Water Scarcity: Impacts on Food security at Macro, Meso and Micro levels in Pakistan.

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Abstract

This paper aims to assess the impact of water scarcity on food security at macro, meso and micro levels. The data of food security and water availability has been taken from Pakistan where water scarcity is fast approaching with a substantial decline from 1950's until now. A series of models have been created to capture the impact of water scarcity on food security at macro, meso and micro levels. The models have employed Logistic regression equations and simultaneous equations to catch the effect of growing water scarcity on three components of food security (food access, food absorption and food availability) separately. The equations have traced an adverse impact of water scarcity on food security at macro, meso and micro levels. The findings so obtained may help in proposing the policy guidelines for overcoming the water scarcity and handling with food insecurity caused by looming water scarcity.

Key Words: Water scarcity, Water demand, Water supply, Food security, Macro, Meso and Micro

1 Introduction

Water scarcity is an imbalance between demand and availability (FAO, 2010). It occurs when demand for water exceeds the supply for water (Molle and Molinga, 2003).It can be defined either in terms of existing and potential supply or in terms of present and future demands for water or both. It can also be defined as a relative concept and be regarded partly as a "Social Construct" because determin ing water scarcity varies fro m country to country and region to region in a country and within the social construct as well–the scarcity is therefore determined by both the availability and consumption pattern (IWMI). Moreover, it can be classified on the basis of five contexts
(a) physical water scarcity; (b) economic water scarcity; (c) institutional water scarcity; (d) managerial water scarcity and (e) political water scarcity. These types of water scarcity can occur concurrently thereby enhancing both the severity and impacts of water scarcity (CGIAR challenges for food and water).

Falkenmark (1989) proposed an index which is widely known as Falkenmark water stress index. It measures water stress, water scarcity and absolute water scarcity conditions at different levels of water availability per capita. It ranges between water availability of 1700 C^3 to 1000 C^3 per capita: a threshold below which water scarcity starts on and ends at another threshold of 500 C^3 per capita per annum. An absolute water scarcity starts on below this minimum threshold of 500 C^3. As a result, a country is generally said to be water scarce when annual water supplies fall below the benchmark of 1000 C^3 per Capita.

Most of the studies emphasize on a benchmark of 1000 C^3 per capita water availability as a basis for the conceptualization of water stress, water scarce and absolute water scarce conditions of a region within a country and across many countries in the world. It's because, the Falken mark index p rovides a fabulous distinction between climate and human induced water scarcity (Vorosmarty et al., 2005). Most importantly, the usage of this index is to provide an assessment on a country scale where data is readily available and the results of this index can easily be understood by researchers (Rijsberman 2006). For that reason, the present study is conceptualising water scarcity on the basis of Falkenmark index and is not fundamentally incorporating other types of water scarcity into the analysis. Moreover, the food security framework with three categorical elements (food availability, food access and food absorption) is being used for determining the impact of water scarcity on food security.

Cline (2003) examined the impact of water scarcity on food production. His work synthesised that the water scarcity could cut food production and consequently it would render an adverse impact on food security. His study proposed that self-sufficiency in food grain production could be achieved through the expansion of existing irrigation infrastructure, control of population, increased crop yield, development and management of water resources and the construction of small dams. The similar findings were also revealed by the United Nations Development Programme (UNDP), which came up with a conclusion that it is not the lack of arable land which will cut the food production; it is the water scarcity which will risk the food security in the coming decades (UNDP, 2007). Hanjra and Qureshi (2010) have also examined the impact of water scarcity on future food security in an era of climate change. Their study brings to close that the future food security is being threatened by a constant decline of water resources, climate change and energy shortfalls. In order to cope with such worsening state of food security and water resources across the globe, the policy measures such as investments in water conservation, modernization of irrigation infrastructure, preservation of land and mitigation of climate change are emphasized. Above all, food security and rural livelihood are fundamentally linked to water availability and consumption (Callow, 2002; Nicol and Slaymaker, 2003).Therefore; the United Nations development program (UNDP, 2007) has regarded the water scarcity as the most important determinant of food security.

With the rapid growth in Pakistan's population, the country is ranked lowest on global development indices. For instance, United Nations (2017) ranks Pakistan at 147 among 188 countries on human development index. German watch ranks Pakistan the seventh most vulnerable country to climate change. International food policy research institute (IFPRI) ranks Pakistan at 107 out of 118 developing countries on global food security index, and Wilson center for scholars, a think tank of United States of America, says nearly half of Pakistan's population is food insecure, while hunger and malnutrition-related disease are widespread. Global terroris m index ranks Pakistan the third worst terrorist hit country. World economic forum (2016) ranks Pakistan at 143 out of 144 countries on gender inequality index. So, in view of such poverty, illiteracy, inequality, violence, demographic pressures, system losses, distribution inequalities, climate change and ecosystem degradation (Kamal, 2009), the country is approaching fast to the status of water scarce (Michael Kugelman, 2009). By best estimates, per capita water availability has decreased from 5,000 C^3 per annum in 1951 to 1,090 in 2005 (Pak-SCEA 2006). It has witnessed a further decline to around 850 C^3 (below benchmark 1000 C^3) in 2013 and will further go down to 659 C^3 in the year 2025 (Environmental draft , 2006).

Impact of water scarcity on food security can be grave and chronic because climate change and population growth are acting simultaneously on water resources and agriculture. The rapid growth of population has exerted pressure on water resources, as an excessive pumping and discriminatory use of water has caused the water tables to recede fast in aquifer. Factually, aquifer is depleting fast in Pakistan. At the same time Pakistan will need more food supplies to feed its water scarce-food insecure rapidly growing population. This growing water scarcity along with food insecurity and climate change is relentlessly exacerbating water resources and agriculture. This scenario is distressing and has implications for Pakistan as a state and society. In other words, water scarcity is regarded as an important determinant of food security (UNDP).

1.1Research Questions and objectives

In view of growing water scarcity and its adverse impact on the food security several questions need to be addressed. For instance how does water scarcity influence the three categorical elements of food security; What is the impact of water scarcity at macro level of food security; What is the impact of food security at meso level of food security; What is the impact of water scarcity at micro level of food security; how economics of food security is affected by water scarcity; what will be the situation of water security under scarce water scenario; how declining water supplies will pose risks to future food security; and finally what is the comprehensive picture of relationship among components of food security, poverty, safe drinking water, income levels, climate change and water scarcity . The present study attempts to answer such and similar kind of questions. Specifically, the following objectives are being pursued to answer the research questions.

I. To determine the impact of water scarcity on three categorical elements of food security at macro level.

II. To determine the impact of water scarcity on three categorical elements of food security macro level.

III. To determine the impact of water scarcity on the three categorical elements of food security at micro level.

IV. To propose the policy guidelines for overcoming the growing water scarcity and handling with food insecurity in Pakistan.

1.2Data

Data on food security is partially collected fro m Food Security & Nutrit ion Analysis (2012-13), Sustainable development institute (SDPI). The analysis ranks the districts of Pakistan on the basis of food security and gives a comparison of the current food security situation. In addition, some data have been obtained from Food Insecurity and Vulnerability Information Mapping system (FIVIMS), United Nations (UN) and Govern ment of Pakistan (GOP). The information generated through FIVIMS is useful for policy makers; Govern ment officials, civ il society including NGOs, District Govern ments, Donor Co mmun ity including UN agencies, bilateral donors, researchers, academ ia and train ing institutions. National FIVIMS program of Pakistan included the followings: National Nutrit ion Surveys, Agriculture Statistics of Pakistan (yearly)/Food Vu lnerability, Economic Surveys of Pakistan (Yearly), Household Integrated Economic Survey, Household Income and Expenditure Survey, Food Balance Sheets, Health Statistics, National Data fro m International Agencies/NGOs, Provincial Surveys and Population Surveys/Census/Population Welfare. Water data were obtained partially fro m the repo rt, Tit led “Pakistan is running empty”. Th is report was released by the Wilson centre for scholar in the USA and the remaining data were taken fro m, planning commission, International Water management institute, Reports of International agencies/NGOs and Research papers .

1.3Variable Description

Each variable has its own definition at any of the three levels of the food security i.e. macro, meso and micro. The operational definitions of all variables are given in table1.

Table 1 Operational definitions of variables

Variables	Operational Definitions

*denotes food absorption of population /districts, ** denotes food availability to

FAB(Food Absorption)* FAV(Food Availability)** FAC(Food Access)***	Population in millions/districts are extreme food deficit=1 Population in millions/districts are high food deficit=2 Population in millions/districts are low food deficit=3 Population in millions/districts are sufficient=4 Population in millions/districts are in surplus=5

PUN	Punjab
NTB	Northern Areas of Pakistan
SIN	Sindh
WSC	Water Scarcity on the basis of Water availability C^3 Per capita
POV	Percentage of population living below poverty line
CAS	Caloric supplies in term of Cal/K
INC	Per capita income
FS	Food insecure

2Econometric Modelling

A series of models is being used to assess the impact of water scarcity on food security in Pakistan. All models d iffer in their nature, functional form, operational defin ition and estimation methodology. These models have employed simple Logistic equations derived from the functional forms.

2.1Macro Model

The first model consists of three models: Model A, Model B, Model C. Each model is analysing the impact of water scarcity on food security at macro level wh ich refers to a natio n or population. The core d ifference between the three models lies in the functional form o f equations. The population of all provinces is co mbined to make it macro. Besides, the functional form of equation is specified in such a way that the impact of wat er scarcity can be analysed on the changing severity of food insecurity for the population in respective provinces in general and fo r the entire population of Pakistan in particular.

In order to assess the impact of water scarcity on food security, the three categorical elements of food security (food absorption, food access, food availability) have been transformed in accordance with the population millions for incremental values ranging fro m 1 to 5.These values show that population is extremely low deficit, very low deficit, low deficit , surplus production respectively . The data set has been transferred into a new set of variables. They are fewer in number than the original set of variables.

2.1.1Model A: Impact of water scarcity on Food availability

In this model the first categorical element food availability is specified as a function of water scarcity in terms of per capita cubic meter (C^3) water availability and water scarcity in terms of million acre feet(MAF) for irrigation. The rest of the variables are dummy and specify the locality of population in respective provinces. The functional form of the models is as follows.

$$FAV = f(WSC, BAL, KPK, SIN, PUN, NTB) \quad (1)$$

The equation of this model is as follows:

$$FAV = \alpha_0 + \alpha_1 WSC + \alpha_2 BAL + \alpha_3 KPK + \alpha_4 SIN + \alpha_5 PUN + \alpha_6 NTB + \mu \quad (2)$$

The model simply runs the OLS regression with binary FAV. The coefficients express change in probability that FAV is associated with a unit change in water scarcity. FAV^ is expressing a probability that FAV=1 and in so doing the following equation is formulated.

$$\rho r(FAV = 1 | WSC, BAL, KPK, SIN, PUN, NTB) = \alpha_0 + \alpha_1 WSC + \alpha_2 BAL + \alpha_3 KPK + \alpha_4 SIN + \alpha_5 PUN + \alpha_6 NTB + \mu \quad (3)$$

2.1.2Model B: Impact of water scarcity on food absorption

In this model, the second categorical element food absorption is specified as a function of water scarcity in terms of per capita cubic meter (c3) water availability, poverty and caloric supply. The rest of the variables are dummy and specify the locality of population in respective provinces. The functional form of the models is as follows:

$$FAB = f(WSC, POV\ CAS, BAL, KPK, SIN, PUN, NTB) \quad (4)$$

The equation of this model is as:

$$FAB = \beta_0 + \beta_1 WSC + \beta_2 POV + \beta_3 CAS + \beta_4 KPK + \beta_5 SIN + \beta_6 PUN + \beta_7 NTB + \epsilon \quad (5)$$

The model simply runs the OLS regression with binary FAB. The coefficients express change in probability that FAB is associated with a unit change in water scarcity. FAB^ is indicating a probability that FAV=1 and in so doing the following equation is obtained.

$$\rho r(FAB = 1 | WSC, POV, CAS, BAL, KPK, SIN, PUN, NTB) = \beta_0 + \beta_1 WSC + \beta_2 POV + \beta_3 CAS + \beta_4 KPK + \beta_5 SIN + \beta_6 PUN + \beta_7 NTB + \epsilon \quad (6)$$

2.1.3Model C: Impact of water scarcity on food access

In this model the third categorical element food access is a function of water scarcity in terms of water scarcity in terms of per capita cubic meter (c3) water availability income, poverty and caloric supply. The rest of the variables are dummy and specify the locality of population in respective provinces. The functional form of the models is as follows:

$$FAC = f(WSC, INC, POV, BAL, KPK, SIN, PUN, NTB) \quad (7)$$

The equation of this model is as follows:

$$FAC = \gamma_0 + \gamma_1 WSC + \gamma_2 POV + \gamma_3 CAS + \gamma_4 KPK + \gamma_5 SIN + \gamma_6 PUN + \gamma_7 NTB + \nu$$

The model simply runs the OLS regression with binary FAC. The coefficients express change in probability that FAC is associated with a unit change in water scarcity. FAC^ is expressing a probability that FAC=1.

$$\rho r(FAC = 1|WSC, POV, CAS, BAL, KPK, SIN, PUN, NTB) = \gamma_0 + \gamma_1 WSC + \gamma_2 POV + \gamma_3 CAS + \gamma_4 KPK + \gamma_5 SIN + \gamma_6 PUN + \gamma_7 NTB + \nu \quad (8)$$

2.2Meso Model

This model is conducting an analysis on data at Meso level (Districts) of food security. The data set has been transferred into a new set of variables. The three categorical elements of food security have been assigned five incremental values ranging from 1 to 5, showing that the district is extremely low deficit, very low deficit, low deficit and surplus production.

This model is divided into two models: Model D and Model F .Three Simultaneous equations for food absorption, food access, food availability and water availability per capita on the basis of cubic meters (C3) have been employed in the model D. For model B there is change in the number of simultaneous equations. Instead of three simultaneous equations the model has employed only two simultaneous equations.

2.2.1Model D: Joint Determination with three simultaneous equation systems

The three simultaneous equations of this model are as follows:

$$\text{Food Absorption} = \alpha_1 + \alpha_2 (\text{Food Access}) + \alpha_3 (\text{Safe Drinking Water}) + \mu_1 \quad (9)$$

$$\text{Food Access} = \beta_1 + \beta_2 (\text{Food Absorption}) + \beta_3 (\text{Food Availiability}) + \mu_2 \quad (10)$$

$$\text{Food Availability} = \gamma_1 + \gamma_2 (\text{Food Access}) + \gamma_3 (\text{Water Scarcity Cubic Meters}) + \mu_3 \quad (11)$$

In order to apply the correct estimation method, the identification rules require a structural model with structural parameters and a derivation of reduced form equations with reduced form parameters. Therefore, a structural model with a derivation of reduced form equations is being used in the model A.

2.4.1.1. The structural model: Causal relationship

The equations of this model are as follows:

$$FAB = \alpha_1 + \alpha_2 (FAC) + \alpha_3 (SDW) + \mu_1 \quad (12)$$

$$FAC = \beta_1 + \beta_2 (FAB) + \beta_3 (FAV) + \mu_2 \quad (13)$$

$$FAV = \gamma_1 + \gamma_2 (FAC) + \gamma_3 WSC + \mu_3 \quad (14)$$

Structural parameters = $\alpha_1, \alpha_2, \alpha_3$, $\beta_1, \beta_2, \beta_3$, $\gamma_1, \gamma_2 \gamma_3$
Number of structural parameter(NSP) = 9

2.4.1.2. Reduced form equations

For reduced form equations endogenous variables are expressed as a function of exogenous (predetermined) variables and these variables are not correlated in error. Reduced form equations with reduced form parameters are derived by replacing equation (13) into equation (12) i.e.

$FAB = \alpha_1 + \alpha_2 (\beta_1 + \beta_2 FAB + \beta_3 FAV + \mu_2 + \alpha_3 SDW + \mu_1$

$$FAB = \alpha_1 + \alpha_2\beta_1 + \alpha_2\beta_2 FAB + \alpha_2\beta_3 FAV + \alpha_2\mu_2 + \alpha_3 SDW + \mu_1$$

$$(1 - \alpha_2\beta_2)FAB = \alpha_1 + \alpha_2\beta_1 + \alpha_2\beta_2 FAB + \alpha_2\beta_3 FAV + \alpha_3 SDW + \alpha_2\mu_2 + \mu_1 \quad (15)$$

By Dividing $1 - \alpha_2\beta_2$ on both sides of equation (15), the following equation is obtained.

$$FAB = \left(\frac{\alpha_1 + \alpha_2\beta_1}{1 + \alpha_2\beta_2}\right) + \left(\frac{\alpha_2\beta_3}{1 - \alpha_2\beta_2}\right)FAV + \left(\frac{\alpha_3}{1 - \alpha_2\beta_2}\right)SDW + \left(\frac{\alpha_2\mu_2 + \mu_1}{1 - \alpha_2\beta_2}\right)$$

This equation now gives the reduced form parameters i.e.

$$a = \left(\frac{\alpha_1 + \alpha_2\beta_1}{1 + \alpha_2\beta_2}\right),\ b = \left(\frac{\alpha_2\beta_3}{1 - \alpha_2\beta_2}\right),\ c = \left(\frac{\alpha_3}{1 - \alpha_2\beta_2}\right) \text{ and } \epsilon_1 = \left(\frac{\alpha_2\mu_2 + \mu_1}{1 - \alpha_2\beta_2}\right)$$

Hence, the first reduced form equation with reduced form parameters can be written as follows.

$$FAB = a + bFAV + cSDW + \epsilon_1 \quad (16)$$

By repeating the same procedure, six reduced form parameter (f, g, h, i, j, k)are obtained and the other two reduced form equations are given as follows .

$$FAC = f + gFAV + hSDW + \epsilon_2 \quad (17)$$

$$FAV = i + jFAB + kWSC + e_3 \quad (18)$$

Reduced from parameters = a, b, c, f, g, h, i,j, k
Number of reduced form parameters = 9

Identification and Estimation Method

Identification is done to check which estimation method can be applied to the equation for analysis.The equation is just identified when the number of structural parameters is equal to the number of reduced form parameters. Since equations have equal number of structural parameters and reduced form meters, therefore both 2SLS and ILS can be equally applied. The choice of 2SLS estimation method is being made for the documentation of results in section 3.There are two steps of 2SLS estimation method. Reduced-form equations are estimated in first step of 2SLS by using Ordinary least square method (OLS) and structural equations are estimated in the second step of 2SLS. The rules of identification are given in the table 2.

Table 1 Rules of Identification

Name	Number of reduced and structural parameters	Estimation method
*Just identified	*NRFP = NSP	*2SLS = ILS
Over identified	NRFP > NSP	2SLS
Under identified	NRFP< NSP	NSP Cannot be estimated

*denotes equations are just identified

2.2.2Model F: Joint determination with two simultaneous equations systems

Two Simultaneous equations are as follows

$$\text{Food Availability} = \alpha + \beta(\text{Food Absorption}) + \theta(\text{Water Scarcity Cubic Meter}) + \epsilon \quad (19)$$

$$\text{Food Absorption} = \lambda + \theta(\text{Food Availability}) + \eta(\text{Food Access}) + \mu \quad (20)$$

2.4.2.1. The structural model: Causal relationship

Two structural equations are as follows.

$$FAV = \alpha + \beta(FAB) + \theta(WSC) + \epsilon \quad (21)$$

$$FAB = \lambda + \phi(FAV) + \eta(FAC) + \mu \ (22)$$

Structural Parameters = α, β, θ , λ, θ,η

Number of structural parameters(NSP) = 6

Reduced form equations

In these equations endogenous variables are expressed as a function of exogenous variables and exogenous variables are not correlated in error. Reduced form parameters are obtained by replacing equation (22) into equation (21).

$$FAV = \alpha + \beta(\lambda + \phi FAV + \eta FAC + \mu) + \theta(WSC) + \epsilon$$

$$FAV = \alpha + \beta\lambda + \beta\phi FAV + \beta\eta FAC + \theta WSC + \beta\mu + \epsilon$$

$$(1 - \beta\phi)FAV = \alpha + \beta\lambda + \beta\eta FAC + \theta WSC + \beta\mu + \epsilon \quad (23)$$

Dividing $1 - \beta\phi$ on both sides of equation 22, the following equation is obtained.

$$FAV = \left(\frac{\alpha + \beta\lambda}{1-\beta\phi}\right) + \left(\frac{\beta\eta}{1-\beta\phi}\right) FAC + \left(\frac{\theta}{1-\beta\phi}\right) WSC + \left(\frac{\beta\mu + \epsilon}{1-\beta\phi}\right) \quad (24)$$

This equation now gives the reduced form parameters i.e..

$$a = \left(\frac{\alpha + \beta\lambda}{1-\beta\phi}\right),\ b = \left(\frac{\beta\eta}{1-\beta\phi}\right), c = \left(\frac{\theta}{1-\beta\phi}\right) \text{ and } e = \left(\frac{\beta\mu + \epsilon}{1-\beta\phi}\right)$$

Hence, the first reduced form equation of this model with reduced form parameters can be written as follows.

$$FAV = a + bFAC + c(WSC) + \epsilon \quad (25)$$

Similarly, by replacing equation (21) into (22) and dividing $1 - \beta\phi$ on both sides of equation, the following equation is obtained.

$$FAB = \left(\frac{\lambda + \phi\alpha}{1-\beta\phi}\right) + \left(\frac{\eta}{1-\beta\phi}\right) FAC + \left(\frac{\phi\theta}{1-\beta\phi}\right) WSC + \left(\frac{\phi\epsilon + \mu}{1-\beta\phi}\right) (26)$$

This equation now gives reduced form parameters i.e.

$$d = \left(\frac{\lambda+\phi\alpha}{1-\beta\phi}\right),\ f = \left(\frac{\eta}{1-\beta\phi}\right),\ g = \left(\frac{\phi\theta}{1-\beta\phi}\right) \text{ and } u = \left(\frac{\phi\epsilon+\mu}{1-\beta\phi}\right) \quad (27)$$

By replacing d, f, g and u in equation (27) a reduced form equation is obtained i.e.

$$FAB = d + f\,(FAC) + g(\,WSC) + u \quad (28)$$

Reduced form parameters = a, b, c, d, f, g

Number of reduced form parameters = 6

There is a relation between the reduced form parameters and the structural parameters. The reduced form parameters give a full effect of a change in an exogenous variable. For example WSC increases by one unit then:

(a)FAV decreases by θ

(b)FAB decreases by$\phi\theta$
(c)FAV decreases by β [$\phi\theta$]
(d) FAB decreases by $\phi[\phi\theta] = \beta\phi^2 \theta$

(e)FAV decreases by$\beta[\beta\phi^2\theta]=\beta^2\phi^3\theta$

(f)FAV decreases by $\beta[\beta^2\phi^3\theta]=\beta^2\phi^3\theta$

Thus, total effect on FAV: $\theta+\beta\phi\theta+(\beta\phi)^2+(\beta\phi)^3\theta+\cdots+=\sum(\beta\theta)^t\theta=\frac{\theta}{1-\beta\theta}$

Similarly, total effect on FAB: $\phi\theta+\beta\phi^2\theta+\beta\phi^3\theta=\phi\theta+(\beta\phi)\phi\theta+(\beta\phi)^{2}\phi\theta+=\sum(\beta\phi)^t\theta\phi=\frac{\theta\phi}{1-\beta\theta}$

2.3Micro Model

This model is running logistic regression. The logistic equation of this model is as follows.

$$\text{logit}(\rho)=\beta_0+\beta_1(WSC)+\beta_2(FS) \quad (29)$$

Where p is the probability of presence of the characteristic of interest i.e. Household is food secure or Food insecure. The logit transformation is defined as the logged odds i.e.

$$\text{Odds}=\frac{\rho}{1-\rho}=\frac{\text{probability of presence of characterisitics}}{\text{probability of absence of charactersistics}} \quad (30)$$

3 Results and Discussions

The estimated results show that all models are theoretically correct in their relationships and linkages. The estimated coefficients have correct signs and are in conformity with the theory (See Food Security Theoretical framework). The overall fit shown by R^2 reports an accurate, reliable prediction .It gives simplest measure of the degree of the statistical fit forth estimated equations. The t-values also justify the models and denote significance at 5 % level and 10 % level. The F-statistics which shows overall significance of an equation is also good for all models.

3.1 Results and discussion of Macro Model

Water scarcity is posing major risks to the categorical elements of national food Security. The results show that the water scarcity is negatively related to food availability, food absorption and food access. The growing water scarcity is causing a decline in three categorical elements of food security. Therefore, the water scarcity can be regarded as a major determinant of food security (see UNDP).

3.1.1Model A

The results at macro level show that water scarcity is negatively related to food availability of entire nation

.The water scarcity is trapping more population from sufficient to low and from low deficit to extreme low deficit in food availability. In other words an increase in the water scarcity will push the food availability from sufficient production to the low production .As estimated, an increase of water scarcity by 1 unit is decreasing the food availability of 0.27 million population. Hence, higher the water scarcity is the lower will be food availability in Pakistan.

The locality of population among respective provinces is also crucial to a relative understanding. As reported by results, the population of Northern frontier areas and Sind enjoy higher probability to have food availability than the population of Baluchistan, Punjab, and

Khyber Pakhtoon Khaw. In other words, the population of Baluchistan is more food insecure than that of Punjab and Khyber Pakhtoon Khaw. Further comparison among respective provinces imply that population of Baluchistan is more food insecure than the population of Khyber Pakhtoon Khaw and population of Khyber Pakhtoon is more food insecure than population of Punjab. Results are given in table (4).

Table 2 Results of Model A

Variable	Coefficients	t-statistics
Constant	-	2.7654
WSC	-0.279	3.4236*
BAL	-0.343	-3.0896*
KPK	-0.235	-2.4635*
SIN	0.086	-1.5873**
PUN	-0.076	-1.8671**
NTB	0.177	2.2287*
Dependent Variable=FAV		
Total Number of Observations=110		
$R2=0.834$		
F=5		

3.1.2 Model B

Same like the previous model, the results of Macro model B show that water scarcity is rendering negative impact on food security. The water scarcity is found to be negatively related to the second categorical element of food security the food absorption. As estimated by model, an increase of water scarcity by one hundred unit is decreasing the food absorption of a 0.35 million population. In this manner, it is causing low deficit population to become a very low deficit in food absorption.

Safe drinking is the major cause of low absorption of food (See SDPI). The results have established a positive link between safe drinking water and food absorption. The food absorption is increasing with an increase in the availability of safe drinking water. It is already a scarce resource, as reported by SDPI; only 50 percent population has access to safe drinking water in Pakistan. It is the right of every individual in a society (See UNDP). It is denied to people on the account of few factors such as poverty, low income, the lack of knowledge about the benefits of drinking portable water, unhygienic practices, lack of infrastructure for the provision of safe drinking water; out-dated methods of making the water cleaner by the government, corruption and inefficacy of government officials (see WWF).

The disparity regarding the access to safe drinking water centres on poverty and low income in the urban areas of Pakistan. The rich and affluent have frequent and easy access to safe drinking water at the same time as poor cannot pay the price of safe drinking water. Therefore, the demand of safe drinking water is originally a function of income in urban areas of Pakistan. Therefore, demand of safe drinking water is higher in the urban areas of Pakistan. Similarly, the huge disparity between rural and urban areas is also a big factor that prevents the rural people to have access to safe drinking water. Therefore, lack of access to safe drinking water amid high incidence of poverty has some profound effects on food absorption at macro level. Poverty coupled with a lack of access to safe drinking water is impeding the food absorption of entire population as results show that with an decrease in poverty by one hundred unit will increase the food absorption of 0.18 million population and in the same manner and increase in the access to safe drinking water will increase the food absorption of 0.034 million population.

The results regarding the population of respective provinces reveal that population of Baluchistan, Punjab, Sind, and KPK is more food insecure than that of Northern areas in food absorption. In other words, population of Baluchistan is more food insecure than population Sind and population of Sind is more food insecure than the population KPK .Similarly, population of KPK is more food insecure than the population of Punjab. However, on the broader scenario---at macro level; the results show water scarcity is causing food absorption status of entire population to shift from low deficit to very low deficit in Pakistan.

Results of this model are given in table (c).

Variable	Coefficients	t-statistics
Constant	-	2.8634
WSC	-0.353	3.4239*
POV	-0.189	2.8346*
SDW	0.034	1.1783**
BAL	-0.421	-0.7347**
KPK	-0.121	-2.4635*
SIN	-0.374	-1.5873**
PUN	-0.154	-1.8671**
NTB	-0.077	2.2287*

Dependent Variable=FAB
Total Number of
Observations=116

R2=0.844

F=5

*denotes significance at 5 per cent level and ** denotes significance at 10 per cent level.

3.1.3. Model C

The results show that the water scarcity is negatively related to food access as well. The growing water scarcity brings about a decline in food access. Therefore, the water scarcity can be regarded as a major determinant of food security (see also, UNDP). The results show that an increase of water scarcity by 1 cubic meter d ecreases the food access of a population which is already sufficient and pushes it further to low deficit. Poverty is the major cause of low food access and bars the people have access to food. In Pakistan, more than 70 percent populations live below the international poverty line. Higher incidence of poverty coupled with food inflation poses obstacles to accessibility. As shown by the results of this model, the poverty is negatively associated with the food access. The higher the poverty is the lower will be the food access. In the same way, the income is positively related to the food access. The accessibility increases with the increase in income. The locality of population in different provinces matters and result confirm that no population of any locality has the probability to a food secure in food access. Among the food insecure population, the population of Baluchistan is more probable to insecure than the population of Sind, KPK and Punjab and In other words, the population of Baluchistan is more foo d insecure than the population of Sind and the population of Sind is more insecure than the population KPK and the population of KPK is more food insecure than the population of Punjab. However, on the broader scenario at the macro level, the result of the impact of water on the food security show that the water scarcity is trapping more population from the sufficient to lower deficit in food access. Results of model 3 are given in table

Table 6. Regression of Water scarcity on Food Access

Variable	Coefficients	t-statistics
Constant	-	2.7654
WSC	-0.034	3.4236 *
POV	-0.253	- 2.3356

		*
INC	0.0183	1.4634**
BAL	-0.123	-3.0896*

KPK	-0.153	-2.4635*
SIN	-0.045	-1.5873**
PUN	-0.076	-1.8571**
NTB	-0.177	2.2286*
Dependent Variable=FAC		
Total Number of Observations=116		
R2=0.739		
F=5		

Note: Single asterisks denote significance at 5 per cent level and two asterisks denote significance at 10 per cent level.

3.2Meso Models

Food security theoretical framework has implicitly established a negative relationship between water scarcity and food availability .It is therefore of great interest to create two models at meso level: Model D and model F. Each model is using a joint determination of simultaneous equation system.

In a joint determination of simultaneous equation system, the linkages among all the components of food security are specified in accordance with the theory (See food security theoretical framework). Food availability is dependent on water availability whereas food access and food absorption are dependent on food availability. In so doing, impact of water scarcity with joint determination of all the components can easily be assessed.

3.2.1Model D

The results of this model are based on the two stages. In the first stage, the two components, food availability and food absorption are decreasing with the increase in water scarcity and the third component food access is increasing with the increase in water scarcity. The reason behind this negative and positive relationship can be interpreted from the second stage in which food absorption is positively linked with the food access which in turn is positively related to food availability whereas food availability itself is negatively associated with the water scarcity. Thus it can be deduced, that the water scarcity has a negative relationship with food access. However, the food availability and food absorption are negatively related with water scarcity at meso level. In other words ,under water scarce conditions the food security status of districts is deteriorating constantly from surplus to sufficient; from sufficient to low; from low to very low and from very low to extreme low. Therefore, this study may conclude that water scarcity is posing major risks and challenges to food security (see Hanjra, Molden, Khalil, UNDP, FAO and WB). Results of Model D are given in the table 7 and 8.

OLS on reduced form equations 1, 2 and 3

Variable	Coefficients	t-statistics
OLS on reduced form equation1		

Constant	-	3.7325
SDW	0.232	2.1869
FAV	0.118	2.2321
Dependent Variable=FAB Number of Observations=120		
R2=0.745 OLS on reduced form equation 2		
Constant		3.6345
SDW	0.243	2.1455
FAV	0.116	2.2342
Dependent Variable=FAC Number of Observations=120		
R2=0.735 OLS on Reduced form Equation 3		
Constant	-	3.3242
WSC	0.234	2.1367
FAB	0.128	2.2232
Dependent Variable=FAV Number of Observations=120		
R2=0.731		

Estimated FAC^, FAB^, FAV^

Variable	Coefficients	t-statistics
Estimated FAC^		
Constant		2.7061
SDW	-0.237	-3.1568
FAV	0.324	2.0324
FAC^	0.165	2.7543
Dependent Variable =FAB		
Number of observations=120		
$R2=0.742$		
Estimated FAB^		
Constant	-	2.9387
WSC	0.234	-3.3479
FAB(1)	-	-
FAB^	0.3473	2.3422
Dependent Variable=FAV		
Number of Observations=120		
$R2=0.753$		
Estimated FAV^		
Constant	-	3.3242
WSC	0.2376	-3.3435
FAB	0.128	2.2232
FAB-1	-	-
FAV ^	02345	2.7543
Dependent Variable=FAB		
Number of Observations=120		

$R2=0.742$

3.2.2: Model F

As shown by the results, water scarcity is not only causing the food availability to decline but also posing threats to the other two components of food security. The growing water scarcity will cause the food security status of districts to shift from surplus to sufficient and from sufficient to low and from low to very low. On the account of these findings, the thesis may conclude that water scarcity is posing major risks to food security (see Hanjra, Molden, Khalil, UNDP, FAO and WB). Results of model F are given in table 9 and 10.

OLS on Reduced form equations

Variable	Coefficients	t-statistics
OLS on Reduced form Equation 5		
	-	2.9623
Constant		
WSC	0.2641	-3.1265
FAC	0.1872	3.1354
Dependent Variable=FAV		
Number of Observations=120		
R2=0.731		
OLS on Reduced form Equation 7		
Constant		
WSC	-0.2741	-3.4569
FAC	0.1563	-2.7691
Dependent Variable=FAB		
Number of Observations =111		
R2=0.743		

Estimated FAB^ and FAV^

Variable	Coefficients	t-statistics
Estimated FAB^		
Constant	-	3.2732
WSC	0.2873	-3.3958
FAC	0.1375	2.3985
FAB^		
Dependent Variable=FAV		
Number of Observations=120		
R2=0.734		
Estimated FAV^		
Constant		2.8436
WSC	-0.2182	-3.0128
FAC	0.1341	-2.2854
FAV^	2.1642	3.02163
Dependent Variable=FAB		
Number of Observations =111		
R2=0.749		

3.3Result and discussion of Micro model

At micro level, odds ratios for food insecure cases are greater than food secure cases. The probability of the water scarce-food insecure households is 0.76. Consequently, most of the households will suffer from both water scarcity and food insecurity which has some implications for the water security as well. In fact, there is an implicit relationship between water security and water scarcity. Supply of efficient quantities of water with acceptable quality for household use is a key step towards achieving the satisfactory level of water security. Therefore, a minimum requirement of water must be made available to the household.

Water security is related to the nation and households. For this reason, Macro model can also be applied at micro level by converting the population in millions to individuals and households in millions and vice versa. The lesser the water availability the lesser will be the water security and vice versa. Therefore, the growing water scarcity is posing major risks to food security and water security at household, community, national, regional and global level. The results of micro model are given in the table 11.

Logistic Regression

Variable	Coefficient	Odd Ratio	Probability	95% CI
WSC	0.1153	1.1324	0.03445	1.03534-1.2066
FS	1.1738	3.4202	0.0109	1.3519-8.8634

Total Number of Cases=110

4. Conclusion and Policy guidelines

The water scarcity is rendering a negative impact on all categorical components of food security at macro, meso and micro levels. It is causing the entire population to fall from high food insecure status to extreme food insecure status. Similarly, the food security is deteriorating for all provinces and districts. Under water scarce conditions , the districts that have been found moderate food secure are becoming low food secure; the districts that were found low food secure are becoming very low food secure and the districts that are already very low food secure will become extreme food secure. The same is true for respective provinces. The food security of Baluchistan, Sind, Khyber Pakhtoon Khawa and Punjab is negatively related to water scarcity in the results. The food security is falling alternatively moderate to low, from low to very low and from very low to extreme. In the same way, water scarcity is posing major risks to water security of water scarce-food insecure households. All in all, water scarcity is posing major risks and challenges to the food security in Pakistan. The severity of water scarcity can be lessened by taking certain policy measures. These policy guidelines and measures are as follows.

- Sustainable management of water resources must be made a part of the national discourse. This national discourse must be made the part of a social convention and social responsibility in Pakistan. Effective and efficient use of water by government, businesses, farmers, private sector, communities and people must be considered as a moral duty
- The optimal use of water with a sustainable agriculture will lessen the adverse impact of water scarcity on food security. Therefore, water productivity must be

enhanced and productivity enhancement of major crops should be accentuated in the policies.

- Nation should enter an exo-somatic mode of production.
- Shifting dependence from staple food to other foods which require lesser water for production might be a good initiative.
- Pakistan should build environmentally friendly water reservoirs and water must be prioritized at national level. Moreover, farmers should be provided with water conserving agriculture technologies.

- Appropriate balance between centralized and decentralized water management must be achieved. Moreover, there is a need to address the structural obstacles at national and policy level.
- Water provision at local and individual level coupled with the empowerment of citizenry particularly gender must be emphasized in water policies. Promotion of private sector for the
  management of water resources will be effective to alleviate the crisis.
- Success stories are good learning for overcoming the water scarcity in Pakistan and these success stories should be followed in their true essence.
- Identification and targeting the food insecure people will enormously help to alleviate the food insecurity.
- Distribution of land and access to resources should be emphasized equally for both small and large
  farmers.
- Improving the nutritional aspects of food will be beneficial for every individual of the society.
- Vegetable and pulses production, rural poultry, inland fisheries and rearing of small ruminants must be adopted at household level.
- Policy bias in macro framework against agriculture must be removed immediately.

These policy measures must be followed at war footing, because absolute water scarcity is approaching fast and food insecurity is already much higher in Pakistan. Climate change is adding fuel to fire, a challenge though being accepted superficially but in reality it is the ever greatest threat to water resources and food production. It will not only exacerbate water scarcity and food insecurity but will also push poor and vulnerable to more vulnerability. Therefore, the consequences of water scarcity are beyond any description--- hunger, famines, conflict, diseases, and extreme poverty.

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