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Hot Spots of Household Water Insecurity in India's Current and Future Climates: Association with Gender Inequalities

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Introduction

Access to clean water in an equitable manner is imperative for quality of life, sustainable development, and poverty alleviation. Almost 800 million people—most of whom are poor and live in developing countries—have inadequate access to water, especially for drinking and sanitation purposes (WHO/UNICEF 2012). The demand for water, moreover, is continuously increasing with rapid demographic, technological, and socio-economic changes. As per the widely accepted Falkenmark water stress indicator, the number of people living under the critical water stress threshold of 1,700 cubic meters per person per year is projected to range between 0.4-1.7 billion by 2020s; between 1.0 and 2.0 billion by the 2050s; and exceed the three billion mark by the 2080s (Arnell 2004). Climate change associated with growing population, and increasing urbanization and industrialization will significantly reduce the per capita water availability in many parts of the world (Parish et al. 2012). In India, for instance, the per capita availability of water in 1951 stood at 5,177m³/year. By 2010, this value had reduced drastically to 1,588m³/year; it is likely to decrease further to below 1,140 m³/year by 2050 (MoWR 2011). The declining availability of overall water supply currently causes negative effects on the quality of people's lives; and without drastic change, the situation is likely to worsen in the future.

Several hydrological assessments of water resources are available (Bates et al. 2008, Parish et al. 2012) and play a significant role in understanding and addressing problems related to spatial and temporal availability of water, its storage and runoff at local and global scales (Mazumdar 2011). Most of these assessments, however, do not depict the vulnerability of populations to water stresses resulting from a combination of social, economic and environmental factors. It is thus important to link the physical availability of water with human resources, as well as with the socio-economic drivers determining people's capacity to access and manage their water resources. The role of composite indices, therefore, becomes an important element in capturing the diverse dimensions that make a population vulnerable to water access issues (Sullivan et al. 2005).

Several indices—such as the watershed sustainability index, the water supply stress index, the water poverty index, and the water footprint index—have been developed to address measurement of water-related issues (Brown 2011). Despite criticism of these indices—such as the choice of components and sub-components, data availability at different scales, arbitrary and contextual modes of assigning weights to components, as well

as loss of data in aggregation—they continue to be useful guides for assessing and comparing vulnerabilities of regions, as well as for environmental monitoring and management (Komnencic et al. 2009, Sullivan et al. 2005).

An especially important index in this regard is the Water Poverty Index (WPI) introduced by Sullivan et al in 2002 and later extended to the Climate Vulnerability Index (CVI) in 2005. The CVI aims to make a holistic and consistent assessment of vulnerability to water related issues at different spatial and temporal scales (Sullivan et al., 2005, 2009). CVI is able to link physical estimates of water availability to socio-economic and environmental factors, which have an impact on the availability of water at the household level. The index is calculated using a methodology similar to the Human Development Index (HDI), using six key components that characterize:

- i. the overall availability of water resources,
- ii. access to safe drinking water and sanitation,
- iii. the capacity of people to avail safe water supply and manage water sources (interpreted in terms of levels of education and income, and investment in the health sector),
- iv. use or consumption of water for domestic, industrial and agricultural purposes,
- v. the state of the environment, and
- vi. climatic stresses in the region

The CVI has been used to characterize hotspots of water insecurity at a country level (Sullivan et al. 2005), which is useful as a general guide to conditions within the country. However, a more decentralized, site-specific approach is required for guiding policy and action. This is especially true in large countries such as India (comprised of thirty five states and union territories) where regional differences are large. The present study was, therefore, undertaken to determine the hotspots of water insecurity at the household level for various states of India. For this purpose we took the reciprocal of CVI components to better reflect water insecurity at the household level in terms of the above key components, viz. lack of resources, limited capacity and access to water, inadequate use of water, poor environment and climatic stresses. An average of these six values provided an index, which will henceforth be called the Water Insecurity Index (WII) in this paper. The index and its components ranged from zero (most secure) to one (least secure).

Another objective of our study was to examine how water insecurity at the household level is related to commonly measured indices of gender development and inequities. The role of women as water managers for the family is undisputed in most parts of the developing world. Several studies have shown that

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in developing nations women shoulder the bulk of the burden of water collection (MOSPI 1998-99, UNICEF/WHO 2008 and 2012, Desai 2010, Koolwal 2011, Sorenson 2011, Asaba 2013). It is estimated that in Sub-Saharan Africa, women and children spend almost 20 million hours/day and up to 40 billion hours/year collecting water (UNDP 2009, UNICEF/WHO 2012). It is expected that in the coming years, climate change will have a profound effect on the quantity and quality of available water resources which in turn will have a negative impact on quality of life, especially for women who are responsible for the procurement and management of water. The work burden on women is anticipated to magnify several times due to climate change-mediated environmental stresses, making them much more vulnerable to climate change (UNDP 2009).

There has been an increased sensitization among national and global planning bodies towards focusing development efforts on the welfare and equitable development of women. Several indicators are now being used for measuring the status of gender development. The Gender-related Development Index (GDI), for example, has been used since 1995 by UNDP as a composite index for capturing the gender dimension of human development. It accounts for gender inequalities adjusted for the same variables that are used for estimating HDI based on indicators of health, knowledge, education, and standard of living. The greater the gender disparity in basic capabilities, the lower a nation's GDI is compared with its HDI (UNDP 2007-08). The GDI/HDI ratio is therefore a measure of gender inequality in a region. The Gender Inequality Index (GII), created by UNDP, has recently replaced the GDI, but its state-level values for India are not yet available.

Climate change is likely to further influence all of these indicators in the future due to its impact on the hydrological cycle and consequent decreased water resource availability. Since future water insecurity at the household level will be affected not only by these climatic changes alone but also by the rapidly changing state of other socio-economic indicators, an additional objective of this study was to examine how the various indicators of WII at the household level will change in future.

Methodology

WII and its components

Table 1 describes the 21 variables used in this study for characterizing the six components of the WII, which were selected based on their relevance and suitability for the present study, as well as on data availability.

The 'Resource' component reflects physical availability of surface and ground water. It has five components:

- i. average annual rainfall in the region
- ii. number of rainy days
- iii. per capita availability of ground water resources that can be replenished

- iv. area irrigated by canals and tanks, and
- v. length of rivers

With these five indicators, we were able to capture the major regional differences in surface and ground water.

The 'Access' component measures the access families have to safe water for human consumption and other domestic chores. This was quantified in terms of availability of a safe source of water for use by families (tap, hand pump and tube well in this study), as well as the location of this water source. A water source within 100m in urban areas and within 500m in rural areas was considered to be a safe location for a water source as defined by the Census of India, 2011.

The 'Capacity' component reflects the ability of people to access, lobby for, and manage water. It was captured by the literacy and education level of the population, the per capita consumption expenditure, and the state of their health as reflected by their life expectancy at birth. This component reflected the ability of people to avail themselves to adequate housing and accompanying services of safe water supplies and sanitation. The 'Use' component focuses on the actual consumption of water and was defined by the per capita consumption of water for domestic, industrial and agricultural purposes, in addition to the percentage of irrigated agricultural area.

The 'Environment' component is meant to reflect on the environmental integrity of a region as well as the quality of water available to people. It is comprised of the percent population with access to safe sanitation facilities (toilets and bathrooms within the house), percent sewerage treated, and the percentage of slum population to total urban population living in that state since all of these have a profound impact on the quality of available water. Finally the 'Climate' component consisted of areas prone to floods and droughts and future changes in mean annual temperature.

Values of the WII and its components were then derived by the normalization method in the same manner as is used for calculating the HDI by UNDP. The WII values ranged from zero (least insecure) to one (most insecure) and were calculated as follows:

$$WII = Wr^* (1-R) + Wa^*(1-A) + Wc^* (1-C) + Wu^* (1-U) + We^* (1-E) + Wcl^* (1-CI)$$

Where R is resources, A is access, C is capacity, U is use, E is environment, and CI is climate; variables used for calculating these indicators are listed in Table 1. Wr, Wa, Wc, Wu, We, and Wcl are weights for resources, access, capacity, use, environment, and climate component, respectively. These weights were taken uniformly as 16.67%. The states with WII values lower than 0.25 were considered least water insecure, while those with values greater than 0.75 were considered extremely insecure. The states with values between 0.25 and 0.5 were considered

Table 1: The six components of the Water Insecurity Index and the variables used to calculate them in the present study. Signs after the variable indicate if this was used as a positive (+) or negative (-) indicator.

Component	Variables used
Water resources	* ^a Average annual rainfall (+)
	Number of rainy days (+)
	* ^b Total replenishable ground water per capita (+)
	Percentage area irrigated by canals and tanks (+)
	* ^b Per capita length of rivers (+)
Access to water	* ^c Percent population with access to safe water supply (+)
	Percent population with access to safe location of safe source of drinking water from home
Capacity to lobby for water	* ^c Literacy rate (+)
	Secondary school but below graduate (+)
	* ^d Life expectancy at birth (+)
	* ^c Per capita consumption expenditure (+)
Water use	* ^{b,e} Per capita ground water used for domestic and industrial use (+)
	* ^b Per capita ground water draft (+)
	Percent of net irrigated area to net sown area (+)
Environmental component of water	* ^c Percentage of population having access to safe toilet facilities in the house (+)
	Percentage of population having access to bathrooms in the house (+)
	* ^c Percent slum population to total urban population (-)
	Percentage wastes treated (+)
Climate component	* ^f Percent area affected by floods (-)
	* ^f Percent area affected by droughts (-)
	* ^a Annual mean temperature rise (-)

* indicates the variables used to compute Water Insecurity Index values for the years 2000 and 2025.*^a: Values from IITM Pune 2010, *^b: Computed using population figures from General of India 2006, *^c: Computed using change rate from 1991-2001, *^d: Registrar General of India 2006, *^e: Central Ground Water Board, *^f: Values are assumed to be same for 2000 and 2025

moderately insecure; and those with values between 0.5 and 0.75 were considered highly insecure.

Water insecurity and gender development

For the purpose of studying the relationship of WII with indicators of gender development and inequities, the most recent available values of GDI and GDI/HDI ratios for different states of India were obtained from the Ministry of Women and Child Development, Government of India, 2009.

Impact of climate change on household water insecurity

To understand future changes in water insecurity at the household level due to changes in climate and other water related parameters, WII was recalculated for the year 2000 (by considering it as the base year) and 2025. Climate change data for the A1B scenario for the period 2020-2030 (henceforth referred to as 2025) were obtained from the Indian Institute of Tropical Meteorology, using PRECIS, (Providing Regional Climates for Impact Studies), a regional climate modeling system based on Hadley Center's Regional Climate Model and were obtained from the Indian Institute of Tropical Meteorology. The A1B socio-economics scenario developed by IPCC is characterized by rapid economic growth and significant improvement in

energy efficiency (IPCC 2007). In general, projected changes in temperature were close to 1-1.5°C and absolute rainfall was within 10% of the current values. Changes in rainfall were directly added to the resource component of the WII, whereas the changes in mean temperature were added to the climate component and considered to be a negative indicator. The percent area likely to be affected by droughts and floods was taken to be the same as the current values—assuming that there will be no consequential changes in the magnitude of floods and droughts within the relatively shorter time period used for the purposes of this study.

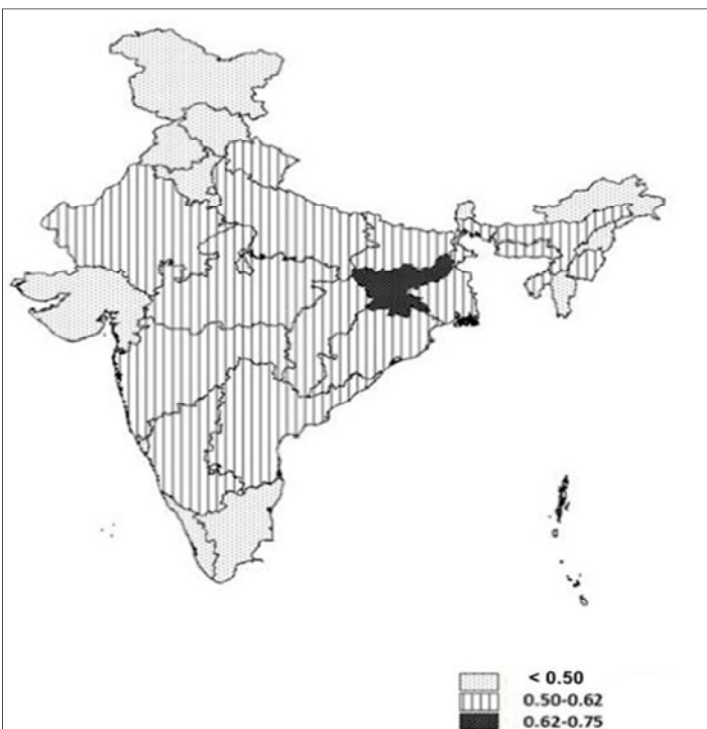
For the analysis of climate change impacts, calculations for current and future climates were arrived at by using only those variables for which projected values for 2025 were also available or could be computed using the rate of change of the previous decade (variables indicated in Table 1). While data for most variables was available for 2025, certain variables (access to safe water, sanitation, literacy, percent slum population, and consumption expenditure of families) were computed assuming past growth rates would continue at this rate.

Results and Discussion

Regional variation in water insecurity

The results of the study showed that India as a whole was water insecure at the household level (WII=0.54) although there were large regional differences (Figure 1). The WII values ranged from as low as 0.36 in Goa to as high as 0.69 in Jharkhand—indicating a wide variation in the level of water insecurity across states (Figures 1 & 2). It was interesting to note that none of the states fell in the category of either least water insecure (WII values between zero and 0.25), or most insecure (WII between 0.76 and 1.0). Results showed that 17 states, covering almost three fourths of the geographical area and housing 78% of the population of the country, were highly water insecure (WII values between 0.51 and 0.75, Figure 1). These states had a relatively higher exposure to climatic and other environmental stresses but relatively limited human capacity, leading to highly inadequate access to and use of water resources (Figure 2). Most states of the north-eastern region (including Meghalaya and Assam) were also highly water insecure even though their water availability was moderate to very high. The remaining 18 states, which occupy only one-fourth of the geographical area and were home to 22% of the population of the country, were moderately water insecure (WII values between 0.26 and 0.50), because they generally enjoyed higher levels of human development and hence better 'Capacity' and 'Access' to water resources. Within this group, Delhi and Punjab had relatively lower insecurity to water at the household level (WII<0.4) despite having extremely limited water resources. This was largely because of their higher human capacity resulting in better access to and use of water resources, as well as better environmental integrity as compared to many other states. It is to be

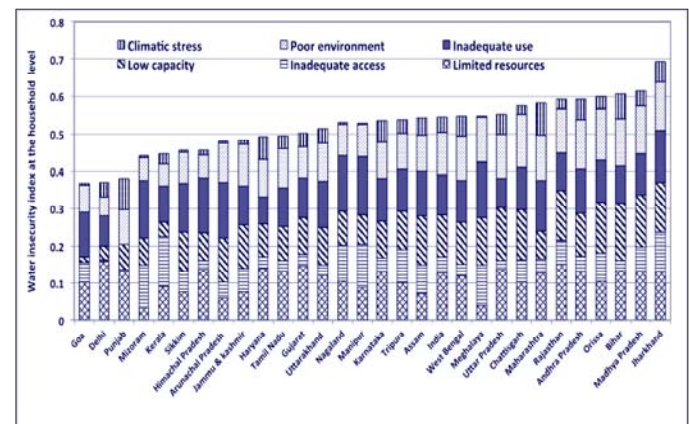
Figure 1: Spatial variation in Water Insecurity Index at the household level in states of India.



noted that the state of Punjab has benefitted the most from the Green Revolution in agriculture, leading to an increase in per capita income and overall development even in rural areas. Similarly, the capital, Delhi, experiences relatively higher investments in infrastructure and enjoys higher per capita income as compared to other states.

The results also showed that the key reasons for relative water insecurity among states were their limited 'Capacity' and their current state of poor 'Environment'; not necessarily their state of water 'Resources' (Figure 3). It is made clear from this observation that when water insecurity is analyzed from a purely hydrological perspective it may not reflect the holistic picture of water availability at the household level. As a case in point, states such as Arunachal Pradesh, Meghalaya, and Mizoram, despite having abundant water resources, continue to be either moderately or highly water insecure. Conversely, the Union Territories of Delhi, Chandigarh, and Pondicherry have limited water resources, but face much lower water insecurity because of their higher human capacity and consequent ability of people to benefit from better housing, safe water, and sanitation facilities. In light of the above observations, it may therefore be concluded that to increase water security in the

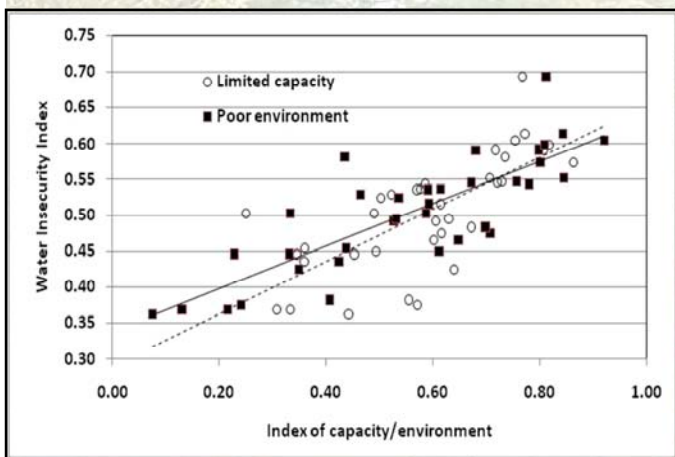
Figure 2: Variation in Water Insecurity Index and its components across different states of India.



most vulnerable states, there is a greater need to improve both the availability of water resources and the overall capacity of people to benefit from and manage water supply from improved sources. Additionally, enhancing the state of water supply sources' environmental integrity plays a crucial role in decreasing water insecurity. These issues are, in turn, governed by the level of education, income, health, sanitation, the overall infrastructure and other conventional development indicators of the region. In other words, one may argue that as the overall development of the states increases, their vulnerability to environmental stresses may be expected to decrease; and their overall water insecurity would also possibly decrease despite their physical water resources not necessarily being satisfactory.

Recent research in Ethiopia has shown that investments in irrigation can contribute to poverty reduction, but that such poverty reducing impacts are greater when accompanied with proper conservation practices, literacy of the household head and education level of adults are all achieved (Hanzra et al. 2009). Several governments across the developing world including India are making considerable investments in water resource development to reduce the overall poverty of their nations. It is therefore important that along with investments in water resource development, simultaneous efforts are required to address literacy, environment and related policy that support issues for reducing poverty levels.

Figure 3: Relationship between index of 'Capacity' and 'Environment' with Water Insecurity Index at the household level.



In general, more limited a state had Capacity or Environment component, more water insecure it was. The relationship of WII with Resources, Climate, Access and Use components was not significant.

Water insecurity and gender development

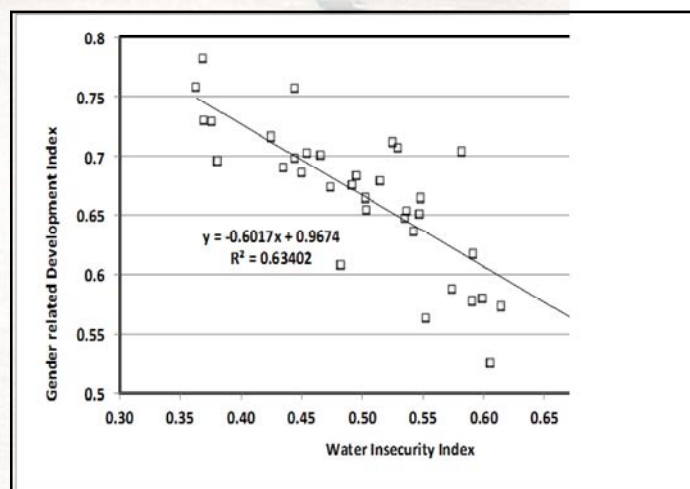
An analysis of the GDI scores of the different states further supports the relationship between water insecurity at the household level with overall human development, especially gender development. Figure 4 indicates a significant inverse relationship between GDI and WII. To better illustrate this point, it was found that states with high GDI values (above 0.7) such as Kerala, Goa, Delhi and Himachal Pradesh were moderately water insecure; while states with low values of GDI (below 0.6) such as Chhattisgarh, Orissa, Bihar, Jharkhand and Rajasthan were faced high water insecurity. One of the reasons for this may be that the states experiencing extreme climatic stresses also face shortages of natural resources, which in turn exerts undue pressure on the local population, especially on women.

Under such circumstances, women are forced to put in long hours of work in fulfilling their Practical Gender Needs – defined in gender analysis as women’s traditional roles and responsibilities – related to the procurement of freshwater, fuel wood, livestock fodder and food for their families. In the process, the Strategic Gender Needs of education, participation in

decision-making control over assets and resources, employment and income are grossly neglected. Ergas and York (2012) and Buckingham (2010) have suggested that to increase gender equity and efficiency in such regions, there is a need for greater involvement of women in environmental decision-making by way of increased political participation of women. Arora-Jonsson (2011) however, argued recently that the inclusion of women in existing institutional decision making bodies does not necessarily address the removal of gender inequities and indirectly leads to maintaining the status quo of women. This is because women are expected to abide by existing rules and laws and are discouraged from questioning the prevailing power structures, which most often favor men. It is therefore necessary to bring about a change in the structure of institutions for democratizing the policy making process by enabling participation of different social groups including women. At the same time, while making policies, it is important to understand the existing gender inequalities that prevent women from seeking institutional support. Considering all of these factors, however, would enable women to build long-term capacity to adapt to changing climate while ensuring their livelihood (Lambrou and Nelson 2010).

It must, however, be noted that the GDI by itself is not a measure of gender inequality, it is rather the HDI adjusted for gender disparities in its basic components and hence cannot be interpreted independent of the HDI. The difference between the HDI and the GDI may appear to be small (because of relatively small differences in the three dimensions used for its calculation), giving the misleading impression that gender gaps are irrelevant. The ratio of the two indicators (GDI/HDI), however, is a more appropriate measure of gender inequality—the lower the ratio, the higher the gender inequality. As per analysis conducted by the World Bank, a ratio of 0.98 and above is considered to be most desirable. In fact, a comparison across nations have shown

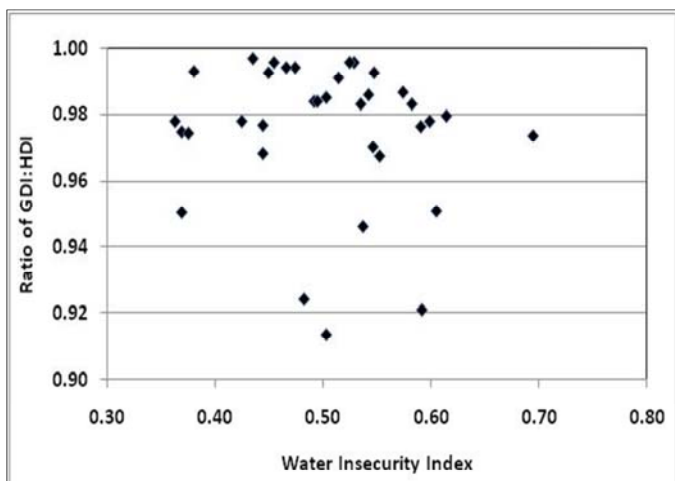
Figure 4: Relationship between Gender-related Development Index and Water Insecurity Index at the household level



Afghanistan, Niger, Pakistan and Yemen to have the worst record of gender inequality with GDI/HDI values less than 0.94; whereas most European and northern American nations exhibit the least inequality, with a GDI/HDI ratio of 0.975 or more. Interestingly, despite its regional variations, India demonstrates an overall moderate record with a value of 0.971.

Our results indicate considerable variations in GDI/HDI ratio across Indian states, signifying regional differences in gender inequality (Figure 5). Although most states present a satisfactory record of gender equality by attaining a ratio of 0.975 or more, the states of Andhra Pradesh and Jammu and Kashmir reflect poorly in terms of gender inequality ($GDI/HDI < 0.94$). While highly populous states of Bihar, Uttar Pradesh, West Bengal, Jharkhand, and Rajasthan were intermediate performers, the north-eastern region and the prosperous state of Punjab had a GDI/HDI ratio of 0.99 (similar to the HDI) indicating considerable gender equality in these states.

Figure 5: Variation in the ratio of GDI:HDI and Water Insecurity Index among states of India



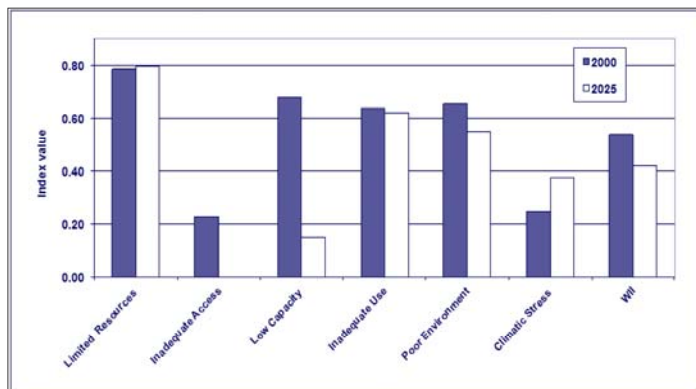
Most states that were relatively less water insecure such as Goa, Punjab, Kerala and Himachal Pradesh also exhibited the least gender inequality ($GDI/HDI > 0.975$) and conversely several highly water insecure states such as Jharkhand, Bihar and Andhra Pradesh exhibited greater gender inequalities ($GDI/HDI < 0.975$). There were, however, some exceptions to the rule. Jammu and Kashmir and Delhi, for instance, enjoyed low water insecurity, but had a very high level of gender inequality. The north-eastern states of Meghalaya and Manipur had excellent performance in terms of gender equality ($GDI/HDI > 0.99$), due to a very large majority of the population being part of tribes that are matrilineal in nature, but yet were in the category of highly water insecure states (Figure 5). Despite these exceptions, it may still be concluded that highly water insecure states are also likely to be the ones experiencing greater gender inequalities. In most instances where the measurement of the WII is not feasible, GDI/HDI ratio values may also point towards the hotspots of water insecurity at the household level. Thus,

addressing gender inequalities will most often reduce hot spots of water insecurity at the household level too.

Climate change and water insecurity at the household level

Water resources in India will continue to decrease due to climate change and large population growth. Despite this, our results indicate that the Water Insecurity Index at the household level is expected to decrease from 0.54 in 2000 to 0.42 by 2025 (Figure 6) for India. The key reason for this is the projected growth in human development anticipated by 2025. The results show that inadequate water access is likely to completely disappear by 2025, together with a tremendous improvement expected in the 'Capacity' of the population (Figure 6). As far as the 'Use' and 'Environment' components are concerned, only a marginal change is anticipated. India will, however, continue to remain moderately water insecure at the household level despite development in different sectors.

Figure 6: Change in the Water Insecurity Index and its components at the country scale in current and future scenarios of climate change

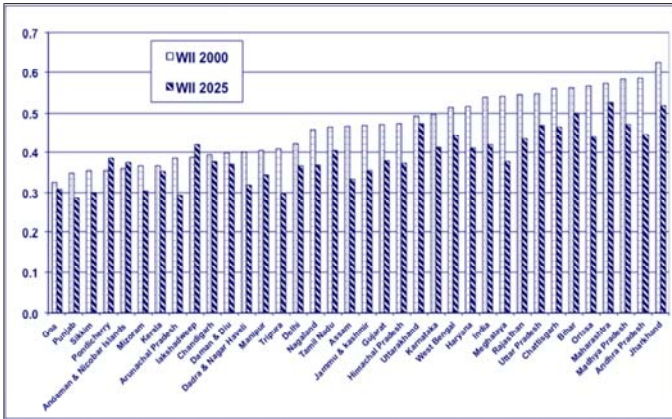


Our findings at the national level—which show reduction in future water insecurity—are also reflected across most states (Figure 7). The only exceptions are Lakshadweep and Pondicherry, because of the improvement in their 'Capacity', 'Access', and 'Environment' components that is offset by an increase in the 'Use' component because of high levels of population growth, a marginal decrease in the 'Resource' component, and a substantial addition to the 'Climatic stress' component. Interestingly, some of the least water insecure states in 2000—such as Goa, Kerala and Chandigarh—indicate only a marginal improvement. By comparison, however, the moderately and highly water insecure states of the year 2000—such as Andhra Pradesh, Jharkhand, and Orissa—are projected to become comparatively more secure by 2025 because of their greater scope for improvement in the 'Capacity', 'Access' and 'Use' components.

Nevertheless, despite the growth in human capacity and infrastructure development expected by 2025, almost all states will remain highly or moderately water insecure due to increasing climatic stress. India's island states may also become more

insecure due to the projected increase in sea-level affecting lives and livelihoods. This aspect, however, falls beyond the scope of this present study. Such climatic stresses cause greater distress to women because of their higher workloads, putting a negative impact on their health, food security, income, and overall quality of life (Lambrou and Nelson 2010, Vincent et al. 2013). This situation is not likely to change very soon, especially as long as women remain at a socio-economically disadvantaged position.

Figure 7: Water Insecurity Index for different states of India in current and future scenarios of climate change.



Conclusion

India as a whole is water insecure at the household level, with large regional variations. The states with overall higher per capita income and consequently better access to and use of water resources—such as Goa, Delhi and Punjab—are relatively less water insecure; while states—such as Jharkhand, Bihar, Orissa, and Madhya Pradesh—which are comparatively poor performers in terms of income and other socio-economic indicators, are the most water insecure. The key reasons for such differences in water insecurity patterns, therefore, have more to do with the overall capacity to avail of and manage water and environmental components, rather than other factors including availability of water resources.

As a consequence, hotspots of water insecurity at the household level are different from hotspots of water availability. This is also evident from the negligible relationship between water resource availability and water insecurity. Even individual components, such as groundwater resource, do not seem to have any significant relation with WII at the household level (results not shown). Addressing water availability issues from a purely hydrological perspective, therefore, may not be enough to ensure water availability at the household level. The need to thus address gender development and improve equality is imperative for India.

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