Water Stress in Pakistan: Influencing Factors

By

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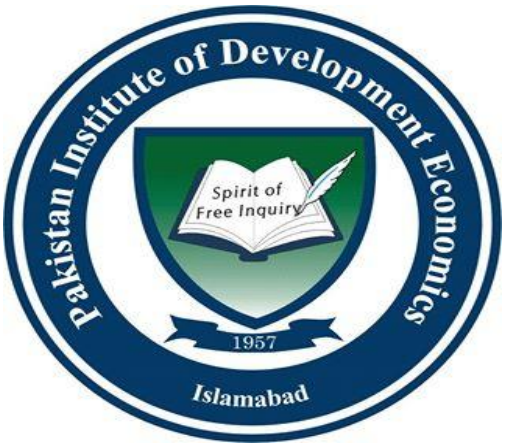
13/MPhil-ENV/PIDE/2015



Department of Environmental Economics,

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Water Stress in Pakistan: Influencing Factors

A thesis submitted to Pakistan Institute of Development Economics Islamabad, Pakistan in partial fulfillment of the requirements for the degree of Master of Philosophy in Environmental Economics.

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Dedicated to My Beloved Parents

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List of Abbreviations

GDP= Gross domestic product

WSI= Water stress index

LCU= Local currency unit

TWW= Total water withdrawals

OLS= Ordinary least square

POP= Population

TEMP= Temperature

RF= Rainfall

TA= Total area

INDV= Industrial Development

ABSTRACT

This study is investigating the impact of various influencing factors on water stress during the time period from 1980-2014. In order to analyze this impact the study employed time series econometrics technique namely ordinary least square method (OLS). Water stress index has represented by per capita water availability indicator. The results clearly demonstrate that population, GDP per capita, electricity production, deforestation, total area under cultivation and industrial development have positive and statistically significant impact on water stress in Pakistan. Besides, temperature and rainfall have negative impact on water stress. On the basis of the results of this research it is recommended that deforestation should be banned and area under cultivation should be restricted to produce low water consuming agricultural products. Electricity production should be shifted from thermal to hydel electricity production. There is need to increase storage capacity by the constructions of small dams and reservoirs to absorb water.

CHAPTER 1

INTRODUCTION

1.1 Background and Statement of Problem

Water is most important natural resource for human being as well as for ecosystem functioning. The total volume of water on earth represents in three forms like liquid, solid and vapor. Fresh water availability has been declared as global issue because climate change and economic developments are affecting quantity and quality of water resources. Now a days Fresh water is scarce resource because it is only 2.5% of total volume of water whereas on earth total volume of water is about 1400 million km^3. In total volume of fresh water, less than 1% exists in earth liquid surface fresh water and remaining part represents in ice caps and ground water (UNEP, 2002). In some regions water demand has increased than the water supply. Over the last 50 years water use has tripled because of human activities like using it for domestic, industrial and agricultural purposes. Moreover water scarcity severely reduces biodiversity in both aquatic and terrestrial ecosystem and also threatens human food supply(Pimentel et al., 2004; Postel, Daily, & Ehrlich, 1996).

The world's water resources exists in different forms such as glaciers and ice caps, reservoirs, wetlands, ground water and fresh water lakes. Glaciers and icecaps contain approximately 70% of world's fresh water and it covers 10% of world landmasses (UNEP, 2002). Reservoirs are formed by building physical walls across the river. Basically these are artificial lakes. The predictable amount of water stored in reservoir is 4286 km^3at world level (Groombridge & Jenkins, 1998).

Wetlands contained bogs, marsh, swamps, mires, lagoons and floodplains. These wetlands have total area 2900000km^2 at global level. Groundwater is the most plentiful

and readily accessible reserve of fresh water. It contains more than 90% of the fresh water resource. But pressure on these water resources is increasing day by day mainly due to human activity such as growing population, urbanization, pollution and increased economic activities (UNEP, 2002).

Urbanization puts enlarged pressure on freshwater resources as people become more concentrated in one area which limits freshwater resources through a change in natural landscape to water impermeable land. With the growing population the demand for water has increased in the world due to which ground water is extensively used to supplement the accessible surface water especially in those countries where the major source of drinking water is ground water (Okello, Tomasello, Greggio, Wambiji, & Antonellini, 2015).

The development of water resource crisis may have resulted partially due to climate change and partly due to mismanagement of the water resources by the relevant authorities. A changing climate and proper management of resources in the face of land use requires a reliable knowledge of their availability, recharge and demand. It is widely established that future freshwater availability will be challenged by the combined effects of population growth and climate change (Bukhari & Sayal, 2011).

Global climate change have different impacts on water resources like high ice melting, increased evaporation rates due to rising temperature, earlier and smaller runoff periods, reduced water quality in internal area and coastal areas and rise in sea level(Adams & Peck, 2008).

In Pakistan water is very imperative because Pakistan's economy is agrarian in nature and agriculture sector is contributing 24% share in gross domestic product (GDP) of Pakistan(Statistics, 2017). As agriculture sector is main consumer of water in Pakistan so

sustainability of agriculture depends on sufficient supply of water. Agriculture is using 95% water and remaining two sectors industry and household is using 2% and 3% respectively (Hussain & Mumtaz, 2014). According to Pakistan's national water resource strategy agriculture, domestic and industry sector is using 100MAF (million acre feet per year), 4.5MAF, and 3.5MAF of the total amount of water respectively. It has projected that till 2025 agriculture, domestic and industry sectors will use 122MAF, 10.5MAF and 4.8MAF respectively (paper, 2003).

Once a Pakistan was water surplus country with the huge water resources but now it is listed in water stressed countries and it is near to chronic conditions of water stress (Kahlown & Majeed, 2003). It is at 31st number in the list of water scarce countries with water stress index of 4.1 (WRI, 2015). At current situation in Pakistan the per capita water availability has decreased to 1032 cubic meter from 5260 cubic meter in 1995.(wasif, 2017). Pakistan's water resources are surface water, ground water and rain fall. Water resources are affecting with the rising factors such as population growth, economic development, technological development and climatic variations. According to FAO from 1961 t0 2002, 17% of food supplies per capita have declined due to increase in population and shortages of fresh water. Growing population and industrialization have put burden on water demand and use due to which the gap between demand and supply of water has increased (Kahlown & Majeed, 2003).

In Pakistan water supply systems are based on two sources of water either by the utilization of the surface water or ground water withdrawals through tube wells or pumping systems. In urban areas drinking water needs mostly depend on surface water whereas in Rural areas depend on ground water for domestic use or for household water supply where ever available. In irrigated areas, canal water and saline ground water are used to satisfy domestic requirements. If ground water is not available in any area then for

agricultural purposes water used from available stream flows in the highland areas or on rainfall (NARC, 2001).

Surface temperature of Pakistan is rising and it has linear trend since the period of 1947. Rising temperature will affect rainfall and runoff. Rainfall is one of the most significant sources of water for Pakistan but the intensity of rainfall is decreasing continuously especially in the areas of Punjab and Sindh. Summer monsoon season is the major rainfall season of Pakistan. Pattern of rain has changed now; sometime there is occurrence of flood in one part of the region and in other part there is drought. A major portion of rainfall flows into rivers and sea without serving any use or floods the areas due to low storage capacity of dams and reservoirs (Bukhari & Sayal, 2011; Kahlown & Majeed, 2003).

Global warming is also enhancing glaciers melting process. The upper Indus glacier covers about 2250 km^2 and it is major source of river runoff in summer. Approximately 80% of the Indus river flow supply form ice and snow melt from glacial area of Indus catchment in summer(Khan, Ullah, & Muhammad, 2002). The rate of ice and snow melting from glacier has increased since 1990s due to warming climate. The impact of warming climate on rainfall and glacier melting is pressurizing water resources and creating water stress in Pakistan (Bukhari & Sayal, 2011).

The government of Pakistan warned that water storage problem will become more severe in future. The total water storage in river system is inadequate and it will reduce the overall capacity of the system to supply water unless some urgent measures are taken. The storage capacity of present dams is diminishing at the rate of 0.18 billion cubic meters per year which is reducing 20% storage for irrigation system. Moreover population is rising so water resources of 0.62 billion cubic meters are required to extend the irrigated area to fulfill the needs of food for growing population(Piracha & Majeed,

2011). Pakistan has three major reservoirs namely, Mangla, Chashma and Tarbela and storage capacity of these reservoirs is decreasing due to sedimentation. By the end of the year 2010 it has decreased almost 40% (Kahlown & Majeed, 2003).

1.2 Significance of the study

As Pakistan is agricultural country and because of agricultural dependency on water it is important to know the status of water and analyze the factors that are affecting water resources in country. Water resources are depleting in Pakistan that's why this study is focusing on factors that are affecting water resources in Pakistan. Much of the studies have been conducted on water pollution and other dimensions of water like (water resource situation, water crisis related to Indus water treaty, water use in agriculture sector, issues of water, water pollution)[1] in Pakistan but no research has been conducted on factors affecting water stress in Pakistan earlier. It is important to investigate the factors making Pakistan water stress, So this study will empirically investigate the impact of climate change and other influencing factors of water stress covering the time period from 1980-2014 in Pakistan.

1.3 Research Question

1. How much climatic and non climatic factors impact water stress in Pakistan?
2. Is Pakistan becoming more stressed in terms of water availability?

1.4 Objectives of the Study

This study will be conducted to:

1. Estimate trends in water stress, water availability and other water related variables in Pakistan.
2. Estimate impact of various influencing factors on water stress in Pakistan.

[1](Iqbal, 2010), (Kahlown & Majeed, 2003), (Piracha & Majeed, 2011), (Azizullah, Khattak, Richter, & Häder, 2011)

1.5 Organization of the study

Study is divided into 5 chapters. Introduction has been presented in chapter 1. Chapter 2 provides detailed literature on water stress. Chapter 3 provides information about data sources and methodology while results and discussions are presented in chapter 4. Conclusion and recommendations are presented in chapter 5.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Water is very important for productive environment for the population, animals and plants and for maintaining adequate food supply. With the rising population and economic activities water availability has become a global issue (Pimentel et al., 2004). According to UN comprehensive assessment water resources are depleting because the withdrawing of water is more than 20% of the available water resources (Arnell, 2004).

Water is very essential for many sectors of the economy mainly for agriculture sector and also important for human survival and well being. Water resources are not distributed regularly in space and time and human activities put a pressure on water resources, whereas information on quality and quantity of water availability is still required (UN report 2). Almost 85% of fresh water resources are used by agriculture sector around the globe. There are many factors which contribute to increased demand for water like population growth, urbanization, technological development and economic development.

In this chapter studies on the influencing factors of water resources are reviewed. This section is divided into three sub sections. 2.2 review studies on calculations of water stress. 2.3 section include studies reviews on environmental factors affecting water resources while studies on economic factors affecting water resources are presented in section2.4

2.2 Reviews of Studies on Calculation of Water Stress

Water stress can be defined as it is an indicator for measuring intensity of pressure put on water resources and aquatic ecosystem caused by climate change and external drivers of change. Water stress can be computed by three indicators: annual withdrawals to availability ratio, consumption to Q90 ratio, per capita water availability(Alcamo, Flörke, & Märker, 2007). The most widely used measure of water stress is the Falkenmark indicator. It is defined as "*fraction of total annual runoff available for human use*". This is generally expressed in terms of annual per capita water availability on country scale where data is available(Brown & Matlock, 2011). In 1989 Falkenmark purposed some water barrier differentiation. According to that if person per capita water availability is more than $1700m^3$ then there is no water stress. But if per capita water availability is lies between $1000m^3$ to $1700m^3$ then person will consider under water stress.

Another most used indicator of water stress is the water withdrawals to availability ratio which is developed by (Smakhtin & 2005). It recognizes the important parameter of available freshwater is an environmental water requirements. He used mean annual runoff (MAR) as a proxy for water availability and global annual water withdrawals data from FAO. Then author applied this indicator in their water resource assessment analysis.

2.3 Environmental Factors

According to literature several factors affect the water stress but the climate change is playing critical role in affecting water resources worldwide. Moreover globally climate change has serious allegation for water resources including rising temperature, increasing evaporation rate and precipitation with the higher proportion of rain rather than snow. Rising temperature has increased proportion of precipitation received as rain in winter

with the declined proportion of snow. Due to which river flow has declined in summer (Adams & Peck, 2008).

Shilong Piao and YuecunMa1 (2010) have investigated the impact of climate change on water resources and on agriculture in China. They have found regional warming has increased the glacier river runoff and extended the length of potential growing season for crops. They believed warming is beneficial for irrigated crops and harmful for rain fed crops in China. Water resources in yellow river region have decreased because of rising temperature which in turn is increasing the evapotranspiration. There is need to cope up with the problem of climate change before it reaches to threshold level and affect water and other economic activities negatively. Another study has done byChang et al. (2007) on the influencing factors of water resources in the region of yellow river in China because northeastern part of china is facing warming conditions and reduction in rainfall. The researcher has used meteorological variable such as precipitation, evaporation and temperature. By using water balance model for assessing impact of these variables on water resources of yellow river region the researcher reaches to conclusion that rise of temperature has great impact on ice and snow melting and increased evaporation rate which in turn decrease discharge of water. They have also found that almost 70% of water discharge reduction resulted from climate change.

In some parts of the world climate change increases water resource stresses where runoff decreases and in other parts of the world runoff increases but this will not be beneficial in practice because extra water will be available in wet season not in dry season. Almost 1400 million people had lived in water stressed countries since 1995. Arnell (2004) has conducted study to estimate the impact of climate change and population growth on global and regional water resource. The researcher has used macro-scale hydrological model and general circulation model to estimate current and future water availability at

spatial resolution of 0.5 X 0.5^{o}. He has found that over the next 25 years climate change would have less effect on water resource stress than population growth and by 2025 from 2.9 to 3.3 billion people would live in water stressed watersheds.

From 1950s it has recorded that atmospheric carbon dioxide (CO_2) levels are increasing continuously and this phenomenon is changing global and local climate characteristics such as water resources and temperature. Due to co_2 emissions and other green house gases generation global temperature is rising. It has predicted that in Taiwan 0.13^{0}c temperature per year is increasing that's why pao-shan yu (2002) in Taiwan has analyzed the impact of climate change on water resources. The historical trends of meteorological variables such as temperature and precipitation on daily and monthly basis were detected. Trends of these variables then employed to generate future climatic conditions. The results have explained that daily precipitation significantly influence the precipitation generation and for future climatic conditions the generated runoff will increase during wet season and decline during dry season.

Pakistan is now becoming water stressed country because of its depleting water resources. Global warming is affecting water resources of Pakistan and it impacts the behavior of rainfall, glaciers and green house gas emissions. Hussain and Mumtaz (2014) have analyzed the impact of climate change on water resources of Pakistan. They have explained that per capita water availability has declined from $5140m^3$ to $1000m^3$ in 1950. According to water scarcity index it is moving towards water scarce country. Similarly another study has conducted by Bukhari and Sayal (2011) for analyzing climatic impact on water crisis. They have reviewed different studies and found that crisis of water resources are due to climate change and mismanagement of water resources by the concerned authorities. Rising temperature is causing depletion of ozone layer in different regions of the world which in turn would cause severe drought in the hotter areas of

Pakistan. Himalayan mountain glaciers are melting which would reduce river flow in long term period.

Once Pakistan was water surplus country but now it is water stressed country. Pakistan's water resources consist on flows of Indus River and on other 3 rivers such as Ravi, Jhelum and Sutlej. Now water resources has exploited by the increase in public and private tube wells. In order to know water resource situation in Pakistan (Kahlown & Majeed, 2003) has done study and purposed strategies to cope with situation. They have done review of past stock and provide strategies which include short term, medium term and long term strategies. They have suggested that change cropping patterns; install tube wells in technically feasible area, construction of water storage sites and forecasting about floods and droughts. Global warming is very serious issue and it is affecting water resources of the whole world. (Ahmed, 2004) has investigated the global climate change and its effect on water resource of Pakistan. They have mentioned some reasons of global warming which include variation of solar output and green house effect. Green house gases are releasing because of anthropogenic activities and from fossil fuel burnings and forest destruction. Researcher has explained that due to rising temperature the rainfall intensity has changed, sea level has raised and snow cover is melting in Pakistan.

2.4 Economic Factors

Around the world climatic factors are reducing the availability of water resources. There are some socio economic factors which are increasing pressure on water resources including, population growth, living standard, urbanization, technological change and other driving forces. Menzel, Flörke, Matovelle, and Alcamo (2007) have applied water gap model to analyze the combined impact of climate change and socio economic factors on water resources. They have applied total four scenarios the IPCC A2 and B2 scenarios

and strength and techno garden scenario from the millennium ecosystem assessment. They have done projections related to future distribution of water resources and water stress. The results show that impact of population, water use efficiency, and other factors cannot be ignored with the climate change. The socio economic development such as population growth has high significant impact on water resource stress as a result of increasing water withdrawals. Projections have shown that the impact of climate change is less important than other economic factors on water stress. Similarly another study has done by Alcamo et al. (2007) to examine the impact of socio economic and climatic factors on future long term changes in water resources by using same scenarios and models. This research has extended the work by incorporating the more economic variables. Results showed that water stress will increase over 62-75.8% till 2050s and decrease over 19.7-29% in some areas. The reason of decreasing and increasing water stress is availability of water due to increased precipitation and growing water withdrawals respectively. The reason of this growing water withdrawal is the income growth and population growth is less important factor than the income growth. The results have shown that although population has direct impact on increased water consumption but income has been found as important factor which will increase per capita water use.

However another study has conducted to find the impact of climate change and socio economic factors that influence water availability and water demand with in Europe. It also has provided impact of social economic variables on water resources but he explained there should be more focus on policy and legislation to reduce the future impact of climate change and other driving forces on water resources. Household should adopt some strategies to cope up with the issue of water scarcity and water availability. Agriculture sector should use water efficient technologies. The output from these policies

should make a significant contribution in assessing future impact of climatic and anthropogenic activities on water resources (Houghton-Carr, Fry, & Farquharson, 2008).

Demand for fresh water will increase with the increase in population and other economic activities. It is most widely used natural resource. Urbanization process is also linked with water use changes. Therefore Okello et al. (2015) has investigated the specifically influence of population and urbanization on freshwater resources in Kenya. They have applied LAPSSET project and no industrial development model. The results have shown population will increase more than 1.25 million people by 2050. With the increase in population the total demand for water will increase whether per capita demand for water increase or not. According to this study it has expected people move from rural to urban areas so urban population have higher demand for water. Both model suggested that population growth has more significant impact in effecting water availability than climate change. Similarly another study by Srinivasan, Seto, Emerson, and Gorelick (2013) has hold for investigating the relationship between urbanization and water vulnerability in Chennai, India. The researchers have applied coupled human environment systems modeling approach. Several factors are responsible for urban vulnerability to water shortages such as water infrastructure, land use changes, adaptation and type of ground and surface water system. The results have suggested that there should be new forms of governance and planning institutions that are capable for managing millions of households. Urban water demand is increasing because of urbanization and it also creating vulnerability to water stress and impacting carbon emissions and energy use. Urbanization is very serious issue almost everywhere in the world people are moving from rural to urban areas. Therefore Jiang, Wu, Liu, and Deng (2014) investigated the impact of urbanization and industrial transformation on water resources in China. They have used multi regional computable general equilibrium model and the enormous

regional model. They have selected nine water shed regions for future water scenarios. The results of this study have shown that competition for water between industrial sectors will increase and opportunity cost of water will also rise. With the growing urbanization and industrial transformation the demand for water will increase and it will reduce the amount of water allocated to agriculture sector.

Deforestation is increasing in whole world and has impact on water pattern. It is reducing absorbing capacity of water and rain continues to fall with the increase in cutting of trees. Therefore Pereira, Almeida, Martinez, and Rosa (2014) examined the impacts of deforestation on water balance on the Brazilian east coast. They have applied SWAT model and used data from 1997 to 2000. This model has used for simulation of daily flow of watershed. These simulations have shown that deforestation would increase the total runoff generated in the basin and decrease the evapotranspiration. Similarly another study has incorporated by Masese, Raburu, Mwasi, and Etiégni (2012) to investigate the impact of deforestation on water resources in Kenya. They have employed ANOVA on land use or forest cover area from the time period of 1986 to 2009. They have found that deforestation is degrading streams and rivers. They suggested that reforestation can provide better results related to water quality and in enhancing water through rain. Community groups and committees should manage and conserve forests.

In Pakistan the reason of water shortage is a dispute between Pakistan and India on Indus water treaty. Iqbal (2010) has done research on water shortages in Pakistan and crisis around the corner. He highlights the issue of building the chains of dams on the Pakistani rivers and it is severe challenge for Pakistan. He explained that water flows in river Chenab has decreased by the construction of Indian hydropower projects. Indian projects on western rivers reduce water flows to Pakistan and release store water which cause

floods. He suggested that policy maker should managed conflict resolution and make initiatives on capacity building so no sovereign state act on morality.

After reviewing exiting literature it can be considered that Economic and environmental factors have significant impact on water resources. From the literature it is concluded that water stress is increasing and it is just because of increase in population growth, climate change, industrial development and agricultural development. In Pakistan no specific studies focusing on the empirical estimation of the influencing factors of water stress are available therefore this study is bridges this gap. At international level some projections related to impact of climate change and socio economic factors on water stress have been done. They found that Climate change is natural phenomenon but anthropogenic activities are accelerating the impact of climate change. Population growth and urbanization has more impact on water resources than climate change.

CHAPTER THREE

DATA AND METHODOLOGY

This chapter is organized as follows: section 3.1presents the data and sources of data collection, section 3.2 presents construction of variables, section 3.3 presents methodology, section 3.4 presents expected relationship of explanatory variables with the dependent variable based on theory while estimation technique represents in section 3.5

3.1 Data and Sources of Data Collection

This study used annual data on water availability, per capita GDP, population growth, electricity generation, temperature, precipitation, deforestation, total area under cultivation and industrial value added. Dependent variable is water stress which is calculated by using proxy of per capita water availability (dividing water availability with the total population). This study covers the time period from 1980 to 2014. The data on all variables was collected from World Development Indicator, Economic Survey of Pakistan, Agricultural Statistics of Pakistan and Pakistan metrological department. This study is using data of last 35 years but data on storage capacity and reservoirs is not available. That's why this study is going to skip this variable.

Table No 3.1 Data sources and expected relationships

Variables	Units	source	Expected relationship
WSI=water availability/population	Ratio of million acre feet and millions	Agriculture Statistics of Pakistan	
Temperature	Degree Celsius	Mett. Deptt of Pakistan	uncertain
Rainfall	Millimeters		Negative
Population	Millions	World Development Indicator	Positive
GDP per capita	Current LCU	World Development Indicator	Positive
Electricity production	Giga watt per hour	Pakistan Economic Survey	Positive
Area under cultivation	Million hectares	Pakistan Economic Survey	Positive
Deforestation	Million hectares	Pakistan Economic survey	Positive
Industry value added	Current LCU	World Development Indicator	Positive

3.2 Construction of Variables

3.2.1 Calculation of Water Stress Index (Dependent variable)

Water stress can be defined as *"it is an indicator for the intensity of pressure put on water resources and aquatic ecosystems by external drivers of change"*. Water stress also includes the pressure on water resources caused by climate change since climate change can lead to reduce average water availability. So high levels of water stress lead to high constraints to freshwater ecosystems and consequently chronic or acute shortages of water supply may occur (Alcamo et al., 2007).There are three indicators of water stress (WS):

A. Annual withdrawals-to-availability ratio:

"Water withdrawals" are the total annual water withdrawals from surface or groundwater sources within a river basin for various anthropogenic uses. "Water availability" corresponds to annual river discharge, that is, combined surface runoff and groundwater recharge. This indicator has used by (Alcamo et al., 2007; Smakhtin & 2005).

$$WSI = \frac{water\ withdrawals}{total\ water\ availability} \text{.................................(1)}$$

B. The consumption-to-Q90 ratio:

"Consumption" is the average monthly volume of water that is withdrawn, used, evaporated and not directly available for downstream users and "Q90" is a measure of the monthly river discharge that occurs under dry conditions.

C. The per capita water availability:

It is calculated by dividing water availability with the population.

$$WSI = \frac{annaul\ water\ availability}{total\ population} \text{...................(2)}$$

This indicators has used by (Arnell, 2004; Menzel et al., 2007).

This study will use per capita water availability because the required data on water withdrawals for Pakistan is not available.

3.2.2 Climatic and Non Climatic Independent Variables

Temperature and rainfall are important climatic independent variables. Whereas population, GDP per capita, deforestation, electricity production, total area under cultivation and industrial value added are non climatic independent variables. Industrial

value added has used for industrial development. Deforestation is calculated by applying ratio of deforested rate on forest area. Data on temperature and rainfall have collected from metrological department.

3.3 Methodology

Many studies have conducted to explore the impact of socio economic and climatic factors on water resources such as Menzel et al. (2007), Alcamo, Florke and Marker (2007) and Houghton et al. (2008). According to these studies, socio economic factors and climatic factors affect water resources significantly. Gouging (2007) explained that because of global warming temperature is rising and it resulted in increase of evaporation and the decrease of discharge, which has great effect on ice-snow melting. For the purpose of analyzing the effect of influencing factors of water stress in Pakistan, this study specified the following model.

$$\ln WSI_t=\beta_0+\beta_1 \ln TEMP_t+\beta_2 \ln RF_t+\beta_3 \ln POP_t+\beta_4 \ln GDPC_t+\beta_5 \ln EP_t+\beta_6 \ln DEF+\beta_7 \ln TA_t$$

$$+\beta_8 \ln INDV+\mu t \text{……..(3)}$$

Where:

ln= Natural Log

WSI= water stress index

This is represented by using per capita water availability

TEMP= Temperature in degree celsius

RF= Rainfall in mm

POP= Population in millions

GDPC= Per capita gross domestic product at current LCU

EP= Electricity production (Thermal) in Giga watt per Hour

DEF= Deforestation (area deforested in million hectares)

It is calculated by applying deforestation rate on forest area.[2]

TA= Total area under cultivation (million hectares)

INDV= Industrial value added (current LCU)

μ_t =error terms

t= 1, 2, 3….., 35

β_0= Intercept term

β_1.....β_8 = Slope terms

Then OLS estimation of log-log model suffered from autocorrelation problem (results attached as appendix). So Durbin two step methods have been used for solving problem of autocorrelation from the following model. At first step the subsequent model has estimated to find out the value of ρ^ (i.e coefficient of $WS_{-1,}$ which is $\beta_1$here).

$$lnWSI= \beta_0+\beta_1 lnWS_{-1} + \beta_2 lnTEMP+\beta_3 lnTEMP_{-1}+\beta_4 lnRF+\beta_5 lnRF_{-1}+\beta_6 lnPOP+$$

$$\beta_7 lnPOP_{-1}+\beta_8 lnGDPC+\beta_9 lnGDPC_{-1}+\beta_{10} lnEP+\beta_{11} lnEP_{-1}+\beta_{12} lnDEF+\beta_{13} lnDEF_{-1}+$$

$$\beta_{13} lnTA+\beta_{14} lnTA_{-1}+ \beta_{15} lnINDV + \beta_{16} lnINDV_{-1} +\mu t \ldots\ldots\ldots\ldots (4)$$

At second step, the following model has regressed.

$$WSI^*=\beta_0+\beta_1 TEMP^*+\beta_2 RF^*+\beta_3 POP^*+\beta_4 GDPC^*+\beta_5 EP^*+\beta_6 DEF^*+\beta_7 TA^*+\beta_8 INDV^*$$

[2]According to Agriculture Statistics of Pakistan the deforestation rate in 1990, 2000 and 2011 are 1.63%, 1.91% and 2.55% respectively. The average of these deforestation rates is 2.03% and by applying this average the series of deforested area has calculated.

+μt……..(5)

Where:

WSI* = lnWSI - ρ^ $lnWSI_{-1}$

TEMP* = lnTEMP- ρ^$lnTEMP_{-1}$

RF* = lnRF*- ρ^$lnRF_{-1}$

POP* = lnPOP- ρ^$lnPOP_{-1}$

GDPC* = lnGDPC- ρ^$lnGDPC_{-1}$

EP* = lnEP- ρ^$lnEP_{-1}$

DEF* = lnDEF- ρ^$lnDEF_{-1}$

TA* = lnTA- ρ^$lnTA_{-1}$

.INDV*=lnINDV- ρ^$lnINDV_{-1}$

3.4 Theoretical Justification of Variables:

The expected relationship between dependent and explanatory variables mentioned in the above model is presented as follows:

3.4.1 Temperature

Under environmental factors temperature is very important factors. With the passage of time temperature is rising and expected to increase water stress. Many studies have proved negative relation of temperature with the water stress (Guogang et al. 2007; Alcamo et al. 2007). If temperature raises resultantly it will increase evaporation and decrease discharge supply. The summer discharge is more sensitive to temperature. Global warming will put a pressure on water resources by decreasing water availability.

While some studies have proved that climate change or global warming is a major cause of decreasing water stress which has great effect on ice and snow melting. Snow melting will increase river runoff in wet season but it will not provide enough water in dry season. It is only beneficial in wet season (Arnell, 2004; Menzel et al. 2007; Adams and Peck, 2008).

3.4.2 Precipitation

Increased precipitation is the principal cause of decreasing water stress by providing greater amount of water. The increase in annual water availability is a positive development for water shed areas. Increased precipitation has a significant and persistent influence on discharge of water so the expected relationship between precipitation and water stress is negative (Alcamo et al. 2007).

3.4.3 Population growth

Population growth is an important factor for increasing water stress and it is expected that with the growing population, water stress will increase. The magnitude of water use in the domestic sector will clearly demonstrate by the number of future water users. Population growth will limit the per capita water availability and water demand will intensify because of an increase in per capita water consumption. In future Population growth will play direct role in increasing the number of water consumers. It will increase water stress by increasing water withdrawals so there is positive association between population and water stress (Okello et al. 2015; Vorosmarty, 2000; Alcamo, 2007).

3.4.4 GDP per capita/Income

Other than population growth water demand is also expected to be influenced by economic development. From historical trends it has been observed that water use tends to increase as a country becomes wealthier. Change in income is an important driving

force of future water use. With the increasing income per capita water use in the domestic sector will increase and it will increase water stress (Vorosmarty, 2000; Alcamo, 2007). So it is expected that GDP per capita affect water stress indicator positively.

3.4.5 Electricity production (Thermal)

Increasing water stress is mainly caused by increasing water withdrawals and the most important factor for this increase is the growth of domestic water use, followed by increasing water use for industry and agriculture sector. In industry for electricity production water is needed. So it is expected that electricity will influence water stress positively. The volume of water needed for thermal power plants is dependent on their electricity production. Thermal power plant is major user of water than coal power plant (Menzel et al. (2007); Houghton, 2008).

3.4.6 Total area under cultivation

Population of Pakistan is growing rapidly so the demand for food is also increasing which require more land to be cultivated; for this purpose farmer cultivate all the existing pieces of land including the slopes. In Pakistan almost 80% land is cultivated through the irrigation system. Surface and ground water mostly used in irrigation system which is limiting water resources. So there is positive association between total area under cultivation and water stress (Baig, Shahid, & Straquadine, 2013).

3.4.7 Deforestation

Cutting vast areas of trees will have an impact on water patterns. The forest follows a hydraulic cycle by absorbing the water when it rains and releasing it by evapotranspiration. With deforestation, the hydraulic regulation is destroyed and reduces the absorption capacity. Therefore rain continues to fall just as much after the trees are cut. So there is positive association between deforestation and water stress (Pereira et al., 2014).

3.4.7 Industrial Development

Industrial development has increased share of water consumed by industrial sector. Industry demands water for the production of final goods, cooling, washing and for transportation; it depends on the process of manufacturing. The required volume of water is different for different branch of industry and it is also different with in the production process. With the growth of the industrial water use, the amount of water allocated to other sectors has declined and it also has increased competition between industrial sectors. The growing water demand by the industrial development is pressurizing water resources and creating water stress in Pakistan; so there is positive relationship between industrial development and water stress(Jiang et al., 2014; Shiklomanov, 1998).For capturing the impact of industrial development on water stress the data on industrial value added has used.

3.5 Estimation Technique

In order to examine the impact of various influencing factors on water stress Ordinary least square method (OLS) has used. There are some assumptions that must hold to applying OLS method. These assumptions include no presence of autocorrelation, homoscedasticity and multicollinearity among the independent variables(Gujarati, 2009). There are detections test to check these assumption such as Durbin Watson for autocorrelation, Breusch Pagan Godfrey for heteroscedasticity and correlation matrix for multicollinearity. However after estimating the model the autocorrelation problem was detected in the model (see appendix). To resolve the problem of autocorrelation the Durbin two step method has used.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

In this chapter impact of various influencing factors on water stress has discussed. Literature shows that not only climatic variables but non climatic variables are also affecting water stress index. Population growth, GDP per capita, electricity production (thermal), area under cultivation, deforestation and industrial development is also playing crucial in creating water stress in country.

This chapter further has divided into subsections. Section 4.2 gives descriptive statistics of the data; section 4.3 presents trends of water related variables while results of estimations are represented in section 4.4.

4.2 Descriptive Statistics

Descriptive statistics are basically used for describing basic features of the data, for example the measures of central tendency and measures of dispersion. It helps the researcher to manage the data and present the summary statistics for the variables.

Table No 4.2: Descriptive Statistics

Descriptive Statistics						
Variables	**Units**	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Dev**
Water stress index	Million acre feet/millions	36	0.7336	1.695	0.998	0.182
Temperature	Degree celsius	35	14.72	16.28	15.50	0.398
Rainfall	Millimeters	35	27.1	68.6	42.08	7.955
Population	Millions	36	78	189	131.07	32.96
GDP per capita	Current LCU	36	3003.99	144945.03	37795.10	41681.31
Electricity Production	Giga watt per hour	36	6258	66707	36847.75	20692.47
Deforestation	Million hectares	36	0.0420	0.0924	0.0733	0.0123
Area under cultivation	Million hectares	36	20.2	22.2	21.40	0.6655
Industry value added	Current LCU	36	52487.0001	5217366	1274523.334	257676.2686

These stats show that mean value of water stress indicator (per capita water availability) is 0.998. The maximum value of per capita water availability is 1.695 in 1980. In 1980 the per capita water availability has high value because water was available in favorable amount. Afterwards it start decreasing due to increase in cultivated land and crop production (Tasleem, 2011).Temperature has 15.50 mean value. The temperature attains 16.28 maximum values with the minimum value of 14.72. The value of rainfall shows that average rain in Pakistan is 42.08 millimeters (mm) with the maximum value of 68.6mm.

In 1980 population of Pakistan was 78 million but in 2015 it increased to 189 million because of the moderate birth rates. Pakistan's population growth rate is 1.89 percent which is more than the Bangladesh, Indonesia, Turkey, Iran, Egypt and Morocco growth

rate, lies between 1.2-1.6 percent. Pakistani population is increasing with the passage of time and 3.7 million people are increasing every year(Qasim, 2016)

GDP per capita play a major role in affecting water resources. It has taken at current local currency units. Data depicts that income level of economy remains 37795.10 on average. The maximum value of GDP per capita reaches to 144945.03in 2015 in economy with the minimum value of 3003.99 in 1980. Economic growth of Pakistan has continuous increase and it reaches to 5.28 percent growth rate which is the highest growth rate in last 10 years because of the highest growth of agriculture sector than the last year (Economic Survey of Pakistan 2014-15). But if we compare our GDP per capita with the GDP per capita of Bangladesh then Bangladesh has $1,538 GDP per person and Pakistan has $1,470 GDP per person. Bangladesh has high GDP per capita because of economic progress, its industrial sector contribute 29% in GDP(News, 2017).

Take electricity production form thermal power plants under consideration, it represents the average production of electricity is 36847.75giga watt per hour with the maximum production of 66707 GW/H in 2014 and minimum production is 6258 GW/H in 1980.The production of electricity has increased by the increase in demand of electricity. Almost 67.78% electricity is producing by the use of thermal power plants (government of Pakistan).

Forest cutting is the common practice now in economy; therefore deforestation rate remains 0.073% on average. The maximum rate of deforestation is 0.092 in the year of 2015.The reason of decline in forest area is the population growth. Due to population growth the construction of housing and infrastructure is taking place at the place of forest area. Another reason of the deforested area is the agricultural expansion. Most of forest area has converted in to the agricultural area (Nazir & Olabisi).

Descriptive statistics of the data indicate that average value of total area under cultivation is 21.40 with the extreme value of 22.2 in 2015.Area under cultivation contains high value in 2015 because population of Pakistan is growing rapidly and agriculture sector is the main sector to fulfill the required need of food(Baig et al., 2013).

4.3 Trends of Water in Pakistan

In order to conduct trends of water in Pakistan the data on water availability, water stress index, reservoirs and dams capacity, and total water withdrawals has taken. Data on reservoirs and dam capacity and total water withdrawals has taken from the time period of 1974 to 2010.water availability and water stress index has taken from 1980 to 2015.

4.3.1 Trend of water stress index

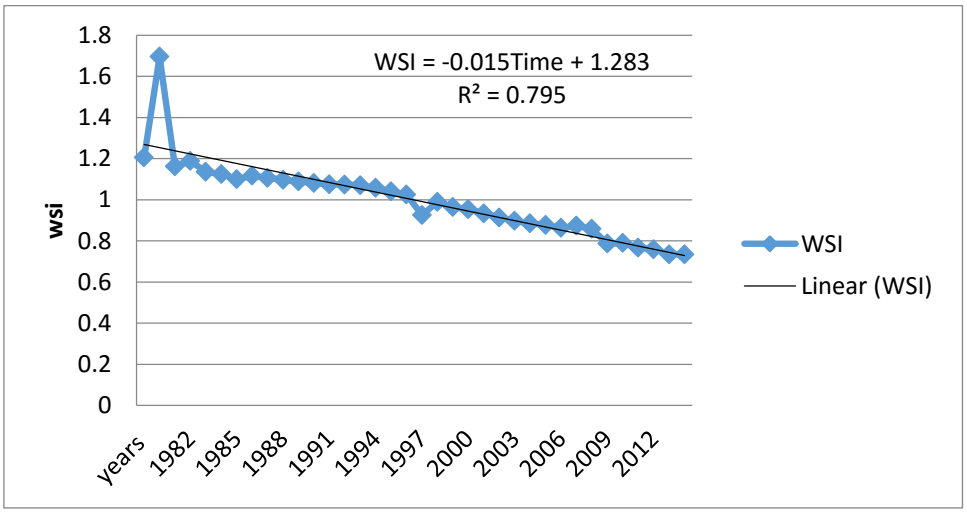

Fig 4.1: [water stress index (MAF/Millions)]

Fig 4.1 is showing decreasing trend of water stress index in Pakistan. In this study water stress index has measured by per capita water availability so the overall trend line is decreasing which is showing per capita water availability is declining and water stress is increasing in Pakistan. In 1980's per capita water availability reached to its maximum value, as at the time of independence and till 1980s water was available in favorable amount. In 1997 water stress increase and per capita water availability decreased because

of population growth and increased irrigated area. Almost 17% irrigated area increased in Pakistan in 1990s, due to which more water used in production of crops. Population has increased from during the period of 1951-1998(Tasleem, 2011).

4.2 Trend of Reservoir Capacity and Dam Capacity

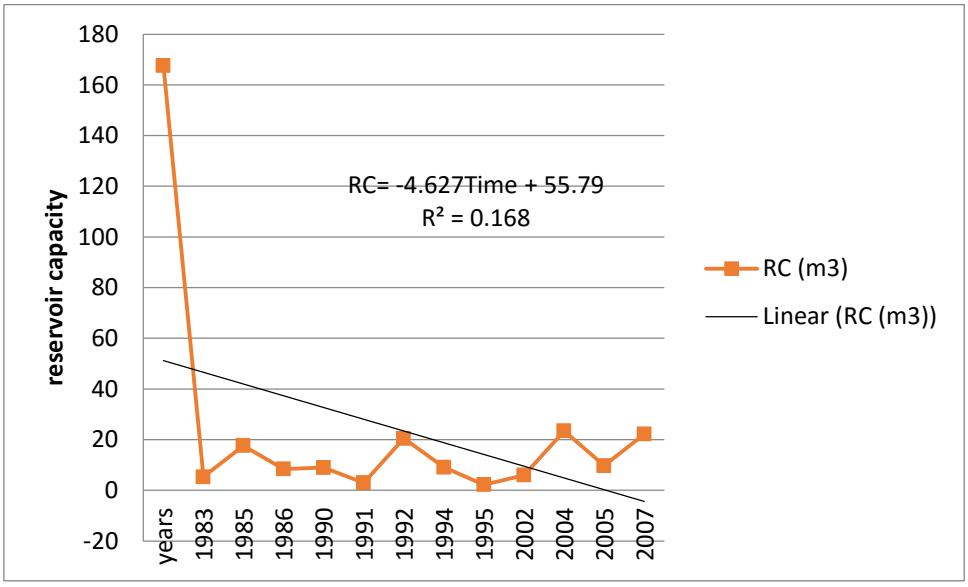

Fig 4.2: [Reservoir Capacity (m^3)]

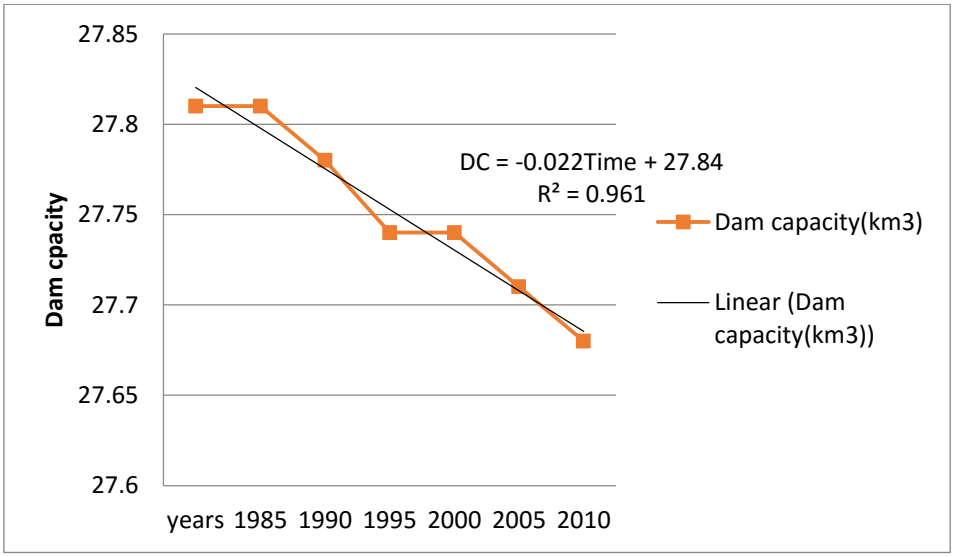

Fig 4.3: [Dam Capacity (km^3)]

The trend of reservoir capacity and dam capacity is showing in fig 4.2 and fig 4.3 respectively. Reservoir capacity and dam capacity trends are fluctuating with the passage of time. Both reach to its maximum point in 1980 because mostly dams and reservoirs constructed at the time period of 1960-1975(hadi, 2015).While in 2000 storage capacity of reservoirs and dams had declined due to the sedimentation in major reservoirs. Major reservoirs had reduced 13% storage capacity in 2000(Kahlown & Majeed, 2003). In 2005 capacity of dams and reservoirs increased because of the construction of new dams in this year, whereas overall trend of dam and reservoir capacity is declining(hadi, 2015).

4.3.4 Trend of Water Availability

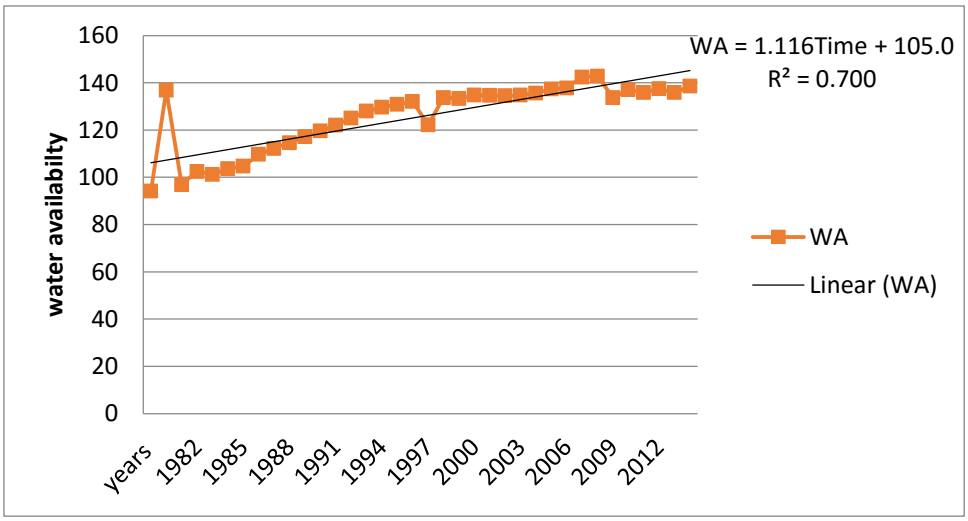

Fig 4.4: [Water availability (MAF)]

Fig 4.4 is showing trend of water availability in Pakistan. In 1981 it achieves maximum point because most of the dams and reservoirs are constructed in this time period(hadi, 2015). In 1998 water availability slightly decline due to the decline in ground water pumping. There was an increase in electricity and diesel fuel prices and soil salinity in time period of 1997-1998.However trend of overall water availability is upward sloping because temperature of Pakistan is rising day by day due to which our glaciers, snow and

ice is melting. The speed of glaciers, ice and snow melting has risen since 1990s (Randhawa, 2010).

4.3.5 Trend of Total Water Withdrawal

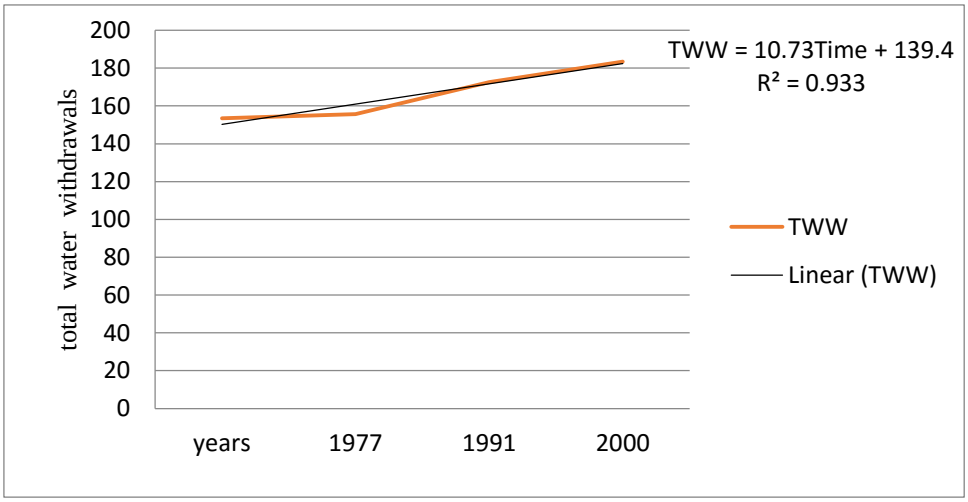

Fig 4.5:[TWW(million hectares)]

Total Water withdrawals is also showing increasing trend in fig 4.5. The trend is continuously increasing because in 1970s the ground water extraction has increased due to the installation of electric tube wells. Another reason of the water withdrawal is the increase in the production of crops, vegetables and fruits for the fulfillment of required needs of food during the period of 1980-2000. Ground water is exploited in Pakistan because laws related to ground water are not defined in Pakistan and every farmer is free to pump water as much as they want. That's why water withdrawal has increasing trend in Pakistan (Khair, Culas, & Hafeez, 2010).

4.4 Regression Analysis of the Determinants of Water Stress

This study has used OLS regression and the results of estimated model are given in table below.

Table 4.4: Regression Results of the Determinants of Water Stress

Variable	coefficients	Std.Error	t-statistics	Prob.
Dependent variable: lnWSI*				
lnTemp*	-0.516939***	0.276138	-1.872036	0.0729
lnRF*	-0.043419	0.041268	-1.052112	0.3028
lnPOP*	3.958939*	0.451308	8.772141	0.0000
lnGDPC*	0.219510**	0.106255	2.065883	0.0494
lnDEF*	0.264870*	0.062251	4.254877	0.0003
lnEP*	0.404989*	0.051602	7.848297	0.0000
lnTA*	0.721601***	0.417456	1.728565	0.0957
lnINDV*	0.174938***	0.113716	1.538374	0.1365
C	113.2298	11.73638	9.647759	0.0000
R squared	0.985769		D.W(stat)	2.117644
Adjusted R^2	0.981215			
F-statistics	216.4637			
F-Prob.	0.000000			

Note: C shows intercept term.
L with variable notation denotes natural logarithm.
*denotes significance at 1% level of significance
**denotes significance at 5% level of significance
***denotes significance at 10% level of significance

The results show that estimated model is statistically significant, as supported by probability of F-statistics. The diagnostics (R^2 and adjusted R^2) show that the model estimated is good fit and indicating that 98% variations in water stress are explained by explanatory variables.

The results indicate that temperature affect water stress index negatively and significantly that is 1% increase in temperature will lead to 0.51% decrease in water stress index. This

is because rising temperature impact ice, snow and glaciers melting. Because of ice, snow and glaciers melting surface water flow will increase. But it is only beneficial in wet season rather dry season. Wet season like spring and winter water discharges are mainly fed by snow and glaciers melting but in summer it increases evaporation and decreases discharge supply. This result is in line with the findings of (Arnell, 2004; Chang et al., 2007; Menzel et al., 2007).

The elasticity of rainfall shows that rainfall affect water stress index inversely. With the increase in rainfall the water stress will decrease although it is statistically insignificant this shows that it is not affecting water stress in Pakistan. The pattern of rain has changed overtime which means that heavy rains occur in selected months of the year. These rains increase water flows in high flow seasons and may not eliminate problems of dry season. An increase in water availability in wet season or high flow season is not beneficial for the other season and the surplus water is not transferable to another season because the extra water is not stored. This extra water may also accompany with a higher risk of flooding instead of reducing water resources stresses. These findings are in line with the(Arnell, 2004; Menzel et al., 2007). In Pakistan the spatial variation in monsoon rainfall has exists. Major part of the country has receiving summer monsoon rainfall than the other part of the country. During the monsoon Season, Rivers like Indus, Ravi and Sutlej face floods. Pakistan does not have enough storage capacity to store the water of summer rainfall even the existing dams and reservoirs have decreased their storage capacity due to sedimentations. This insignificant impact of rainfall on water stress was also found by(Bukhari & Sayal, 2011; Hussain & Mumtaz, 2014; Kahlown & Majeed, 2003).

The population coefficient is statistically significant at 1% level of significance with positive sign. The positive sign of population indicate that with 1% increase in

population, lead to 3.95% increase in water stress index. The increasing population put pressure on water resources. It limits the per capita water availability and enhances water stress in country because intensity of water withdrawal is high relative to water availability in the world. This impact of population on water stress is also explain by the studies of (Alcamo et al., 2007; Menzel et al., 2007; Okello et al., 2015; Vörösmarty, Green, Salisbury, & Lammers, 2000). They all found that population growth is a major contributor to creating water stress. It creates competition for water users where population density is high and water resources are few. Population is linearly proportional to water stress that population play important role in pressurizing water resources and in creating water stress.

Moreover the results show that GDP per capita is impacting water stress index positively i.e with the 1% increase in GDP per capita will cause 0.21% increase in water stress. It is significant at 5% level of significance. Over the last four decades both water use and GDP has increased. With the increase in economic growth the demand for water in agriculture, households and industrial sector has increased. As the countries become wealthier, the people of these countries prefer to change their dietary habits and tend towards more water intensive food items. The relationship between income growth and water use is not simple or direct, initially people start demanding products from agriculture sector like food items and industrial sector due to which production has increased, and resultantly water withdrawals will increase for production process. In this way GDP per capita is causing water stress in Pakistan. These findings are similar to the studies of (Alcamo et al., 2007; Menzel et al., 2007; Ringler, 2010).

The electricity production (from thermal sources) has positive and statistically significant impact on water stress index. With 1% increase in electricity production (thermal electricity) will increase water index by 0.40%. It is significant at 1% level of

significance. Pakistan is producing much of the electricity from thermal power plant. Turbines of thermal power plant are mostly steam turbines, to run these turbines water turns into steam by heating process. Then the steam spins turbine which ultimately produce electricity. Almost 67.74% thermal power is producing in country in the year 2015 (Government of Pakistan). So water withdrawals are increasing with the increase in electricity production due to which it is affecting water resources in country and ultimately pressurizing the per capita water availability. This relationship of electricity production with water stress is also found by ((Siddiqui, 2016);(Alcamo et al., 2007; Houghton-Carr et al., 2008).

Deforestation has positive and significant impact on the water stress index. With 1% increase in deforestation rate will lead to 0.26% increase in water stress. It is also significant at 1% level of significance. Deforestation plays an important role in decreasing water resources. Water patterns are affecting by cutting vast areas of trees. Forests have their own climate due to which attracts humidity and create rain clouds and they act as massive reservoirs of water. Plants experience transpiration which is similar to sweating in humans and plants also follow hydraulic cycle.[3]. In this way deforestation is creating water stress in Pakistan and it is also found by studies of(Masese et al., 2012; Pereira et al., 2014).

The results indicate that the increase in area under cultivation has positive and statistically significant impact on water stress index. A 1% increase in cultivation area will increase water stress index by 0.72%. Population of Pakistan is growing rapidly so the demand for food is also increasing which require more land to be cultivated. Crop production has

[3]Hydraulic cycle is the cycle in which plants absorb water when it rains then release in to atmosphere by evapotranspiration. Then this water evaporates formed rain clouds. The process of deforestation is destroying hydraulic regulation and reducing absorption capacity

increased and almost 80% area is irrigated in Pakistan. For crop production number of tube wells, canal water, surface water and groundwater abstraction is increasing which is limiting water resources. The increasing trend of cropped area and cultivated area demands more water and it is increasing water stress. These findings are in line with the studies of (Baig et al., 2013; Kahlown & Majeed, 2003). So there is needed to grow less water consuming crops.

The coefficient of industrial development affect water stress index positively. With the 1% increase in industrial value added (industrial development) will increase water stress index by 0.17%. Countries are moving towards industrialization for economic development due to which industry needs water for different production processes such as washing, cooling and transportation. Sometimes industry requires water for the final composition of products. Every industry has different volume of water withdrawals for their production process. In this way industrial development is creating water stress. These findings are also studied by (Jiang et al., 2014; Shiklomanov, 1998).

CHAPTER 5

CONCLUSION AND POLICY RECOMMENDATIONS

5.1 Summary Findings

Pakistan was surplus country with the huge water resources but now it is listed in water stressed country and it is near to chronic condition of water stress. Water resources are affecting with the rising factors such as population growth, economic development, industrial development, agricultural development and climatic variations. This study is an effort to determine the impact of climatic and non climatic variation on water stress in Pakistan. The impact of climatic and non climatic variables has estimated by using OLS estimation technique for time period 1980 – 2014. Moreover in this research the water stress is measured by using indicator of per capita water availability. The explanatory variables of this study are temperature, rainfall, population, GDP per capita, thermal electricity production, deforestation and land under cultivation. The problem of autocorrelation was present is this study which has been removed by using Durbin two step method.

The results indicate that all the explanatory variables significantly affect the water stress except rainfall. Rainfall is not impacting water resources in Pakistan because intensity of rainfall has changed now. Water increase in high flow season but it is not transferable to another season because the extra water is not stored and it flows to rivers without any utilization. This is the reason due to which rainfall has no affect on water stress.

The estimation results show that temperature has negative impact on water stress index. Due to rising temperature the glaciers and snow is melting and it increase surface water flows. Wet season like spring and winter are mainly fed by snow and glacier melting.

Population is impacting water stress more than other variables. The increasing population put pressure on water resources. It limits per capita water availability and enhances water stress in country. Economic growth or income has statistically significant impact on water stress. The total area under cultivation has positive impact on water stress. Population of Pakistan is growing rapidly so the demand for food is also increasing. To meet the needs of food more land is required to be cultivated so it is pressurizing the surface and ground water. The coefficients of thermal electricity production, deforestation and industrial development are also statistically significant and carry positive sign. Due to economic activities and agricultural development the water demand has increased due to which water abstraction increased rapidly and it is imposing pressure on water resources and resultantly it is creating water stress in Pakistan.

5.2 Policy Recommendations

Based on the findings it is recommended that.

- Cultivated area should be used for low water consuming crops to save water and reduce water stress.
- Deforestation should be restricted by the government.
- In Pakistan electricity production should be shifted from thermal to hydel electricity production to reduce burden on water resources.
- The storage capacity needs to be increased by the construction of dams and reservoirs to absorb the water in monsoon season.
- In industrial sector water efficient technology should be used to reduce the water stress.

5.3 Limitations of the Study

Major limitations of the study are this study has skipped the variable of storage capacity of dams and reservoirs because only data of 17 years out of 35 years is available. This study has not used the water withdrawals to availability ratio indicator of water stress because the data on water withdrawal is not available. This indicator might be provided more accurate results.

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APPENDIX

Table 1: Regression results of water stress function

Variables	coefficients	Std. Error	t-statistics	Prob.
C	39.88749	16.72169	2.385374	0.0246
LTEMP	-0.228588	0.489288	-0.467185	0.6443
LRF	-0.013879	0.068002	-0.204096	0.8399
LPOP	2.321561	1.132517	2.049913	0.0506
LGDPC	0.264146	0.232445	1.136380	0.2662
LEP	0.113369	0.140717	0.805650	0.4278
LDEF	0.301246	0.141070	2.135441	0.0423
LTA	0.274410	0.608753	0.450774	0.6559
LINDV	-0.078668	0.226506	-0.347312	0.7312
R- Squared		0.892052		
Adjusted R- Squared		0.858838		
D.W stat		2.986464		

Table 2: Regression results using Durbin first step

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	92.10105	28.42128	3.240567	0.0051
L(WSI-1)	-0.788932	0.177375	-4.447809	0.0004
L(TEMP)	-0.555334	0.433923	-1.279799	0.2189
L(TEMP-1)	-0.529515	0.440619	-1.201752	0.2469
L(RF)	-0.037764	0.064828	-0.582526	0.5683
L(RF-1)	0.036255	0.063307	0.572693	0.5748
L(POP)	36.04527	21.78132	1.654871	0.1174
L(POP-1)	30.94899	23.17187	1.335628	0.2004
L(GDPC)	0.521604	0.240150	2.171994	0.0452
L(GDPC-1)	-0.058705	0.264012	-0.222356	0.8269
L(EP)	0.520384	0.293543	1.772768	0.0953
L(EP-1)	-0.171860	0.315078	-0.545453	0.5930
L(DEF)	0.276265	0.115772	2.386284	0.0297
L(DEF-1)	0.242894	0.124535	1.950407	0.0689
L(TA)	0.306249	0.792516	0.386426	0.7043
L(TA-1)	-0.305170	0.750734	-0.406496	0.6898
L(INDV)	0.050861	0.010833	0.061441	0.9518
L(INDV-1)	-0.004192	0.010231	-0.409705	0.6875
R-squared	0.969236		Durbin-Watson stat	1.846218
Adjusted R-squared	0.936549			
F-statistic	29.65230			0.000000

Table 3: Regression results using Durbin first step

Variable	coefficients	Std. Error	t-statistics	Prob.
Dependent variable: lnWSI*				
lnTemp*	-0.516939***	0.276138	-1.872036	0.0729
lnRF*	-0.043419	0.041268	-1.052112	0.3028
lnPOP*	3.958939*	0.451308	8.772141	0.0000
lnGDPC*	0.219510**	0.106255	2.065883	0.0494
lnDEF*	0.264870*	0.062251	4.254877	0.0003
lnEP*	0.404989*	0.051602	7.848297	0.0000
lnTA*	0.721601***	0.417456	1.728565	0.0957
lnINDV*	0.174938***	0.113716	1.538374	0.1365
C	113.2298	11.73638	9.647759	0.0000
R squared	0.985769		D.W(stat)	2.117644
Adjusted R^2	0.981215			
F-statistics	216.4637			
F-Prob.	0.000000			

Data on Reservoir and Dam Capacity

years	RC (m3)	Dam capacity(km3)
1980		27.81
1981	2.747124	
1982		
1983	167.6794	
1984		
1985	5.32656	27.81
1986	17.65656	
1987		
1988		
1989		
1990	8.389332	27.78
1991	8.979939	
1992	2.998656	
1993		
1994	20.45547	
1995	9.1242	27.74
1996		
1997		
1998		
1999		
2000		27.74
2001		
2002	2.229264	
2003		
2004	6.025671	
2005	23.42947	27.71
2006		
2007	9.76536	
2008	22.16687	
2009		
2010		27.68
2011		
2012		
2013		
2014		
2015		27.5