An Assessment of Water Poverty Indices in the Context of Climate Change: *A Study of Selected Climate Vulnerable Developing Countries*

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ABSTRACT

Water is one of the most critically stressed natural resources considering its expanding uses for economic activities, household demand and widespread misuses and mismanagement against a declining supply. The phenomenon of climate change, with clear changes in the trends and patterns of rainfall and temperature and their seasonal variability, has posed an additional blow to the severity of the water supply. In this context, water poverty index is considered to be useful for designing an integrated water management system for any country against climate change. It is a composite index that combines five water related components i.e. resource, access, capacity, use and environment with its seventeen sub-components to ensure that all the major water issues involving physical, social, economic and environmental aspects are included. The WPI score ranges between 0 and 100; a low score indicates water poverty and a high score indicates good water provision. For the present study, both water scarcity and climatic vulnerability have been considered and a total of sixteen low income and climatically vulnerable countries have been considered: Bangladesh, Ethiopia, Haiti, India, Indonesia, Kenya, Malawi, Mali, Mozambique, Nepal, Nigeria, Pakistan, Sri Lanka, Sudan, Vietnam and Zimbabwe. The findings suggest that Indonesia scores the highest (61.34) and Sudan the lowest (24.65) among all the countries, while Bangladesh's position (45.60) is fairly mild, which signifies that the country is not in a good position and there is a need to think about water management seriously against the looming climate change and water stress.

Key words: Water poverty index, Vulnerability, Developing countries, Water management.

JEL Code: I30, I31, I32, I38. I39

CITATION:

Chattapadhya. S. and Islam, A.K.M.N. (2018). "An Assessment of Water Poverty Indices in the Context of Climate Change: A Study of Selected Climate Vulnerable Developing Countries." *Inter. J. Res. Methodol. Soc. Sci.*, Vol., 4, No. 2: pp. 34-48. (Apr. – Jun. 2018); ISSN: 2415-0371.

1.0 INTRODUCTION

Water is important for human use, it ensures a country's food security and other sectoral uses like for agriculture and industry, it is important for maintaining a country's economy, ecology and social progress is equally critical. Many countries in the world have much water resources available, but do not have the capacity to use them properly although there is high demand. Similarly, there are countries which have limited stock, but could use it more efficiently. In between, there are countries that either do not have the luxury of misusing their water resources because of poor stock of water or are not technically or capable to tap the maximum benefits from their water resources. Most vulnerable and water poor countries are developing and even many with abundant stock of water just do not have the capacity to make them useful for their economies. Their economic progress and prosperity are subject to water use efficiency in many respects. Moreover, most water vulnerable developing countries are also vulnerable to global warming-led climate change. Climate change for these countries bars their economic progress, and may pose a serious threat to make the situation worse in days to come. It is important to understand, assess and evaluate their water resource availability, build capacity in using them properly and level of threats in the form of water pollution, to suggest a way-out and propose some effective water management mechanisms that are useful for tackling water crisis with changes in climatic conditions in the years to come. In this context, water poverty index, a recently developed index, is considered to be useful for designing an integrated water management system for any country against climate change.

There is not enough study that linked climatically vulnerable developing economies with their WPIs to improve water management strategy for their economies in face of the climatic wrath in the years to come. The current study aims to fill the gap and serves to generate adequate policy inputs for better water management. Its main purpose is more of a policy-oriented and is expected to address narrowly a country's internal or regional water dynamics. It is mainly designed to improve the situation for people facing poor water endowments and poor adaptive capacity.

The study has the following objectives: (i) To assess water availability and the anticipated crisis in the context of climate change for the selected developing countries; (ii) To construct water poverty indices for the selected vulnerable developing countries; and (iii) Suggest policy measures for better water resource management strategies against the climate change.

2.0 LITERATURE REVIEW

Falkenmark, *et al.* (1989) proposed his first water scarcity indicator which became widely used as the water stressed index. It was defined as the total annual runoff for human use. This index categorized the condition as: *no stress, stress, scarcity,* and *absolute scarcity*.

Sullivan, *et al.* (2002, 2003) anticipated that WPI has been a strong tool to determine priorities for the poorer areas and it also helps local communities to express their needs of water in a systematic way. The WPI was appealing to decision makers for its simplicity and transparency. The methodology of WPI was developed through a pilot project in South Africa, Tanzania and Sri Lanka.

Lawrence, *et al.* (2002) conducted a study on water poverty index and stated that this index has made a rank of countries taking into account both physical and socio-economic factors associated with water scarcity. That study presented water poverty index for 140 countries and has compared it to the UNDP's Human Development Index and the Falkenmark Index.

Soussan, *et al.* (2009) attempted to analyze the relationship between water management and poverty reduction. The main focus of their paper was to understand that water management plays a key role in removing of extreme poverty for the developing world. Livelihood (health and productivity) of the poor depends much on improved access to water resource. In many parts of the developing world, one of the main causes of death is water-borne (diarrhoea) and vector-borne

(malaria) diseases. Thus, managing water resources for ensuring improved and quality water for household consumption, besides agricultural and expanding industrial water demands, can be a mechanism for pro-poor growth and development.

Prudhomme (2002) showed the applicability of WPI by incorporating the climate change through using GCM method. The paper stated that the world is now going through extreme events of climate change, such as long-lasting droughts and very severe flooding. Four indicators of WPI which used in this study are considered to be directly linked to climate. It is observed that access to water is affected due to a change in temperature conditions, while the 'use' and 'environment' components would also be affected by temperature. It is predicted by the authors that regions with high increase in their demographic characteristics, such as South Asia, would expect to face vulnerability in its stock of fresh-water resources as the climate is becoming more extreme for the region.

3.0 METHODOLOGY

3.1 Water Poverty Index and its Components

The WPI is a number between 0 and 100 where a low score indicates water poverty and a high score indicates good water provision. Traditional water scarcity assessment focuses only on the vulnerability of communities and physical water scarcity; WPI attempts to combine social, economic and environmental aspects of water scarcity.

Water poverty index is a composite index comprising of availability, access, capacity, use and environmental components of water sector in a country or region. Every component of WPI consists of some sub indicators. In this paper, seventeen subcomponents are used to calculate WPI. The list of sub indicators are given in (Table 2) in annex.

Table 1: Components of water poverty index

WPI Components	Description
Resource	Physical availability of water including surface and ground water. It also means total amount of water.
Access	Access to water for daily use and it is calculated by summing up the distance of water source and time required to collect it. It also includes industrial and agricultural use of water use.
Capacity	The income that allows purchasing fresh water, education and health services and the capacity of managing water supply.
Use	The use of water for domestic, agricultural and industrial purposes.
Environment	Environmental integration of water, performance of ecosystem services of aquatic habitats.

Source: Sullivan, *et al,* 2002; 2003

3.2 Methodological Clarification

3.2.1Normalization of the Sub-components

The sub-components of WPI are normalized by using the method of calculating UNDP's Human Development Index to solve the problem of different units of measurement for different sub-components. The value of normalized sub-components falls between 0 and 1. There are two formulae used for normalizing sub-components in case of the HDI. For the present study, the following formula is used for normalizing the value of the selected sub-components because all the sub-components are expected to have a one-way direction to the water poverty:

$$X_{ij} = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}} \qquad (1)$$

where, X_i= original values for country I, X_{max} = highest value the country concerned, and

X_{min}= lowest value of the country concerned

3.2.2 Methods of Calculating Water Poverty Index

After normalization, the value of the sub-components ranges from 0 to 1. Then the weight of each component are given. The model can be expressed as:

$$WPI = \frac{\sum_{i=1}^{N} w_i X_i}{\sum_{i=1}^{N} w_i} \quad (2)$$

where X_i = component of WPI structure for any location, and W_i = weight applied to that component.

The following equation provides the weight of each component of WPI. There are many ways of combining the data to calculate WPI. However, this process is the most used one because of its simplicity and straight forwardness. The weighted average for the sub-components of WPI is expressed as:

$$WPI = \frac{W_r R + W_a A + W_c C + W_u U + W_e E}{W_r + W_a + W_c + W_u + W_e} \quad (3)$$

where, WPI = Water Poverty Index score of a particular location, R = Resources component, A = Access component, C = Capacity component, U = Use component, E = Environment component, and w = weighting factor for each component. Then components are standardized to fall in the range 0 to 100 by multiplying each of the five components with 20 and then summed up to obtain the final index score.

3.2.3 Country selection process

This study is based on secondary data the Global Climate Risk Index 2014 by 'Germanwatch' and the World Risk Report 2012 by the UN-University (UN-EHS) have made lists of climate vulnerable and climate-induced disaster vulnerable countries. According to the list of Global Climate Risk Index, the most affected countries are Haiti, Pakistan, Philippines, Bangladesh, Vietnam, and Myanmar. There are many other similar reports published by inter-governmental agencies or independent think-tanks which ranked countries according to their climatic vulnerabilities. Most of the reports show that most vulnerable countries are LDCs or developing countries, which are poor in capacities and have limited means to fight against climatic havoc. Although among the sixteen selected countries, all are not climatically ranked, but they are poor in water resources either because of lack of availability or poor capacity to manage and use efficiently. Similarly, data scarcity and lack of authentic data on the prescribed sub-components to construct WPI forced us to opt for the countries chosen in the current study. From the sixteen countries selected, there are countries from the SAARC region, African countries and a few countries from other parts of the world which are both climatically vulnerable and water poor. List of selected countries are presented in (Table 3) in annex.

3.2.4 Sources of Available Data

Data for the sub-components of WPI have been collected mainly from the World Development Indicators, 2014 and 2017 of the World Bank. Some data have also been collected from the Environmental Performance Index, 2014 and 2017 by the Yale University. Recent data on net

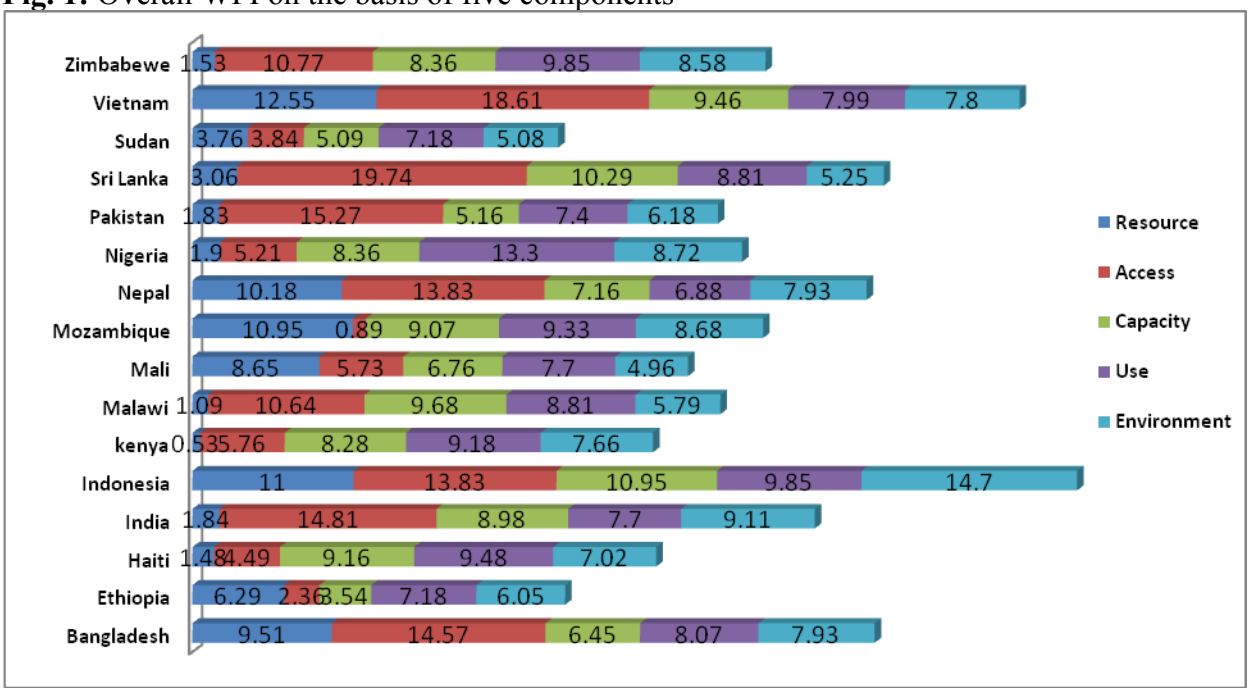
primary school enrolment is not found, so the data from the year 2009 has been considered in this case. Data for 2009 is not found for Ethiopia, Haiti, Nepal, Sudan and Zimbabwe. For Ethiopia, the data for 2006, Nepal for 2011 and Zimbabwe for 2003 have been taken from the World Development Indicators, 2014. For Haiti data on net primary school enrolment (average of 2008 to 2012) has been taken from UNICEF and for Sudan from the UNDP. Information on percentage of water pollution for Ethiopia, Haiti and Sudan has been taken from year 2013. The sources of data are provided in (Table 4) in annex.

4.0 FINDINGS AND DISCUSSION

4.1 Overall Water Poverty Index

A high WPI score shows a good water provision for a country, while a poor score indicates that the country is water poor. The calculated WPI scores from the current study fall within a range between 24.65 and 61.34. Among the sixteen countries, Indonesia scores the highest and Sudan the lowest. Bangladesh scores 45.60. The graph of overall WPI scores for selected countries is shown in Fig. 1. WPI is a combination of five components: resource, access, capacity, use and environment concerning water resources by any country. Values of each component fall between 0 and 20. From Fig. 1, Vietnam scored 12.55 for resource, which also is the highest score on water resource and Kenya's score of 0.53 in this category which is the lowest in the group. It means that Vietnam is good at external and internal renewable water resources, whereas Kenya is poor. Fig. 1 shows the overall WPI scores for selected countries on the basis of five components.

Fig. 1: Overall WPI on the basis of five components



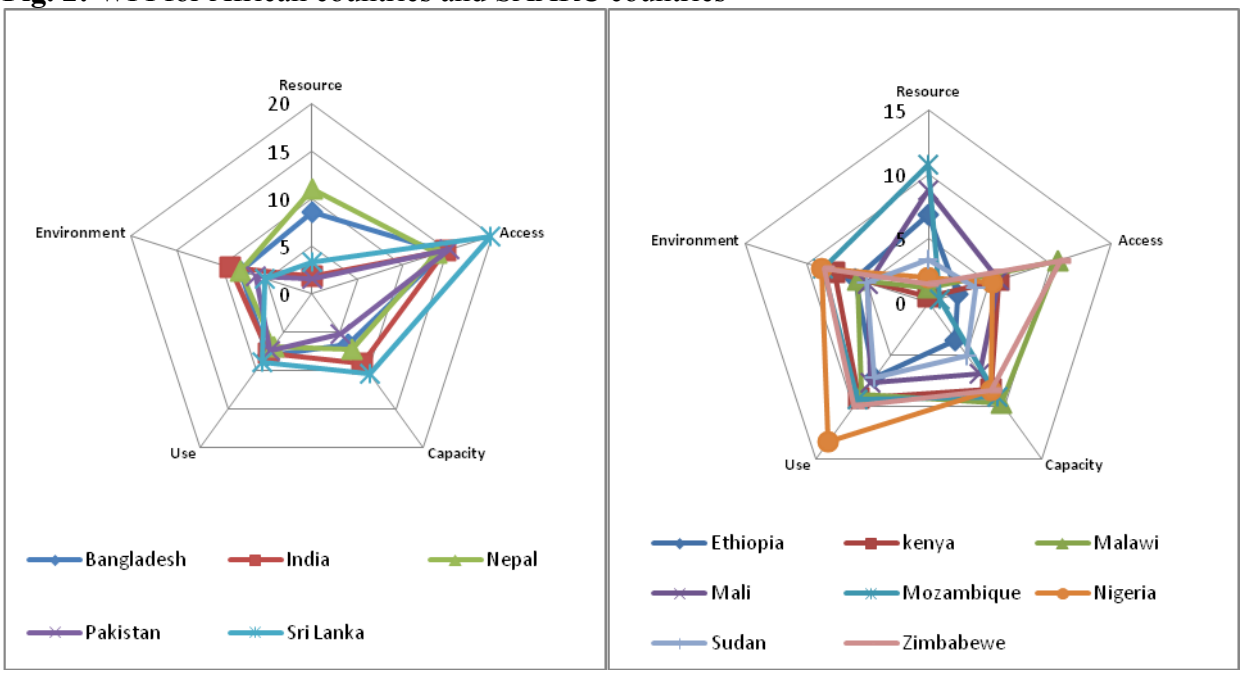
Source: Author's estimation

In case of water access, Sri Lanka scores 19.74 out of 20 and takes the first place. On the other hand, Mozambique's score of a 0.89 is the lowest score in case of water access among the sixteen countries. That means access to clean water and sanitation services are comparatively high in Sri Lanka and very low in Mozambique. For capacity, Indonesia scores 10.95, while Ethiopia scores 3.54. These two are the highest and the lowest scores in case of water capacity. The fourth component of WPI is water use and it consists of water withdrawal for the purpose of agriculture, industry and domestic uses. Nigeria scores the highest at 13.33, while Nepal's score of 6.88. In case of environment, Indonesia scores 14.70 taking the highest place, whereas Mali scores 4.96 and taking the lowest place.

4.2 WPI Scores Analysis for South Asian Countries and African Countries

The following two graphs (Fig. 2) show the WPI scores (on the basis of five components- resource, access, capacity, use and environment) for five South Asian countries and eight African countries. WPI for other three countries are shown in Fig. 2 in annex.

Fig. 2: WPI for African countries and SAARC countries



Source: Author's compilation

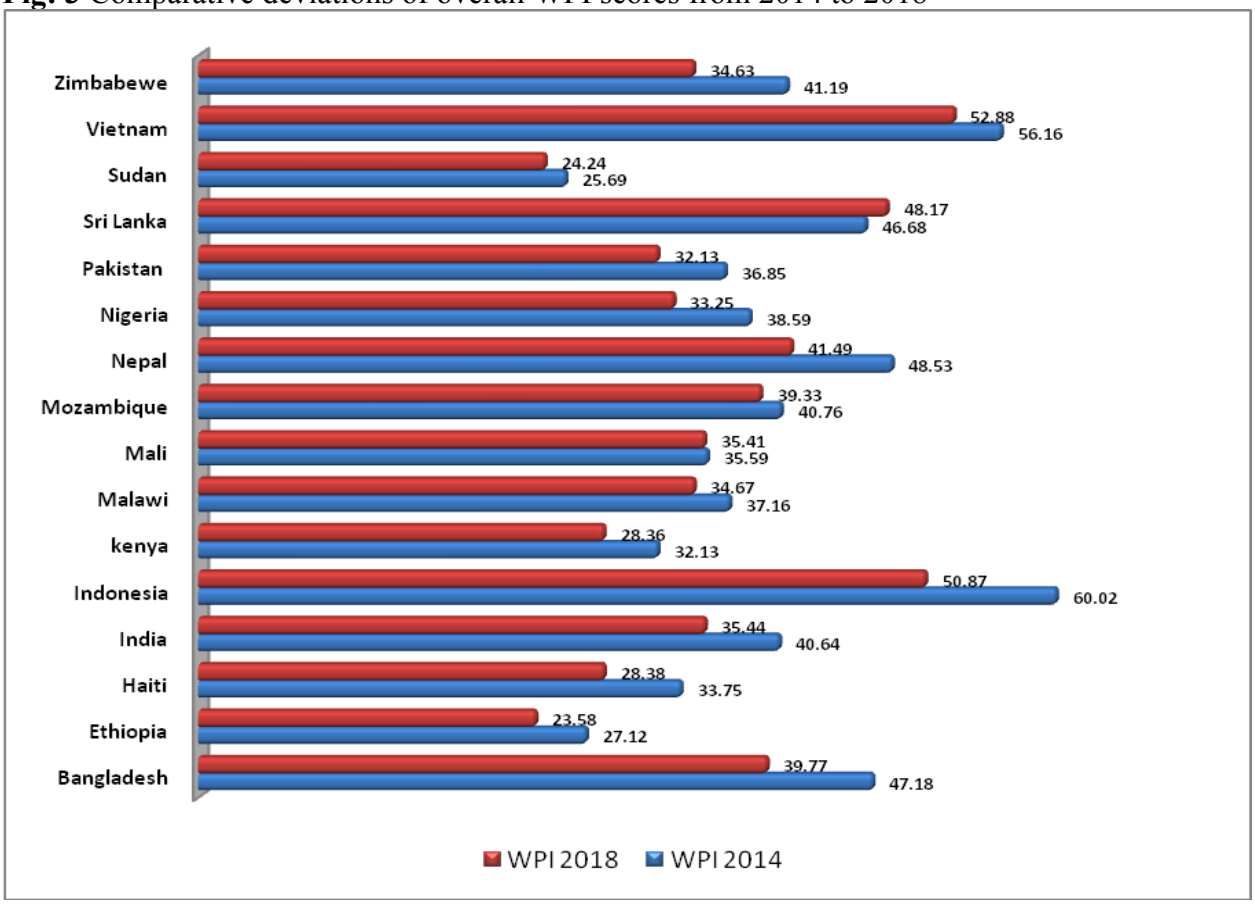
Management of water resources and ecosystems assumes high significance and are necessary for any country's long lasting economic growth. Bangladesh, India, and Sri Lanka are in their initial stage of economic growth; environmental pollutions (water and air pollution) are expected to be rampant and common. Sri Lanka scored the lowest (5.25) and India the highest (9.11) in case of water environment i.e. water pollution. In the study conducted by Lawrence, *et.al* (2002), in the environment component, Bangladesh scored 9, India 9.5, Nepal 11.8, Pakistan 11.5 and Sri Lanka 10.8. Thus, the water environment of these countries might have been degraded if compared to the 2002 standard. These countries have to go a long way to achieve proper management of their water resources, prevent water pollution and water stress for protecting the environment and their ecosystems.

If the scores estimated for the African countries are analyzed, a different picture emerges. The overall WPI score by Ethiopia was 26.01, Kenya 31.43, Malawi 36.11, Mali 33.93, Mozambique 38.77, Nigeria 37.62, Sudan 24.65 and Zimbabwe 39.11. They are mostly the lowest scorers among all the selected countries for the current study. Resource is the first component of WPI. Ethiopia scored 6.86, Kenya 0.52, Malawi 1.18, Mali 8.76, Mozambique 10.78, Nigeria 1.98, Sudan 3.43 and Zimbabwe 1.53 in resource. These scores represent that these countries are geographically disadvantaged in water resources. In resource, Ethiopia scored 6.6, Kenya 4.9, Malawi 6.4, Mali 9.8, Mozambique 10, Nigeria 7.4, Sudan 7.9 and Zimbabwe 6.1 in the year 2002 in the study by Lawrence et al, (2002). Though factors like time period, considered number of countries and variables are different for the two studies, it can also be assumed that water resources in the African states have been shrinking rapidly due to rapid consumption, misuse, pollution, climate change and water related politics.

4.3 Comeprative Analysis of WPI from 2014 to 2018

The calculated WPI for 2018 falls with a range of 52.88 to 23.58. Vietnam is the highest scorer and Ethiopia is the lowest scorer. Bangladesh scores 39.77. Comparing WPI scores of 2014 with the scores of 2018, it is observed that the overall situation has been deteriorating. The WPI scores of Bangladesh, Indonesia, Nepal and Zimbabwe has declined significantly than other countries. Within 4 years, the scores lower from 47.18 to 39.77 for Bangladesh, 60.02 to 50.87 for Indonesia, 48.53 to 41.49 for Nepal and 41.19 to 34.63 for Zimbabwe. Here, Sri Lanka is an extraordinary example that maintains its score upward from 46.68 to 48.17 for their efficient water management policy. Other African countries, such as Sudan, Nigeria, Mali to lose WPI scores due to lack of managing their water resources. Figure 3 shows a comparative scenario of WPI scores shifting from 2014 to 2018.

Fig: 3 Comparative deviations of overall WPI scores from 2014 to 2018

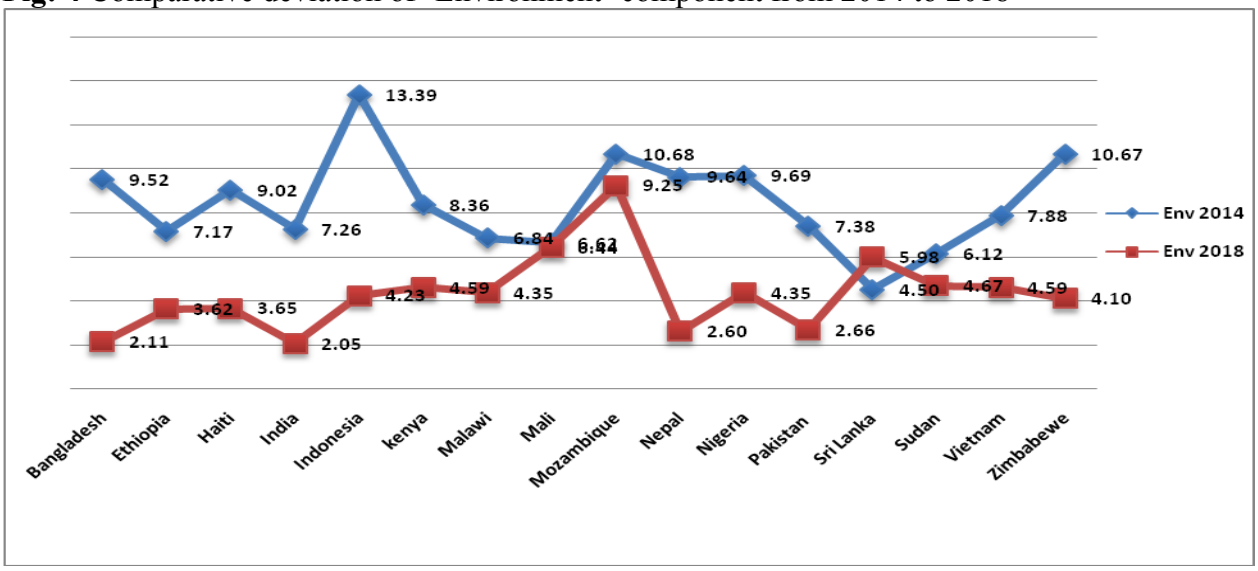


Source: Author's estimation

The study tried to look at the underlying causes of this score deviation and found that the selected countries scored very poor in 'Environment' component. The 'Environment' component consists of five sub components namely 'water quality', 'water stress', 'environmental regulation and management', 'informational capacity' and 'biodiversity based on threatened species'. A low score in 'Environment' component implies that the country has less capacity to control water pollution and to maintain biodiversity through environmental regulation.

Figure 4 shows a comparative picture of 'Environment' component from 2014 to 2018. Bangladesh scores 9.52 in 2014 and 2.11 in 2018. Indonesia scores 13.39 in 2014 and 4.23 in 2018. Zimbabwe scores 10.67 in 2014 and 4.10 in 2018. In spite of straggling with low water resource, domestic wars and other socio economic issues, Mozambique, Mali and Sudan scored better in 2018 than other countries. South Asian countries such as Bangladesh, India, Nepal and Pakistan are the lowest scorer consecutively 2.11, 2.05, 2.60 and 2.66 in 2018.

Fig: 4 Comparative deviation of 'Environment' component from 2014 to 2018



Source: Author's estimation

4.4 Climate Change leads to Livelihood Vulnerability

It has been claimed that there is a direct link between climate change and water poverty. The process of climate change may change the pattern of rainfall, quantity of run-off, and accelerate the rise of sea-level. As a result, access to water could be more uncertain by the process of on-going climate change. Impacts of climate change are thought to be multidimensional and multi-sectoral in nature. Observations and expected impacts of climate change on water demand and supply are discussed in the following section.

4.4.1 Observed Impacts

The fresh water flows have already been shrinking due to the process of climate change. The cycle of precipitation and evaporation has altered due to climate change and as a result, the level of precipitation has changed in recent years. People of South Asian countries like Pakistan, India, Indonesia and 25 percent people of African countries have already observed shortage of fresh water resource as precipitation is the main source of fresh water (Bates *et al,* Eds., 2008).

Another observed impact of climate change is sea level rise. Coastal countries like Bangladesh have already faced the impact of sea level rising. Increasing frequency of flood, tidal surge, and cyclone has responsible for salinization of water and shorten the source of fresh water in Bangladesh, India, Indonesia, and Haiti.

4.4.2 Expected impacts

Water flow of rivers is expected to be decreased by 15 percent in Asia. The frequency of flood is expected to increase in Asian and for the Sub-Saharan African countries. Salinity intrusion may increase up to 20 kilometers into the inland. By 2020, the number of water stressed people would also increase from 122 million to 1.2 billion in Asia and South Asia (Arnell, 2004). Per capita water availability is expected to decrease up to 680 cubic meters per year in India by 2050. By 2020, water supply in South African countries like Mozambique and Zimbabwe is expected to be reduced by 0.32 per cent per year and water demand is expected to increase by 0.6 per cent due to climate change (New, 2002).

4.5 Climate Change induced Water Shortage on Agriculture and Rural Livelihoods

When fresh-water flow is reduced, it hampers agricultural activities and life and livelihoods of a vast majority of the people in a country where a large percentage of its people live on agriculture

and rural activities. Thus, with climate change, agriculture, fisheries and livestock may be hampered due to water scarcity.

4.5.1 Observed Impacts

Water is directly related to agricultural productivity and about 85 per cent water is required for agriculture. As high as 68 percent of the South Asian people still live in rural areas and their primary occupation is agriculture. Production of rice, wheat, maize supposed to be decreased and in certain cases is already decreasing due to increase of water stress and temperature in many areas of the region (Agarwal *et al,* 2000). At least 10 per cent irrigation demand is expected to increase due to the rise in temperature by 1 degree Celsius (Fischer *et al,* 2002). This implies that with climate change, agriculture and other rural activities would directly be affected and the most vulnerable segment of the people would also be affected from climate change and water stress.

4.5.2 Expected Impacts

The average contribution of agriculture to GDP for the selected countries is estimated to be 26 per cent and an average 57 per cent of the people of these selected countries are engaged in agricultural activities (Annex Table 1). It implies that these developing and populous countries in the coming years may come under serious difficulties in their drives towards economic growth, development and to maintain a standard of living that they are aspiring to establish for the vast majority of their people who are either below the poverty line or have limited income**.**

5. CONCLUSION AND RECOMMENDATIONS

Water is important for human use and to ensure the country's food security and other sectorial uses like for agriculture and industry, the importance for maintaining a country's economy, ecology and social progress. Many countries in the world either have much water resources available, but do not have the capacity to use them properly despite its high demand. Similarly, there are countries which have limited stock and still enabled them to ensure a higher water use through efficient management of their stocks. In between there are countries that either do not have the luxury of misusing their water resources because of poor stock of water or are not technically or resource-use capable to tap the maximum benefits from their water resources. Most of the water vulnerable developing countries are also found to be vulnerable to global warming-led climate change which would hinder their economic progress. It is important to understand, assess and evaluate their water resource availability, capacity in using them properly and level of threats in the form of water pollution.

5.1 Findings of the Study

(a) Among the selected climatically vulnerable and water poor developing countries, some countries such as Sundan, Haiti, and Ethiopia are expected to face extremely difficult water stress in the years to come when climatic impacts will be accelerated;

(b) Considering most of these climatic and water vulnerable countries are economically weak in addressing these concerns, they should initiate appropritae adaptation and efficent management measures, the impacts are expected to be quite clear;

(c) Among the listed countries, where it is found that even after having quite good amount of water resources, their 'capacity' to use them efficiently are poor. This indicates that if the required capacity is not strengthened these countries may face severe water crisis;

(d) Capacity building for effective water use is equally important because good capacity helps to make the 'access' and 'environment' scores to push up into a higher level, even if a country has a relatively low score in'resource'.

(e) Low values of 'enviroment' component for most of the selected countries, except for Indonesia, in their WPIs indicates that these countries do hardly bother about maintaining an environmental quality of available water resources, which makes quality of the already stressed water resources in these countries worse. This indicates that there is a need for initiating a widespread awareness building initiative and States should consider investing higher amount of resources for the management of water resources in these countries as their growth and development and human well-being depend much on better water management in the face of climate change.

5.2 Policy Inputs

Even though the countries considered for the present study are not homogeneous in nature, in certain cases they face similar types of threats from climate change against a dwelding water management structure of their respective sector, which may adversely affect the poorest quarter of the people living in these countries. Thus, a number of policy interventions at home and by the international communities are suggested here. These measures may help them to face the wrath of global warming-led climate change in a more prepared manner:

Formulation of efficient water management policies/amendment in existing water management policies: This may help these countries to develop overall water management capacities to deal with anticipated water crisis due to climate change.

Development of sectoral water use guidelines: This may help in better water use and check water pollution and water being misused.

Capacity development for surface water use: Surface water use efficiency is another key area, which needs to be given high attention.

More investment in water resource management: Most of the states considered for the study should divert more resources for developing water management capacities in a more regorous manner.

International funds for water management and emphasis on solution of transboundary water conflicts: An important area of intervention by international communities is in the form of extending resources and technologies to these countries as climate funds and ensure quicker solution for water conflicts through international arbitrations.

REFERENCES

Agarwal, P. K. et al. (2000) Analysis of yield trends of the rice–wheat system in north-western India. *Outlook on agriculture*, vol. 29(4), pp.259–268.

Amarasinghe, U. A., Mutuwatta, L., and Sakthivadivel, R. (1999) Water scarcity variations within a country: a case study of Sri Lanka, *International Water Management Institute* Research Report 32.

EPI (2014) Environmental Performance Index. Yale University, USA. www.epi.yale.edu/epi

Esray, et al. (1991) Effects of improved water supply and sanitation on ascariasis, diarrhea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma.*World Health Organization.*http://www.ncbi.nlm.nih.gov/pmc/articles/PMC23.

Falkenmark, M., Lundqvist, J., and Widstrand, C. (1989) Macro-scale water scarcity requires micro-scale approaches: Aspects of vulnerability in semi-arid development. *Natural Resources Forum,* vol.13(4), pp.258-267.

Fischer, G.H. et al. (2002) Global agro-ecological assessment for agriculture in the 21st century: methodology and Results. International Institute for Applied Systems Analysis. Luxemburg, pp. 119.

Kreft, S. and Eckstein, D. (2014) Global climate risk index 2014: who suffers most from extreme weather events? weather-related loss events in 2012 and 1993 to 2012. http://www.germanwatch.org.

Prudhomme, C. (2002) Assessing the water poverty index in a context of climatic changes, Centre for Ecology and Hydrology at Wallingford (CEH), UK, (Research contract C24).

Salameh, E. (2000) Redefining the water poverty index. *Water Resources Ass.*vol. 25, pp.469–473.

Soussan, J., Vyas Y., and Shalaby, H.R. (2009) *Linking Poverty Reduction and Water Management*, Poverty-Environment Partnership SEI and UNDP.

Sullivan, C. A., Meigh, J. R., and Giacomello, A. M. (2003) The water poverty index: Development and application at the community scale. *Natural Resources Forum,* vol.27(3), pp. 189-199.

Sullivan, C., Meigh, J., and Lawrence, P. (2006) Application of the water poverty index at different scales: a cautionary tale. *Water International*, vol.31(3), pp. 412-426.

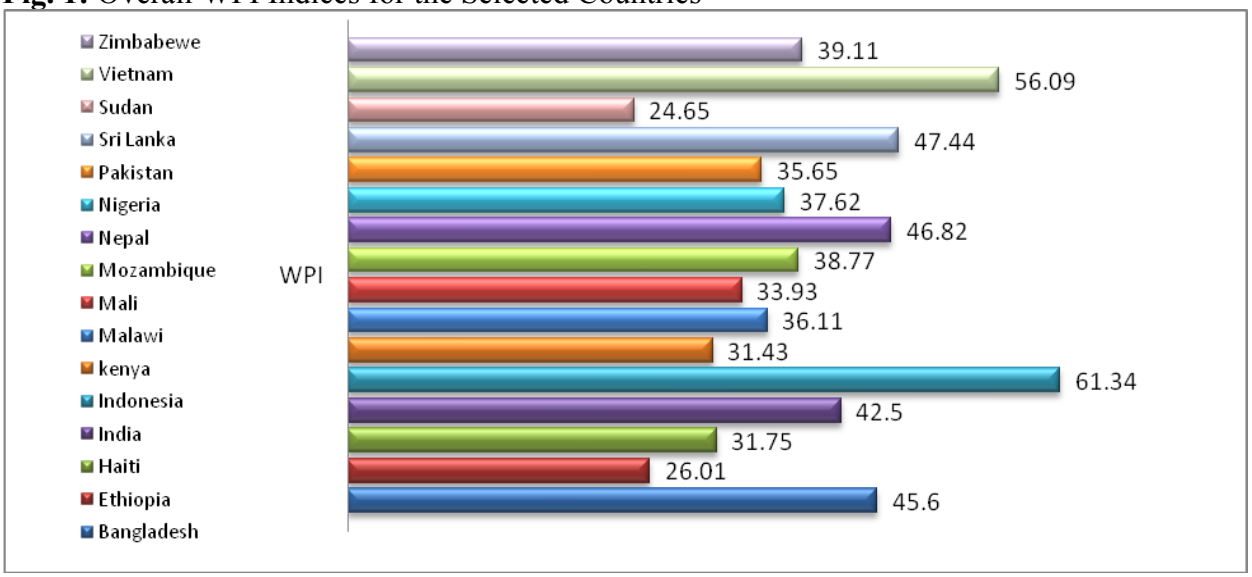
Sullivan, C., Meigh, J., and Lawrence, P. (2010) Perspective: Sudan – land of water and thirst; war and peace. *Circle of blue*

Van der Vyver, C. (2013) Water poverty index calculation: additive or multiplicative function *Journal of South African Business Research,* vol. 2013 (2013), article ID 615770.

World Risk Report (2012) United Nations University Institute for Environment and Human Security (UNU-EHS) Report 435,

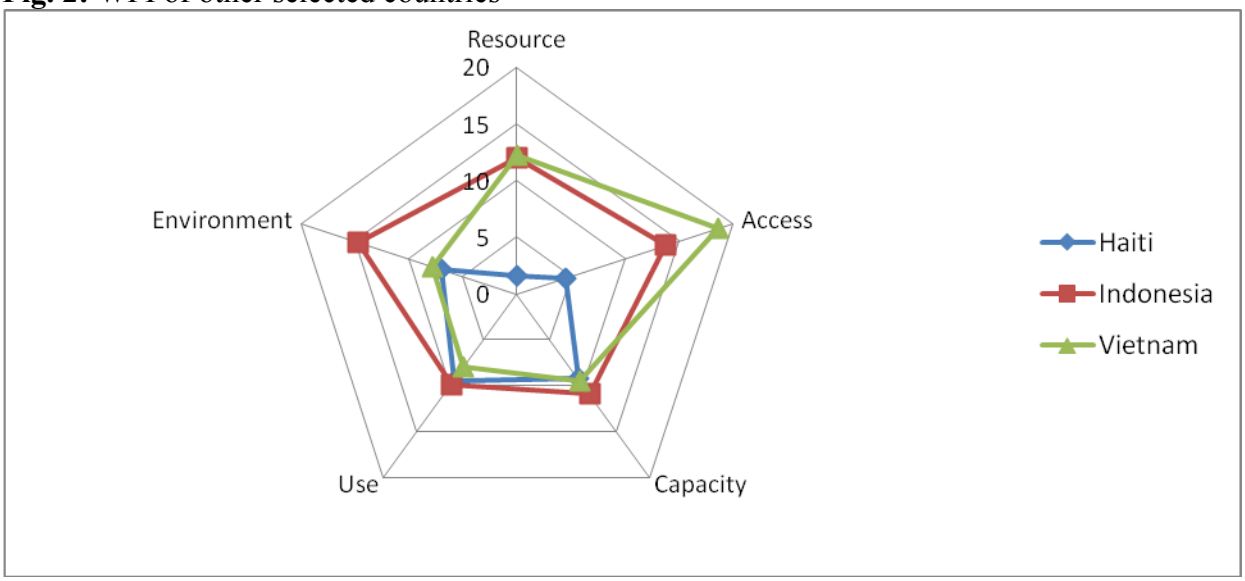
APPENDIX

Fig. 1: Overall WPI Indices for the Selected Countries



Source: Author's estimation

Fig. 2: WPI of other selected countries



Source: Author's estimation

Table 1: Agricultural profile of selected countries

Country	Cultivable land (%) (2012)	Contribution of agriculture sector to GDP (%) (2012)	Population engaged in agriculture (%) (2009)
Bangladesh	70.1	18	48
Ethiopia	36.5	49	79
Haiti	64.2	-	-
India	60.3	18	56
Indonesia	31.2	15	44
Kenya	48.2	30	61
Malawi	60.8	29	-
Mali	34.1	42	66
Mozambique	63.5	30	81
Nepal	28.7	36	66
Nigeria	79.1	22	45
Pakistan	35.1	24	43
Sri Lanka	42.9	11	31
Sudan	47.4	28	-
Vietnam	35.0	20	52
Zimbabwe	41.9	13	65

Source: World Development Indicators, 2014

Table 2: Sub-components of water poverty index

WPI Components	**Sub components of WPI**	**Available Sub components**
Resources	1.Internal freshwater flows 2.External inflows 3.Population	1.Per capita internal fresh water flow 2. Per capita external inflows
Access	1.% Population with access to clean water 2.% Population with access to sanitation 3. % Population with access to irrigation adjusted by per capita water resources	1.% Population with access to clean water 2.% Population with access to sanitation 3. % Rural population with access to improved water sources
Capacity	1. Per capita income (ppp) 2.Under-five mortality rates 3.Education enrolment rates 4.Gini coefficients of income distribution	1. Per capita income (ppp) 2.Under-five mortality rates 3.Education enrolment rates 4.Gini coefficients of income distribution
Use	1.Domestic water use in liters per day 2.Share of water use by industry and agriculture adjusted by the share of GDP	1.% Annual fresh water withdrawal for domestic purpose 2.% Annual fresh water withdrawal for industry purpose 3. %Annual fresh water withdrawal for agriculture purpose
Environment	1.Water quality 2.Water stress (pollution) 3. Environmental regulation and	1. % water pollution 2. % drinking water pollutionEffects of 3. % water pollution on ecosystem

	management 4.Informational capacity 5.Biodiversity based on threatened species	4. GEF benefit index 5. Number of threatened species

Source: Lawrence, *et al.* 2002

Table 3: List of selected countries

Bangladesh	Indonesia	Mozambique	SriLanka
Ethiopia	Kenya	Nepal	Sudan
Haiti	Malawi	Nigeria	Vietnam
India	Mali	Pakistan	Zimbabwe

Source: Global Climate Risk Index, 2014 and World Risk Report, 2012

Table 4: Sources of data

Variables/ indicators of WPI	**Year of data**	**Sources of data**
Resource		
Per capita internal renewable fresh water resource	2011	World Development Indicators, 2014 and 2017
Per capita external renewable water resource	2012	External inflow/ population
Access		
Population with access to clean water	2012	World Development Indicators, 2014 and 2017
Rural population with access to improved water sources	2012	World Development Indicators, 2014 and 2017
Population with access to sanitation	2012	World Development Indicators, 2014 and 2017
Capacity		
Gross domestic product per capita, ppp	2013	World Development Indicators, 2014 and 2017
Children mortality rate	2011	World Development Indicators, 2013
Net school enrolment, primary	2009	World Development Indicators, 2014 and 2017
GINI Index	2010	World Development Indicators, 2014 and 2017
Use		
Annual fresh water withdrawal for domestic purpose	2011	World Development Indicators, 2014 and 2017
Annual fresh water withdrawal for industry purpose	2011	World Development Indicators, 2014 and 2017
Annual fresh water withdrawal for agriculture purpose	2011	World Development Indicators, 2014 and 2017
Environment		
Effects of water pollution on ecosystem	2013	Environmental Performance Index, 2014 and 2017
GEF benefit index	2014	World Development Indicators, 2014

		and 2017
Percentage of water pollution	2014	Nation master, 2014
Percentage of drinking water pollution	2014	Nation master, 2014
Number of threatened species	2013	World Development Indicators, 2014

Source: Author's compilation