. Thus, these resulted in use of mechanical power to lift water and increased energy use as reflected in increased Horse Power from 5 HP centrifugal pumps to above 10 HP submersible pump sets.

3.1.2. Water Demand for Industrial Sector:

Water demand for Industrial needs are fast growing in the state with the flow of foreign direct investment and government policy of crating more industrial parks. Karnataka is the fifth most industrialized state in India with the rapid expansion of the economy under the liberalization. Present water demand of the industry is estimated at 47.60 TMC and which will be increased to 125 TMC by 2025. Further the ground water demand for Industrial needs will also increase. As per the Karnataka Industrial Policy, 2014-19, the demand for water from all the types of industry is estimated at 240 MLD by 2025. Expansion plans for thermal power will considerably increase demand for water, while growth of the steel industry will require a billion cubic meters (34 TMC) (Table 12).

Table 12: Water Demand for Industrial Sector in Karnataka

Sector	No. of Units	Investment (Crore)	Water requirement (Million liter/ day)
Micro	150000	25000	15
Small	15000	50000	10
Medium	3000	50000	15
Large	1500	75000	30
Mega	300	100000	20
Ultra-Mega	150	100000	50
Super Mega	75	100000	100
Total	170025	500000	240

Source: Karnataka Industrial Policy, 2014-19

The water needs for industrial use in Karnataka have been estimated for Krishna Basin to be 16.62 TMC in 2010, which comprises of 4.99 TMC of groundwater and 11.64 TMC of surface water. This is expected to grow to 29.64 TMC in 2025 (4.59 TMC of groundwater and 25.06 TMC of surface water) and to 50.45 TMC in 2050 (4.22 TMC of groundwater and 46.23 TMC of surface water). The groundwater scarcity is largely responsible for shift to surface water for industrial use in the State. Though the areas other than Krishna basin approximately form 25 percent of State's area, the industrial development is almost 50 percent of the State. Thus, it can be hypothesized that the industrial use in Karnataka will be double of the estimate for Krishna basin. Hence the total water use / demand for industry is accordingly 33.24 TMC in 2010, 59.28 TMC in 2025 and 100.9 TMC in 2050 with corresponding proportions of groundwater and surface water as already estimated above (GOK).

3.1.3. Water Demand Household:

The total population of Karnataka is projected to increase from about 61 million in 2011 to 80 million by 2030. Considering the per capita requirement of 150 liters per day for rural and 220 liters per day for urban, the drinking water needs are 115.62 TMC for rural and 59.78 TMC for urban population. The total requirement for water is 150.31 TMC for rural and 77.71 TMC for urban including the T and D losses of 30 percent. The total demand for the State including all areas can be conveniently taken as twice that of the demand for Krishna basin. Accordingly, the total requirement for domestic water needs for urban and rural population in Karnataka in 2050 is 456.04 TMC. The total demand for domestic consumption of water in urban areas is projected to increase from 46 thousand million cubic feet (TMC) per year in 2011 to about 84 TMC by 2030. An additional supply of about 49 TMC annually would be needed to close the demand-supply gap. The Greater Bangalore region will account for two-thirds of the additional water requirement. Bangalore's gross water demand, which was 1,556 MLD in 2010, is expected to rise to 1,775 MLD in 2018 and 1,986 MLD in 2020. While Bangalore's supply, with the completion of Cauvery Stage 4, Phase 2, went up from 900 MLD to 1,400 MLD, it is inadequate to meet even the current and the demand.

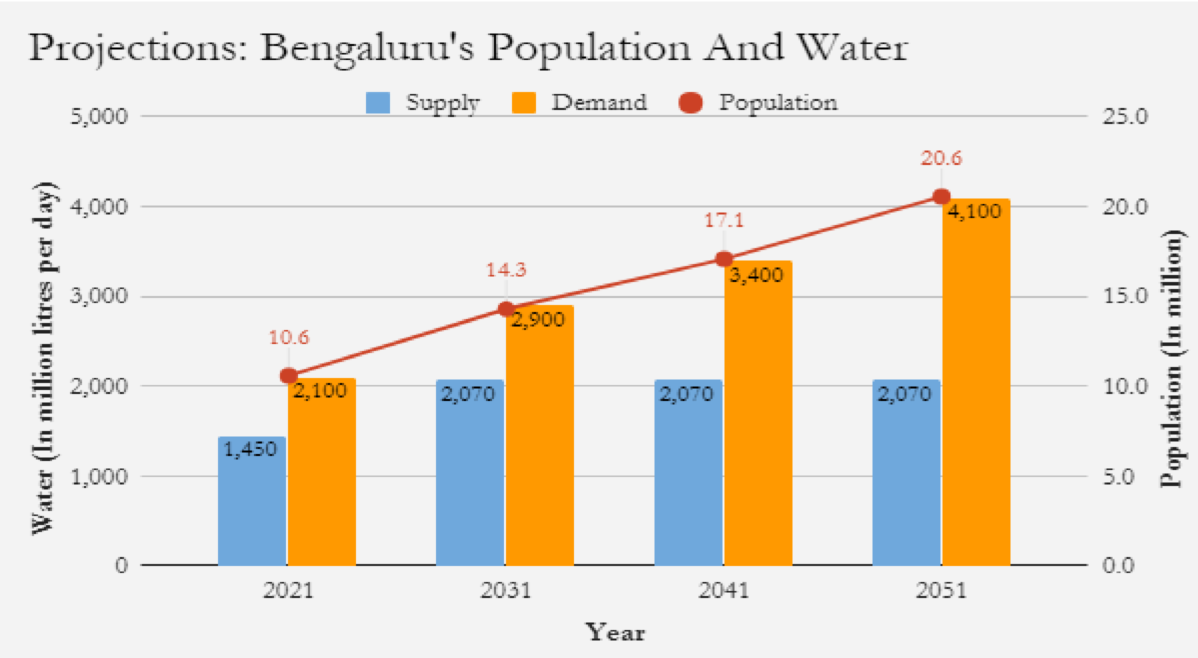
Table 13: Projected water Requirement for Bengaluru, Karnataka

Year	Population (Million)	Water Demand in MLD	Present Supply in MLD	Gap in MLD
2011	8.49	1400 (18.05)	950 (12.25)	450 (5.8)
2021	10.58	2100 (27.10)	1450 (18.7)	650 (0.4)

2031	14.29	2900 (37.39)	2070 (26.7)	830 (10.69)
2041	17.08	3400 (43.84)	2070 (26.7)	1330 (17.14)
2051	20.56	4100 (52.86)	2070 (26.7)	2030 (26.16)

Note: MLD- Million Liters per Day, Figures in parenthesis indicate respective values in TMC

Figure 8: Projections for Bengaluru Population and Water Demand



The State by 2030 is likely to double its water demand from all the sector. In the agriculture and municipal sectors, that demand is expected to rise many fold. The agriculture sector alone consumes 85 percent of the state's water, further, the demand for water has dramatically increased from urban and industrial sectors. The largest cities and most water-intensive industries are located where water is relatively scarce, which may create stress among competing water users. Already the State's largest and most economically significant rivers Krishna and Cauvery face a water demand-supply deficit (Table 13 and Figure 8).

4. Major Challenges:

4.1.Ground Water Depletion:

Further, groundwater exploitation has exceeded 50% of the available ground water resources in 29 taluks of the State. These 72 taluks are critical taluks from the point of view of the ground water exploitation. In the 72 critical taluks about 4 lakh wells irrigate an area of 7.5 lakh ha. Due to over exploitation of ground water resources, more than 3 lakh Dug-wells have dried. Shallow bore wells have failed and yield in deep bore wells are declining. Area irrigated by ground water extraction structures is decreasing. Consequently, farmers are bearing additional investment on the construction of wells, pumping equipment, pipelines, development (Table 14 and 15, Figure 9).

Table 14: Depth of Ground water table across different districts of Karnataka

Districts	Maximum Depth (mbgl)	Minimum Depth (mbgl)
Bagalkot	1.84	15.65

Bangalore Rural	0.67	13.9
Bangalore Urban	0.03	29.35
Belgaum	0.072	21.23
Bellary	0.6	21.35
Bidar	0.45	21.57
Bijapur	0.43	18.5
Chamarajanagar	0.71	21
Chikmagalur	0.11	19.9
Dakshin Kannada	1	18.9
Davanagere	0.95	13.6
Dharwad	1.31	24.09
Gadag	1.43	25.71
Gulbarga	0.6	15.77
Hassan	0.69	19.25
Haveri	0.89	16.3
Kodagu	1.65	16
Kolar	0.7	19.21
Koppal	1.1	15.5
Mandya	0.58	26.95
Mysore	0.38	24.4
Raichur	0.35	25.5
Shimoga	0.65	16.5
Udupi	0.09	16
Uttara Kannada	0.92	15.78
Total	0.03	29.25

Source: Ground Water year book, Karnataka, 2015 (mbgl: meter below ground level)

Table 15: Districts with Highest Contamination of Ground Water in Karnataka

Districts	No. of Water Sources
Excess Fluoride	
Chickballapur	689
Tumkur	689
Bellary	489
Chitradurga	360
Kolar	289
Excess Nitrate	
Mandya	767
Kolar	647
Davangere	442
Bangalore Urban	399
Tumkur	359

Figure 9: Percentage of Assessed Units in Over-Exploited, Critical or Semi Critical State

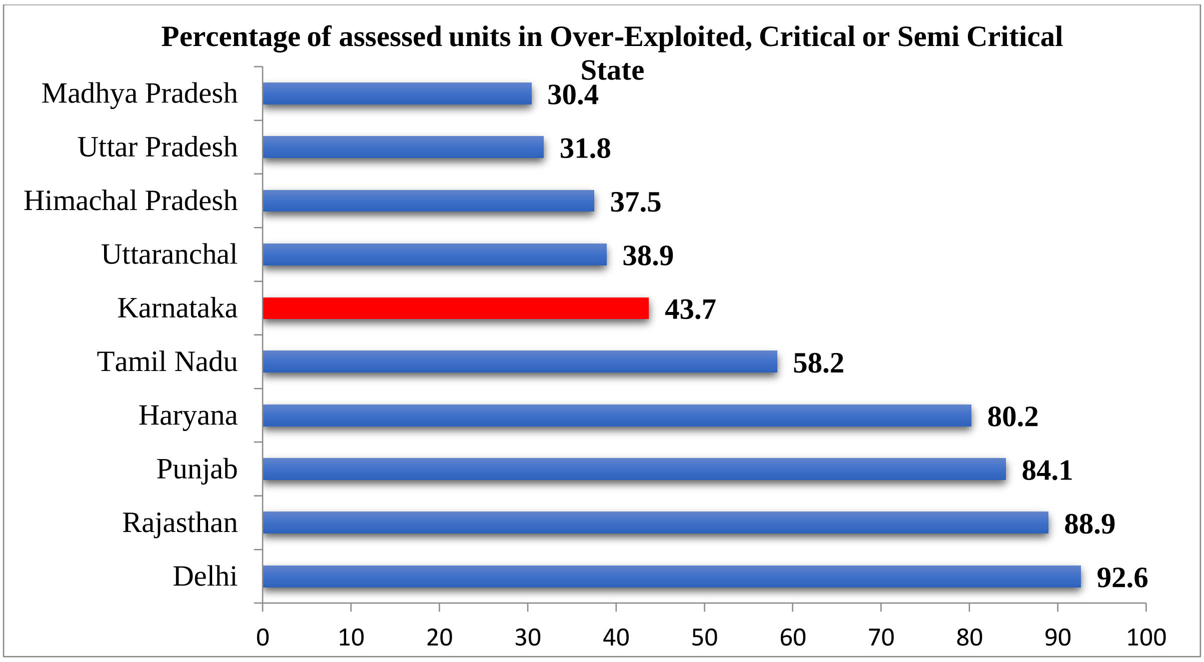


Table 16: States Affected by Arsenic and Fluoride Contamination of Water in India

State	Total Water Quality Affected Habitations	Arsenic (>0.05 mg/l)	Fluoride (>1.5 mg/l)
Rajasthan	20895	0	6855
West Bengal	10004	962	1053
Assam	8840	284	155
Jharkhand	6834	119	998
Bihar	5574	102	1087
Punjab	3770	206	285
Odisha	2799	0	70
Karnataka	2117	4	1054
Telangana	1484	0	1041
Chhattisgarh	1148	0	75
Kerala	656	0	73
Andhra Pradesh	571	0	491
Maharashtra	394	0	100
Uttar Pradesh	361	57	200
Haryana	209	0	200
Madhya Pradesh	193	0	148
Gujarat	17	0	11

Source: Ministry of Drinking Water and Sanitation, 2016

The drinking water in the State is affected with high concentration of Arsenic and Fluoride 2117 habitants as per the Survey of Union Ministry of Drinking water and Sanitation during 2009-10. Many samples have shown that presence of high levels of fluoride, nitrate, iron and heavy metals which is against the drinking water standards fixed by the government of India (Table 16 and 17).

Table 17: Drinking Water Specifications

Sl.No.	Characteristics	Desirable Limit	Permissible Limit
Essential Characteristics			
1	Colour (Hazen units)	5	25
2	Odour	Unobjectionable	-
3	Taste	Agreeable	-
4	Turbidity (NTU)	5	10
5	PH	6.5 to 8.5	-
6	Total hardness (mg/l)	300	600
7	Iron (mg/l)	0.3	1.0
8	Chloride(mg/l)	250	1000
9	Residual free chloride (mg/l)	0.2	-
Desirable Characteristics (mg/l)			
10	Dissolved soils	500	2000
11	calcium	75	200
12	Magnesium	30	75
13	Copper	0.05	1.5
14	Manganese	0.1	0.3
15	Sulphate	200	400
16	Nitrate	45	100
17	Fluoride	1.0	1.5
18	Phenolic compound	0.001	0.002
19	Mercury	0.001	
20	Cadmium	0.01	
21	Selenium	0.01	
22	Arsenic	0.05	
23	Cyanide	0.05	
24	Lead	0.05	
25	Anionic detergents	0.2	1.0
26	Chromium as Cr	0.05	-
27	PAH		
28	Mineral oil	0.01	0.03
29	Pesticides	Absent	0.001
30	Alkalinity	200	600
31	Aluminum	0.03	0.2
32	Boron	1	5

4.2. Water Resources and Irrigation Management:

Agricultural water productivity will help to grow more crops per drop of water. Reducing agricultural water use is important for the sustainability of agriculture, raising farm-level incomes, and alleviating poverty and water inequity. Sustainable use of water in agriculture sector helps to supply of fresh water to water scarcity areas and sectors like industry and domestic sectors. The ratio of water consumed by crops to relative to water applied has to be reduced drastically with adoption of minor irrigation. While enhancing the total ultimate irrigation potential (UIP) of the state which at about 60 lakhs hectares the overriding importance must be given on minor irrigation. Therefore, there is an urgent need to bring more and more areas under micro irrigation in the state. Water efficiency or productivity has to be improved in the ultimate potential areas of State to allocate water resource for other competing sectors (Table 18).

Table 18: Ultimate Irrigation Potential ('000 ha) in Karnataka and India

States	**Major & Medium**	**Minor**			Total
		Surface	**Ground**	**Sub-total**	
Andhra Pradesh	5000	2300	3960	6260	11260
Arunachal Pradesh	0	150	18	168	168
Assam	970	1000	900	1900	2870
Bihar	5224	1544	4120	5664	10888
Chhattisgarh	1147	81	490	571	1718
Goa	62	25	0	25	87
Gujarat	3000	347	2756	3103	6103
Haryana	3000	50	1462	1512	4512
Himachal Pradesh	50	235	68	303	353
Jammu & Kashmir	250	400	708	1108	1358
Jharkhand	1276	354	830	1184	2460
Karnataka	**2500**	**900**	**2574**	**3474**	**5974**
Kerala	1000	800	879	1679	2679
Madhya Pradesh	4853	2111	9250	11361	16214
Maharashtra	4100	1200	3652	4852	8952
Manipur	135	100	369	469	604
Meghalaya	20	85	63	148	168
Mizoram	0	65	5	70	70
Nagaland	10	70	5	75	85
Orissa	3600	1000	4203	5203	8803
Punjab	3000	50	2917	2967	5967
Rajasthan	2750	600	1778	2378	5128
Sikkim	20	50	0	50	70
Tamil Nadu	1500	1200	2832	4032	5532
Tripura	100	100	81	181	281
Uttar Pradesh	12154	1186	16295	17481	29635
Uttarakhand	346	14	504	518	864
West Bengal	2300	1300	3318	4618	6918
All States	58367	17317	64066	81383	139750
All UTs	98	20	26	46	144
All-India	**58465**	**17337**	**64092**	**81429**	**139894**

4.3.Water use Efficiency through Micro Irrigation:

The Potential and Actual Area under Micro Irrigation in given for Selected States and Karnataka which shows there is scope for bring more area under drip and sprinkler irrigation technology in the State. The water use efficiency varies widely across sectors. The efficiency is the lowest in irrigation followed by industry and domestic uses. The water use efficiency varies with method of irrigation also. The efficiency is the highest for drip irrigation farms while the lowest for flood or conventional irrigation farms. Since agriculture is the largest user of water (using 92 percent of all water), it is pertinent to deal in detail. The crops, area irrigated, productivity, consumptive use, common method of irrigation and water use efficiency (Table 19, 20, and 21) indicates that the highest area irrigated is in paddy crop followed by sugarcane, maize, groundnut, sunflower, coconut, arecanut, wheat, Bengal gram. Flow irrigation is the common method followed while drip irrigation is emerging as the innovative method for crops like coconut, grapes, mulberry. The water use efficiency obtained by dividing the yield obtained per ha by the water used per ha, gives the highest value for cabbage followed by grapes, brinjal, mulberry, banana. Thus, water use efficiency is higher for fruits and vegetable crops compared to cereals and pulses. Even in value terms this holds good.

Table 19: Potential and Actual Area under Micro Irrigation in Selected States (thousand ha)

State	Drip Irrigation			Sprinkler Irrigation			Total		
	Potential	Actual	%	Potential	Actual	%	Potential	Actual	%
Andhra Pradesh	730	363.07	49.74	387	200.95	51.93	1117	564.02	50.49
Gujarat	1599	169.69	10.61	1679	136.28	8.12	3278	305.97	9.33
Maharashtra	1116	482.34	43.22	1598	214.67	13.43	2714	697.02	25.68
Karnataka	745	177.33	23.8	697	228.62	32.8	1442	405.95	28.15
Chhattisgarh	22	3.65	16.58	189	59.27	31.36	211	62.92	29.82
Haryana	398	7.14	1.79	1992	518.37	26.02	2390	525.5	21.99
Tamil Nadu	544	131.34	24.14	158	27.19	17.21	702	158.52	22.58
All India	11659	1428.46	12.25	30578	2442.41	7.99	42237	3870.86	9.16

Source: Indiastat (2010)

Table 20: Irrigation practices, crop yield, water use efficiency in Karnataka

No	Crop	Total Area (Ha)	Crop Yield (Kg/ha)	Irrigation in acre inches (or ha cms)	Irrigation practice	Water use efficiency = (kgs per acre inch = kgs/ ha cm)
1	Paddy	1032902	2985	45	Flow	66.33
2	Jowar	148906	1675	12	Flow, sprinkler	139.58
3	Ragi	38539	2250	12	Flow	187.50
4	Bajra	49521	819	12	Flow, sprinkler	68.25
5	Maize	447042	3716	24	Flow, sprinkler	154.83
6	Wheat	142900	1251	24	Flow, sprinkler	52.13
8	Navane	16225	244	8	Flow	30.50
12	Red gram	29178	464	20	Flow, sprinkler	23.20
13	Horse gram	934	335	8	Flow	41.88
14	Black gram	1463	175	12	Flow	14.58
15	Green gram	4691	126	10	Flow	12.60
16	Avare	2824	907	6	Flow	151.17
17	Cowpea	12274	562	10	Flow, sprinkler	56.20

18	Other pulses	17186	299	12	Flow	24.92
19	Bengalgram	100456	759	10	Flow	75.90
21	Sugarcane	479063	92000	79	Flow, drip	1164
22	Dry Chilli	43002	1032	28	Flow, sprinkler	36.86
23	Dry Ginger	9135	1322	31	Flow	42.65
24	Turmeric	13259	5049	31	Flow	162.87
25	Cardamom	859	58	28	Flow	2.07
26	Coriander	3231	150	16	Flow	9.38

Table 21: Irrigation practices, crop yield, water use efficiency in Karnataka (continued)

No	Crop	Total Area (Ha)	Yield (Kg/ha)	Irrigation in acre inches = ha cm	Irrigation practice	Water use efficiency = (kgs per acre inch = kgs /ha cm)
27	Garlic	1672	672	20	Flow, sprinkler	33.60
28	Pepper	3186	214	20	Flow	10.70
29	Areca nut	154868	2250	31	Flow, drip	72.58
30	Coconut	219506	4093	39	Flow, drip	104.95
31	Cashew	301	565	20	Flow	28.25
32	mango	9504	5218	20	Flow, drip	260.90
33	grapes	12106	27313	28	Flow, drip	975.46
34	Banana	48371	19965	39	Flow	511.92
35	Papaya	2246	2428	24	Flow	101.17
36	Pomegranate	17467	6332	24	Flow, drip	263.83
37	lemon	7982	4451	20	Flow, drip	222.55
38	guava	3559	2915	24	Flow, drip	121.46
39	sputa	10478	3782	20	Flow, drip	189.10
40	Potato	9615	9318	26	Flow, sprinkler, drip	358.38
41	Sweet Potato	485	8387	24	Flow	349.46
42	Onion	53534	5978	24	Flow, sprinkler	249.08
43	brinjal	11782	9720	16	Flow	607.50
44	Tomato	30854	10201	24	Flow, drip	425.04
45	Beans	5622	6437	16	Flow	402.31
46	Cabbage	4449	20068	18	Flow, sprinkler	1114.89
47	groundnut	206820	799	14	Flow, sprinkler	57.07
48	Sesamum	1155	619	10	Flow	61.90
49	Safflower	1291	782	12	Flow	65.17
50	Sunflower	215624	750	14	Flow, sprinkler	53.57
51	Soyabean	12556	780	20	Flow	39.00
52	Castor	333	841	10	Flow	84.10
53	Linseed	202	322	14	Flow	23.00
54	Niger	74	191	10	Flow	19.10

55	Rape&Mustard	243	267	8	Flow	33.38
56	Cotton	55920	536	28	Flow, sprinkler	19.14
57	Mulberry	28767	20000	36	Flow, drip	555

Figures 10: Cultivation of Various Crops with Drip Irrigation Technology

Carrot cultivation under drip irrigation in Kolar, Eastern Dry Zone

Potato cultivation under drip irrigation in Kolar, Eastern Dry Zone

Field beans cultivation under drip irrigation in Kolar, Eastern Dry Zone

Cabbage cultivated under drip irrigation in Kolar, Eastern Dry Zone

4.4. Water Recharge programs:

The major groundwater recharge program is through Watershed development programs through the Watershed development department of Karnataka (Table 22). It has been estimated that around 18180 micro watersheds have to be treated covering an area of 24,05,187 ha at a cost of Rs. 8397 per ha.

Table 22: Watershed investment in Karnataka

Particulars	Number	Area / cost
No. of micro watersheds delineated	18180 (@ 500ha per micro watershed)	2405187 ha
No. of micro watershed treated/developed	5694	1702814 ha,

Total cost		Rs. 12992.8 million
Average Cost (Rs/ha)		Rs. 8397 per ha
Overall performance level (satisfactory/good/very good)	Satisfactory	Satisfactory
Key implementing agencies (such as Govt. depts.. NGOs etc.,	Eight, NWDPRA, RVP, DPADP, DDP, IWDP, WGDP, KWDP, NABARD, SUJALA	Watershed Development Department, Government of Karnataka, Bangalore
Major issues in watershed development	Three	Governance, accountability, transparency, property rights, e governance necessary for effective implementation

4.5. Karnataka's Growing Water Scarcity:

Karnataka's scarcity of water resources has already limited access and availability in various sectors. It has become reality in the state as ground water table reached rock-bottom whereas percolation is unable to restore the balance of water table. However, in case of surface water, overall it is unfit for consumptive and productive use due to awful quality issues such as water pollution. Water crisis is increasingly being viewed in terms of increasing imbalance between water supply and demand however, it's economic, ecological, social and health causes and consequences are pervasive in nature. The world water resources (both surface and ground) are unequally distributed among countries of the world. The world statistics on wealth of nations and water resources or availability suggest that countries with high GNP have also high per capita water availability. The paradox is that the western developed countries abundantly endowed with water but largely export less water intensive industrial goods, whereas, developing countries scarcely endowed still export water intensive agricultural goods like rice and sugarcane. India with 2.4 per cent of the world's total area supporting 16 per cent of the world's population endows only 4 per cent of the total available fresh water. The international standard suggests that if per-capita water availability is less than 1700 m^3 and 1000 m^3 per year then the country is categorized as water stressed and water scarce respectively. India is in threshold of reaching these stages as per capita surface water availability in the years 1991 and 2001 were 2309 and 1902 m^3. It is estimated that by 2017, India will be "water stressed" with the decline in per capita availability to 1600 m^3 (Biswas et al, 2010). Projections for the years 2025 and 2050 also show that per capita water availability will be further drastically reduced to 1401 and 1191 m^3 respectively (Kumar et al, 2005). The scarcity of water has been estimated based on per capita availability of water.

Water scarcity is growing with increasing population and growing demand for water from all sectors of the economy; consequently, the per capita availability of water in parts of Karnataka is very low and it also varies in time and season. This clearly gives stark diagnosis of dwindling water resources in Karnataka with imminent realisms like growing population, sprawling utilization and ever expanding economic activities. Water demand for consumptive (drinking, health and sanitation needs) and productive uses (agricultural, industrial production, power generation, mining operations and navigation, and recreational activities) has increased tremendously while water supply has declined with depletion and degradation of water resources causing water distress or scarcity. The progressive water shortage and competitive demand with mounting population and economic growth has posed a challenge to water management particularly in the context of equitable access to water and its benefits. This will largely alter economic activities and limit productive capability of the economy. The declining trend in the economic contribution of water resources has occurred due to physical and economic water scarcity which results in insufficient use, poor management, declining water productivity, and increasing environmental and economic costs. Obviously, the outcome is growing imbalance between water needs and supply augmentation capability in the State. Inefficiency in water use and management mainly caused by market failure, poor property rights and improper allocation has further complicated operationalizing water policies.

4.6. Climate Change and Water Resources:

Frequent incidents of climate change make water scarcer and also expensive as rainfall pattern are uneven over the years. Water demand and supply are particularly sensitive to variations in climate change. Alteration in water levels in river basins or stream flows, watersheds and ground water have already impacted on the performance of different sectors of the economy which results in search for alternate sources of water to ensure reliability of drinking water needs. For instance, residents over depend on ground water and water markets when water sources from piped water supply developed into irregular and insufficient. This situation is aggravated the ground water depletion in India causing water quality to deteriorate with the depth of extraction which directly imposes health cost on the society and limits system's resilience. The climate condition makes water scarce and expensive. Recent estimates indicate that 20 per cent of global water scarcity is directly induced by climate change. The climate change can also exacerbate water scarcity which can cost 6 per of India's GDP. Besides, depletion of quantity and degradation of quality of water has restricted the availability of water for consumptive and productive uses and consequently caused "negative externality" which imposes high economic and social cost on the society. India faces serious water problems throughout the year (8 to 12 months) as per the world bank study which has a serious implication on production and consumption behaviour of economic agents. Severe droughts in the State has adversely affected the water flow in the river basins and replenishing ground water. Increasing reliability on river water supply for meeting various economic needs and particularly drinking water is unsustainable unless we take coping and adaptation measures.

4.7. Adaptation to Climate change:

Developed countries are quickly evolved coping mechanisms to face climate change led economic implications, however, developing countries including India lag behind taking climate change very seriously to protect the river basins. Therefore, adoption of New York City Model will help protection of River Catchment Areas for lasting supply of water. There are striking similarities in dependence and impounding of water for New York and Bangalore cities. Both cities impound water away from more than 100 km and depend on critical watersheds or river catchments. New York City completely depends on Cats Skill and Delaware Watersheds for water supply and Bangalore depends entirely on the River Cauvery which has watershed in Tala-Cauvery and Bhagamandala in Western Ghats in Kodagu. When

New York City faced severe drought conditions in 1980's protection of Cats Skill and Delaware water bodies was taken up. The New York City Corporation made one-time huge investment to protect both forest and agricultural lands by compensating farming community, taking afforestation and also imposing restrictions on using chemical fertilizers and pesticides by promoting organic farming. This includes practices of sustainable farming, limiting use of fertilizers and preventing of dumping waste products. All these efforts have ensured high water quality with the strong partnership with local stakeholders and communities. This has led to increasing availability of clean water which serves 8 million New York population even without the cost of water treatment. These challenging efforts to mitigate climate change led water shortage in catchment areas has reduced the huge cost of water treatment and ensured reliability of water supply. Whereas, in case of Bangalore city, drinking water needs of 8.5 million people rest with water drawn from the river Cauvery. Failure to protect the watershed of Western Ghats, unabated deforestation in the river catchments have largely impacted on the raining pattern which caused lasting catastrophe to end abundance of Cauvery Water. The reduced the flow of the water in the riparian states of the river Cauvery River rarely appreciate this fact and value the water and watershed of Western Ghats. Creating Cauvery River Watershed Protection Fund by the river riparian states particularly Karnataka and Tamil Nadu will help addressing climate change or droughts, helps afforestation efforts, compensates the farming community to protect the forests and ensures water availability for all the states. The creation of Payment for Ecosystem Services (PES) in Kodagu districts on the lines of New York City Model for conservation of forests in Kodagu district is very important for the sustainability of the river Cauvery river basin for meeting water demands of riparian states.

New York city has effectively adopted both supply-side (water enhancement) management through catchment area conservation and demand-side management by efficiently managing water by reducing the demand (See Figure). Both supply enhancement and demand reduction policies have effectively addressed climate change led water scarcity in New York City. The demand for water has come down from 1500 million gallons daily to 1000 MGD despite growth of population from 7.5 million in 1980s to 8.25 million in 2010 (Figure).

Figure 11: Supply and Demand Side Management of New York City Water:

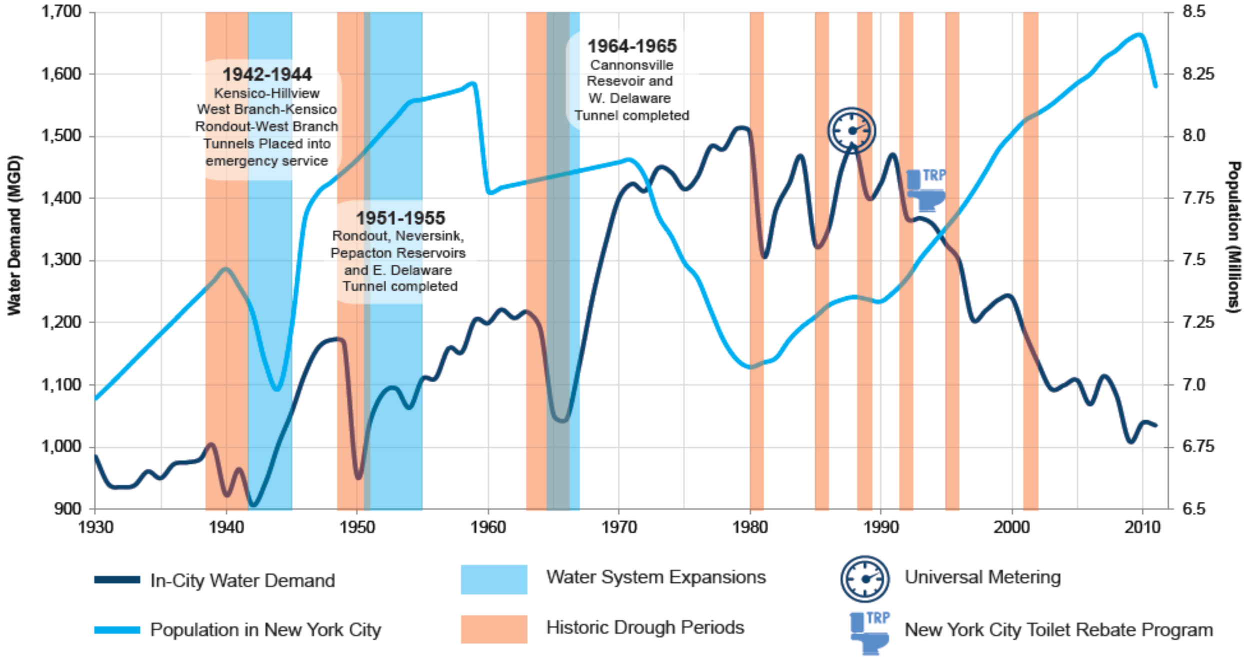


Figure 3: Timeline showing New York City water demand compared with population growth, and other factors affecting overall demand.

4.8. Water as Capital:

Present economic growth models account the relative economic contribution of man-made capital and human capital to overall increase in Gross Domestic Product (GDP) and rarely recognize the natural capital including water. Thus, the stock of natural capital has decreased over time due to its underpricing or missing markets. The recent international attempts to include Natural Capital in the Integrated Economic and Environmental Accounting or Green GDP take into account the role of total economic value of water to economic growth. The **wi**dening gap in water supply and water demand for various economic needs calls for adoption of Green GDP approach and realizing sustainable development. The term sustainability needs to be understood both form strong sustainability and weak sustainability views. Whether improvement in infrastructure and knowledge are appropriate and adequate substitutes for environmental or water losses? These concerns about ecosystems and limited availability of adequate substitute on account of depletion of water resources, demand adequate institutional measures and investment priorities to mitigate deforestation and address climate change.

4.9. **Water is No More a Free Good:**

The main issue surrounding water is that if water is recognized as economic, environmental, social and cultural good it allows understanding of the importance of water from various needs (consumptive and non-consumptive) and also easy to assess and compare its varied benefits (direct and indirect). Even today, Indian text books conceptualize water as “free good” and “abundant in supply” which creates the wrong or notional impression that it can be used recklessly as it is observed in the behavior of the economy or society be it for agricultural, industrial and domestic use. Water is most disregarded and abused good in terms of over extraction (excessive use of ground water) and exploitation (pollution of water bodies like The River Cauvery). This has resulted in scarcity of water where water is no more treated as renewable resource rather it is treated as conditionally renewable if there is a huge mismatch between excessive water use and over its percolation of water table over time. It has become reality in India as ground water table reached rock-bottom whereas percolation is unable to restore the balance of water table. However, in case of surface water, overall it is unfit for consumptive and productive use due to awful quality issues such as water pollution. Both reckless use and abuse have made the water resource the scarce or economic good and it no more a renewable resource and it has become already a conditionally renewable resource. Therefore, the traditional societal attitude towards water as free good and renewable resource should change as water is essential for survival and it is already scarce it needs to be efficiently and equitably distributed among various needs of the economy and environment. Apart from treating water as economic good, water also be treated as social good as the right or entitlement of the society is involved, a minimum of 50 to 100 liters of water per person per day (WHO, 2016) are needed to be ensured to meet essential drinking and health needs at free of cost by the government.

4.10. Water as Environmental Good:

Water as an environmental good is very crucial to maintain the biodiversity or ecosystem or hydrological cycle. Water as cultural and aesthetic good, the implicit value must be recognized. This implies that water has multiple uses and benefits and overriding importance should be given to all attributes of water by considering the total economic value for its conservation. Therefore, a wide variety of economic models are needed to assess the economic benefits of water. Further, surface water bodies including rivers and lakes are considered as common pool resources which involve multiple users and water is non-excludable and hence, government plays an important role in ensuring equitable access and efficient allocation of water on a sustainable basis.

4.11. Privatization of Water is not a Best Solution:

Today, even though water is becoming scarce commodity, due to obligation to people and their entitlement to right to water, governments are willingly not favoring markets to dominate water supply in many cities of the world despite cash crunch, inefficiency or institutional failures, etc. Under the globalization, markets tend to pose themselves with animal spirit (confidence) to manage water efficiently, but equity issues concern governments. Globalisation has impacted on the growing stress of water resources with increasing corporate siphoning off of water for surplus production of various goods and services without treating and reusing wastewater this “free-riding” approach systematically undermines societal drinking water needs. But there are international benchmarks of in urban water management which show that without leaving water supply to market mechanism, government agencies have efficiently managed water in large metropolitan cities like New York. Therefore, public ethos towards conservation of water and environment is just euphoria as people worship the rivers but hardly respect, value and conserve them including the most revered rivers The Ganges and The Cauvery. The payment for ecosystem approach makes riparian states more economically and environmentally responsible in equitable sharing of water and avoid interstate water disputes.

4.12. Water Poverty:

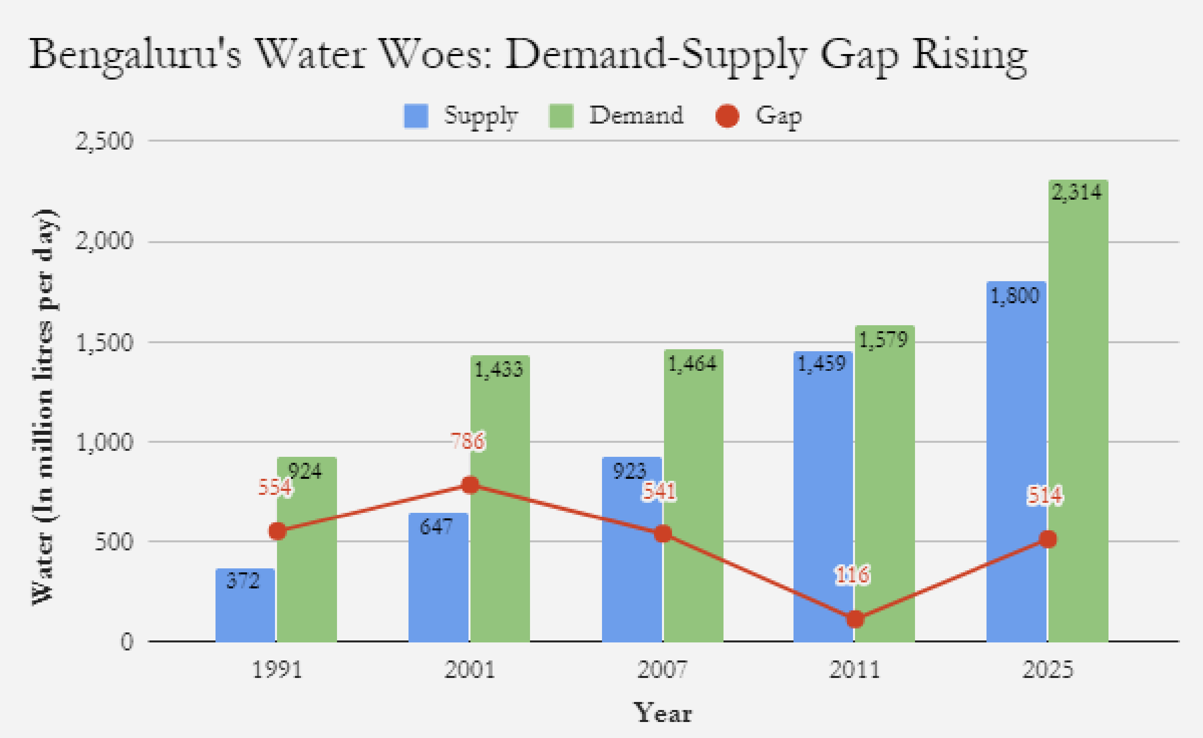
Water poverty is already ubiquitous in many parts of rural and urban areas where water access is limited due to deficit in supply exceeding demand. Water scarcity, water use inefficiency and inequity in water distribution have already resulted in prevalence of water poverty all over Karnataka. In many villages and cities water availability both surface and ground water is limited, access to drinking water is reduced, water use efficiency is low. Water poverty Index estimates the water stress due to water scarcity and availability of water among socio-economic groups. This shows that poor households often suffer from insufficiency, unsafe, inaccessible, unaffordability of water which result in economic loss of labour and time. Majority of the Karnataka cities despite growing scarcity of water have achieved neither equity nor efficiency in water supply and sufficiency (Krishna Raj 2015). The details of slab-wise water connections and consumption (2013) in Bangalore city (Table) shows that about 68 per cent of water connections at less than 25000 water slabs in the city consume 32 per cent of water or (127 million liters daily), whereas, 32 per cent connections above 25000 water slabs consume high quantity of water at 68 per cent water or 273 MLD. This shows high water inequality in water consumption of rich and poor households. Further, 32 per cent of connections or households consume or get 28 liters per capita daily which is highly insufficient whereas the remaining 68 per cent households consume from 129 to 1789 LPCD. The water consumption differentials cause water inefficiency and households depend more on water market to meet the insufficiency in water availability.

Table 23: Water Inequity in Bangalore city

Slabs	No of Connections	Consumption in MLD	Consumption per HH or connection	Per capita Water Consumption	Water Rates Per 1000 liters (Rs)
0-8000	187055 (32.2)	21 (5.2)	111.3	28	6
8001-25000	205863 (35.4)	106 (26.5)	514.2	129	9
25001-50000	143990 (24.8)	165 (41.3)	1148.6	287	15
50001-75000	34457 (5.9)	68 (17.0)	1969.0	492	30
75001-100000	7275 (1.3)	21 (5.2)	2853.9	713	36
>100001	2701 (0.5)	19 (4.8)	7154.4	1789	36
Total	581341 (100)	400 (100)	688.0	172	-

Author's Estimation using BWSSB Data 2013

Figure 12: Bengaluru Water Demand and Supply Gap



The inequitable distribution of water among various socio-economic groups and inefficient use of water with high theft of water without legal connection, leakages, wastage of water have clearly reflected in intermittent supply of water which imposed high costs on the society or economy as water market emerged as alternative to the public water scarcity.

4.13. Water Market: Bottled Water Industry:

Increasing inaccessibility to potable water supply, people are increasingly depending on market for meeting their drinking water needs particularly from private water suppliers such as bottled or packaged water industry. The demand for packaged water is in increase due to health concerns among the people with increasing pollution of water bodies particularly ground water and also poor-quality water supply by public water supply authorities. The Karnataka state, as per the Bureau of Indian Standards, has 200 bottled water manufacturing industries. Private appropriation of water bodies has resulted in absolute loot of ground water in the absence of ground water regulation authority. Augmentation of drinking water supply through an integrated approach of accessing water from rivers, tank rehabilitation, rain water harvest and conservation and appropriate valuation of drinking water is a rational option. Bottling plants industries have been proliferated all over the cities making use of both surface and ground water indiscriminately for quick profiting. If they are not controlled ground water is siphoned off indiscriminately imposing high costs on the neighbours who depend on ground water for drinking. The unregulated ground water exploitation has resulted in water table has reached on an average 822 feet to get the water which clearly reflects the quantum of water extracted over replenishment. Bangalore and surrounding areas have 408 (Bangalore urban 283, Bangalore Rural 57 and surround districts 64 (Kolar, Tumkuru, Chikkaballpur and Ramanagaram) comprising 57 per cent of the total bottling units of 708 in the entire state with an extraction of 1500 liters to 25000 liters. The scarcity of drinking water also reflected in the omnipresence of water tankers in many areas particularly where the water is intermittently supplied and newly added villages of BBMP. The water price for each tank varies from Rs 600 to 1500 but water quality is not assured. The water poverty among lower income groups is highly prevalent in all the major cities of India.

4.14. Save Western Ghats and Save Karnataka:

Economic development of Karnataka depends on sustainable availability of water resources in the river basins. Major cities and towns impound water from the river basins for drinking water needs of billions of urban households. Bangalore, Mysore, Mandya and other cities meets 90 per cent of drinking water needs from the River Cauvery (Figure 12). The water system becomes inefficient and costly in case water ecosystem dries up, that situation warrants allocate water to the highest value uses such as drinking water needs over agricultural and industrial needs which affect their economic activities and cause lasting water disputes among riparian states in recent years between Karnataka and Tamil Nadu (Figure 13). The Western Ghat forests give birth to many rivers including the river Cauvery. Protection of these virgin forests which attract rain is completely neglected as deforestation and encroachment continues unabated. Commercial crops like coffee, tea, rubber, areca nut, have successively replaced virgin forests for many years. Fast growing species like eucalyptus and other trees which are alien to the ecologically sensitive region are rapidly introduced substituting native shade trees in coffee plantation areas. The recent land use change in Kodagu districts gives the stark reality of the Cauvery River, about 3000 acres of agricultural land is being put to commercial and housing needs making the Kodagu forest fast dwindling which will catastrophically impact on the flow of river and availability of water both in catchment and command areas. Many developmental activities like erecting of power lines, construction of roads and hydel projects, sand extraction continues without valuing ecological sensitivity of the regions. The trees hold more than 30000 liters of water that slowly makes its way into rivulets and rivers. Land use change, uncontrolled growth of home stay and tourism activities have destroyed the forests in Kodagu district. Kodagu district alone contributes for 70 per cent inflow of water to the Krishna Raja Sagar dam in Mandya district of Karnataka state.

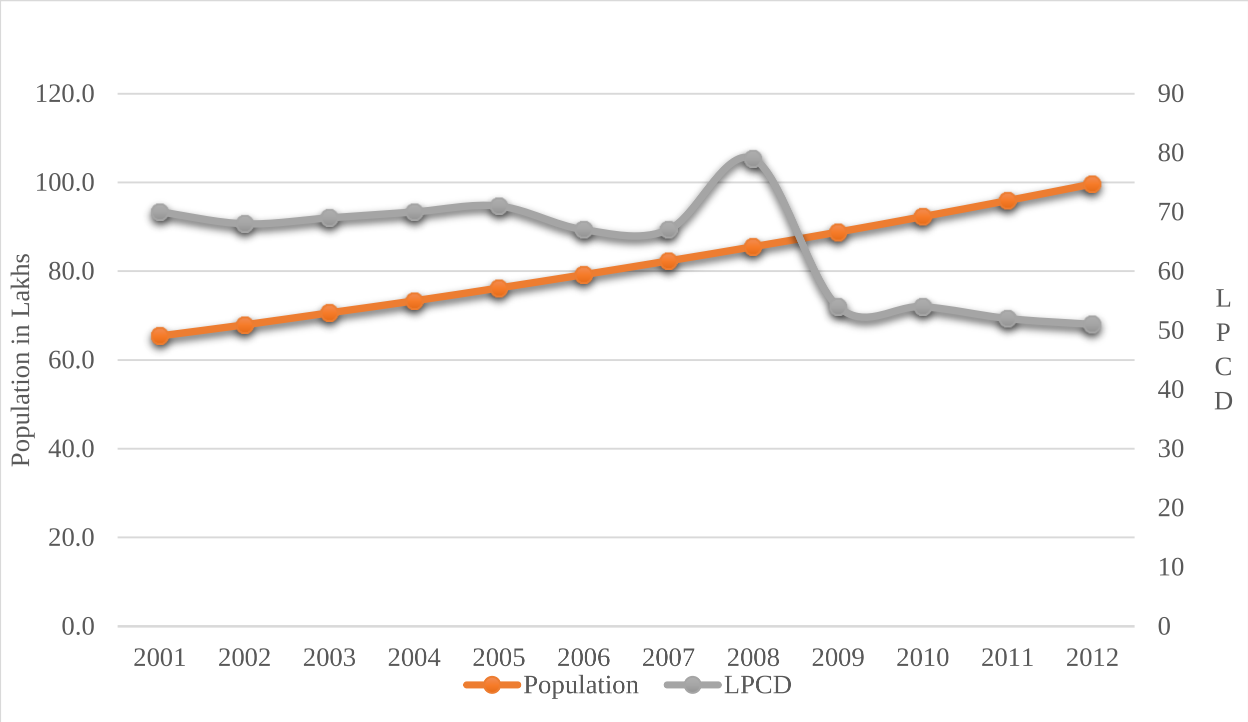
Figure 12: The River Cauvery:

Figure 13: Burning of Property against Releasing of Cauvery Water to Tamil Nadu

4.15. Unaccounted for Water in Bengaluru City:

Bangalore city regardless of climate change and water scarcity continues to depend on supply enhancement strategy which is leading to high rate of Non-revenue water or UFW and revenue loss. The present status of water supply in Bangalore city shows that the city is excessively relying on surface water sources from the river Cauvery for meeting drinking water necessities with the unprecedented fall in the ground water table due to over exploitation and pollution of lakes in and around the city. The city is also constantly searching new water sources for meeting drinking water needs in future. Bangalore city currently receives 1350 Million Liters Daily water meet the drinking water needs of 8.5 million people which is sufficient. However, water is supplied in alternate days with limited to 3-4 hours and water available at 50 LPCD which reflects growing water scarcity not due non-availability of water but due to an increasing share (48 per cent) of Unaccounted for Water (UFW) in total water production (Figure 14). The shortage or inadequate provision of water in the city is mainly due to lack of demand side management including reducing the loss of water due to leakages and theft. The 48 per cent of UFW is very high compare to the optimum level of UFW in well managed urban water utility (5-10%) in the world cities (Krishna Raj 2013). This implies that the problem of water is not associated with economics or scarcity but politics (poor governance).

Figure 14: Reduction in per capita availability of water in Bangalore city



5. Achieve Water Efficiency:

Water is economic good and capital resources, the end of surplus or abundance gives the stark reality of the water economy. Therefore, the production and consumption behaviours in Agriculture, Industry and Domestic Sector should be on the path of sustainable development practices. Drinking water is supplied at free of cost in major cities which is cost high operation and maintenance cost. Universal water metering and rationing can effectively reduce water theft as well as water leakage which are alarming high in many metropolitan cities of India. Water utilities need to change flat rate to meter billing to improve in the system performance and ensure water reliability and reduce consumption of water by 50 per cent. Further, all India campaign in support of production of water saving fixtures or taps, water tubs, and their replacement in all the households as government measure will reduce the water wastage or slow the flow of water, this policy measure which will save nearly 70 per cent of the drinking water. Replacement of high water flush toilets with low water consuming toilets will result in significant water saving. Waste water recycle, and reuse is made compulsory for the industries, commercial establishment, apartments, malls, hospitals, institutes and large buildings. The city corporations should also prohibit sale of high flow showerhead, faucets, and toilets. Consumer awareness programme and computerization of water billing are more effective in water saving as proved in New York City where consumers receive text message for excess consumption of water may be due to actual use or wastage of water. New buildings should have rainwater harvesting provision which will reduce water consumption for gardening and other activities. Restriction on vanity projects like water recreation and swimming pools help reduce water or should be encouraged to use recycled water rather using fresh or drinking water. Improvement of economic efficiency depends on evolving an effective water pricing mechanism considering the economic status and ability to pay by the households. Economic status influences the peoples' willingness to pay for improvement in access and quality of water supply. Policy of water pricing, therefore, needs to achieve two objectives simultaneously: recovery of the full cost of production from supply of water, and provision of efficient and reliable water supply service to the consumers. Without any provision for better water supply services, mere increase in water tariffs are doomed to fail in this objective as observed in many research studies.

6. References:

1. Adam Smith (1776). An Inquiry into the Nature and Causes of the Wealth of Nations, University of Chicago Press, Chicago.
2. David F. Batten (2007) Can economists value water's multiple benefits? Water Policy Vol No. 9, 345–362
3. David Zetland (2011) The End of Abundance: Economic solution to Water Scarcity, Aquanomics Press, Amsterdam.
4. Krishna Raj (2013) "Sustainable Urban Habitats and Urban Water Supply: Accounting for Unaccounted for Water in Bangalore city, India, in International Journal "Current Urban Studies" published by Scientific Research, Vol.1, No.4, 156-165 Print: ISSN-2328-4900, online: 2328-4919 http://www.scirp.org/journal/cus
5. Krishna Raj (2015) Urbanization and Water Supply: An Analysis of Unreliable Water Supply in Bangalore City, India in edited book by INSEE on "Nature, Economy and Society" published by Springer, New Delhi.
6. Krishna Raj (2016) The Economics of Water: Understanding India's Water Balance in a Globalized Economy, Productivity Journal
7. W. M. Hanemann (accessed online 2015) The Economic Conception of Water University of California. Berkeley, USA
8. Ward, F.A. & Michelsen, A. (2002). The economic value of water in Agriculture: concepts and policy applications, Water Policy, 4: 423-446.
9. World Resources Report (2011) "Decision Making in a Changing Climate: Adaptation challenges and Choices published WRI, Washington DC.
10. 2. MG Chandrakanth, Water resource economics: Towards a sustainable use of water for irrigation in India, Springer, 2015.
11. Government of Karnataka (2004) Technical Consultancy Services Organization of Karnataka, Forecast of Water Needs of Industrial Units in Districts/Areas Falling Under Krishna Basin, Bangalore