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Impact of Climate Change on local use of rainwater: The case of two Indian cities

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Abstract: *The finite fresh water resource available to cities is under stress and projected to worsen. For Indian cities water available for domestic use is marginalized in the backdrop of its dynamic population growth. It has been well established that current centralized practice of water supply, sanitation and storm water drainage is unsustainable in economic and environmental terms if domestic water security is to be assured. In the 'Soft Path' of water proposed by Peter Gleick, a decentralized, people centric and integrated approach to deliver varying qualities of water for use is emphasized. Herbert Giraldet advocates the cyclic metabolism for utilizing resources to make cities more sustainable. Unlike the current linear metabolism in cities which leads to large quantities of waste, the suggestion is to move towards technologies which will enable cyclic metabolism to ensure a zero waste scenario. In the first part the paper briefly demonstrates the possibility of using grey water, rain water and city supply, in a neighborhood to optimize throughputs without reducing the quantity of water available for each activity. Thereafter the paper examines the issue of rainwater availability for neighborhood cyclic metabolism in coastal Chennai and interior New Delhi. Due to climate change the overall quantum of monsoon rainfall has reduced due to weakening of the Tibetan anticyclone. This has lead to long term rainfall variation with reduced rain in interior cities and increased rain in coastal cities. This paper will examine the implications of long term variation of rainfall on rain water use for the practice of cyclic metabolism.*
Keywords: *Domestic Use, Soft Path, Neighborhood, Cyclic Metabolism, Rainwater, Co-efficient of Variability*

I. Introduction

Fresh water Availability

While three-fourth of the earth's surface is water, fresh water forms a miniscule 2.4 percent of it. A finite quantum of this water is made available by the total hydrological cycle of evaporation, precipitation and surface and underground flows. This finite quantum of water has been recycled from the days of the dinosaurs. In the last 100 years demand for this resource has multiplied due population explosion on one hand and development on the other.

In the drier regions of the world most water is drawn for agriculture. In the first world industry dominates. By comparison water for domestic use i.e. the water people drink, use to keep themselves, their clothes, dishes and homes clean is relatively insignificant. The world average accounts for about 10% of the total water used per capita per day. Indian domestic consumption is less than world average. In 2000, the world average was 170 lpcd while the figure from India was 72 lpcd accounting for only 5% of per capita consumption

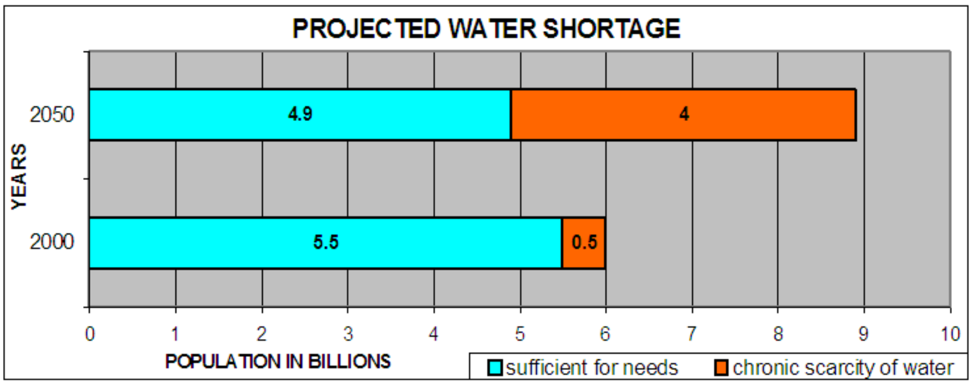


Figure 1.0: Projected Water Shortage

Source: UNESCO World Water Assessment Program 2003, **Water for People, Water for Life: The United Nations World Water Development Report**, Berghahn Books, Paris, 2003, p. 161

Projections paint a grim future ahead. In 2000 out of 6 billion people living on the planet 0.5 billion lived in countries chronically short of water. Chronic scarcity is a condition where less than 1000 cu m is available per annum per person for all his water needs. It is expected that in 2050, out of the 8.9 billion people on the planet, 4 billion will live in countries that would be chronically short of water. India unfortunately is on this list of countries. With industrialization and higher demands from agriculture to meet the needs of exploding population growth, water available to meet domestic demand in the future would be drastically marginalized in the case of Indian cities. The call for water use optimization could not be louder.

II. Sustainability By Cyclic Metabolism Of Water

In 1972 the term 'sustainable development' was coined by Meadows, Meadows and Randers in their seminal work **Limits to Growth**. In 1987, The Bruntdland Commission defined sustainable development as … **development that meets the needs of the present without jeopardizing the ability of future generations to meet their own needs**. The Bruntdland Commission attended by 178 countries was responsible for bringing the issue into world policy debate.

Herbert Girardet, the social anthropologist and cultural ecologist has argued that sustainable development implies sustainable urban development as there is no looking back for this form of population concentration. Pointing towards a fifteen-fold growth in urban population in comparison to a decadal four-fold growth in world population he infers that cities would be mankind's preferred habitat. The demographic transition of the planet from rural to urban as estimated to have taken place on 23rd May 2007 goes to show that this future is already upon us. With 2% the earth's surface and air space being the arena for using 75% of her resources and creating proportionate waste, there is an urgent need is to create city structures and systems to function in a sustainable manner.

An advocate of cyclic metabolism, Girardet makes a case for mimicking natural ecosystems like coral reefs where waste materials are reabsorbed into their living fabric, contributing to the long-term viability of the whole system. Natural systems have a circular metabolism wherein any discharge by one organism becomes an essential input for another organism ensuring the continuity of the environment of which they are a part. The web of life is connected in a chain of mutual benefits due to the flow of nutrients. Systems and components of systems, which are themselves nestled systems co-exist in unique niches of varying scales. System scales modulate naturally to demand and supply conditions, blooming and hibernating intelligently in response to variations in environmental conditions.

Modern city metabolisms in contrast are essentially linear. Resources are pumped through the system without thought to origin or destination, resulting in creation of 'waste' unknown to natural systems. Scalar dimensions and the opportunity to create internal loops are ignored. Depending upon the sphere of influence of the city the tentacles of absorption and rejection extend into the hinterland. To be ecologically viable, cities of the future would need to adopt circular metabolic systems. Outputs will need to become inputs both within the city as well as in its sphere of influence. Nestled systems, which operate on closed loops within the city, would modulate demand and supply by bringing the unique dimensions and resources of their niche into play. Fresh water, soil fertility, fossil fuels, metals and other resources of the planet would have to be put into a cycle of repeated use to achieve a minimal rate of maintenance throughput. Approaching this steady state is essential to existence on earth, as world resources are finite.

Peter Gleick feels that 20th century planning and management ensured that a centennial population growth of 4400 million was fed and assured a higher standard of living. But this was at enormous economic and environmental cost i.e. destruction of ecosystems, dislocation of human population, inundation of cultural sites and contamination of water sources. He argues that water a common community resource is being used as an economic commodity ignoring the reality that it is a basic necessity of life, imbued with cultural values and playing a pivotal role in the fabric of our habitat.

To quote… **people do not 'use' water. They want water to drink, bathe, swim, produce goods, grow food and meet human needs and desires. Achieving these can be done in different ways with radically different implications for water**.

Thereafter, he borrows the term 'Soft Path' from the arena of energy to generate an alternate paradigm to meet 21st century needs around water. The characteristics of the 'Soft Path' of water are as follows:

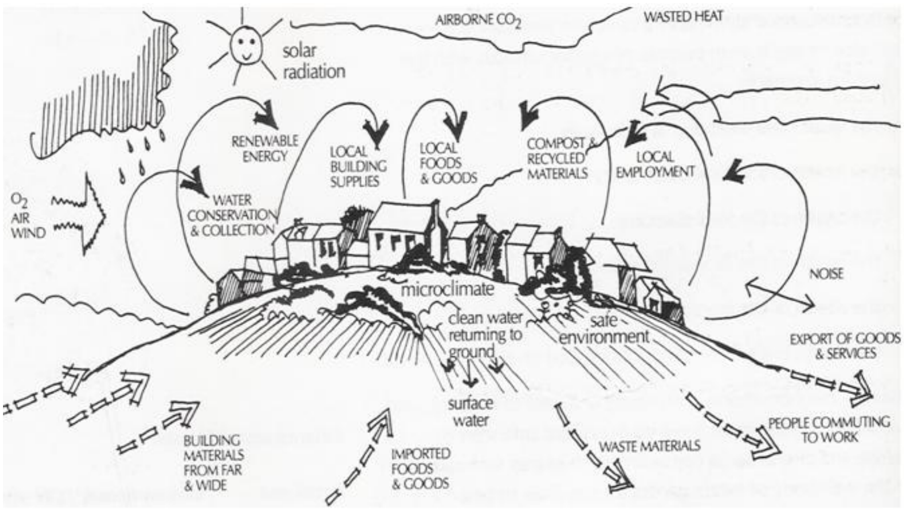
- The intentions are to meet human needs of drinking, washing utensils or watering plants. Focus shifts from supply to promoting efficiency and optimizing use by matching quality with nature of use.
- The soft path recognizes that after the easiest opportunities for creation of centralized supply systems are exhausted, investments in decentralized solutions can be as cost-effective as further investments in centralized options.
- The soft path recognizes the need to include investment in human capital i.e. people who manage and use facilities, to effectively implement soft path options.

- The soft path requires constant interaction of water management agencies with end users to identify nature of need and modify demands; it also calls for networking of communities with their neighbors in exploration of local solutions, hitherto unknown.
- The soft path recognizes that other than humans other denizens of the Blue Planet also require water. Water is a component of ecosystem services and water not being abstracted, treated and distributed for human use is being productively used by nature in ways essential for ecosystem balance and health.
- The soft path recognizes the notion of the economy of scope, wherein a combined decision making process around water would lead to overall mutual benefit. This could call for integrated approach to currently independent areas of water supply and sanitation, management of rainwater, management of riverine systems, slum rehabilitation, appropriate land-use and development controls.

By destroying the myths around water, by hard facts he demonstrates clearly that the way to a sustainable future calls for rethinking the current water use patterns and all the embedded value systems it represents.

III. The Significance Of Neighborhoods

The notion of neighborhood has gained importance in the Local Agenda 21 (LA21) of many European countries due to the focus on reduction of green house gas emissions by reducing the use of the automobile at the local area and adoption of sustainable resource use. Hugh Barton Executive Director, of WHO Collaborative Center for Healthy Cities and Urban Policy argues that to take the issue of sustainability seriously the neighborhood would have to be placed center-stage. Therefore if sustainability and Local Agenda 21 concerns were the future of cities, neighborhoods would become relevant like never before. He argues in favor of reinventing urban neighborhoods both from the general point of view of making safer and better cities, and for their specific ability to close resource loops.



Visual 1.0: Closing Resource Loops at the Neighborhood

Source: Hugh Barton et al, **Sustainable Communities – The Potential for Eco-Neighborhoods**, Earthscan Publications Ltd., London, 2000. p.88.

Cyclic metabolism when applied to neighborhood increases local autonomy and use of local resources, has better responsiveness to place and user control, has better connectivity (between neighborhoods) and integration of part to whole (between neighborhood and city structure). The neighborhood if so enabled can function as a complex ecosystem in supporting a diversity of ecological niches within it, for diverse groups with different needs in a state of dynamic equilibrium. Visual 1.0 demonstrates the many advantages of closing resource loops at the neighborhood.

Cyclic metabolism with respect to water implies new ways of looking at groundwater, rainwater, greywater, faecal matter, kitchen waste and garden waste. The act of cyclic metabolism at the neighborhood would mean:

- Adopt or move towards technologies which treat fresh water as a finite resource;
- Optimize or reject the practice of using water as a conveyer of waste; Reduce length of conveyance systems to control losses and save energy;
- Catch rainwater where it falls; Use water close to catchments by adopting suitable storage strategies;
- Create conditions of zero run-off to improve ground water status and create a surplus account for use during times of stress;
- Adopt technologies which use natural principles to treat waste;

- Match water quality with use it is put to and optimize levels of water treatment;
- Recycle water; Adopt measures to re-use water at the point of consumption;
- Close nutrient loops in wastewater treatment to ensure better health of agricultural land and waterways;
- Move towards local management and control;

IV. Cyclic Metabolism And A Neighborhood Water Use Scenario

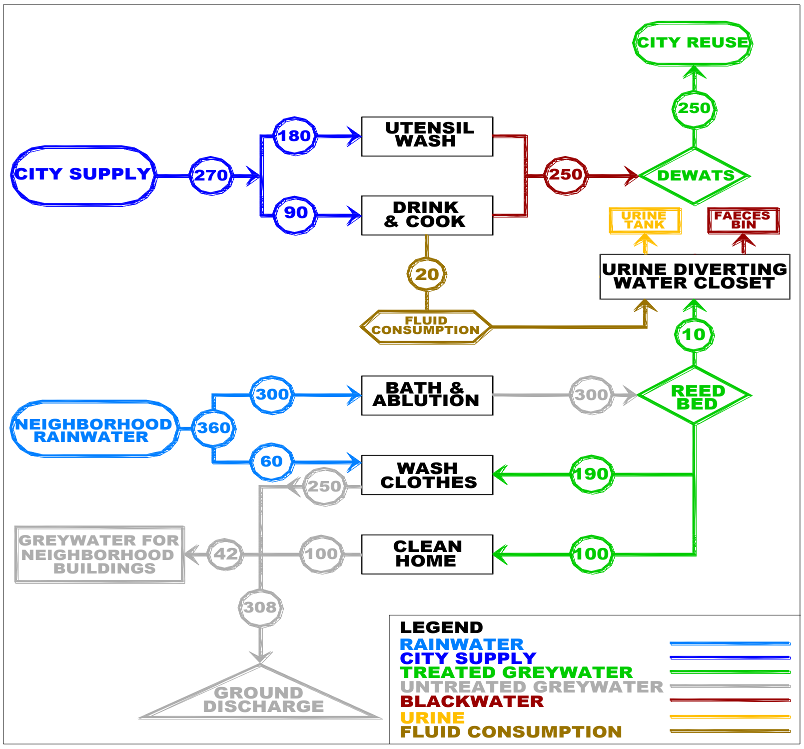
Based on the principles mentioned and rejecting the current practice of using potable water for all purposes to replace it with a more rationalized approach yields the results indicated in table 01. Herein a consensus national standard for urban areas, of 135 litres per capita per day is set against consumption figures based on studies available and the proposed alternative of matching quality with purpose to optimize water-use. By accepting suitable technological opportunities for cyclic metabolism and by matching quality with purpose high quality water use has reduced from 135 litres to a mere 27-30 litres.

no	Activity	Norm (lpcd)	Availability (lpcd)	Optimized (lpcd)	Optimized Quality
1	Drinking	03	3.8		
2	Cooking	04	2.7	09	Potable quality water
3	Washing utensils	20	14.9	18	
4	Bathing and ablution	20	25.8	30	Rain water
5	Washing clothes	25	17	25	
6a	Toilet flush: conventional	40	18.3	18	
6b	Toilet flush: ECOSAN (wet)			07	Rain / recycled water
	Toilet flush: ECOSAN (dry)			01	
7	Cleaning home	08	6.7		
8	Garden/ others	15	2.4	10	
	TOTAL	**135**	**91.5**	**110 (a), 99(b) & 93 (c)**	

Table 1.0: Optimized per capita water quality and quantity for domestic use

Source: Author

Using the figures from the table it is possible to generate tailor made neighborhood water use scenarios with a palate of technologies depending upon the water availability, the hydro-geology and the desirable land man ratio at the neighborhood. It has been demonstrated elsewhere that it is possible reduce quantum of resource and waste, without reducing the total water available for use while taking into account the situation at specific neighborhoods.



Visual 2.0: Neighborhood Water Use Scenario

Source: Author

In one such Water use Scenario water available at the neighborhood comprises of city supply, collected rainwater and recycled water. Households have urine separation closets which use greywater for flushing. Blackwater along with kitchen discharge is collected and digested in a DEWATS system. Urine is collected and transported out of the neighborhood. Stored rainwater is used for bathing, ablution and part of the water for washing clothes. It is recycled and used for flushing, cleaning homes and partly for washing clothes. Visual 2.0 and table 2.0 illustrates the details.

	Activity	**Consumption (cum)**	**Quality**	**The loop**
1	Drinking & cooking	90	Potable	City supply to city reuse
2	Washing utensils	180	Potable	via DEWATS
3	Bathing & ablution	300	Rainwater	Rainwater to reed bed
4	Washing clothes	60+190	Rainwater & Recycled	Rainwater & Recycled to sub-surface drainage
5	Flushing toilet	10	Recycled	Greywater to DEWATS system
6	Cleaning home/ other	100	Recycled	Greywater to sub-surface drainage
	Totals	**cum**	**Quality**	**Arena for action**
1	City supply	270	Potable	City
2	Available for use	930	Potable & recycled	Neighborhood
3	Neighborhood supply	360	Rainwater	Neighborhood
4	Sub-surface drainage	304	Greywater	Neighborhood
5	To reed bed	300	Greywater	Neighborhood
6	Kitchen wastewater	250	Blackwater	200 cum for city reuse
7	To compost bin	06	Faeces & wash water	Neighborhood to agriculture
8	To urine tank	19	Urine	Neighborhood to agriculture

Table 2.0: Water Use volumes in the Neighborhood Scenario

Source: Author

V. Rainfall And Its Impact On Meeting Scenario Need Of Harvested Rainwater.

India gets an average of 1170 mm of annual precipitation. Figures from other parts of the world are 750 mm in United States of America, 600 mm in Canada, 350 mm in Australia, 300 mm in Africa and 650 mm in Europe.

Despite high precipitation its other characteristics ensure that the rainfall endowment is an untapped potential. Firstly there is a time skew with 75% precipitation occurring in 33% time, leading to poor natural recharge and high runoff. Secondly there is a large spatial variation of 280 - 3580 mm in annual precipitation. With 60% of the area of India falling in the semi-arid tropical zone the Co-efficient of variation of rainfall (CVR) creates uncertainty on average annual precipitation. The Indian monsoon is characterized by rainfall intensity in the range of 10mm/hour compared to rain in the midlands, which are in the range of 1-2 mm per hour. This intensity factor also has a uniform spatial distribution. Thus 50% of the annual rainfall is delivered in a very short span of time, 20-30 hours. This leads to very high runoffs, flooding and poor recharge when holding areas are not available for recharge. Based on these characteristics it is recommended that storage to tanks is a logical method for use of rainwater. The innumerable traditional water harvesting and storage structures are a silent affirmation of this fact.

In table 3.0 the amount of annual rainfall required to support a 360 cubic metre of daily rainwater use at neighborhood with varying population density, using established parameters of run-off co-efficient and the first-flush component is indicated. Using the available annual normals generated from 1917 onwards, cities can calibrate and moderate densities to ensure that rainwater becomes a significant contributor to the daily water needs of the neighborhood. With 61% of major cites getting annual rainfall of 1200 mm or less variations in rainfall figures assume significance if rainwater is to form a significant contributor to neighborhood needs.

s.no	Gross residential	percentage	ground	coverage
	density in pph	25%	30%	35%
1	150	378	374	369
2	225	578	571	564
3	300	785	776	767
4	375	1000	989	977
5	450	1224	1210	1197
6	525	1456	1440	1425
		rainfall	in	mm

Table 3.0: Minimum Rainfall requirements for the Water Use Scenario

Source: Author

VI. Long Term Variability Factor Due To Climate Change

The conventional belief is that global warming would ensure that rainfall would increase substantially. In the context of India, it has been found that the overall quantum of monsoon rainfall is decreasing due to a weakening of the Tibetan anticyclone, the weather phenomenon responsible for the Indian monsoon. This weakening is due to several reasons connected to global warming, though specific findings are yet to be clearly established.

The outcome of this weakening of the monsoon has ensured that annual rainfall over India from 1944-1969 to 1970-2006 has decreased by 4.11% with 22.4% area of the country shows increasing trend, 68.1% decreasing trend and the balance 9.5% showing no trend. Map 1.0 indicates the long-term variability in annual rainfall pattern. This variation is not constant. On the one hand decline in winter and monsoon rainfalls over some areas contributes to decrease in annual rainfall and, while on the other, an increase in summer and the post-monsoon rainfalls over other areas modifies this decrease to some extent.

VII. Rainfall Patterns Of Chennai And Delhi

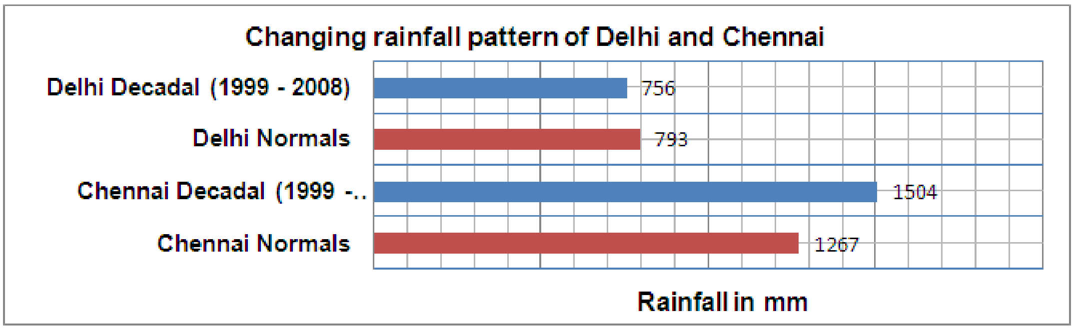
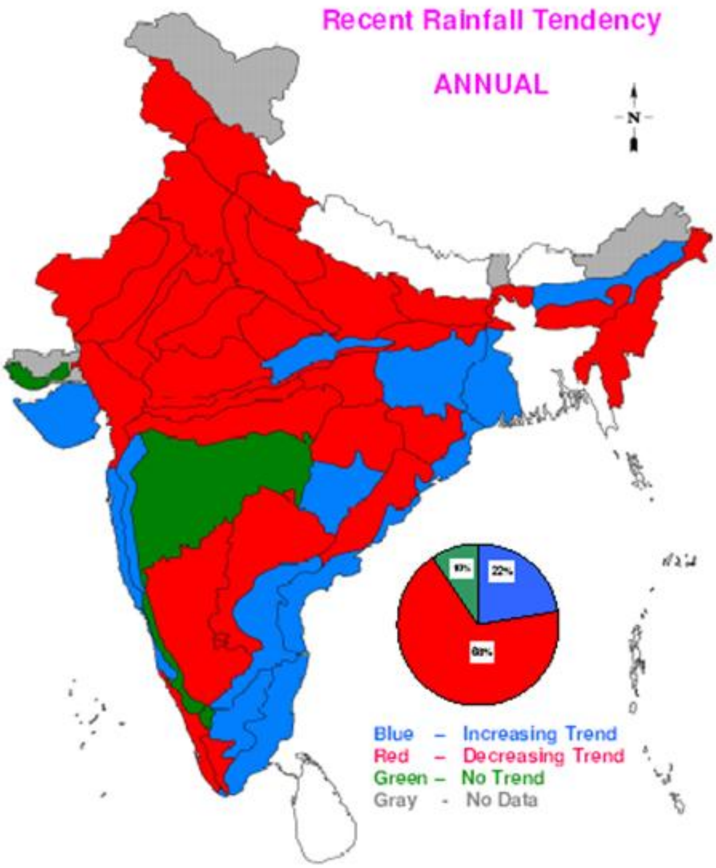


Figure 2.0: Changing rainfall patterns of Delhi and Chennai.

Source: Climatological Tables, Indian Meteorological Department, Government of India.



Map 1.0: Long term variability in annual rainfall pattern: India

Source: N A Sontakke, H N Singh and Nityanand Singh, **Report on Chief Features of Physiographic rainfall variations across India during instrumentation period (1813 – 2006)**, Indian Institute of Tropical Meteorology, Pune, 2007, p. 125.

In the last section of this paper a detailed examination of the impact of the long term variation due to climate change has been undertaken for two cities. These are the coastal city of Chennai and the interior city of Delhi. Figure 2 indicated the normals as well as the recent decadal averages of rainfall in these two cities. It is seen that while the average rainfall of Delhi has decreased by about 36 mm only in the case of coastal Chennai the increase is a as much as 19%. By comparing the actual rainfall pattern with the requirements of the Water use Scenario one may conclude that:

- While it was never really possible to practice the particular Water Use Scenario in Delhi for higher density housing the situation has become even more constrained in the recent past. From about 300-310 pph the operational density for the Scenario has reduced to 280 - 290 pph.
- The current practice in Delhi is to store water in aquifers and withdraw the same for use. With the withdrawal co-efficent of 0.7 of recharged volume this practice would render rainwater harvesting for use a more difficult proposition.
- In the case of Chennai the dramatic 19% increase in the annual rainfall figure implies that neighborhoods with gross residential densities of 525 persons per hectare could model their water use patterns on the suggested Scenario.
- The increase in density bandwidth of about 65 pph from 470 to 525 pph is extremely relevant for Chennai as housing densification is a central strategy in the master plan for optimum utilization of urban land.

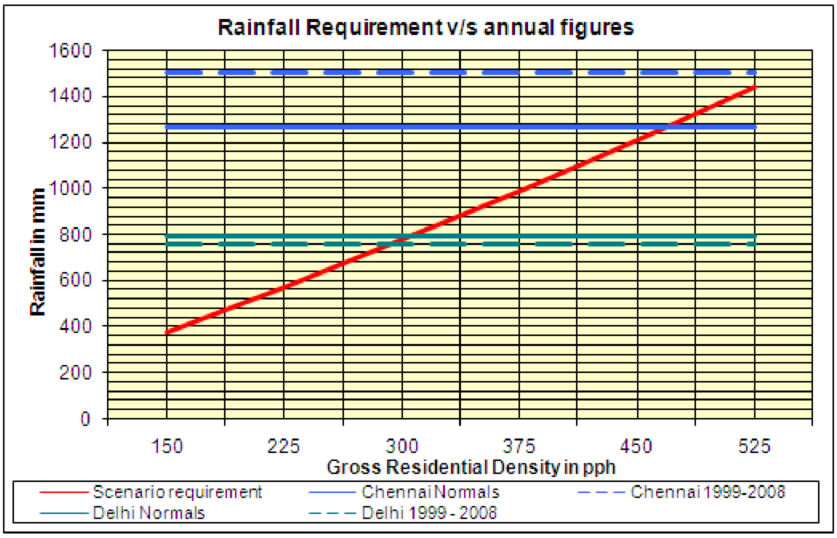


Figure 3.0: Impact of rainfall on operational densities in Chennai and Delhi.

Source: Author

VIII. Climate Change And Neighborhood Storage Capacities

In a city scenario the annual storage requirements for a neighborhood translate into large structures. The ideal condition for a neighborhood is to receive rain daily, equal to its need, requiring only a day's storage capacity. However, the monsoon or its source word mausam literally means seasonal. This ensures that while storage volume is much lower than annual water requirement, it is directly dependent on the precipitation pattern. This works on the principle that water is stored after every rainfall event, but is extracted on a daily basis, with the possibility of the same storage volume being used several times in a year.

It has been demonstrated that the factors which affect the storage capacity are:

- The density or land man ratio of the neighborhood in question.
- The spread of annual rainfall of the city which dictates the primary storage capacity to be achieved at the neighborhood level.
- The co-efficient of rainfall variation of the city which dictates the figures of additional storage capacities to be built at the neighborhood or city level.

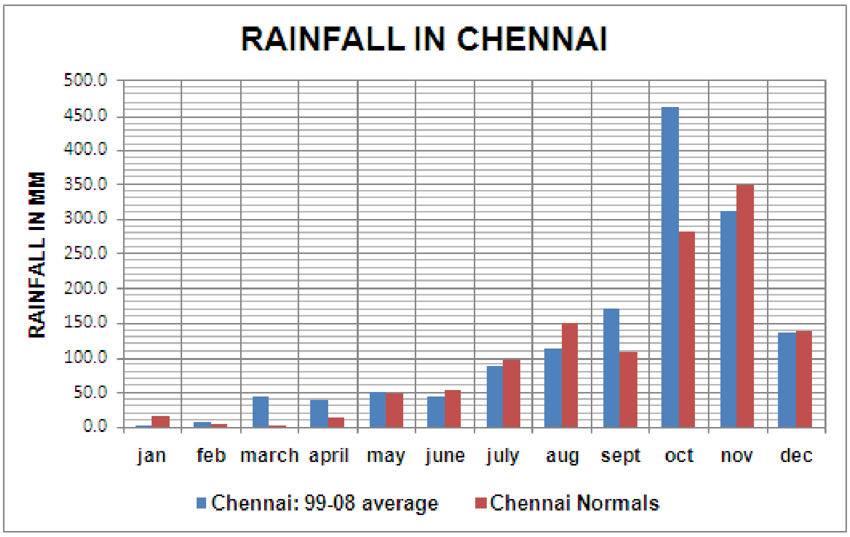


Figure 4.0: Rainfall in Chennai

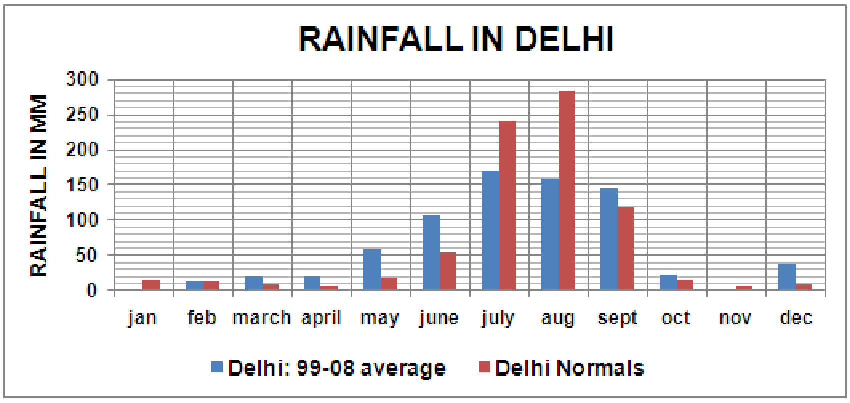


Figure 5.0: **Rainfall in Delhi**

Source: Climatological Tables, Indian Meteorological Department, Government of India.

In figures 4.0 and 5.0 the normal rainfall figures and the average rainfall figures of the decade 1999 – 2008 have been plotted for Chennai and Delhi. Chennai, used to receive some rainfall from the south west monsoon in August and its major rain from the returning monsoon in the month of November. In the case of Delhi there was one annual peak in the month of August.

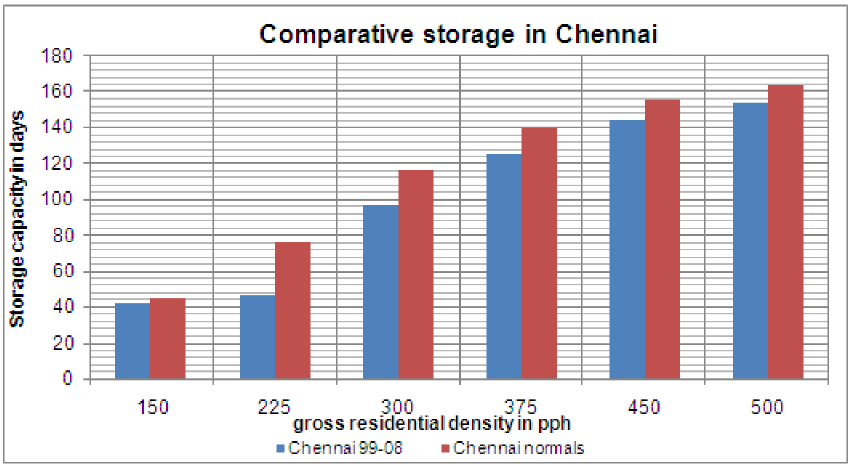


Figure 6.0: Comparative storage capacity in Chennai

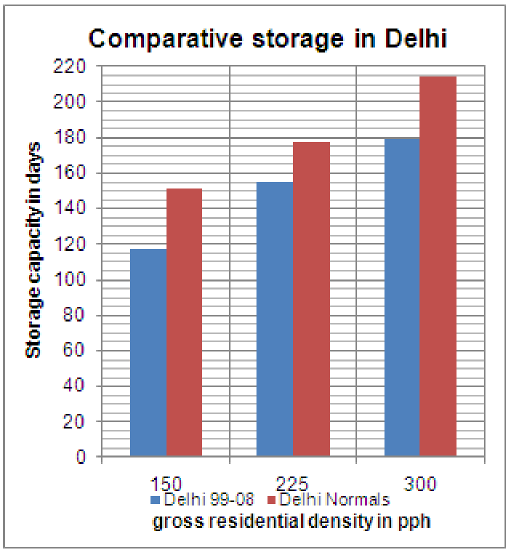


Figure 7.0: **Comparative storage capacity in Delhi**

Source: Author

As a consequence of two annual peaks in Chennai, the average storage capacities at the neighborhood were modest as compared to other cities which received similar amount of rain only from the south west monsoon. But Chennai now receives 19% more rain than before the impact on storage capacities is minimal as 53% of the total annual rainfall is delivered over a 60 day period. This translates into the reality of storage capacities not being recycled over a one year period. Figure 6.0 indicates the storage capacity requirements for gross residential densities 150 – 525 pph in Chennai. On the other hand despite a 5.3% reduction in rainfall, with the spread of the major rainfall season over a period of almost 5 months compared to a 2.5 month period earlier, and precipitation in December, there is a reduction in storage capacities for Delhi neighborhoods, as plotted in Figure 7.0.

IX. Conclusions

From the point of view of this paper, this observed long-term variation could have the following implication on a neighborhood water use:

- Depending upon the location of the city, there would be a need to look at long term annual rainfall averages along with the published 30 year normals period average for design of neighborhood Water Use Scenario;
- It has been demonstrated that annual rainfall pattern and storage capacities are directly related. The recent rainfall trends point towards new emerging city level rainfall patterns, requiring storage designs with additional safety factors built in.

With rainfall variations bringing in the element of time, a neighborhood Scenario would need to contend with the temporal dimension as well. Climate change is an ongoing phenomenon, trends are changing at current points of time and could change further as systems are built and put to use. While safety factors could be brought into system design their efficacy could be suspect under such dynamic conditions. Cities would therefore need to build neighborhood and city level strategies with a lot of care, if cyclical metabolism is to be the way of the future.

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