become damaging when the basic superstructure of the work itself (as it now appears in the DNA barcoding exercise) is itself slippery. This therefore seems to be the plight in which smaller labs and groups trying to emulate the DNA barcoding programme find themselves in. Therein lies the peril of followers.

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Population rise and growing water scarcity in India – revised estimates and required initiatives

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Preliminary results of the 2011 census released recently by the Government of India show that the current population is higher than the earlier projections. As the requirement of water chiefly depends upon population, earlier estimates have been revised in view of the revised population projections. Initiatives to overcome the impending water scarcity have also been suggested.

Demand for water depends on several factors such as population, income level or lifestyle and industrialization. Demand for water increases with the population as water is needed to sustain life, for sanitation, agriculture, generate energy, run industries, etc. As income rises, people tend to use more water. City-dwellers consume more water than those living in rural areas. The affluent section of the society consumes more water for cleaning, maintaining gardens/lawns, etc.

Preliminary results of the 2011 census released by the Government of India (http://censusindia.gov.in/) have estimated the current population of the country to be 1210 million. The population numbers indicate a rapid growth as the earlier estimates had projected the population to be around 1189 million by 2010 (ref. 1). Revised projections of the population are also available from different sources, including the United Nations (UN). The medium variant of the UN population projection shows that the population of India is expected to stabilize at a level of about 1718 million by 2065 against the earlier estimates which had projected the population to stabilize at about 1580 million by 2050. Thus, the updated estimates show that the population will stabilize at a higher value and at a later date.

Table 1 presents the projections of population for some selected years according to the UN medium variant.

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. Earlier, an exhaustive assessment of the water requirement for various uses was made by the National Commission for Integrated Water Resources Development (NCIWRD)[1] using the data available at that time and the projections for the future. Table 2 shows the water requirement for different uses for 2025 and 2050, computed by NCIWRD[1].

With the availability of the revised population data, a quick exercise to update the estimates of future water use was taken up. This exercise would give useful inputs in planning of water resources development projects and other related infrastructure projects. It has been realized that owing to the importance of the subject, a more exhaustive analysis by compiling the data from various sectors should be taken up. Further, this study has not considered the impacts likely to arise from climate change as a lot has already been written on it[2] and there has not been any major recent global or country-wide assessment after the IPCC Fourth Assessment Report (2007).

It will be helpful to study the current and future per capita water availability for the country in view of the revised estimates.

Per capita water availability

Table 3 provides details of the population of India and the per capita water availability. At present the per capita surface water availability is about 1614 m^3 per year. Rise in population may reduce the per capita water availability to 1137 m^3 by 2065. As the availability of water has wide spatial and temporal variations (including inter-annual variations), the general availability situation is more alarming than that depicted by the averages.

Several indicators of water scarcity have been developed. Falkenmark *et al*.[3] developed the Falkenmark Water Stress Indicator (FWSI). According to FWSI, per capita water availability of 1000–1600 billion cubic metres (BCM) per annum indicates water stress; availability of 500–1000 BCM indicates chronic water scarcity, while per capita water availability of 500 BCM or less indicates a country or region below manageable capability. According to this criterion, the country will shortly enter the water-stressed category and the stress will progressively become more severe.

Brahmaputra and Barak rivers flow through the north-eastern region of India. Their surface water potential is 677.41 BCM and the utilizable flow is about 24 BCM. According to the recent census, the combined population of the states in the north-eastern region is 45.59 million which is about 3.77% of the population of the country and the hydropower potential of the north-eastern region is also largely undeveloped. Hence, if the population and waters of the north-east are ignored, the current per capita water availability for the remaining country is about 1096 BCM per annum.

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 1096 BCM per annum appears to be more relevant which means that most of the country will soon enter in the 'chronic water scarcity' category according to FWSI. More on this aspect will be discussed later and at this stage, attention is focused on estimation of water requirement for different sectors.

Irrigation water requirement

Water is used to irrigate crops to achieve higher and assured production. To estimate irrigation water requirement, it is

Table 1. Projected population for a few selected years – UN medium variant

Year	Population as per UN medium variant (million)
2025	1459
2050	1692
2060	1718
2065	1718

Source: http://esa.un.org/unpd/wpp/unpp/panel_population.htm

Table 2. Annual water requirement (BCM) for different uses

	Year 2025			Year 2050		
Uses	Low	High	Percentage	Low	High	Percentage
Irrigation	561	611	72	628	807	68
Domestic	55	62	7	90	111	9
Industries	67	67	8	81	81	7
Power	31	33	4	63	70	6
Inland navigation	10	10	1	15	15	1
Environment – ecology	10	10	1	20	20	2
Evaporation losses	50	50	6	76	76	7
Total	784	843	100	973	1180	100
Population (million)	1286	1333		1346	1581	

Source: NCIWRD[1].

Table 3. Per capita per year availability and utilizable surface water in India

Year	Population (in million)	Per-capita surface water availability (BCM)	Per-capita utilizable surface water (BCM)
1951	361	5410	1911
2001	1027	1902	672
2011	1210	1614	570
2025	1459	1339	473
2050	1692	1154	408
2065	1718	1137	402

Table 4. Food requirement for India for the years 2050 and 2065

Item	Unit	Year 2050	Year 2065
Population	Million	1692	1718
Per capita food and feed demand	kg per annum	284	300
Total demand	Million tonnes	481	515
With addition of seed, feed, wastage, etc.	Million tonnes	529	567

Table 5. Computation of future water requirement for irrigation

Particulars	Unit	Year 2010* Low demand	Year 2010* High demand	Year 2050* Low demand	Year 2050* High demand	Revised estimates 2050	Revised estimates 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	80.2	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 unirrigated 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 – unirrigated	Million hectares	76.4	75.2	68.9	56.7	52.9	54.6
Average yield – irrigated food crop	Tonne/hectare	3.0	3.0	4.0	4.0	4.25	4.40
Average yield – unirrigated food crop	Tonne/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 unirrigated 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	66.8	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	0.49	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	218.1	253.3	327.3	333.5	344.0
Total water required for irrigation	BCM	543.1	556.7	627.9	811.4	826.7	852.9

*Estimates by NCIWRD[1].

necessary to first estimate the total food requirement for the future.

NCIWRD[1] studied the future food and feed demand in detail and estimated the food grain demand as 284 kg per head for 2050 considering the trends in food consumption and socio-economic factors. This study has also adopted the same value. In addition, a slightly higher value of 300 kg per head is assumed for 2065 to account for improvement in the standard of living in the intervening period and hence higher nutrition level. The total demand has been increased by 10% to account for seed, feed, wastage, etc. Thus the total food requirement for 2050 and 2065 is 529 and 567 million tonnes respectively (Table 4).

Knowing the requirements to produce food, irrigation water requirements for 2050 and 2065 were computed as shown in Table 5. The columns ‘Year 2010’ and ‘Year 2050’ pertain to the results of NCIWRD[1] and ‘Revised estimates’ are the results of this study. Row 1 shows the food demand as computed and row 2, the net cultivated area which may stabilize at 145 million hectare (m ha). The required cropping intensity is iteratively calculated to produce the required food. By following the estimates of NCIWRD[1], about 65% of the cropped area is assumed to be irrigated. For average yield, values slightly higher than the NCIWRD[1] values have been considered. Average yield from irrigated areas has been taken as 4.25 and 4.40 tonne/ha for 2050 and 2065; for unirrigated areas, average yields have been taken as 1.60 and 1.70 tonne/ha for 2050 and 2065 respectively. NCIWRD[1] assumed efficiency of surface and ground water irrigation as 60% and 75% for 2050 and the same value has been adopted here to compute the gross irrigation requirement or ‘Delta’. Other indicators such as the foodcrop area as percentage of irrigated area and average yield from irrigated and unirrigated area are the same as assumed by NCIWRD[1]. With these, the total water requirement for irrigation is calculated as 827 and 853 BCM for 2050 and 2065 respectively.

Domestic water requirement

Table 6 gives the computation of domestic water requirement for 2050 and 2065. The norms for per capita water requirements are similar to those adopted by NCIWRD[1]. Per capita demand for the urban and rural areas has been taken as 220 and 70 litres per capita per day (lpcd) until 2025. The commission adopted a figure of 150 lpcd for rural areas for 2050 and beyond, considering the changes in lifestyles which will result in higher per capita water demand. Further, based on the trends and estimates for the future, it is likely that about 60% of the population of India by 2050 and nearly 65% by 2065 will live in urban areas. It can be seen that this sector will require about 119 and 123 BCM of water by 2050 and 2065 respectively.

Industrial water requirement

Industrial water use in the country is growing at a fast pace but unfortunately, reliable information about water use by industries is not easily available and there are large differences in the estimates from different sources. According to the Ministry of Water Resources, industrial water use in India was at about 40 BCM in

2010 (www.cseindia.org). According to the Central Pollution Control Board, in the year 2000, Indian industry consumed about 10 BCM of water as process water and 30 BCM as cooling water. The World Bank noted that the water demand for industrial uses and energy production will grow at a rate of 4.2% per year, rising from 67 BCM in 1999 to 228 BCM by 2025 (www.cseindia.org).

Water requirement for power generation and navigation

NCIWRD[1] had estimated water requirement for power generation and navigation at 70 and 15 BCM respectively, for 2050. For power generation, this study has considered the water demand of 70 and 75 BCM for 2050 and 2065 respectively. In the absence of better estimates and considering the fact that there has not been any dramatic growth in navigation sector, the values suggested by the commission have been retained in this study.

Water requirement for environment and ecology

In the early 1990s, the concept of environmental flows (E-Flows) was not practised in India. Gradually, the concept of minimum flows was introduced and the early stipulations were based on directions that, for example, at least 10% of the lean season flow should be set aside for environmental needs. However, this practice is considered to be inadequate these days and there has been a demand for a higher allocation for environmental needs. The NCIWRD[1] had allocated 5 BCM for E-Flows for 2010 and 20 BCM for 2050. Currently, long stretches of many rivers are severely polluted and health of the aquatic eco-system is under threat. Considering these and the fact that the surface water potential of the country is 1953 BCM, an allocation of at least 5% of the total potential or about 90 BCM of water by 2050 is considered bare minimum for this purpose.

Total water requirement

Table 7 gives the total water requirements for the country. The columns 'Year 2010' and 'Year 2050' show the assessments by NCIWRD[1] and the column 'Revised estimates' shows the assessments made in this study. The Commission had provided estimates for two scenarios of population growth: low and high. According to the estimates, the total water availability in India is 690 + 433 = 1123 BCM. It can be seen from Table 7 that the demand will exceed the availability before the year 2050.

Table 6. Domestic water requirement for the years 2050 and 2065

Item	Unit	Year 2025	Year 2050	Year 2065
Population	Million	1333	1692	1718
Percentage urban		0.45	0.6	0.65
Percentage rural		0.55	0.4	0.35
Norm – urban area	lpcd	220	220	220
Norm – rural area	lpcd	70	150	150
Demand – urban	BCM	48.17	81.52	89.67
Demand – rural	BCM	18.73	37.05	32.92
Total	BCM	66.90	118.58	122.59

Initiatives to control water scarcity

Water scarcity may become more common in many parts of the world because the world population is rising, more and more people are growing richer (thus demanding more water) and global warming is increasing aridity and reducing water supply in many regions. The health of many water bodies is threatened by disposal of untreated waste from municipalities and industries, non-point source pollution (mainly from agricultural areas) and influx of saltwater into coastal aquifers. Lack of access to clean and adequate water can lead to malnutrition, sickness and social unrest. Failure to take timely remedial actions can lead to grave consequences.

It is clear from Table 7 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. Note that the water availability estimates given earlier refer to an average year and there will be years of weak monsoon when the river flows will be much less than the mean values. Further, a few studies[4] have questioned the assessments of water potential and have pointed out that the actual utilizable water may be less than 1123 BCM. When these two are combined, it is likely that the country will begin to face occasional water shortages much before the year 2050 and the situation will progressively become more critical.

To overcome the problems caused by water shortage, a range of supply side and demand side measures will have to be adopted.

As seen from Table 7, the agriculture sector is the largest consumer of water. Hence the irrigation use has the largest potential to save water. Calculations show that about 20% savings in the irrigation and domestic water sector will yield about 170 BCM of water and this will make the demand nearly equal to the availability. In the agriculture sector, enough possibilities to increase crop yield per drop of water exist as the crop yield per unit land area and water in India are low compared to other countries. Irrigational practices such as use of drips and sprinkler (including micro-irrigation) have the potential to save large quantity of water. New farming techniques such as the system of rice intensification can save appreciable quantity of water from this water guzzling crop. The concept of virtual water[5] can 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. The loss of domestic water supply owing to leakage and/or theft in some cities is as high as 25–50% (ref. 6). Thus, a saving of 20% or even higher can be achieved through sincere efforts.

Very low tariffs on water supply is 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. 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.

Table 7. Total water requirements (BCM) for the years 2050 and 2065

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	1327
Population (million)	1286	1333	1346	1581	1692	1718

*Estimates by NCIWRD[1].

Most urban water systems have seen limited expansion over the past few decades because the urban local bodies do not have enough financial resources owing to the low water charges and poor recovery. As a result, very few new colonies in major cities are provided water by municipalities. As most households have their own pumps to extract ground water, there is little incentive to avoid wastage. If the municipal water supply network provides good quality water round the clock, then the tendency of the individual households to install their own pumps and tanks will be curbed and this will result in large savings on infrastructure as well as energy to extract ground water. Recycle and reuse of water should also be practiced.

Innovative methods such as desalination of ocean water can provide drinking water as in Andaman and Lakshadweep islands and a few coastal cities in different states. Increased recharge of ground water, particularly during the monsoon season will help arrest the decline of water table and more water can be utilized in the non-monsoon season. Interlinking of rivers has the potential to overcome water deficit in many areas and should be pursued with a well-defined time line.

The capacity of a country or region to support a certain population depends on its natural resources. There is a growing feeling worldwide that we are exploiting nature at an unprecedented rate. Launching the WWF's 2006 Living Planet Report, the Director General, James Leape, had said, 'For more than 20 years we have exceeded the earth's ability to support a consumptive lifestyle that is unsustainable and we cannot afford to continue down this path'. India and her various regions also have a finite capacity to support a certain population. The environmental degradation indicates that this capacity has been exceeded in many states/regions. Hence, India should formulate and implement a population control policy which sets a target on the population of various regions and the country keeping in view the natural resources. High population density (e.g. about 600 persons/sq. km) causes a severe stress on the infrastructure and natural resources and is difficult to sustain in the long run. Hence, special attention should be focused on regions with high population density.

Rogers[7] has reported on the result of studies examining the effects of climate change, and population and economic growth on water availability by 2025. It was found that 'climate change alone will bring scarcity in many places. Population growth, however, is even more dangerous. In the absence of concerted action to save water, the combination of population growth and climate change will create scarcity far and wide'. The National Action Plan on Climate Change announced by the Government of India (2008) recognizes these concerns and these are covered in some detail in the proposed National Water Mission which needs to be made operational at the earliest.

Water quality aspects

Degraded ecosystems will not be able to benefit the society and may in fact cause more harm than good. Hence, environmental restoration should be one of the key objectives of any future water management plan. However, among other things, this will require a change in mindset and larger quantity of environmental flows will have to set aside for this purpose.

Water of good quality is desirable for many reasons. Good quality water in rivers and lakes is a pleasant sight and provides a feeling of well-being. On the other hand, poor quality water emits foul smell and is detrimental to public health. Also, the uses of poor quality water are limited.

In the computations of water requirement for various uses, it is implicitly assumed that water of desirable quality is available but a review of water quality status of natural resources shows that this may not be a valid assumption for some cases. In addition to the pollution of surface water bodies, there are reports of increasing pollution of sub-surface sources, at times by deliberate human actions of pumping polluting water in aquifers to avoid treatment costs and detection by law enforcing agencies. Pollution of aquifers will be disastrous and it will be extremely difficult to restore them. Hence, strict laws to check aquifer pollution should be enacted and enforced.

Rogers[7] concludes that to solve the global water crisis 'We do not have to invent new technologies; we must simply accelerate the adoption of existing techniques to conserve and enhance the water supply. Solving the water problem will not be easy, but we can succeed if we start right away and stick to it. Otherwise, much of the world will go thirsty.'

Conclusions

This study has computed the requirement of water for the various uses for the years 2050 and 2065 based on the results of the recent census and future projections. It has been found that the demand for water is likely to exceed the availability much before 2050. However, the situation can be saved if sincere attempts are made to conserve water, particularly the water used for agriculture and municipal purposes. It will also be important to restore the quality of water of natural sources by setting aside more water. Further, a detailed study to compute future water demand should be taken up. These aspects should be addressed through the National Water Policy[8] which is under revision and then necessary actions should be implemented earnestly.

Disclaimer. The views expressed herein are those of the author and not of the institute to which he belongs.

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