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HUMAN DEVELOPMENT, INCLUSIVE GROWTH AND POVERTY ALLEVIATION THROUGH WATER SECURITY: GLOBAL EVIDENCE

M. Dinesh Kumar, J. David Foster, R. Maria Saleth, OP Singh and MVK Sivamohan

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INSTITUTE FOR RESOURCE ANALYSIS AND POLICY
202, Riviera, Dwarakapuri Colony, Punjagutta, Hyderabad - 500 082
Tel: 91-40-4261 7392 E-mail: info@irapindia.org www.irapindia.org

Human Development, Inclusive Growth and Poverty Alleviation through Water Security: Global Evidence

M. Dinesh Kumar, J. David Foster, R. Maria Saleth, OP Singh and MVK Sivamohan[1]

Abstract

In this paper, an attempt is made first to analyze the nature of linkage between water scenario of a country and its economic growth. For this, data on sustainable water use index derived from Water Poverty Index (WPI); human development and per capita GDP for 145 countries, human poverty index for 113 countries, and global hunger index (GHI) for 117 countries were analyzed. In order to illustrate how creating water storages supports economic growth of countries which fall in hot and arid, tropical climates index, data on per capita dam storage were analyzed for 24 countries. Sustainable Water Use Index (SWUI) was derived from WPI to reliably assess the water situation of a country.

The analysis shows that improving water situation of a country can trigger economic growth, as indicated by the exponential relationship between SWUI and per capita GDP (R2=0.69). This phenomenon is explained by the linear relationship between SWUI and HDI (R2 =0.80), with improvement in water situation raising the value of HDI. While it is a truism that all the three sun-indices of human development have the potential to trigger economic growth in a country, the exponential relation between HDI and per capita GDP (R2=0.90) further reinforce this. Whereas the regression between per capita GDP and decomposed HDI showed a logarithmic relationship (R2=0.75), suggesting that a country's progress in human development has little to do with its economic prosperity and that human development can be achieved even at low levels of economic growth, through welfare oriented policies which encourage investments in water, health and education infrastructure. The causality of SWUI acting as a driver of economic growth was tested by running two-stage least square method with HDI as the instrumental variable, SWUI as the predictor variable and per capita GDP as independent variable, which showed a regression coefficient of 0.50.

This growth is inclusive, as shown by low income inequality and low human poverty indices displayed by countries with better water security and human development indices. The relationship between SWUI and income inequality, and HDI and income inequality were inverse linear for countries in the medium to high SWUI and HDI ranges. A stronger relationship was found between SWUI and human poverty index when countries in all ranges of water security were included in the analysis. Further analysis suggest that countries which fall in tropical semi arid and arid climate can and should improve their water security through enhancing their per capita storage by building large water resource systems and fuel economic growth, as suggested by the relationship between per capita reservoir storage and SWUI, and per capita reservoir storage and per capita GDP of 24 countries.

Key Words: *Water Poverty Index, Sustainable Water Use Index, decomposed Human Development Index, per capita GDP, Global Hunger Index, per capita dam storage, Income Inequity, Human Poverty Index, Human Development Path*

Highlights

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[1] Executive Director, Institute for Resource Analysis and Policy (IRAP), Hyderabad, Senior Resident Advisor-CEEUGI, Administrative Staff College of India, Hyderabad; Director, Madras Institute of Development Studies, Chennai; Asst. Professor, Dept. of Agricultural Economics, and Principal Consultant, IRAP, respectively. Email: dinesh@irapindia.org/dineshcgiar@gmail.com.

1. Water security, expressed in terms of sustainable water use index (SWUI), can drive economic growth of a nation through the human development route

2. Improved water security raises the indices of human development as indicated by linear relationship between SWUI and HDI

3. Improved water security reduces incidence of hunger, as indicated by inverse relationship between SWUI and global hunger index (GHI)

4. Improved water security reduces human poverty, and at medium to high ranges it also reduces the income inequality within nations

5. Countries in the semi arid and arid tropics, increase in per capita storage ensures improved water security and better economic conditions

1.0 Introduction

As water scarcity hits many developing regions of the world, there is now a renewed interest to understand how growing threats to water security affects future progress in human development and economic growth of nations (Sadoff and Grey, 2005; Grey and Sadoff, 2007). The international development debate is, however, heavily polarized between those who believe that policy reforms in the water sector would be crucial for bringing about progress in human development and those who believe that economic growth itself would help solve many of the water problems, which countries are facing today (HDR, 2006: pp66). Such debates, which are often not healthy, cause delays in deciding investment priorities in water sector, particularly in the developing world (Biswas and Tortajada, 2001; Shah and Kumar, 2008).

The theoretical discussion on the returns on investment by countries in water infrastructure and institutions are abundant (Grey and Sadoff, 2007; HDR, 2006; Sadoff and Grey, 2005). The evidence available internationally to the effect that water security can catalyze human development and growth is quite robust (see World Bank, 2004; 2006a & b; Briscoe, 2005). However, the number of regions for which these are available is not large enough for evolving a global consensus on this complex issue**.** Till recently, there were no comprehensive database on various factors influencing water security for sufficient number of countries which are at different stages of human development path and economic growth. This contributed to the complexity of the debate. The water poverty index (WPI), conceived and developed for countries by C. Sullivan (2002), and the international comparisons now available from a recent work by Laurence, Meigh and Sullivan (2003) for 145 countries enable us to provide an empirical basis for enriching the debate.

The WPI is a composite index consisting of five sub-indices, viz., water access index, water use index, water endowment index, water environment index and institutional capacities in water sector (Sullivan, 2002). In order to realistically assess the water situation of a country, a new index called Sustainable Water Use Index (SWUI) was derived from WPI (Shah and Kumar, 2008; Kumar, 2009). The paper provides empirical analysis using global database on SWUI and many other water and development indicators such as global hunger index (GHI), human poverty index (HPI) and income inequality index to enrich the debate "how water security is linked to human development, poverty reduction and inclusive growth".

2.0 Objectives, Hypothesis, Methods and Data Sources

The objectives of the paper are to: i] analyze the nature of linkage between water situation of a country comprising improved water access and use, water environment and institutional capacities in the water sector, and its economic growth; ii] analyze the nature of linkage between water situation and income inequality and poverty; and, iii] understand the role of large water storages in reducing hunger and boosting economic growth of countries which fall in hot and arid, tropical climates.

We have three propositions. First: improving the water situation through investments in water infrastructure, institutions and policies would help ensure economic growth through the human development route. Second: nations can achieve reasonable progress in human development even at low levels of economic growth, through investment in water infrastructure, and welfare policies. Third: countries need to invest in building large water storages to support economic prosperity, and ensure water security for social advancements. The hypotheses are: 1] improved water situation supports economic growth through the human development route; and 2] countries, which are in tropical climates with aridity, can support their economic growth through enhancing per capita reservoir storage that improves their water security.

The values of Sustainable Water Use Index were calculated by adding up the values of four of the sub-indices of Water Poverty Index, viz., water access index, water use index, water environment index and water capacity index. All the sub-indices have values ranging from 0 to 20. The maximum value of SWUI for a country therefore is 80.

The first hypothesis was tested using a regression of global data on: Sustainable Water Use Index (SWUI), and data on per capita GDP (ppp adjusted); SWUI and GHI; and SWUI and HDI. GHI is an indicator of the proportion of the population living in under-nourished conditions and the child mortality rate (see Wiesmann, 2006)

Since regression between SWUI and HDI showed a strong relationship (R^2= 0.80), the causality, i.e., whether SWUI influences GDP growth or vice versa, can be tested by running regression between per capita GDP and a decomposed HDI, which contain the indices for health and education. Alternatively, it was tested by running a two-stage least square method, with SWUI as the predictor variable, HDI as the instrumental variable, and per capita GDP as the dependent variable. The underlying premise is that if economic growth drives water situation, then it should change the indicators of human development that are independent of income levels, such as health and education, and that which are inter-related with water situation. The second hypothesis was tested by analyzing the link between per capita GDP (ppp adjusted) and per capita dam storage (m^3/annum) of 22 selected countries falling in hot and arid tropical climate.

Data on per capita GDP and HDI were obtained from Human Development Report 2009. Data on GHI for 117 countries were drawn from Wiesmann Doris (2007). Data on WPI for 145 countries were obtained from Laurence et al. (2003). Data on dam storage and human population in 24 countries were obtained from FAO AQUASTAT-2006. Data on income inequality (Gini coefficients) for 125 countries were obtained from the Human Development Report-2009 of UNDP. Data on Human Poverty Index (HPI) for 113 countries, for the year 2007 were obtained from the Human Development Report –d 2009 of UNDP.

3.0 The Global Debate on Water, Development and Growth

The debate on the linkage between water, growth and development is mounting internationally. While the general view of international scholars, who support large water resource projects, is that increased investment in water projects such as irrigation, hydropower and water supply and sanitation acts as engines of growth in the economy, while supporting progress in human development (for instance see Briscoe, 2005; Braga, 2005; HDR, 2006). They harp on the need for investment in water infrastructure and institutions. Grey and Sadoff (2007) suggests that there is a minimum platform of water security, achieved through the right combination of investment in water infrastructure and institutions and governance, which is essential if poor countries are to use water resources effectively and efficiently to achieve rapid economic growth to benefit vast numbers of their population. They suggest an S-curve for growth impacts of investment in water infrastructure and institutions in which returns continue to be nil for early investments. They argue that for poor countries, which experience highly variable climates, the level of investment required to reach the tipping point of water security[2] would be much higher as compared to countries, which fall in temperate climate with low variability. But, they suggest that for developing countries, the returns on investment in infrastructure would be higher than in management, and vice versa in the case of developed countries.

Many environmental groups, on the other hand, advocate small water projects which, according to them, can be managed by the communities. The solutions advocated are: watershed management; small water harvesting interventions; and community-based water supply systems; and, micro-hydro electric projects (Dharmadhikary, 2005; D'Souza, 2002).

International literature provides many clues to the fact that water security has the potential to promote inclusive growth. For instance, access to safe water and sanitation can partly determine income. The marginal productivity per unit of water, measured in terms of good health, longevity or income is much greater for the poor than for the rich (World Water Council, 2000; Jha, 2010; van Koppen *et al*., 2009). Secured water for irrigation, while enabling the poor landholding communities to grow food for their own consumption (Kumar, 2003), would generate sufficient employment in rural areas and lower cereal prices (Perry, 2001), while supplying cereals to the markets. In poor and developing countries, where large section of the population depends on agriculture and rural wage labour, this is likely to have significant distributional effects on income.

4.0 Water and Inclusive Growth

Before we begin to answer this complex question of "what drives what", we need to understand what realistically represents the water richness or water poverty of a country. A recent work by Kellee Institute of Hydrology and Ecology which came out with international comparisons on water poverty of nations had used five indices, viz., water resources endowment; water access; water use; capacity building in water sector; and water environment, to develop a composite index of water poverty (see Laurence, Meigh and Sullivan, 2003).

Among these five indices, we chose four indices as important determinants of water situation of a country, and the only sub-index we excluded is the water resources endowment. We consider that this sub-index is more or less redundant, as three other sub-indices viz., water access, water use and water environment take care of what the resource endowment is expected to provide. Our contention is that natural water resource endowment becomes an important determinant of water situation of a country only when governance is poor and institutions are ineffective, adversely affecting the community's access to and use of water, and water environment. Examples are the droughts in Sub-Saharan African countries. This argument is validated by a recent analysis which showed strong correlation between rainfall failure and economic growth performance in these countries. That said, all the four sub-indices we chose significant implications for socio-economic conditions, and are influenced by institutional and

[2] Beyond which the investment in water infrastructure and institutions yields positive growth impacts.

policy environment, and therefore have human element in them. Hence, such a parameter will be appropriate to analyze the effect of institutional interventions in water sector on economy.

It is being hypothesized that that the overall water situation of a country (or SWUI) has a strong influence on its economic growth performance. This is somewhat different from the hypothesis postulated by Shah and Koppen (2006), wherein they have argued that economic growth (GDP per capita), and HDI are determinants of water access poverty and water environment.

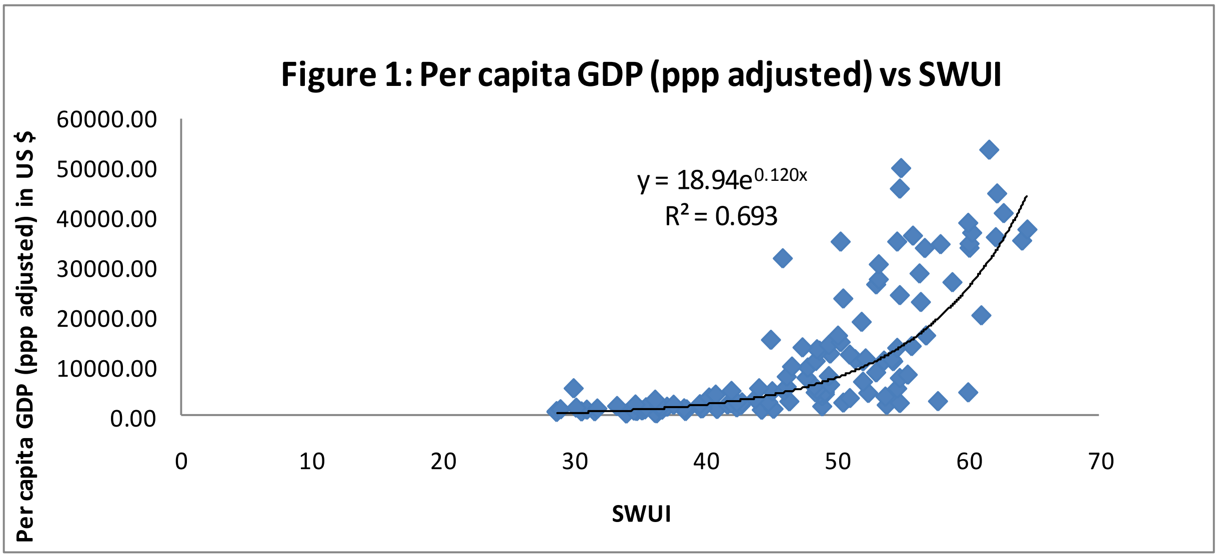
It is important to provide empirical evidence to this. Worldwide, experiences show that improved water situation (in terms of its access to water; levels of use of water; the overall health of water environment; and enhancing the technological and institutional capacities to deal with sectoral challenges) leads to better human health and environmental sanitation; food security and nutrition; livelihoods; and greater access to education for the poor (UNDP, 2006). This aggregate impact can be segregated with irrigation having direct impact on rural poverty (Bhattarai and Narayanamoorthy, 2003; Hussain and Hanjra, 2003); irrigation having impact on food security, livelihoods and nutrition (Hussain and Hanjra, 2003), with positive effects on productive workforce; and domestic water security having positive connotations for health, environmental sanitation, with spin off effects on livelihoods and nutrition (positive), school dropout rates (negative) and productive workforce.

According to the Human Development Report (2006), only one in every five people in the developing world has access to an improved water source. Dirty water and poor sanitation account for vast majority of the 1.8 million child deaths each year (almost 5,000 every day) from diarrhea- making it the second largest cause of child mortality. In many of the poorest countries, only 25% of the poorest households have access to piped water in their homes, compared with 85% of the richest. Diseases and productivity losses linked to water and sanitation in developing countries amount to 2% of GDP, rising to 5% in Sub-Saharan Africa--more than the aid the region gets. Women bear the brunt of responsibility for collecting water, often spending up to 4 hours a day walking, waiting in queues and carrying water; water insecurity linked to climate change threatens to increase malnutrition to 75–125 million people by 2080, with staple food production in many Sub-Saharan African countries falling by more than 25%.

The strong inverse relationship between SWUI and the global hunger index (GHI), developed by IFPRI for 117 countries, provide a broader empirical support for some of the phenomena discussed above. In addition to these 117 countries for which data on GHI are available, we have included 18 developed countries. For these countries, we have considered zero values, assuming that these countries do not face problems of hunger. The estimated R square value for the regression between SWUI and GHI is 0.60. The coefficient is also significant at one per cent level. It shows that with improved water situation, the incidence of infant mortality (below five years of age) and impoverishment reduces. In that case, improved water situation should improve the value of human development index, which captures three key spheres of human development such as health, education and income status.

Thus, all the sub-indices of HDI have strong potential to trigger growth in a country's economy, be it educational status; life expectancy; or income levels. When all these factors improve, they would have a synergetic effect on the economic growth. The growth, which occurs from human development, would also be "broad-based" and inclusive. Hence, the "causality" of water as a prime driver for economic growth can be tested if we are able to establish correlation between water situation and HDI. This we would examine at a later stage.

Before that, let us first look at how water situation and economic growth of nations are correlated. Regression between sustainable water use index (SWUI) and ppp adjusted per capita GDP for the set of 145 countries shows that it explains level of economic development to an extent of 69 per cent (Figure 1). The coefficient is significant at one per cent level. The relation between SWUI and per capita GDP is a power function. Any improvement in water situation beyond a level of 50 in SWUI, leads to exponential growth in per capita GDP.



This only means that for countries to be on the track of sustainable growth, the following steps are required: 1] investment in infrastructure, and institutional mechanisms and policies to: a] improve access to water for all sectors of use and across the board, b] enhance the overall level of use of water in different sectors, and c] regulate the use of water, reduce pollution and provide water for ecological services; and 2] investment in building human resources and technological capabilities in water sector to tackle new challenges in the sector. Regression with different indices of water poverty against economic growth levels shows that the relationship is less strong, meaning all aspects (water access, water use, water environment and water sector capacity) are equally important to ensure growth.

Major variations in economic conditions of countries having same levels of SWU, can be explained by the economic policies of which the country pursues. Some countries of central Asia viz., Uzbekistan, Kyrgyzstan and Turkmenistan and Latin American countries viz., Ecuador, Uruguay, Colombia and Chile have values of SWUI as high as North America and northern European countries, but are at much lower levels of per capita GDP. While North America and north, west and southern European countries have capitalist and liberal economic policies, these countries of old soviet block and Latin America have socialist and welfare oriented policies.

4.1 Can Water Security Ensure Economic Growth?

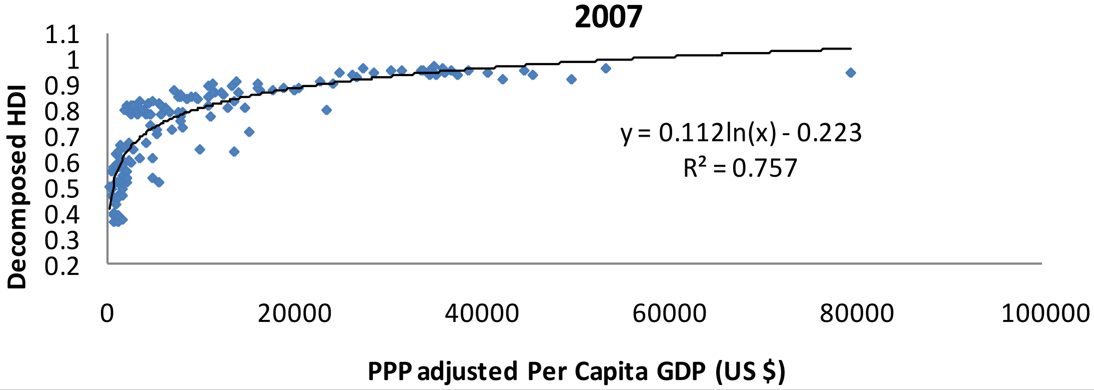
International development discussions are often characterized by polarized contentions on whether money or policy reform is more crucial for progress in human development (various authors as cited in HDR, 2006: pp 66). Scholars have already discussed the two possible “causal chains, one that run between economic growth and human development, and the other that run between human development and economic growth (Ranis, 2004). The causality in the first case occurs when resources from national income are allocated to activities that contribute to human development. Ranis (2004) argued that low level of economic development would result in a vicious cycle of low levels of human development and high level of economic development would result in the virtuous cycle of high level of human development. Whereas in the second case, as indicated by several evidences, better health and nutrition lead to better productivity of labour force (Behrman, 1993; Cornia and Stewart, 1995). Education opens up new economic opportunities in agriculture (Schultz, 1975; Rosenzweig, 1995), impacts on the nature and growth of exports (Wood, 1994), and results in greater income equality, which in itself results in economic growth (Bourgignon and Morrison, 1990; Bourgignon, 1995; Psacharopolous, 1992; Ranis, 2004).

If the stage of economic development determines a country's water situation rather than the reverse, the variation of human development index, should be explained by variation in per capita GDP, rather than water situation in orders of magnitude. We have used data for 145 countries to examine this closely. The regression shows that per capita GDP explains HDI variations to an extent of 90 per cent. The regression equation was Y =0.129ln (X)-0.398. But, it is important to remember that HDI already includes per capita income, as one of the sub-indices.

Therefore, analysis was carried out using decomposed values of HDI index, after subtracting the per capita income index, the graphical representation of which is presented in Figure 2. The regression value came down to 0.75 (R^2=0.75) when the decomposed index, which comprises education index and life expectancy index, was run against per capita GDP. What is more striking is the fact that 21 countries having per capita income below 2,000 dollars per annum have medium levels of decomposed index. Again 50 countries having per capita GDP (ppp adjusted) less than 5,000 dollars per annum have medium levels of decomposed HDI. Significant improvements in HDI values (0.30 to 0.9) occur within the small range in per capita GDP. The remarkable improvement in HDI values with minor improvements in economic conditions, and then "plateauing" means that improvement in HDI is determined more by factors other than economic growth. Our contention is that the remarkable variation in HDI of countries belonging to the low income group can be explained by the quality of governance in these countries, i.e., whether good or poor.

Many countries that show high HDI also have good governance systems and practices, and institutional structures to ensure good literacy and public health. For instance, Hungary in eastern Europe; some countries of Latin America viz., Uruguay, Guatemala, Paraguay, Nicaragua and Bolivia; and countries of erstwhile Soviet Union viz., Turkmenistan, Kyrgykistan and Armenia have welfare-oriented policies. They make substantial investment in water, health and educational infrastructure[3].

Figure 2: Decomposed HDI Vs Per Capita GDP (ppp adjusted) for 2007



Incidentally, many countries, which have extremely low HDI, have highly volatile political systems and ineffective governance, and corruption. The investments in building and maintenance of water infrastructure are consequently very poor in these countries (Shah and Kumar, 2008) in spite of huge external aid. Sub-Saharan African countries, viz., Angola, Benin,

[3] For instance, the USSR had invested in a major way for building hydraulic infrastructure in central Asia (HDR, 2006). As a result, they attain high HDI even at low level of economic growth.

Chad, Eritrea, Ethiopia, Burundi, Niger, Togo, Zambia and Zimbabwe; and Yemen from Middle East belong to this category. Sub-Saharan Africa has the lowest irrigated to rain-fed area ratio of less than 3% (FAO, 2006, Figure 5.2: pp 177), where as Ethiopia has the lowest water storage of $20m^3$/capita in dams (World Bank, 2005). How water security decoupled human development and economic growth in many regions of the world were illustrated in the recent human development report (HDR, 2006: pp 30-31).

The public expenditure on health and education is extremely low in these African countries and Yemen when compared to the many other countries which fall under the same economic category (below US $ 5,000 per capita per annum). Over and above, the pattern of public spending is more skewed towards military (see Table 1 based on data provided in HDR, 2006, Table 19: pp 348-351). Besides, access to water supply and sanitation is much higher in the countries which have higher HDI, as compared to those countries which have very low HDI (based on data in HDR, 2006, Table 7, pp306-309).

Table 1: Pattern of Public Expenditure on Military, Health & Education and Status vis-à-vis Water & Sanitation

Name of Country	Per Capita Expenditure (US $) on		Percentage of Population Having Access to	
	Military	Health and Education	Water Supply	Sanitation
Armenia	106.626	180.444	92	83
Bolivia	54.4	291.04	85	46
Guatemala	17.252	146.642	95	86
Kyrgyzstan	38.7	127.71	77	59
Nicaragua	25.438	247.112	79	47
Paraguay	33.69	317.66	86	80
Peru	68.136	289.578	83	63
Tajikistan	26.444	44.474	59	51
Togo	24.57	58.37	52	35
Yemen	59.202	19.734	67	43
Zambia	34.891	52.808	58	55
Burundi	42.651	39.943	79	36
Ethiopia	64.26	51.408	22	13

Source: based on Data Provided in HDR, 2006: Table 19: pp 348-151 & Table 7, pp306-309

Some of the striking features of these regions are high incidence of water-related diseases such as malaria and diarrhea, high infant mortality, high school dropout rate mainly due to lack of access to safe drinking water; and scarcity of irrigation water in rural areas[4], poor agricultural growth, high food insecurity and malnutrition (source: based on HDR, 2006). Consequently, their HDI is very low.

4.2 Linking Human Development with Water Security

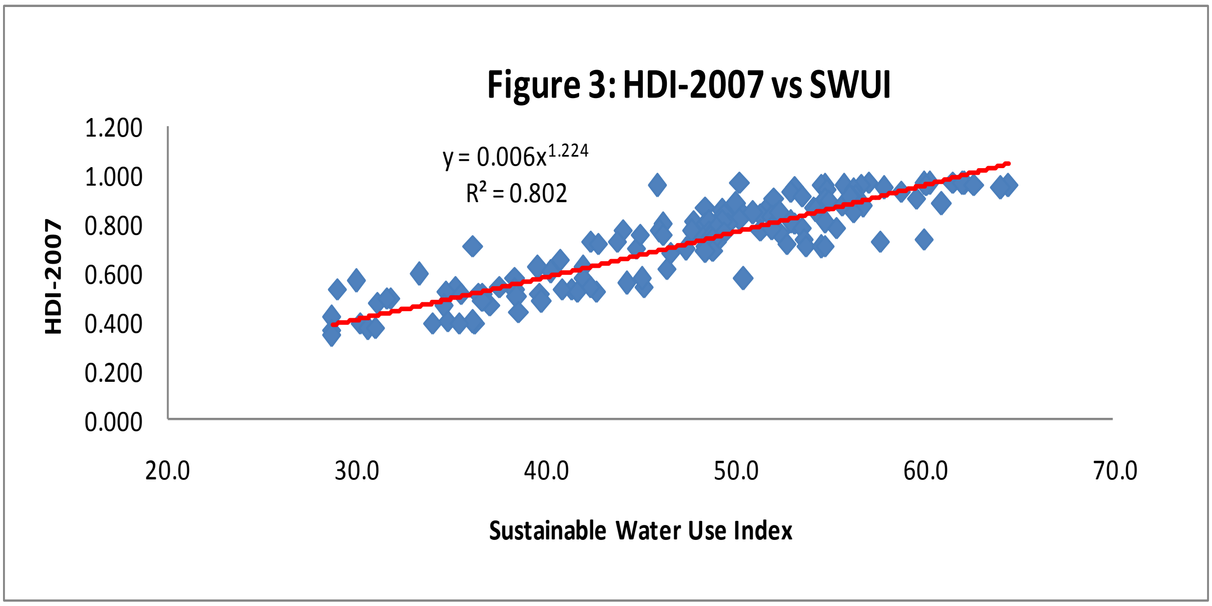
Contrary to the above discussed scenario, regression between sustainable water use index and HDI shows that it explains variation in HDI in a much better way than the level of economic development. This is in spite of the fact that human development index as such does not include any variable that explicitly represents access to and use of water for various uses; overall health of water eco-system; and capacities in the water sector as one of its sub-indices.

4 This includes economic scarcity as well.

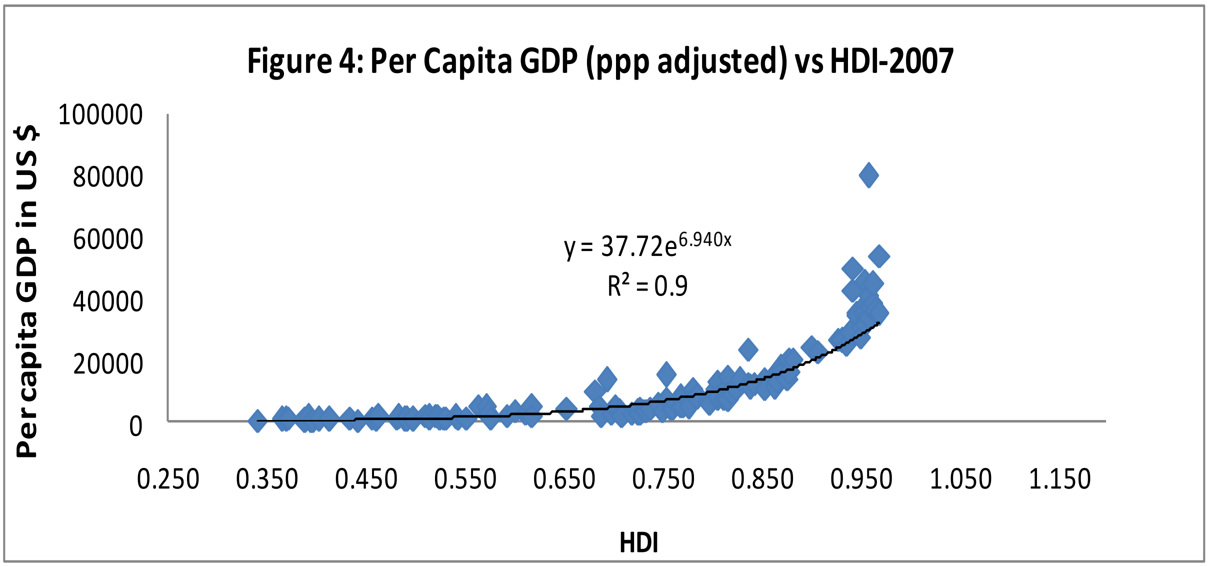
The R square value was 0.80 against 0.75 in the earlier case when per capita GDP is run against decomposed HDI (Figure 3). Also, the coefficient was significant at one per cent level. It means that variation in human development index can better be explained by *water situation* in a country, expressed in terms of sustainable water use index, than the ppp adjusted per capita GDP (Kumar, 2009).

Now, such a strong linear relationship between sustainable water use index and HDI explains the exponential relationship between sustainable water use index and per capita GDP, discussed in the earlier section, as the improvements in sub-indices of HDI contributes to economic growth in its own way (i.e., per capita $GDP = f\{EI, HI\}$; here EI is the education index, and HI is the health index).

This is further reinforced by the empirical relationship between per capita GDP (ppp adjusted) and HDI (for the year 2007) of nations, which show that per capita GDP increases



exponentially with increase in HDI (Figure 4). Higher levels of HDI result in much higher levels of income. As the graph shows, there are some countries, which have medium level of development, but shows very high income. South Africa is one example. They fall off the trajectory which majority of the countries follow. It is important to remember here that this country suffers from high levels of income inequity.



While an alternative to analyze the impact of a country's water situation on its economic growth performance is to look at the historical data on: cumulative investments in water sector, water access and use by population in different sectors, change in water environment, and economic conditions for individual nations. Time series data on these are seldom available on a time series basis. Under such a circumstance, the best way to go ahead is to analyze the impact of natural water endowment, i.e., rainfall on economic growth in a situation where investments in infrastructure and institutions and governance mechanisms for improving water access and use and water environment are poor. The reason is that under such situations, the water access, water use, and water environment would be highly dependent on natural water endowment.

There cannot be a better region than Sub-Saharan Africa to illustrate such effects. A recent analysis showed a strong correlation between rainfall trend since 1960s and GDP growth rates in the region during the same period, which argued that the low economic growth performance could be attributed to long term decline in rainfall which the region experienced (Barrios *et al*., 2004). Such a dramatic outcome of rainfall failure can be explained partly by the failure of the governments to build sufficient water infrastructure. Sub-Saharan Africa has smallest proportion of its cultivated area (< 3%) under irrigation (HDR, 2006). Due to this reason, reduction in rainfall leads to decline in agricultural production, food insecurity, malnutrition, loss of employment opportunities and an overall drop in economic growth in rural areas.

In the absence of empirical evidence which can establish the nature of link between SWUI and economic growth condition, we further test the causality of SWUI acting as a determinant of economic growth by running a two-stage least square method with HDI as the instrumental variable, SWI as the predictor variable and per capita GDP (ppp adjusted) as the dependent variable. Here, is assumed that SWUI will have a major bearing on HDI. The link has also been established through empirical analysis. The results are presented below. It shows an R square value of 0.50, at one per cent level of significance. The beta coefficient is 1192 and the constant is -44636.0.

The foregoing analyses suggest that improving sustainable water use index, which is reflective of how good is the water situation of a country, is of paramount importance if we need to achieve sustained growth. It would be rather improper to assume that a country can wait till its economy improves to a certain level to start tackling its water problems. While the natural water endowment in both qualitative and quantitative terms cannot be improved through ordinary measures, the *water situation* can be improved through economically efficient, just and ecologically sound development and use of water in river basins.

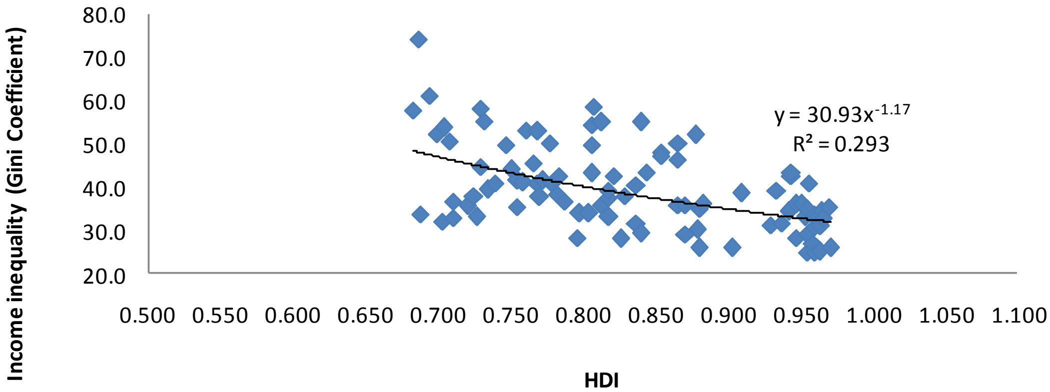
4.3 Linking Water Security with Inclusive Growth

We have already tested the causality of water security as a driver of economic growth by establishing the strong linkage between water security and human development. The relationship was found to be linear with an R^2 value of 0.80. Scholars have earlier shown the negative impact of education on income inequality based on empirical evidence from selected countries around the world (Source: based on Alegandro *et al*., 1997; Psacharopolous, 1992; Bourgignon and Morrison, 1990; Bourgignon, 1995). But, now with the availability of data on income inequality for a large number of countries (for the year 2007) from the Human Development Report of 2009, the impact of improved water security on inclusiveness of economic growth can be empirically tested by analyzing the link between HDI and income inequity existing in the countries. The data on income inequality, expressed in terms of Gini coefficient of income, was obtained for 125 countries from the Human Development Report of 2009 (UNDP, 2009). Higher values of Gini coefficient indicate greater income inequality among people of the nation considered (UNDP, 2009).

Analysis shows that HDI has a direct positive impact on income equality, when countries with high levels of human development (above 0.65 and up to 0.971) are considered for the analysis. The R2 value was 0.29, with an inverse exponential relationship between HDI and income inequality (Figure 5). But, such a relationship did not emerge when the analysis was performed after considering data from all the low HDI as well as high HDI countries. The reason is some of the low HDI countries have low income inequality.

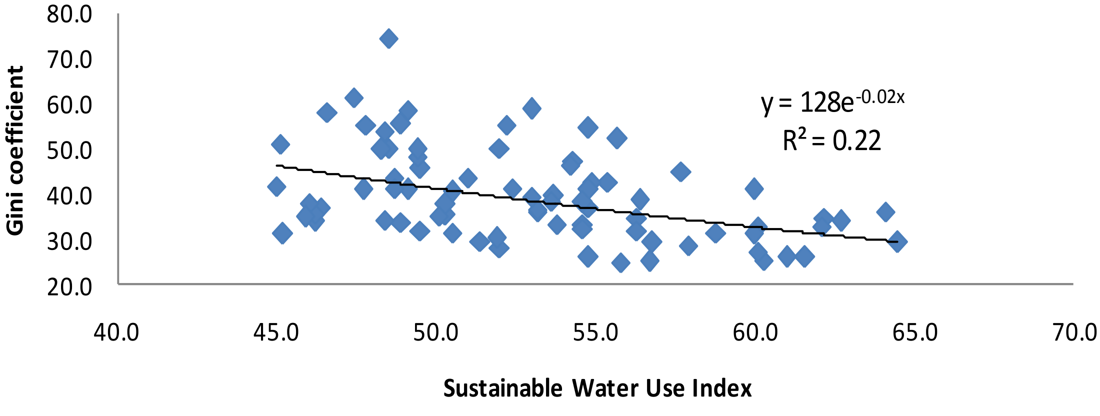
But, we have already seen that countries with low HDI have very low per capita GDP, though the vice versa was not true. It is important to remember that having low income inequality alone cannot be treated as a great virtue for a country, when the income levels are very low. Income equality does not have much relevance from a developmental perspective, when the average income levels are too low.

Figure 5: Income inequality vs HDI for high HDI Countries



Obviously, the most desirable situation is high average income and low income inequality. The foregoing analysis means that when the human development of a country crosses a particular threshold level, the national wealth gets better distributed. Since, water security influences HDI positively, the type of relationship that will emerge between water security and income inequality is likely to be same as the relationship found between HDI and income inequality. This means, improving water security of a nation would be a necessary and sufficient condition for achieving high levels of development and inclusive growth. The analysis carried out using SWI for 79 countries (for which the values are above 45), and the values of income inequality (measured as Gini coefficient) shows an inverse correlation (Figure 6) with an R2 value of 0.22, meaning variation in sustainable water use index explains variations in income inequality by 22 per cent. The relationship was rather weak, when regression was run for all the 125 countries for which data on both SWI and income inequality are available. This leads to the point that the distributional effect of national income gets affected when water security and

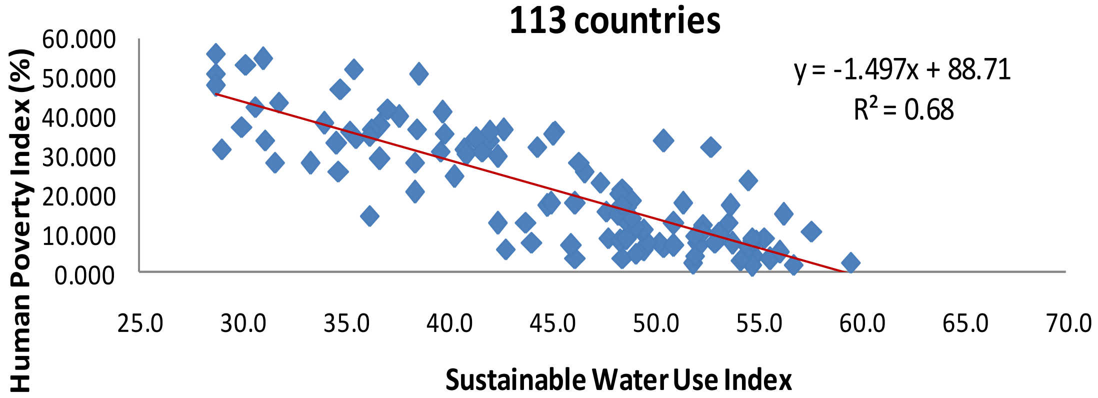
Figure 6: Income inequality (2007) vs sustainable water use index (2003) for selected countries



therefore human development crosses a certain threshold.

Poverty reduction is one of the objectives of economic growth policies, and economic growth is essential for poverty reduction (Pearce and Warford, 1993). We have seen that improved water security results in better economic growth conditions, through the human development path. We have also seen that there is greater distribution of income when the water security situation exceeds certain thresholds. The next step in the line of investigation is to find out whether this has a real impact on poverty reduction. The human poverty index is a sound indicator for cross country comparison of poverty situation existing in nations[5]. Analysis was carried out using the data of HPI (Human Poverty Index-1 (available for 113 countries only) and SWUI[6]. The analysis shows a strong inverse correlation between the two (Figure 7). The countries having higher values of sustainable water use index have lower incidence of poverty. The R2 value was estimated to be 0.68 for linear regression, which provided best fit.

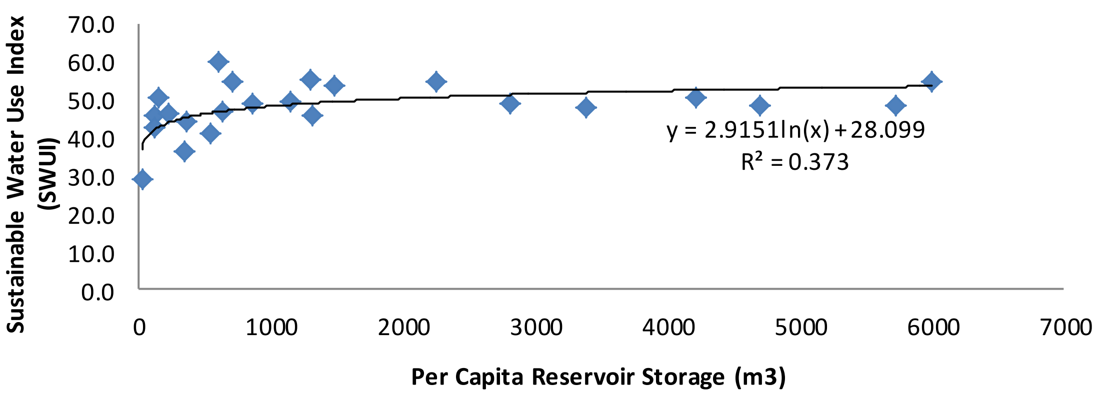
Figure 7: Human Poverty Index -1 (2007) Vs SWUI (2003) for 113 countries



5.0 Impact of Storage Development on Economic Growth in Arid Tropics

Development of reservoir storage has an important role in improving the access to and use of water, the two pre-requisites for improving the water situation of a region, though intensive water development in river basins might cause environmental water stress reducing the values of water environmental index (Shah and Kumar, 2008; Kumar, 2009). This is evident from the direct logarithmic relationship between storage development and water security

Figure 8: SWUI vs per capita reservoir storage



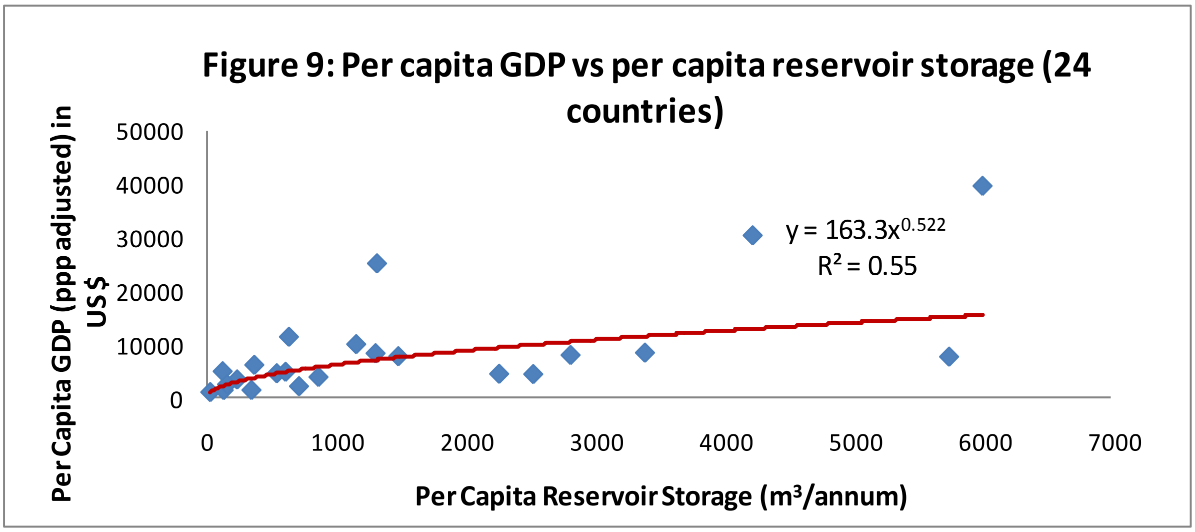
of which (25) having very high human development index, and the rest falling under high human development index category.

(expressed in terms of Sustainable Water Use Index (Figure 8). The R square value was estimated to be 0.39. Figure 6 shows that countries having higher per capita reservoir storage (expressed in m^3 per capita per annum) have higher values of sustainable water use index. Major improvements in water security occurred within the range of 0-1500m^3 per capita per annum, and leveling off thereafter.

However, the amount of storage that needs to be created to improve access to and use of water depends on the type of climatic conditions. It is also important to note that access to arable land would also be an important factor determining the storage requirements, as water requirement for agriculture would change with this. In temperate and cold climates, the demand of irrigation, the largest water use sector, would be considerably small as compared to tropical and hot climates. Hence, the storage requirements in such regions would be much lower, and would be mainly limited to that for meeting domestic/municipal water needs and water for manufacturing. Therefore, it is logical to explore links between storage development for meeting various human needs and economic growth only in tropical and hot climates.

But, as indicated in the Human Development Report of 2006, the sheer scale of water infrastructure in rich countries is not widely recognized and appreciated (HDR, 2006: pp-155). Many developed countries of the world that experience tropical climates had high water storage in per capita terms. The United States, for instance, had created a per capita storage capacity of nearly 6000 m^3. In Australia, the 447 large dams alone create a total storage of 79,000 MCM per annum, providing per capita water storage of nearly 3,808 m^3 per annum. Aquifers supply another 4,000 MCM per annum. China, the fastest growing economy in the world, has a per capita reservoir storage capacity of 2,000 m^3 per annum through dams, and an actual storage of nearly 360m^3 per capita (Kumar, 2009).

When compared to these figures, India, which is still developing, has a per capita storage



of only 220m^3 per annum. Though a much higher level of withdrawal of nearly 600 m^3 per capital per annum is maintained by the country, a large percentage of this (231 BCM per annum or nearly 217 m^3 per capita per annum) comes from groundwater draft and there are increasing evidence to suggest that this won't be sustainable[7]. Ethiopia, the poorest country in the world, has a per capita storage of 20 m^3 per annum. These facts also strengthen the argument that economic prosperity that a country can achieve is a function of available per capita water storage.

[7] As discussed in a recent work by Kumar (2007), many semi arid areas are already facing problems of groundwater over-draft, with serious socio-economic and ecological consequences.

Regression analysis of per capita water storage and the per capita GDP (ppp adjusted) for a group of 24 countries falling in the arid and semi arid tropics shows a strong relationship between level of storage development and country's economic prosperity (Figure 9). The R square value is 0.55, and the coefficient is significant at one per cent level. The strong relationship can be explained in the following way. Storage reservoirs reduce risks, and improve water security. In many regions, investments in hydraulic infrastructure had supported economic prosperity and social progress, though in some regions had caused environmental damage (Gray and Sadoff, 2005; HDR, 2006, based on various authors: pp140)[8].

The returns on investments in building water storages were quite visible in India. The analysis using panel data on gross irrigated area and rural poverty rate for 14 states showed poverty reducing effect of irrigation, with lowest rate of poverty found in Punjab which had the highest level of gross irrigated area, which reduced over time from 1973-74 to 1993-94 (Bhattarai and Narayanamoorthy, 2003). The Bhakra-Nangal Project had transformed the economy of Punjab. The almost perennial water supply from the project enabled farmers in this region to intensify cultivation with irrigated paddy and wheat, making it the country's bread basket.[9] In Gujarat state of western India, the impact of the yet to be completed Sardar Sarovar project (SSP) in reviving the agricultural production, after it experienced a major dip following two consecutive years of drought (1999 and 2000), has been remarkable (Kumar *et al*., 2010). The project, which brings water from the water-rich south Gujarat, to the water-scarce regions of north Gujarat, Saurashtra and Kachchh, reduces the imbalances in water availability and demand in different regions of the state.

The potential positive impact of water infrastructure on economic growth in regions that experience seasonal climates, rainfall variability and floods and droughts can be better demonstrated by the economic losses that water-related natural disasters cause in the regions which lack them (Kumar, 2009). For instance, in Ethiopia, deviation in per capita GDP from the normal values during the 20-year period from 1980-2000 correlated with departure of annual rainfall from normal values (World Bank, 2006a). In Kenya, economic losses due to floods during 1997-98 were to the tune of 11% of the national GDP, where as that due to droughts during 1998-2000 was 16% of the GDP (World Bank, 2004a and World Bank 2006b). In the Indian state of Gujarat, value of agricultural output dropped from Rs. 268.37 billion in 1998-99 to Rs. 189.0 billion in 2000-01 following the droughts in 1999 and 2000 (Kumar *et al*., 2010: Figure 1, pp 4).

Nevertheless, the overall economic growth impact of water storage would depend on the nature of uses for which the resources are developed, the effectiveness of the institutions that are created to allocate the resource and the nature of institutional and policy regimes that govern the use of the resource. As we have seen in the case of incidence of hunger in Zambia and Zimbabwe, use of water storages for hydropower generation had not helped even to improve the overall economic condition of the people (Kumar, 2009). Though the per capita water storage in Israel is quite low (nearly 150 m^3 per annum), the efficiency with which water is

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8 Since 1920, the US Army Corps of Engineers had invested a sum of $ 200 billion on flood management and mitigation alone, yielding a benefit of $ 700 billion. The Tennessee Valley Authority, which built dams for hydropower, transformed a flood-prone, impoverished region in the United States, with some of the worst human development indicators, into an agriculturally prosperous region. In Japan, heavy post war investments in infrastructure supported rapid development of hydropower, flood control and irrigated agriculture. The returns from these investments were tremendous. Until World Water II, the floods and typhoons had resulted in losses often amounting to 20% of GNI, whereas since the 1970s, the losses never exceeded 1% of the GNI (HDR, 2006: pp 156).

9 Now, 90% of the cropped area in Punjab is irrigated, with paddy and wheat accounting for 3/4th of it. Despite having only less than 2% of the geographical area of the country, Punjab accounts for 10% of rice production and 20% of wheat production in India. Agriculture accounts for 40% of the state GDP in the state, which has the highest per capita GDP amongst all Indian states (Cummings *et al*., 2006).

used in different sectors is extremely high. Nearly 90% of the country's irrigated area is under micro irrigation systems. A large portion of the water used in urban areas is recycled and put back to use for irrigation. Water is not only priced on volumetric basis, water allocation for irrigation is rationed (Kumar, 2009).

One could as well argue that access to water could be better improved through local water resources development intervention including small water harvesting structures, or through groundwater development. As a matter of fact, environmental activists advocate decentralized small water harvesting systems as alternatives to large dams (see Agarwal and Narain, 1997). Small water harvesting systems had been suggested for water-scarce regions of India (Agarwal and Narain, 1997; Athavale, 2003), and the poor countries of Sub-Saharan Africa (Rockström *et al*., 2002). But, recent evidence suggest that they cannot make any significant dent in increasing water supplies in countries like India due to the unique hydrological regimes, and can also prove to be prohibitively expensive in many situations (Kumar *et al*., 2006; Kumar *et al*., 2008). Also, to meet large concentrated demands in urban and industrial areas, several thousands of small water harvesting systems would be required. The type of engineering interventions[10] and the economic viability of doing the same are open to question. Recent evidence also suggests that small reservoirs get silted up much faster than the large ones (Vora, 1994), a problem for which large dams are criticized world over (see McCully, 1996).

As regards groundwater development, intensive use of groundwater resources for agricultural production is proving to be catastrophic in many semi arid and arid regions of the world, including some developed countries like Spain, Mexico, Israel, Australia, and parts of United States (Kumar, 2007), and developing countries such as India, China, Pakistan, Yemen and Jordan (HDR, 2006), though some of the developed countries have achieved some degree of success in controlling it through establishment of management regimes (Kumar, 2007) with physical and institutional interventions like in western US, or through physical interventions alone like in Israel or through institutional interventions such as formal water markets like in the Murray Darling basin of Australia.

But, in the basins facing problems of environmental water scarcity and degradation (see Smakhtin, Revenda and Doll, 2004) due to large water projects, river-flows are appropriated and transferred for various consumptive needs. Some of these basins are the Colorado river basin in the western US; Yellow river basin in northern China; Aral sea basins, viz., Amu-Darya and Syr Darya in Central Asia; Indus basin in Pakistan and India; basins of northern Spain; Nile basin in northern Africa; basins of Euphrates, Tigris; the Jordan river; Cauvery, Krishna and Pennar basins of peninsular India; river basins of western India including Sabarmati, Banas and Narmada, located in Gujarat, Rajasthan and Madhya Pradesh in India. Most of the water demands they meet are agricultural[11]. They are also agriculturally prosperous regions. Not only they meet the food requirements of the region, most of these basins export significant chunk of the food to other regions of the world, including some of the water-rich regions, within the country's territory (Amarasinghe *et al*., 2004 for Indus basin and peninsular region in India; Kumar and Singh, 2005 for many water-scarce countries of the world; Yang, 2002 for China).

Strikingly, wherever aquifers are available for exploitation, these regions had experiencing problems of groundwater over-draft, though some developed countries had developed the science to deal with it. The most glaring examples are aquifers in western United States, aquifers in the countries of the Middle East including Yemen, Iran and Jordan; aquifers in Mexico; north China plains (Molden *et al*., 2001); alluvial aquifers of Indus basin areas in India; hard rock aquifers of Peninsular India; and aquifers in western and central India (GOI, 2005).

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[10] Complex engineering interventions would be required for collecting water from such number of small water harvesting and storage systems, and then transporting to a distant location in urban areas.

[11] In Murray Darling basin, 90% of the annual flows are diverted for agricultural use.

Without these large surface water projects, agricultural growth might have caused far more serious negative impact on groundwater resources in these regions. In fact, it is this surface water availability, which to a great extent helps reduce dependence of farmers as well as cities on groundwater (Kumar, 2009). For instance, imported water from Indus basin through canal in Indian and Pakistan Punjab sustain intensive groundwater use in the regions, through continuously providing replenishment through return flows from surface irrigation (Ahmed *et al*., 2004; Hira and Khera, 2002; Kumar, 2007). In India, water imported from a large reservoir named Sardar Sarovar in Narmada basin in Southern Gujarat in India had started supplying water to rejuvenate the rivers in environmentally stressed basins of north Gujarat (Kumar *et al*., 2010).

6.0 Impact of Storage Development on Malnutrition and Child Mortality

Storage development is found to have a direct impact on malnutrition, and infant mortality, the factors considered in estimating global hunger index, when we considered zero values of GHI for developed countries viz., United States, Australia and Spain for which data on GHI are not available (Kumar, 2009). Regression shows an R square value of 0.59. The relationship between per capita storage and GHI is inverse, logarithmic. It means greater water storage reduces the chances of human hunger. This inverse relationship can be explained this way. For the sample countries, the ability to cultivate the available arable land intensively would increase with the amount of water storage facilities available. As HDR (2006: pp 174) notes, "Water security in agriculture pervades all aspects of human development". Increased availability of irrigation water reduces the risk of crop failure; enhances the ability of farmers to produce more crops to improve their own domestic consumption of food, and take care of the cash needs. Also, increased irrigated production improves food and nutritional security of the population at large by lowering cereal prices in the region in question as the gap between cereal demand and supplies is reduced (Hussain and Hanjra, 2003 as cited in HDR, 2006: pp 175).

This was more evident in India than anywhere else, where irrigation expansion through large storages had contributed nearly 47 million tons of additional cereals to India's bread basket (Perry, 2001: pp 104). The most illustrious example of the recent times is the impact of Sardar Sarovar project, which is yet to be completed on food production and agricultural growth in Gujarat. Availability of surface water through canals had motivated farmers in south and central Gujarat to take up paddy and wheat and achieve bumper food grain production in the recent years. Shah and Kumar (2008) made a rough estimate of the positive externality it created in terms of lowering food prices for the consumers in India as US $ 20 per ton of cereals. One could also argue that rich countries could afford to import food. But, what is important is that water had played a big role for these countries to achieve a certain level of economic growth and prosperity, by virtue of which they can now afford to import food instead of resorting to domestic production. The exceptions are some of the oil rich countries of the Middle East, which do not have an agrarian base, but are economically prosperous.

Contrary to what was found from our analysis of 22 countries, countries such as Zambia and Zimbabwe have large storages, but have very high GHI (Kumar, 2009). They were not included in our analysis. These countries use their water storages for creating hydro-power, which is sold to the South Africa, and they earn revenue out of it[12]. Hence, storage development does not lead to increased agricultural production in these countries. The GHI values are very high for these countries (Wiesmann, 2006). In such a situation, the impacts on food security would generally be seen only after many years. But in the case of these Sub-Saharan African

[12] Most of it comes from just one hydropower dam, named, Kariba built in 1955-59 in Zambezi river basin.

countries, three decades of droughts and rainfall reduction had significantly affected the hydropower generation as well (McCully and Wong, 2004).

8.0 Summary, Conclusions and Policy

Scholars have provided robust evidence to the effect that water security catalyses human development and economic growth. But, number of regions for which the evidence is available is too limited to evolve a global consensus on this complex issue. Water poverty index, conceived and developed by C. Sullivan (2002), and the international comparisons now available from Laurence, Meigh and Sullivan (2003) for 147 countries enable us to provide an empirical basis for the argument. A new index called SWUI was derived from WPI using four of its five sub-indices to assess the water situation of a country. Analysis was carried out using data on SWUI, GHI, HDI, per capita GDP and per capita water storage in dams to understand the nature of linkage between water situation of a country and its economic growth.

The analysis shows that improving the water situation can trigger economic condition in a nation. As this occurs through the human development route, the growth would be inclusive. This strong linkage can be partly explained by the reduction in malnutrition and infant mortality, with improvement in water situation. Further, nations could achieve good indicators of development even at low levels of economic growth, through investment in water infrastructure and welfare-oriented policies. Many countries of the erstwhile Soviet Union, and communist countries of Latin America, which have low income, spend a significant portion of public funds in health and education, against many poor countries of Sub-Saharan Africa, which spend much less for health and education and more for military.

Analysis also shows that improving water security also promotes better distribution of national income through the human development route, as indicated by the strong inverse correlation between sustainable water use index and Gini coefficient of income of nations, and inverse correlation between HDI and Gini coefficient of income. Improved water security also reduces poverty, as indicated by the strong inverse relationship between sustainable water use index and human poverty index (1) for a group of 113 countries.

Countries which fall in tropical semi arid and arid climate can improve their economic conditions through enhancing the reservoir storage. Greater storage provides increased water security, which reduces the risks associated with droughts and floods. Such natural calamities, which cause huge economic losses, are characteristic of these countries. Nevertheless, the impact of storage could depend on the nature of uses for which the resources are developed, the effectiveness of the institutions that are created to allocate the resource and the nature of institutional and policy regimes that govern the use of the resource.

Findings show that economically poor countries, which also show very poor indicators of human development, need not wait till the economic conditions improve to address water sector problems. Instead, they should start investing in building water infrastructure, create institutions and introduce policy reforms in water sector that could lead to sustainable water use. Only, this can support progress in human development, and sustain economic growth which is also inclusive. But, a pre-requisite for hot and arid tropical countries is that they invest in large water resource systems to raise the per capita storage. This will help them fight hunger and poverty, malnutrition, infant mortality, and reduce the incidence of water-related disasters.

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