WATER, HUMAN DEVELOPMENT AND ECONOMIC GROWTH: SOME INTERNATIONAL PERSPECTIVES

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Abstract

The recent years have seen renewed interest in understanding how growing threats to water security affects future progress in human development and economic growth of nations. The underlying concern is that water insecurity could decouple economic growth and progress in human development. The international development discourse is, however, characterized by unhealthy debates with divergent views. Though scholars have provided robust evidences to the effect that water security catalyses human development and economic growth, number of regions for which these evidences are available is too limited for a global consensus on this issue. Water poverty index(WPI), conceived and developed by 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.

In order to realistically assess the water situation of a country, which can capture the crucial attributes like access to water for various uses; level of use of water in different sectors; condition of the water environment; and technological and institutional capacities in water sector, a new index named Sustainable Water Use Index (SWUI) was derived from WPI. In this paper, the authors first analyze the nature of linkage between water situation of a country, vis-à-vis access and use, water environment and institutional capabilities in the water sector on economic growth. For this, data on sustainable water use index derived from WPI; human development and per capita GDP (ppp adjusted) for 145 countries, and data on global hunger index (GHI) for 117 countries are 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 22 countries.

The regression analyses between SWUI and per capita GDP show that improving the water situation, vis-à-vis improved access to and use of water, institutional capabilities in water sector and improved water environment, through investments in water infrastructure, creating institutions and making policy reforms, can support economic growth of a nation. This is explained by the regression between SWUI and HDI, which showed that increase in SWUI raised the indicators of human development, paving the foundation for growth. This strong linkage can be partly explained by the reduction in malnutrition and infant mortality with improvement in water situation as indicated by the strong inverse relationship between SWUI and GHI. Whereas regression between per capita GDP and decomposed HDI shows that a country's progress in human development has little to do with its economic prosperity, and that a country can achieve good indicators of development even at low levels of economic growth, through welfare oriented policies which encourage investments in water, health and education infrastructure. This means, economic growth is not a pre-requisite for solving water related problems. Instead, countries should invest in water infrastructure, institutions and policy reforms to achieve human development and sustain economic growth. Further analysis shows that hot and arid tropical countries, the investment in large water storages had helped support economic growth. Also, it seems to reduce malnutrition and incidence of child mortality. Finally, the study also provides a methodology for analyzing the linkage between water situation in a region and its economic growth.

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1. INTRODUCTION

As water scarcity hits many developing regions of the world, internationally, there is a renewed interest in understanding how growing threats to water security affects future progress in human development and economic growth of nations (see Grey and Sadoff, 2005). 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 in their economic transition and many backward regions, are facing today (HDR, 2006: pp66). Such debates, that are often not healthy, are causing delays in deciding investment priorities in water sector, particularly in the developing world (Biswas and Tortajada, 2001). The underlying concern here is that water insecurity could decouple economic growth and progress in human development.

There is rich theoretical discussion on the returns on investment by countries in water infrastructure and institutions (Sadoff and Grey, 2005). Many scholars and international agencies have provided robust evidences to the effect that water security can catalyze human development and growth (World Bank, 2004; 2006a & 2000 b; Briscoe, 2005). But, the number of regions for which these evidences are available is too limited for evolving a global consensus on this complex issue. Till recently, there were no authentic and comprehensive database on various factors influencing water security for sufficient number of countries which are at different stages of human development and economic growth. This contributed to the complexity of the debate. The water poverty index (WPI), conceived and developed for countries by 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.

But, 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. In order to realistically assess the water situation of a country, which can capture the crucial attributes like access to water for various uses; level of use of water in different sectors; condition of the water environment; and technological and institutional capacities in water sector, a new index called Sustainable Water Use Index (SWUI) is derived from WPI. The paper provides empirical analysis using global database on SWUI and many other water and development indicators to enrich the debate "how water security is linked to human development and economic growth".

2. THE GLOBAL DEBATE

The debate on the linkage between water, economic growth and development is characterized by divergent views. 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 (2005) suggest 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 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 would be much higher as compared to countries, which fall in temperate climate with low variability.[1] But, they suggest that for developing countries, the returns on investment in infrastructure would be higher that in management and *vice versa* for developed countries.

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

Many environmental groups, on the other hand, advocate small water projects which, according to them, the communities can themselves manage. 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).

The proponents of sustainable development paradigms believe that the ability of a country to sustain its economic growth depends on the extent to which natural resources, including water, are put to efficient use through technologies and institutions, thereby reducing the stresses on environmental resources (Pearce and Warford, 1993). Here, the focus is on initiating institutional and policy reforms in water sector. An alternative view suggests that countries would be able to tackle their water scarcity and other problems relating to water environment at advanced stages of economic development (Shah and Koppen, 2006). They argue that standard approaches to water management in terms of policies and institutions work when water economies become formal, which are found at an advanced stage of economic development of nations.

3. OBJECTIVES AND HYPOTHESIS

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 economic growth of a nation; and ii) understand the role of large water storages in boosting economic growth and changing human development indicators 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.

4. ANALYSIS AND DATA SOURCES

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.

The first hypothesis is 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. Since regression between SWUI and HDI showed a strong relationship (R^2= 0.79), 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. 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 is 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 2006. Data on GHI for 117 countries were obtained from Wiesmann Doris (2007).[2] Data on WPI for 145 countries were obtained from Laurence et al. (2003). Data on dam storage and human population in 22 countries were obtained from FAO AQUASTAT-2006.

[2] Indicator of the proportion of the population living in under-nourished conditions and the child mortality rate (see Wiesmann, 2006).

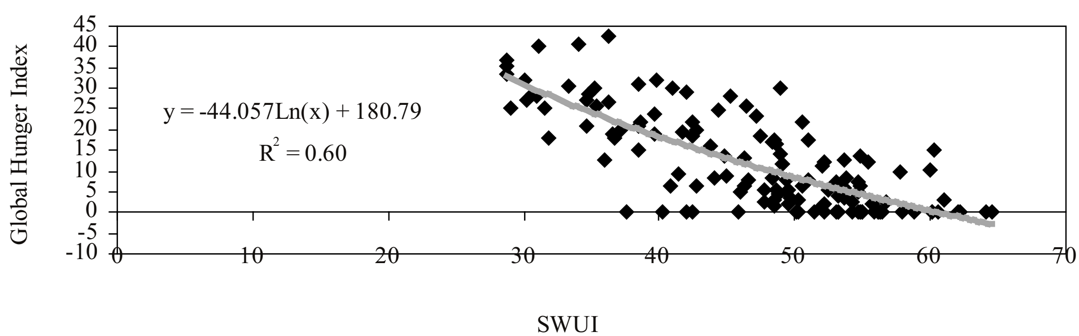
5. WATER AND ECONOMIC GROWTH

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 to be 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 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.

All the sub-indices have values ranging from 0 to 20. The composite index developed, by adding up the values of these indices, is called sustainable water use index (SWUI). It is being hypothesized that that the overall water situation of a country (or SWUI) has a strong influence on its economic growth performance.

Figure 1: Global Hunger Index vs SWUI



This is somewhat different from the hypothesis postulated by Shah and Koppen (2006), where in 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 evidences 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 (see for instance 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 effects on health, environmental sanitation, with spin off effects on livelihoods and nutrition (positive), school drop out rates (negative) and productive workforce.

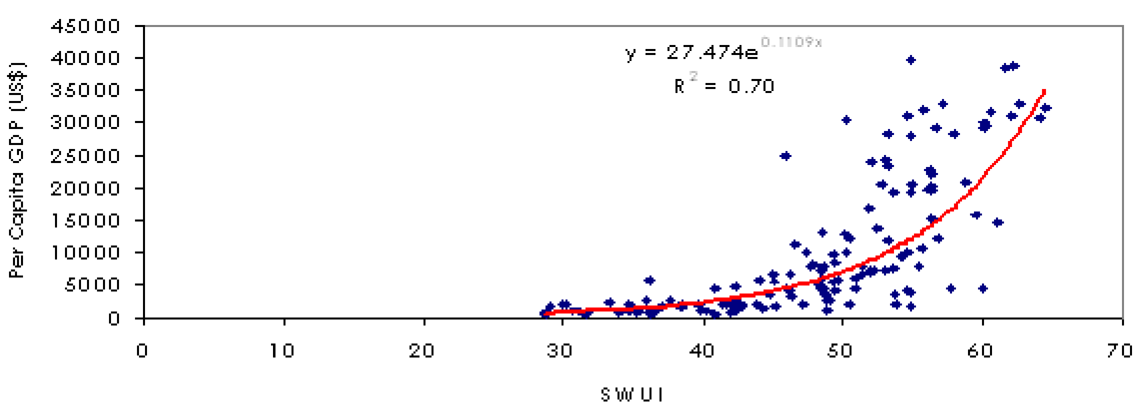
According to the Human Development Report (2006), only one in every five people in the developing world has access to an improved water source. Dirty water and poor sanitation account for vast majority of the 1.8 million child deaths each year (almost 5,000 every day) from diarrhea- making it the second 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^2 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 (Figure 1). 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.

That said all the sub-indices of HDI have strong potential to trigger growth in economy of a country, be it educational status; life expectancy; or income levels. When all these factors improve, they could have a synergetic effect on the economic growth. 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 in this paper.

Before that, we would 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 (see Figure 2). The coefficient is significant at one per cent level. We must mention here that Laurence, Meigh and Sullivan (2003) had estimated an R^2 value of 0.81 for WPI and HDI (Table 2: Page 5 in Laurence et al., 2003). Figure 2 shows that 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.

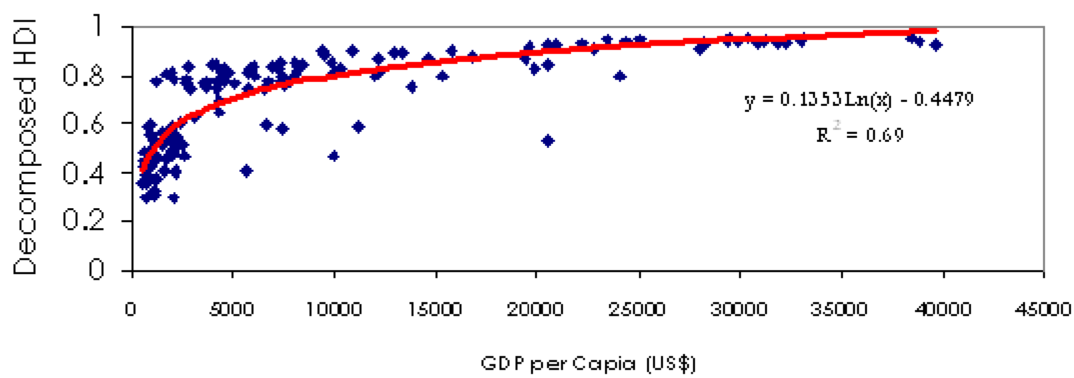
Figure 2: Sustainable Water Use Index Vs GDP Growth



This only means that for countries to be on the track of sustainable growth path, the following steps are needed: 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 SWUI (in the range of 53-56), 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.

Figure 3: Per Capita GDP Vs Decomposed HDI



5.1 What Comes First: Economic Growth or Water Security?

International development discussions are often characterized by polarized positions on whether money or policy reform is more crucial for progress in human development (various authors as cited in HDR, 2006: pp 66). If the stage of economic development determines a country's water situation rather than *vice versa*, 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 between shows economic growth levels (expressed in per capita GDP PPP adjusted) explains HDI variations to an extent of 85 %). This is in spite of the fact that HDI already includes per capita income, as one of the sub-indices.

Subsequently, analysis was carried out using decomposed values of HDI index (after subtracting the GDP index). The regression value came down to 0.69 when the decomposed index, which comprises education index and life expectancy index, was run against per capita GDP (Figure 3). What is more striking is the fact that 16 countries having values of per capita income below 2,000 dollars per annum have medium levels of decomposed index. Again 42 countries having per capita GDP (PPP adjusted) less than 5,000 dollars per annum have medium levels of decomposed human development index. As Figure 3 shows, 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 institutional structures to ensure good literacy and human 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, and have good governance practices.[3]

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

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

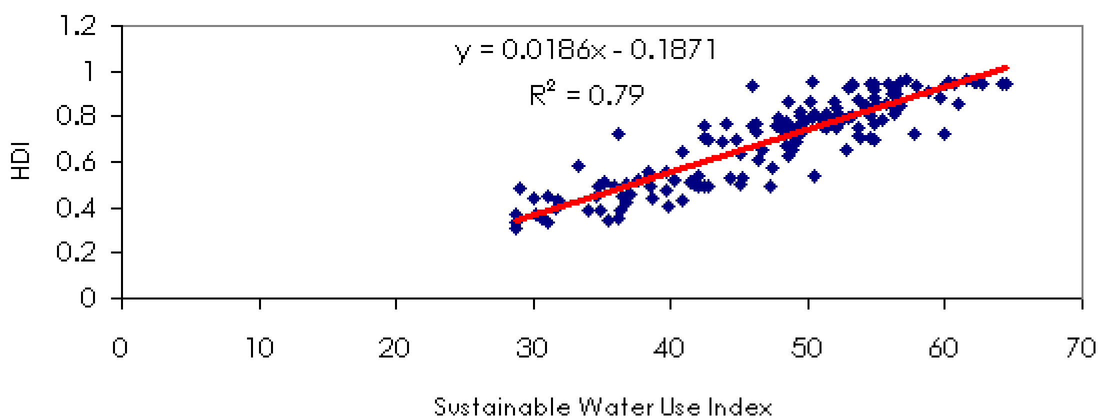
The overall public expenditure on health and education is extremely low in these African countries and Yemen when compared to the many other countries which fall under the same economic category (below US $ 5,000 per capita per annum). Over and above, the pattern of public spending is more skewed towards military (HDR, 2006) (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 (HDR, 2006) .

[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.

High incidence of water-related diseases such as malaria and diarrhea, high infant mortality, high school drop out 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, malnutrition etc. are characteristic of these regions (HDR, 2006). Consequently, their HDI is very low, as also shown by the international literature which illustrates how water insecurity decouples human development from economic growth.

At the same time, regression between water situation (expressed in terms of sustainable water use index) and HDI shows that it explains variation in HDI in a much better way than the level of economic development (Figure 4). 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. The R^2 value was 0.79 against 0.69 in the earlier case when per capita GDP is run against decomposed HDI. Also, the coefficient is 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. Now, such a strong linear relationship between sustainable water use index and HDI explains the exponential relationship

Figure 4: Sustainable Water Use Index Vs HDI



between sustainable water use index and per capita GDP as the improvements in sub-indices of HDI contributes to economic growth in its own way (i.e., per capita here is the education index, and is the health index).

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, such data 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.

[4] This includes economic scarcity as well.

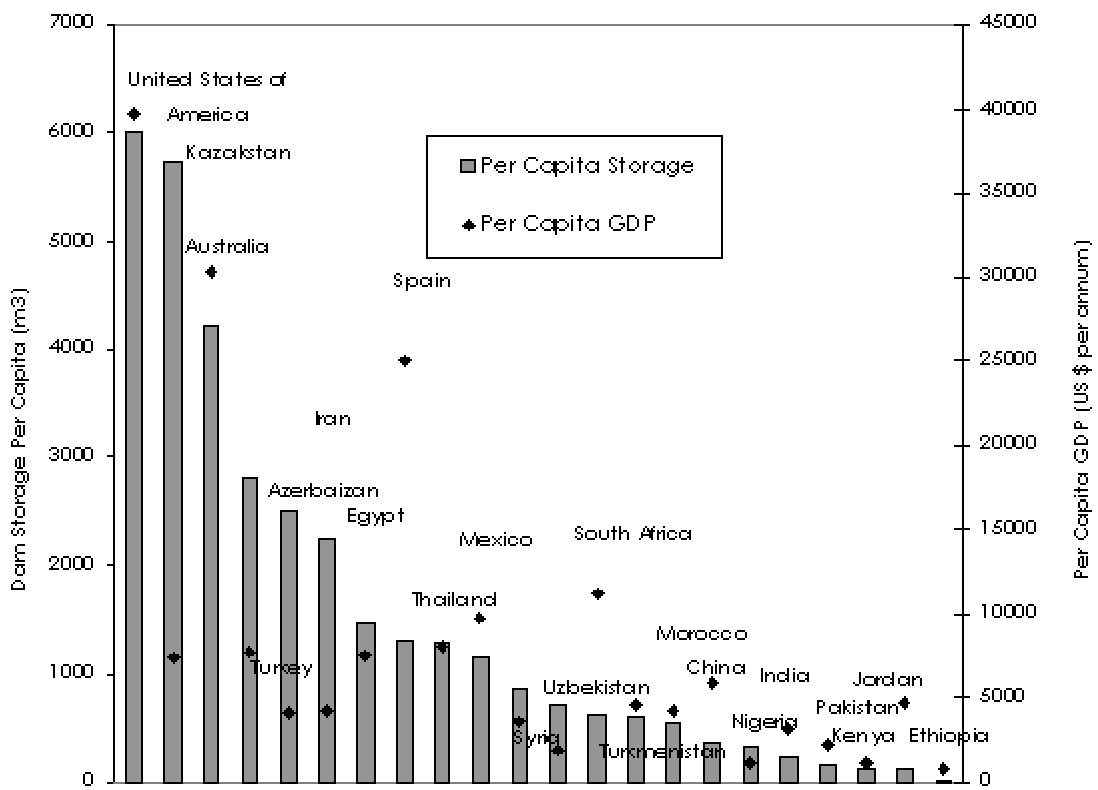
The foregoing analyses suggest that improving water situation of a country, which is represented by Sustainable Water Use Index, is of paramount importance if we need to sustain economic growth in that country. It would be rather an improper logic to consider that a country can wait till its economy 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.

6. STORAGE DEVELOPMENT AND ECONOMIC GROWTH

Now, water development has an important role in improving the access to and use of water, the two pre-requisites for improving the water situation (expressed in terms of SWUI) of a region, though intensive water development in river basins might reduce indicators on the water environment front. The amount of storage that needs to be created to improve access to and use of water depends on the type of climatic conditions. In temperate and cold climates, the demand of water for irrigation, which is the largest user of water in most regions with agricultural base, would be negligible when compared that in tropical and hot climates. Hence, the storage requirements would be much lower, mainly limited to that for meeting domestic/ municipal water needs and water for manufacturing. Hence, it makes logic to explore links between storage development for meeting various human needs and economic growth only in tropical and hot climates.

The sheer scale of water infrastructure in rich countries is not widely appreciated (HDR, 2006: pp-155). Many developed regions 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 provide a per capita water storage facility of nearly 3,808 m^3 per annum or a total of 79,000 MCM per annum. Aquifers supply another 4,000 MCM per annum. Against this, the country maintains a use of nearly 1,160 m^3 per capita per annum for irrigation, industry, drinking and hydropower, with

Figure 5: Per Capital GDP and Dam Storage in selected Countries



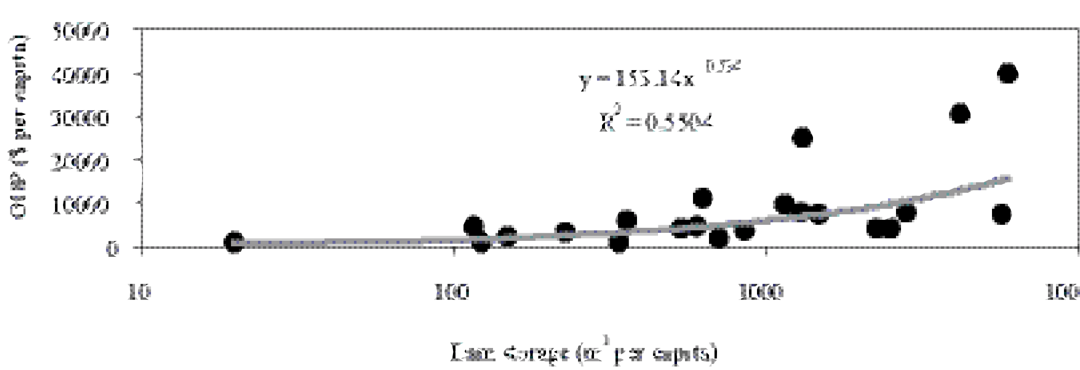
irrigation accounting for 75% of the use (source: www.nlwra.gov.au/atlas). China, one of the fastest growing economies in the world, has per capita reservoir storage capacity of 2,000 m^3 per annum through dams, and an actual storage of nearly 360m^3 per capita. This is in spite of the great technological advancements made by most of these countries in improving water use efficiencies, particularly in sectors such as irrigation and industry.

When compared to these impressive figures, India, which is still developing, has a per capita storage of only 200m^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. But, there are increasing evidences to suggest that this won't be sustainable. Many semi arid areas are already facing problems of groundwater over-draft, with serious socio-economic and ecological consequences as discussed in the recent work by Kumar (2007). 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 water storage per unit of population.

The per capita water storage and the per capita GDP (ppp adjusted) for a group of 22 countries is given in Figure 5. One can see a strong relationship between level of storage development and country's economic prosperity. The R square value is 0.55 (Figure 6), and the coefficient is significant at one per cent level. Such a relationship is understandable. Water storage infrastructure reduces risks, and improves water security.

Investments in hydraulic infrastructure had in many cases supported economic prosperity and social progress, though in some cases had caused environmental damage (HDR, 2006, based on various authors: pp140). 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 the flood-prone, impoverished part of the Dust Bowl, with some of the worst human development indicators of the United States, 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

Figure 6: Per Capita GDP vs Per Capita Dam Storage



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).

The returns on investments in building water storages were more visible in India. The recent 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. Now, 90% of the cropped area in the state is irrigated, three quarter of it going to paddy and wheat.

Despite comprising less than 2% of the geographical area, 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).

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 such regions which lack them badly. For instance, 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).

But, there are many critiques to the argument based on per capita storage. According to Vandana Shiva, a renowned eco-feminist from India, the norms used for estimating per capita water use is fraudulent, and a way to push the large dam agenda by the World Bank. According to her, the many millions of ponds and tanks in rural areas of India themselves capture a lot of water and supplies it to the rural population in a more democratic and decentralized way than the large dams do. But, the contribution of such storage in augmenting our water supplies is often over-estimated by environmentalists. In the case of Australia, the National Heritage Trust's report of the audit of land and water resources say, the many millions of farm dams in Australia create a total storage of 2,000 MCM per annum, against 79,000 MCM by large dams (www.nlwra.gov.au/atlas).

Nevertheless, the overall impact of water storages on economic growth 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 improve the overall economic condition of the people also. Though the per capita water storage in Israel is quite low (nearly 150 m^3 per annum), the efficiency with which water is 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 to agriculture is rationed.

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 evidences 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). 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[5] and the economic viability of doing the same are open to question. Recent evidences also suggest 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, 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 like United States and Australia 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.

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[5] 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.

But, it is important to recognize the fact that in the basins that are facing problems of environmental water scarcity and degradation in the world (see Smakhtin, Revenda and Doll, 2004) are appropriate development of large water projects, and diverted river-flows 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[6]. 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).

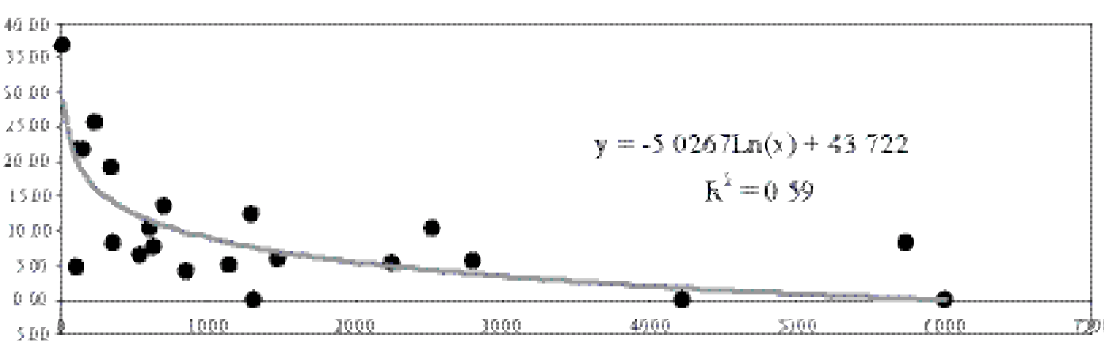
Strikingly, wherever aquifers are available for exploitation, these regions had experiencing problems of groundwater over-draft, though some developed countries had developed the science to deal with it. The most glaring examples are aquifers in western United States, aquifers in the countries of the 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).

For the presence of large surface water projects, the negative impacts agricultural growth in these regions, might have caused on groundwater resources might have been far more serious. In fact, it is this surface water availability, which to a great extent helps reduce dependence of farmers as well as cities on groundwater. 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). Water imported from the Central Valley Project in California is used to buy back the groundwater rights of farmers using water from Ogallala aquifer in Kansas and Texas. 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 and Ranade, 2004).

7. STORAGE DEVELOPMENT AND IMPACT ON MALNUTRITION AND CHILD MORTALITY

As one would expect, storage development has a direct impact on malnutrition, and infant mortality, which is captured in GHI. Here again, we have assumed zero values of GHI for developed countries viz., United States, Australia and Spain for which data on GHI are not available. Regression shows an R^2 value of 0.59

Figure 7: Global Hunger Index vs Per Capital Dam Storage



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

(Figure 7). As Figure 7 indicates, the relationship between per capita storage and GHI is inverse, logarithmic. The regression coefficient is significant at one per cent level. It means greater water storage reduces the chances of human hunger. This inverse relationship can be explained this way. For the countries, which we have chosen for the analysis, 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 food 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). Shah and Kumar (2007) 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 is found in the case of these 22 countries, there are countries which have large storages, but have very high GHI. They are Zambia and Zimbabwe. 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. Most of it comes from just one hydropower dam, named, Kariba built in 1955-59 in Zambezi river basin. Hence, storage development does not lead to increased agricultural production in these countries. The GHI values are very high for these countries, which is 31.77 for Zambia, and 23.2 for Zimbabwe (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 countries, three decades of droughts and rainfall reduction had significantly affected the hydropower generation as well (McCully and Wong, 2004).

8. SUMMARY OF FINDINGS

We first analyzed the nature of impact the water situation of a country has on its economic growth by doing regression between: SWUI and GHI; SWUI and per capita GDP; SWUI and HDI; and per capita GDP and HDI for 145 countries. 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 and per capita GDP were analyzed for 22 countries, which fall in that category. The summary results of regression analyses are presented in Table 2. Based on these results, the findings can be summarized as follows.

Improving the water situation, vis-à-vis improved access to and use of water, institutional capabilities in water sector and improved water environment, through investments in water infrastructure, creation of institutions and introduction of policy reforms, can trigger economic condition in a nation. This occurs through the human development route, as shown by the consistent improvement in human development indicators with increase in values of SWUI. This strong linkage can be partly explained by the reduction in malnutrition and infant mortality, with improvement in water situation as indicated by the strong inverse relationship between SWUI and GHI for 117 countries.

Further, progress in human development has very little to do with their economic growth, and that they 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.

Table 2: Results of Regressions Analysis of Various Water, Human Development and Economic Growth-Related Variables

Dependent Variable	Independent Variable				Adj-R2	F-Stat	Degree of Freedom
	Constant	LNSWUI	SWUI	LNPCSTR			
HDI	-2.459 * (-17.627)	0.822 * (22.655)			0.781	513.24	(1, 143)
LNPCGDP	3.313 * (11.201)		0.111 * (18.132)		0.695	328.76	(1,143)
GHI	180.792 * (14.985)	-44.057 * (-14.012)			0.593	196.33	(1, 133)
GHI	43.722 * (6.971)			-5.027 * (-5.401)	0.573	29.17	(1, 20)
LNPCGDP	5.031 * (6.919)			0.534 * (4.948)	0.528	24.49	(1, 20)

Note: Value in the parenthesis shows the t-stat for the corresponding estimated coefficient
LNPCSTR –Logarithmic value of per capita storage in dams
LNSWUI-Logarithmic value of Sustainable Water Use Index
LNPCGDP-Logarithmic value of per capita GDP PPP adjusted
* implies that the coefficient is significant at one per cent level

Countries which fall in tropical semi arid and arid climate, can improve their economic conditions through enhancing the reservoir storage. This potential impact be explained by increased water security that comes with greater water storage. This reduces the risks associated with natural calamities such as droughts and floods. Such natural calamities, which cause huge economic losses, are characteristic of these countries. For such large surface water development, the negative impacts agricultural growth would have induced on groundwater resources in such regions would have been far more serious. 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. Those countries having high per capita water storage also have very few people living in hunger.

9. CONCLUSIONS

The debate on the linkage between water, economic growth and human development is characterized by divergent views. They can be summarized as: 1] increased investment in water projects would act as engines of growth in the economy, while supporting progress in human development; 2] standard approaches to water management in terms of policies and institutions work when water economies become formal, which are found at an advanced stage of economic development; and 3] ability of a country to sustain its economic growth depends on the extent to which natural resources, including water, are put to efficient use through technologies and institutions, thereby reducing the stresses on environmental resources.

Scholars have provided robust evidences to the effect that water security catalyses human development and economic growth. But, number of regions for which these evidences are available is too limited for evolving 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, vis-à-vis access and use of water, water environment and institutional capabilities in the water sector. 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.

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 improved water situation vis-à-vis access to and use of water, water environment and institutional capabilities. Only, this can support progress in human development, and sustain economic growth, through poverty reduction; food security, improved livelihoods and nutrition, with positive effects on productive workforce; and domestic water security with positive effects on health, environmental sanitation, with spin off effects on livelihoods and nutrition, school drop out rates and productive workforce. But, a pre-requisite for hot and arid tropical countries is that they invest in large water resource systems to raise the per capita available storage. This will help them fight hunger and poverty, malnutrition, infant mortality, and reduce the incidence of water-related disasters. Finally, the study also provides a methodology for analyzing the linkage between water situation in a region and its economic growth.

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REFERENCES

Agarwal; Anil and Sunita Narain (1997), Dying Wisdom: Rise and Fall of Traditional Water Harvesting Systems, Centre for Science and Environment, New Delhi.

Ahmad; M. D., I. Masih and H. Turral (2004), Diagnostic analysis of spatial and temporal variations in crop water productivity: A field scale analysis of the rice-wheat cropping system of Punjab, Pakistan, Journal of Applied Irrigation Science, 39 (10).

Amarasinghe; Upali; R. Bharat Sharma; Noel Aloysius; Christopher Scott; Vladimir Smakhtin; Charlotte de Fraiture; A. K. Sinha and A. K. Shukla (2004), Spatial Variation in Water Supply and Demand across River Basins of India, IWMI Research Report 83, International Water Management Institute, Colombo, Sri Lanka.

Athavale, R. N. (2003), Water Harvesting and Sustainable Supply in India, published for Environment and Development Series, Centre for Environment Education, Rawat Publications, Jaipur and New Delhi.

Barrios; Salvador; Luisito Bertinelli and Eric Strobl (2004), Rainfall and Africa's Growth Tragedy, paper. (un-published).

Bhattarai; Madhusudan and A. Narayanamoorthy (2003), Impact of irrigation on rural poverty in India: an aggregate panel data analysis, *Water Policy*, 5 (2003): 443-458.

Biswas; Asit K. and Cecilia Tortajada (2001), Development and large Dams: A Global Perspective, *International Journal of Water Resources Development,* 17 (1).

Braga B; O. Rocha and J. Tundisi (1998), Dams and the Environment: The Brazilian Experience, International Journal of Water Resources Development, 14 (2).

Briscoe, John (2005), India's Water Economy: Bracing up for a Turbulent Future, key note address at the 4th Annual Partners' Meet of IWMI-Tata Water Policy Research Program, Institute of Rural Management Anand, 26-29 February, 2005.

Cummings Jr. R; S. Rashid and A. Gulati (2006), Grain Price Stabilization Experiences in Asia: What Have We Learned?, Food Policy, 31 (4): 302-312.

Dharmadhikary, S. (2005), Unraveling Bhakra: Assessing the Temple of Resurgent India, Manthan Adhyayan Kendra, New Delhi.

Doris, Wiesmann (2006), Global Hunger Index: A basis for cross country comparison, International Food Policy Research Institute, Washington D. C.

D'Souza, D. (2002), Narmada Dammed: An Enquiry into the Politics of Development, New Delhi: Penguin Books India.

Food and Agriculture Organization of the United Nations (FAO) (2006) The AQUASTAT database. Rome. [www.fao.org/aq/agl/aglw/aquastat/dbase/index.stm]

Government of India (2005), Dynamic Ground Water Resources of India, Central Ground Water Board, Ministry of Water Resources, Government of India, August, New Delhi.

Hira, G. S. and K. L. Khera (2000), Water Resource Management in Punjab under Rice-Wheat Production System, Department of Soils, Punjab Agricultural University, Ludhiana.

Hussain, Intizar and Munir Hanjra (2003), Does Irrigation Water Matter for Rural Poverty Alleviation? Evidence from South and South East Asia, *Water Policy,* 5 (5): 429-442.

Human Development Report (2006), Human Development Report-2006, New York: United Nations.

Kumar, M. Dinesh (2007), Groundwater Management in India: Physical, Institutional and Policy Alternatives, Sage Publications, New Delhi.

Kumar, M. Dinesh and Rahul Ranade (2004), Large Water Projects in The Face Of Hydro Ecological and Socioeconomic Changes in Narmada Valley: Future Prospects and Challenges, *Journal of Indian Water Resources Society.*

Kumar, M. Dinesh and O. P. Singh (2005), Virtual Water in Global Food and Water Policy Making: Is There a Need for Rethinking? Water Resources Management, 19: 759-789.

Kumar, M. Dinesh; Shatanu Ghosh; Ankit Patel; O. P. Singh and R. Ravindranath (2006), Rainwater Harvesting in India: some critical issues for basin planning and research, Land Use and Water Resource Research, 6 (2006): 1-17.

Laurence, Meigh and C. Sullivan (2003), Water Poverty of Nations: International Comparisons, Kellee University, Wallingford, UK.

Mc Cully, Patrick (1996), Climate Change Dooms Dams, Silenced Rivers: The Ecology and Politics of Large Dam, Zed Books, London.

Mc Cully, Patrick and Susanne Wong (2004), Powering a Sustainable Future: The Role of Large Hydropower in Sustainable Development, paper prepared for the UN Symposium on Hydropower and Sustainable Development (Mimeo)

Molden, D. J., Upali Amarasinghe and I. Hussain (2001), Water for Rural Development, Working Paper 32, International Water Management Institute, Colombo.

Pearce, D. W. and Warford, J. (1993), World Without End: Economics, Environment, and Sustainable Development. (published for the World Bank) London and New York: Oxford University Press.

Perry, C. J. (2001) World Commission on Dams: Implications for Food and Irrigation, *Irrigation and Drainage*, 50: 101-107.

Rockström, J., Jennie Barron and Patrick Fox (2002) Rainwater management for improving productivity among small holder farmers in drought prone environments, *Physics and Chemistry of the Earth*, 27 (2002): 949-959.

Sadoff, Claudia and David Grey (2005), Water Resources, Growth and Development, a Working Paper for Discussion, prepared by The World Bank for the panel of Finance Ministers, the UN Commission for Sustainable Development, 18 April, 2005.

Shah, Tushaar and Barbara van Koppen (2006), Is India Ripe for Integrated Water Resources Management? Fitting Water Policy to National Development Context, Special Articles, Economic and Political Weekly, August 5, 2006.

Smakhtin, Vladimir, Carmen Revenda and Petra Doll (2004) "Taking into Account Environmental Water Requirements in Global-Scale Water Resources Assessments," Comprehensive Assessment Report 2, Comprehensive Assessment Secretariat, Colombo.

Sullivan, Caroline (2002), Calculating Water Poverty Index, World Development, 30 (7): 1195-1211.

Vora, B. B. (1994), Major and Medium Dams: Myth and the Reality, *Hindu Survey of the Environment*, The Hindu, Chennai.

World Bank (2004), Towards a Water Secure Kenya: Water Resources Sector Memorandum, Washington D. C.

World Bank (2005), Pakistan Water Economy: Running Dry, Report 34081-PK. South Asia Region, Agriculture and Rural Development Unit, Washington D.C.

World Bank (2006a.), Managing Water Resources to Maximize Sustainable Growth: A Country Water Resources Assistance Strategy for Ethiopia, Washington D. C.

World Bank (2006b.), Hazards of Nature, Risk to Development, An IEG Evaluation of World Bank Assistance to Natural Disasters, Independent Evaluation Group, Washington D. C.

Shah, Zankhana and M. Dinesh Kumar (2007), In the Midst of the Large Dam Controversy: Objectives, Criteria for Assessing Large Water Storages in the Developing World, paper presented at the IWMI Workshop on the Challenge Program project on a Strategic Analysis of India's National River Linking project, New Delhi, October 9-10, 2007.