URBANISATION, CLIMATE CHANGE AND WATER AVAILABILITY

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(Published on the Occasion of the 26th Water Resources Day, May- 2011)

As we all know the vast majority of the Earth's water resources are salt water, with only 2.5% being fresh water. However, approximately 70% of the fresh water available on the planet is frozen in the icecaps of Antarctica and Greenland leaving the remaining 30% (equal to only 0.7% of total water resources worldwide) available for consumption. From this remaining 0.7%, roughly 87% is allocated to agricultural purposes (IPCC 2007). These statistics are particularly illustrative of the drastic problem of water scarcity facing the world. Water scarcity is defined as per capita supplies less than 1700 m^3/year (IPCC 2007).

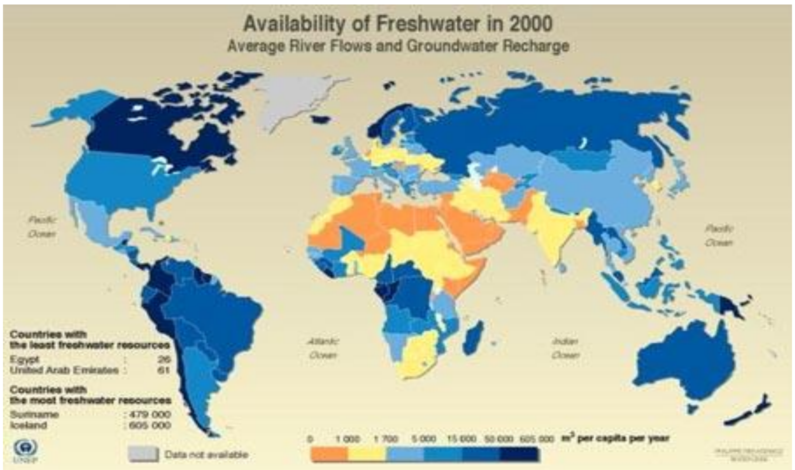

Figure 1: Freshwater availability: groundwater and river flow (2000)

(Source: World Resources 2000-2001)

According to the Comprehensive Assessment of Water Management in Agriculture, one in three people are already facing water shortages (2007). Around 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical scarcity, while another 1.6 billion people or almost one quarter of the world's population, live in a developing country that lacks the necessary infrastructure to take water from rivers and aquifers (known as an economic water shortage).

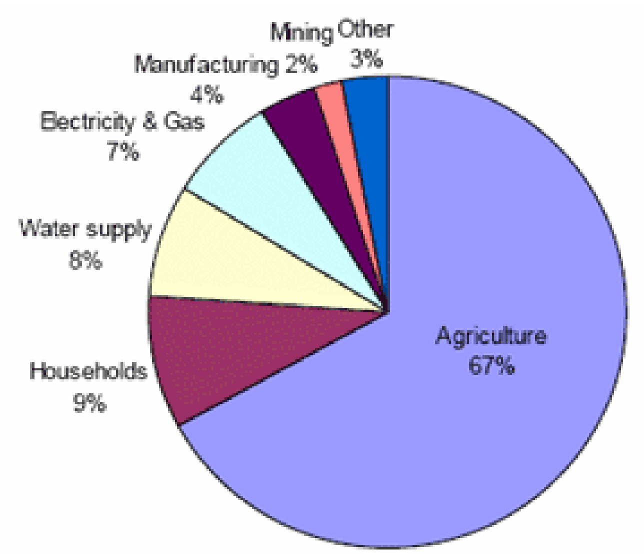

Figure 2: Water use in the world (2005)

There are four main factors aggravating water scarcity according to the IPCC:

- **Population growth:** in the last century, world population has tripled. It is expected to rise from the present 6.5 billion to 8.9 billion by 2050. Water use has been growing at more than twice the rate of population increase in the last century and, although there is no global water scarcity as such, an increasing number of regions are chronically short of water.

- **Increased urbanization:** This will focus on the demand for water among a more concentrated population. Conservatively estimated, Asian cities alone are expected to grow by about 1 billion people in the next 20 years.

- **High level of consumption:** as the world becomes more developed, the amount of domestic water used by each person is expected to rise significantly.

- **Climate change:** This will shrink the resources of freshwater.

Water and Climate Change

Water scarcity is expected to become an ever-increasing problem in the future, for various reasons. **First,** the distribution of precipitation in space and time is very uneven, leading to tremendous temporal variability in water resources worldwide (Oki et al, 2006). For example, the Atacama Desert in Chile, the driest place on earth, receives imperceptible annual quantities of rainfall each year. On the other hand, Mawsynram, Meghalaya, India receives over 450 inches of rainfall annually. If all the freshwater on the planet were divided equally among the global population, there would be 5,000 to 6,000 m^3 of water available for everyone, every year (Vorosmarty 2000).

Second, the rate of evaporation varies a great deal, depending on temperature and relative humidity, which impacts the amount of water available to replenish groundwater supplies. The combination of shorter duration but more intense rainfall (meaning more runoff and less infiltration) combined with increased evapo-transpiration (the sum of evaporation and plant transpiration from the earth's land surface to atmosphere) and increased irrigation is expected to lead to groundwater depletion (Konikow and Kendy 2005).

The Hydrological Cycle

The hydrological cycle begins with evaporation from the surface of the ocean or land, continues as the atmosphere redistributes the water vapour to locations where it forms clouds, and then returns to the surface again as precipitation. The cycle ends when the precipitation is either absorbed into the ground or runs off to the ocean, beginning the process over again. Key changes to the hydrological cycle associated with an increased concentration of greenhouse gases {carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), tropospheric ozone (O_3) and chlorofluorocarbons (CFCs)} in the atmosphere and the resulting changes in climate include:

- Changes in the seasonal spatial distribution and amount of precipitation
- An increase in precipitation intensity under most situations due to intensification of the hydrologic cycle
- Changes in the balance between snow and rain
- Increased evapo-transpiration and a reduction in soil moisture
- Changes in vegetation cover resulting from changes in temperature and precipitation
- Consequent changes in management of land resources
- Accelerated melting glacial ice
- Increased fire risk in many areas
- Increased coastal inundation and wetland loss from sea level rise
- Effects of CO_2 on plant physiology, leading to reduced transpiration and increased water use efficiency (Goudie 2006)

Expected Changes in Precipitation and Drought Patterns

Projections of changes in total annual precipitation indicate that increases are likely in the tropics and at high latitudes, while decreases are likely in the sub-tropics, especially along its pole-ward edge. Thus, latitudinal variation is likely to affect the distribution of water resources. In general, there has been a decrease in precipitation between 10°S and 30°N since the 1980s (IPCC 2007). With the population of these sub-tropical regions increasing, water resources are likely to become more stressed in these areas, especially as climate change intensifies. While some areas are likely to experience a decrease in precipitation, others (such as the tropics and high latitudes) are expected to see increasing amounts of precipitation. More precipitation will increase a region's (may be true for our North Eastern Region too) susceptibility to a variety of factors, including:

- Flooding
- Accelerated Rate of soil erosion severely compounded by deforestation
- Mass movement of land (land and mud slides)
- Less soil moisture availability (less water absorption by soil due to faster runoff)

These factors are likely to affect key economic components of the GDP such as agricultural productivity, land values and an area's habitability (IPCC 2007). In addition, warming accelerates the rate of surface drying, leaving less water moving in near-surface layers of soil. Less soil moisture leads to reduced downward movement of water and so less replenishment of groundwater supplies (Nearing et al 2005). In locations where both precipitation and soil moisture decrease, land surface drying is magnified and areas are left increasingly susceptible to reduced water supplies. Although projecting how changed precipitation patterns will affect runoff is not yet a precise science, historical discharge records indicate it is likely that for each 1°C rise in temperature, global runoff will increase by 4%. Applying this projection to changes in evapo-transpiration and precipitation leads to the reasonable conclusion that global runoff is likely to increase 7.8% by the end of the century (Oki and Kanae 2006). Thus, a region that experiences higher annual precipitation and more runoff increases the likelihood for flooding. This will present a daunting task for water resources planners of the North Eastern Region of India including Assam.

Furthermore, in areas that are already vulnerable due to their limited groundwater storage availability, this cycle intensifies with increased warming and diminishing water supplies. In water stressed regions, variability of precipitation patterns is likely to further reduce groundwater recharge ability. Water availability is likely to be further exacerbated by poor management, elevated water tables, overuse from increasing populations and an increase in water demand primarily from increased agricultural production (IPCC 2007).

A recent global analysis of variations in the Palmer Drought Severity Index (PDSI) indicated that the area of land characterized as very dry has more than doubled since the 1970s, while the area of land characterized as very wet has slightly declined during the same time period. In certain susceptible regions, increased temperatures have already resulted in diminished water availability. Precipitations in both western Africa and southern Asia have decreased by 7.5% between 1900 and 2005 (Dai et al 2004).

Most of the major deserts in the world are likely to experience decreased amounts of precipitation and runoff with increased warming. In addition, both semiarid and arid areas are expected to experience a decrease and seasonal shift in flow patterns. If increased temperatures cause an intensification of the hydrologic cycle there will be more extreme variations in weather events, as droughts will become prolonged and floods will increase in force (Huntington 2005).

Melting Glacial Ice

Water supplies can also be affected by warmer winter temperatures that cause a decrease in the volume of snowpack. The result is diminished water resources during the summer months. This water supply is particularly important at the mid-latitudes and in mountainous regions that depend upon glacial runoff to replenish river systems and groundwater supplies. Consequently, these areas will become increasingly susceptible to water shortages with time, because increased temperatures will initially result in a rapid rise in glacial melt water during the summer months, followed by a decrease in melt as the size of glaciers continue to shrink. This reduction in glacial runoff water is projected to affect approximately one-sixth of the world's population (IPCC 2007). A reduction of glacial runoff has already been observed in the Andes, whereby the usual trend of glacial replenishment during winter months has been insufficient.

Water Quality

Freshwater bodies have a limited capacity to process the pollution stemming from expanding urban, industrial and agricultural uses. Water quality degradation can be a major source of water scarcity. Although the IPCC projects that an increase in average temperatures of several degrees as a result of climate change will lead to an increase in average global precipitation over the course of the 21st century, this amount does not necessarily relate to an increase in the amount of potable water available.

A decline in water quality can result from the increase in runoff and precipitation- and while the water will carry higher levels of nutrients, it will also contain more pathogens and pollutants.

These contaminants were originally stored in the groundwater reserves but the increase in precipitation will flush them out in the discharged water (IPCC 2007). Similarly, when drought conditions persist and groundwater reserves are depleted, the residual water that remains is often of inferior quality. This is a result of the leakage of saline or contaminated water from the land surface, the confining layers or the adjacent water bodies that have high concentration of contaminants. This occurs because decreased precipitation and runoff results in a concentration of pollution in the water, which leads to an increased load of microbes in waterways and drinking-water reservoirs (IPCC 2007).

One of the most significant sources of water degradation results from an increase in water temperature. The increase in water temperatures can lead to a bloom in microbial populations, which can have a negative impact on human health. Additionally, the rise in water temperature can adversely affect different inhabitants of the ecosystem due to a species' sensitivity to temperature. The health of a body of water, such as a river, is dependent upon its ability to effectively self-purify through biodegradation, which is hindered when there is a reduced amount of dissolved oxygen. This occurs when water gets warmer and its ability to hold oxygen decreases. Consequently, when precipitation events do occur, the contaminants are flushed into waterways and drinking reservoirs, leading to significant health implications (IPCC 2007).

Effects on Coastal Populations

For coastal populations, water quality is likely to be affected by salinization or increased quantities of salt in water supplies due to intrusion. This will result from a rise in sea levels, which will increase salt concentrations in groundwater and estuaries. Sea-level rise will not only extend areas of salinity, but will also decrease freshwater availability in coastal areas. Saline intrusion is also a result of increased demand due in part to growing coastal populations that leave groundwater reserves increasingly vulnerable to contamination and diminishing water reserves (IPCC 2007).

Coping with Urban Growth

The biggest challenge the planners and the Government (especially for a country like India) will face is the rapid rural to urban migration of people and unplanned urbanization. Nearly 3 billion additional urban dwellers are forecasted by 2050. This is an unprecedented wave of urban growth. While cities struggle to provide water to these new residents, they will also face equally unprecedented hydrologic changes due to global climate change.

Modelled results show that currently 150 million people live in cities with perennial water shortage, defined as having less than 100 L per person per day of sustainable surface and groundwater flow within their urban extent. By 2050, demographic growth will increase this figure to almost 1 billion people. Freshwater ecosystems in river basins with large populations of urbanites with insufficient water will likely experience flows insufficient to maintain ecological process. It is almost certain that freshwater fish populations will be impacted; an issue of special importance for India's, where there is both rapid urbanization and high levels of fish endemism. Cities in certain regions will struggle to find enough water for their residents and will need significant investment if they are to secure adequate water supplies and safeguard functioning freshwater ecosystems for future generations.

Conclusion

Global climate change, as is occurring, will definitely affect water. Most mechanisms and two-way interactions between water and climate are known, even if not always well understood. It is evident that the relationship between climate change and water is still very much a matter of conjecture with many uncertainties. It is also worth remembering that enormous knowledge gaps still affect the carbon cycle (with a missing sink of about 2 Gt of carbon), the factors behind the recent near-stabilization of the atmospheric methane concentrations or the unexplained reduced rate of CO_2 increase in recent years, the effect of volcanic eruptions, the effect of any increased cloudiness, etc. Despite all the limitations of human knowledge it would be prudent on the part of the planners to incorporate the climate change factor for water resources development and management projects in India in general and the north-eastern region in particular.

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