# Impact of water scarcity on food security at meso level in Pakistan

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16 November 2011

# Impact of Water Scarcity on Food Security at Meso level in Pakistan

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**Abstract:** Pakistan is confronting the problem of water scarcity which is rendering an adverse impact on food security. The study examines the impact of water scarcity on food security in an era of climate change. It further focuses on projecting the future trends of water and food stock. The research effort probes the links among water scarcity, climate change, food security, water security, food inflation, poverty and management of water resources. Data on food security was collected from the FSA (Food Security analysis) of the Sustainable development Policy institute (SDPI) and Food insecurity and Vulnerability Information mapping system (FIVIMS). Simultaneous, structural and reduced form equations have been employed to catch the effect of water scarcity on three components of food security separately. In fact, the present study develops a series of models that captures the impact of water scarcity on the components of food security at Meso level. The models have traced an adverse impact of water scarcity water scarcity on food security at Meso levels. The findings so obtained may help in proposing the policy guidelines for overcoming water scarcity and handling with food insecurity caused by water scarcity and other factors.

**Key Words:** Water scarcity, Water supply, Water Demand, Food security, Meso level, Simultaneous equations

## Introduction

Water is vital for life. It acts as a catalyst of economic growth and development. It is the life blood for the survival of human beings, agriculture, household economy and industry. It is the fundamental right of every individual, the denial of which leads to famines, sufferings, distress, war and chaos. It is an identity and its cultural and social meaning is deeply rooted in heritage. Centuries past the civilizations have taken birth along the natural water courses. Indeed, water is a natural resource unique to planet earth (UNDPI, 1998).

Water scarcity is an imbalance between demand and availability (FAO, 2010) and exists when the demand for water exceeds the supply (Molle and Molinga, 2003. It can be defined either in terms of existing and potential supply of water or in terms of present and future demands for water or both (IWMI). It can also be defined as a relative concept and therefore be regarded partly as a "Social construct" because determining water scarcity varies from country to country and region to region in a country and within the social construct, the scarcity is determined both by the availability and consumption pattern (IWMI).

The pioneering work of Falkenmark (1989) defines water stress, water scarcity and absolute water scarcity on the basis of water availability per person. Falkenmark proposed an index which is widely known as Falkenmark water stress index. This index is based on water availability per person. It measures water stress, water scarcity and absolute water scarcity conditions at different levels of water availability per capita. The water stress index of Falkenmore ranges between water availability of 1700 $C^3$ per person to 1000 $C^3$, a threshold below which water scarcity starts and ends at another threshold of 500 $C^3$ per person and below this starts an absolute water scarcity. Therefore a country is said to be water scarce when annual water supplies fall below the benchmark of 1000 $C^3$ per Capita. Most of the studies emphasized on benchmark of 1000 $C^3$ 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. The Falkenmark index provides 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 be easily understood by researchers (Rijsberman 2006).

Pakistan is facing water scarcity which has its roots in water shortage. Critical factors such as rapid population growth, climate change, reductions in the ice and snow areas of the Himalayas, urbanization, industrial growth, poverty, distribution inequalities, unsustainable water consumption practices, loss of ecosystems, more rapid runoff and bad management of water resources by the government have caused degradation of the resource base and laid huge stress on the quantity and quality of water resources (Shah et al., 2008, Hanja and Gichuki, 2008 ; Kamal, 2009).Scarcity in many areas has posed great challenges like increase competition for water use between and across different sectors, transferring water out of agriculture (Molden, 2007) and leaving less water for food, increased inequality in access to water and food as well thereby perpetuating poverty (Hussian and Hanja, 2003). Inequitable distribution of food supplies, poverty and inequality result in entitlement failure for the poor to aggravate the food security issues (Sen, 1989, 2001, Molden et al., 2007). These factors bring about major risks to food security. The challenges posed by these factors are not only prevalent in water scarce areas but also operative in the area where food production and water productivity is high. The conceptualization of food security and water scarcity is highly dependent on these challenges (Renwick, 2001; Ward, 2007).

The gap between water supply and demand is sharply increasing in Pakistan. This gap has created water shortages in almost all sectors of the economy. By the best estimates of the World Bank, Government of Pakistan and UN agencies, per capita water availability in Pakistan declined from 2500 cubic meters in 1952 to 1150 cubic meters, 1100 cubic meters and 1090 cubic meters per year in the current decade respectively. The terms "water shortage" and water scarcity are often used interchangeably---- while both use the 1,000 $m^3$ per capita measurement as a benchmark, "shortage" is an absolute term and scarcity is a relative concept (WB , 2008, Kamal, 2009).Furthermore, water through irrigation is a key driver of agriculture production. Irrigation has helped boost agricultural yields in semi-arid and even arid environments and stabilized food production and prices (Hanja et al.,2009a, 2009b; Rosegrant and Cline, 2003) and has mobilized revenue from the agricultural sector (Sampath, 1992). The water availability in farm field is in constant decline in Pakistan (Government of Pakistan, 2009). The rising demand for irrigation water over the course of time has brought about significant changes in water flows (Falkenmark and Molden, 2008).

A big chunk of Pakistan's population is food insecure. The increasing water scarcity will cause more food insecurity (IWMI, 2001). According to Oxfam; about 70 percent people of Pakistan are food insecure. Whereas the Government states that 40 percent people is food insecure. United Nations Development Programme estimates the same figure as stated by the government of Pakistan. One of the Food Security Analysis (FSA) undertaken in 2003 by SDPI presented the comprehensive picture of food insecurity in Pakistan. The result indicated that out of 120 districts in Pakistan, only 46 were found food secure while the remaining 74 districts (62 percent) where food deficit (Khalil, 2007).

Climate change poses significant threats to global food security and peace. Certainly it also influences water and food production (Alcamo et al., 2007; Barnett et al., 2005; Doll Droogers and Aerts, 2005). It cuts down the food supply (Arnell et al., 2004; Rosenzweing and Parry, 1994) and costs of adaptation to climate change are high (Kandlikar and Risbey, 2000). Models show that

Pakistan will grow warmer by 1.0 degree $C^0$ by 2030; under water scarcity scenario this may require extra water for wheat and other crops (FAO, 2008).

Most importantly, food security depends critically on other factors such as economic growth, changes to trade flows, food aid policy, poverty, imperfect food markets, inadequate employment opportunities, inequitable distribution, powerlessness, discrimination, and demographic factors (Khalil, 2007). Consequently, these factors lead to increased food and water insecurity in water deficit areas and further reduce the water resources with a higher impact carrying capacity. Therefore, food security and rural livelihood are fundamentally linked to water availability and use (Callow, 2002; Nicol and Slaymaker, 2003).

The essential point of this study is increasing water scarcity which has prompted the United Nations to conclude: it is water scarcity, not a lack of arable land which will pose major impediments to increased food production over the next few decades. For the reason, water scarcity is projected to become more important determinant of food scarcity than land scarcity (UNDP, 2007).

In view of growing water scarcity and its adverse impact on the food security several questions need to be addressed. For instance how water scarcity influences food security; how economics of food security 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; what measures are needed to mitigate the impact of water scarcity on food security and finally what is the comprehensive picture of relationship among poverty, inequality, water scarcity, food production, food security, climate change and food inflation. The present study attempts to answer such and similar kind of questions. Specifically, the following objectives are being pursued in this study.

1. To study the relationships among water scarcity, food security, food production, water security, climate change, water management, poverty, inequality and food inflation.
2. To determine the impact of water scarcity on the economics of food security in an era of climate change.
3. To project future trends in water resources along with its impact on food security in Pakistan.
4. To propose the policy guidelines for overcoming the water scarcity, and handling with food insecurity.

**Review of Literature**

An ample amount of literature is cited on water scarcity and food scarcity in several journals, working paper series, reports released by the government, UN agencies and NGOs. Much of the literature establishes an implicit link of water scarcity with food security. However, an explicit link between water scarcity and food scarcity can be found in a few papers. Therefore, this study has divided literature review into two sections. The first section conceptualizes the water scarcity in both absolute and relative terms. It also reviews the prevalence of different types of water scarcity in Pakistan with special reference to water scarcity problems. The second section is defining food security and provides a conceptual framework of food security at three different levels as for stance Macro, Micro and Meso. The third section reviews both explicit and implicit links between the water scarcity and staple food production in Pakistan. The third section also enumerates external and internal factors affecting water scarcity and food security. The first section conceptualizes the water scarcity in both absolute and relative terms. It also reviews the prevalence of different types of water scarcity in Pakistan with special reference to water scarcity problems. The second section is defining food security and provides a conceptual framework of food security at three different levels as for stance Macro, Micro and Meso. The third section reviews both explicit and implicit links between the water scarcity and staple food production in Pakistan. The third section also enumerates external and internal factors affecting water scarcity and food security

**Conceptualization of Water Scarcity and Water Scarcity Problem in Pakistan**

Water scarcity is an imbalance between demand and availability (FAO, 2010) and exists when the demand for water exceeds the supply (Molle and Molinga, 2003.The pioneering work of Falkenmark (1989) defines water stress, water scarcity and absolute water scarcity on the basis of water availability per person. Falkenmark proposed an index which is widely known as Falkenmark water stress index. This index is based on water availability per person. It measures water stress, water scarcity and absolute water scarcity conditions at different levels of water availability per capita. The water stress index of Falkenmore ranges between water availability of 1700 $C^3$ per person to 1000 $C^3$, a threshold below which water scarcity starts and ends at another threshold of 500 $C^3$ per person and below this starts an absolute water scarcity. Therefore a country is said to be water scarce when annual water supplies fall below the benchmark of 1000 $C^3$ per Capita. Most of the studies emphasized on benchmark of 1000 $C^3$ 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.

Water scarcity can be classified on the basis of five contexts (a) physical 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 enhancing both the severity and impacts of water scarcity (CGIAR challenges for food and water).

Physical water scarcity occurs when water availability is limited by natural availability (Molle and Molinga, 2003). It can be referred to as a situation where there is not enough water to meet all the demands of the population. Most of the studies define physical water scarcity on the basis of 75 percent water availability by rivers. For example, FAO maps refers physical water scarcity to a situation where 75 percent flow of rivers is withdrawn from agriculture, industry and domestic uses. This definition does not include the demand for water in dry areas. FAO maps also define approaching physical water scarcity on the basis of 60 percent river flows withdrawn. This definition implies physical water scarcity in the near future. Physical water scarcity has its own symptoms. These symptoms include declining river seasons flow, groundwater depletion, water pollution and environmental degradation. Physical water scarcity can happen in a particular region or country where there is an excessive development of hydraulic infrastructure (CGIAR, IWMI).

Economic water scarcity refers to a situation where there is not enough human, institutional, and financial capital limit access to water even though the water is naturally available locally to meet human demands (IWMI). It is largely caused by lack of investment in water or insufficient human capacity to satisfy the demands for water. Symptoms of economic water scarcity include lack of infrastructure, poverty and lack of investment in managing water resources as people suffering from economic water scarcity, more often fetch water from lakes, rivers and ponds for domestic and agricultural uses. Large parts of Africa suffer from economic water scarcity; developing water infrastructure there could therefore help to reduce poverty (Molden, 2007).

Political water scarcity is the scarcity caused by political disputes and negligence. It exists when political forces bar the people from accessing the available water resources. Managerial water scarcity exists when management institutions bar the people from accessing the water resources. It is largely due to the inefficiency and docile operations of the management institutions. Institutional water scarcity is more or less akin to the managerial water scarcity. It is caused by the restraints imposed by institutional shortcomings, deficiencies and inadequacies. All types of water scarcity occur concurrently, thereby increasing both the severity and impacts of water scarcity (Molle and Molinga, 2003).

All types of water scarcity problems mentioned above are caused by a large number of factors. The international institute of water management enumerates all the causes of water scarcity. These causes are as: (a) Population growth ( high demand=water stress) ; (b) lack of institutional capacity ; (c) storage competition and water demand) ; (d) climate change and vulnerability ; (e) poverty and economic policy ; (f) political realities ; (g) pollution and poor water quality ; (h) cultural and sociological issues ; (I) international disputes ; (j) sectoral competition and water demand ; (k) inappropriate land use ; and legislation and water resource management. Water scarcity problems matter because there are repercussions for human and environment. For human, food Shortages, health crisis and international conflicts are the outcomes of water scarcity problems and for environment, erosion, waste disposable problems, and pollution are the repercussions of looming water scarcity problems (IWMI).

Pakistan faced with a growing population of 165 million of which at least 25 percent live below the poverty line and; 98 million rely on agriculture; 50 million does not have access to safe drinking water; and 74 million do not have sanitation and hygiene. (GOP, 2008; UNDP, 2009). Facing poverty, growing population, system losses, distribution inequalities and ecosystem degradation (Kamal, 2009 ) , the country is approaching fast to the status of water scarce and the water scarcity presents greatest threats to Pakistan as a state and a society (Michael Kugelman, 2009 ) . Per capita water availability in Pakistan has decreased from 5,000 cubic meters per annum in 1951 to 1,090 in 2005 (Pak-SCEA 2006). It witnesses a further decline and is just at around the benchmark of 1000 at this time. United Nations Development Programme estimates Pakistan's current water availability as 1,090 m3 per capita per year. On the other hand, water scarcity is estimated to be 850 cubic meters in 2013 and will go on declining to 659 cubic meters per annum in 2025 ( Draft State of the Environment Report 2005). The water shortage in the agriculture sector is another grave issue. As per SOE 2005, the shortage has been estimated at 29 percent for the year 2010 and 33 percent for 2025.

Pakistan‘s 92 percent land area is considered to be arid and semiarid. The productivity of this land area depends largely on the irrigation. Around 25 percent of the total land is covered by the Indus plain and 65 percent population subsisting on agriculture draw water by irrigation .This irrigated area accounts for 80 percent total area under cultivation in Pakistan; estimated to produce above 90 percent food and fiber requirement of Pakistan . The irrigated area, which is about 80 percent of the country's total cultivated area, produces 90 percent of Pakistan's food and fiber requirements. (South Asia water vision, Country Report, 2011) Moreover, agriculture accounts for 23 percent of Pakistan's GDP (GOP, 2009).

The Indus water treaty of 1960 entitled the waters of three western rivers of the Indus system (Chenab, Jehlum and Indus) to Pakistan and the remaining tributaries were entitled to India. The average rim station inflow of the Indus river during 1974-2000 was calculated to be around 154 million acre feet MAF per year of which 144.9 MAF was available to Pakistan ( The water accord, 1999) .Another source puts this availability at 140 MAF (South Asia water vision , Country Report, 2011) .

The sharing of water among the provinces was fixed by the Water Accord of 1991 in Pakistan. This sharing was based on 114.35 MAF per year. Another 3 MAF was added to the 114.35 MAF making a total 117.35 MAF. This additional amount was reserved for the ungauged civil canals. Of the total 117 MAF, the share of Punjab was 55.94 MAF; the share of Sind was 48.76 MAF. The share of both provinces was divided equally at 37 percent (Indus Water Accord, 1991). The remaining water from the average rim station flow (154 MAF-114.35 MAF) is estimated at nearly 40 MAF and often designated as "outflow to sea below Kotri. Moreover 10 MAF was reserved for the environmental inflows on the demand of Sind (Indus Water Accord, 1991).

More than 95 percent of available surface is used for irrigation in Pakistan (kamal, 2001). The Indus irrigates around 34 million acres of land on its plain (Tariq, 2002). The capacity storage of this system is low at only 150 m3 per capita per year: only 30 days of supply. The system has significant losses; both Mangla and Tarbela have lost about 25 percent of their capacity. The water losses from canal heads, water courses and within water courses are commonly believed to be two third of the total water losses. The losses of poor transmission and seepage of canals are estimated to be around 76 MAF (GOP, 2007). Another loss of 25 percent also occurs in the farm fields (Kamal, 2001). There might be many reasons for these losses such as power management of water resources, government inefficiency and negligence, minuscule social mobilization on the part of the community, distribution inequalities from head, and middle and tail areas of the water channels and the inability of water users to pay the taxes (Pakistan's economy running dry, 2009). According to the World Bank, a very small percentage of the irrigation water users pay for the irrigation while the costs of maintenance, repair and rehabilitation of the water infrastructure are high. These costs are incurred to the general taxpayers. These taxpayers pay the cost plus interests and no one pays for the replacements (Kamal, 2009). Due to bad management, institutional constraints and inability of water users to pay for the maintenance, only 45 percent of cultivable land is cultivated .Therefore, 97 percent water allocated to the provinces is not utilized fully ( Tariq, 2005). Under this scenario crop productivity goes low at 0.13 kg per cubic meter which is the lowest productivity in the world per unit of water. The reality seems distressing in the national discourse of water (Kamal, 2009). Nevertheless, national discourse accentuates the need of constructing dams. This discourse is politically controversial among the provinces. Sind raises objections to the construction of Kalabagh dam project which was approved in 2008 and is in suspension up till now. The storage capacity of Kalabagh dam was estimated to be 8.1 MAF and the power generation capacity of the dam was estimated to be 45,000 MW. The project was envisaged to benefit $ 600 million in the context of irrigation and $ 1.5 billion in the context of hydropower (Sher Baz Khan, 2008). The need for the construction of the dam was argued on the basis of seven points (a) more storage capacity (b) more water for agriculture and irrigation (c) more flood control (d) more hydropower (e) more food security (f) more carry over from wet months to dry months and vice versa and (f) offsetting the loss of existing dams due to silting (Kamal, 2009).

Groundwater is the principal source of drinking water, agriculture industry and households (WWF, 2006). Punjab has 80 percent fresh groundwater. Sind has less than 30 percent ground water. NWFP has most of the layers of saline ground water caused by abstractions at large. Baluchistan has also saline water (Pak-SCEA2006). Best estimates give a figure of 500,000 operational tube wells in the Indus Basin. These tube wells are generally thought to be a reasonable source of fresh groundwater. However, total Indus basin contains fresh ground water reserves of about 55 MAF (south Asia water vision, country report). Despite six times increase in diesel pumps over a period of 30 years , the ground water contributes only 48percent of the water available (SOE 2005). The unchecked exploitation of ground water has brought about the indication of aquifer mining which occurs when too much water is pumped from the aquifer. The time period of unchecked exploitation of groundwater spans from green revolution up till now. The connective use of ground water increased due to its enhanced access to both big and small farmers in Pakistan. Therefore, currently it accounts for half of all farm irrigation requirements; supplementing 34 MAF of surface water that reaches farmland (Kamal, 2009).

The quality of ground water ranges from both fresh and saline. It is fresh near the major rivers and become saline further away from the rivers. Large areas of Indus basin have poor salinity and retain the lenses of Sweet water at the top. Near major rivers, the salinity in the ground water is measured to be less than 1000 milligrams per liter. But it is more saline at above 3000 milligram per liter away from the rivers and irrigated land. The groundwater can be found close to the edges of irrigated lands at the depth of 20-25 meter. The excessive pumping and heavy use of pesticides has contaminated the aquifer resulting in an increase in the levels of salinity in the groundwater .For the matter of fact both the quantity and quality of ground water is deteriorating fast In Baluchistan, Sind, Potohar, Thar, Kacho, and parts of Khyber Pakhtoon khawa, FATA and Punjab—where the groundwater is the only or major source of water for all uses. Uncontrolled extraction of groundwater and extended dry periods has also caused depletion and drying up of some of the sources. A study in Kirther shows that the water table has dropped by 3 meters per year on average. The drying up of wells has important social consequences, particularly on the women and children responsible for water collection. In Islamabad, the drop has been 50 feet between 1986 and 2001. In Lahore the drop has been about 20 feet between 1993 and 2001. Best estimates reveal without an artificial recharging, groundwater in the sub basin of Quetta would be exhausted by 2016 (SOE 2005). Hence the indiscriminate use of groundwater has caused the water tables in the aquifer are receding at a fast pace. Therefore, a conjunctive conservation along with the monitoring and regulation is badly needed for skimming the shallow lenses of sweet groundwater (Pakistan water partnership, 2002). The proposition of policy guidelines and approaches for brining water with drawls into balance with recharge is badly needed (WB, CWRAS 2005).

Pakistan's population is projected to increase by 221 million by the year 2025 (GOP, 2009). The rapid growth in population will place further pressures on water resources which are already deficient in meeting demand across all sectors. According the environment draft of Pakistan, the water availability will remain same at 104 MAF from 2004 to 2025 while the demand will rise by 35 MAF which will result into an imbalance between demand and supply. The overall shortage may range from 11 MAF to 35 MAF. A study conducted by planning commission reveals that this imbalance of demand and supply will gear up an unhealthy competition amongst the end users thereby causing an environmental degradation of several forms such as: a decline in groundwater levels, an increase in water logging, increase in industrial pollution , contamination drinking water , water born diseases, an increase of toxic materials into the contaminated aquifer and an intrusion of saline water into the fresh reservoirs ( SOE, 2005).

**Conceptualization of Food security: Macro, Meso and Micro levels and linkages with reference to the state of Food security in Pakistan**

Food security is defined by several agencies, institutes, academicians, researchers and agriculturists in their own perspectives. Traditionally, the term food security referred to the global, regional and national food supply shortages in comparison with the food demand. With the passage of time, the research focus increased on this phenomenon and researchers eventually studied the food insufficiency at community, individual and household levels. Their findings applied the term frequently at local, community, individual and household level (Foster 1992). The term was further investigated by the academicians and researchers .For stance; Sen determined the food entitlements in 1981. Watts and Bohle studied vulnerability in 1993 and sustainability was studied by Chambers in Maxwell in 1995. Indeed the concept of food security evolved over time.

The most common definitions vary around the proposed definition of the World Bank (1986) and were summed up by Maxwell and Frankenberg as" secure access at all times to sufficient food for a healthy life"(1992). They conducted and exhaustive review of the literature at household level and listed around 195 studies on the definition of food security. They also enlisted the indicators studied in 175 studies (Maxwell 1995). IFPRI (1999) listed approximately 219 definitions and 450 indicators of food security. In 2001, United nations Food and Agriculture program (FAO) defined food security ( somehow currently accepted ) in the following words , [“Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life]. United Nations Cultural and Scientific organization (UNESCO, 2004) defined food security as an ability of a country to produce or import enough food for normal health and physical activity of people. The European commission incorporated price in its conceptualization of food security and referred this term to the availability of food on the basis of its price. The European commission also defined food safety which refers to the extent to which food is safe to eat. Feeding America (2007) defined this term as an access to all times to enough food for an active and healthy life. Ridge Crickets Farm (2008) referred food security to a situation when all members of our society have access to enough food at all times. Another America based institute known as Sustainable Foods (2006) conceptualizes the notion of food security in the following word “[ The food must be nutritious, sufficient, safe and environmentally sustainable, means access by all people at all times to affordable, nutritious, culturally appropriate food, derived from non-emergency sources and produced through sustainable practices in order to lead healthy and productive lives]”. The Green Bee (2001) referred food security as an ability of individuals to obtain sufficient food on a day-to-day basis. In a nutshell, as revealed from the definitions, the food security was found to have three major elements or components i.e. (a) Food Availability (b) Food Utilization or Absorption and (c) Food access.

Food availability is achieved when sufficient quantities of food are consistently available to all individuals. Access to food is achieved when a household and all members of the household have enough (economic) resources to acquire food for sufficient intake of calories. Besides the physical as an aspect of accessibility, food access is the principal function of a household’s income and food price. Food access and food availability do not ensure food security alone. Food absorption is important at the same level of food availability and food access. Food absorption is achieved when diet provided adequate energy and essential nutrients to the human body. Access to safe drinking water can also be attributed as an important aspect of food absorption. Mother care, child care, morbidity, hospitalization, food processing techniques and the principles of food nutrition are equally important in the context of utilization or absorption of food. These elements are crucial to understanding the conceptual framework of food security. Therefore, holistic understanding of Food and Nutrition Security stresses the various dimensions of the concept: categorical aspects, socio-organizational aspects and managerial aspects (Lioba Weingarter, 2000).

The conceptual framework of food security indicates the categorical relationship of food security components. Two factors influence the conceptual framework of food security: physical factor and temporal factor. The physical factor is the determinant of food flow. It incorporates availability, accessibility and utilization of food. The temporal factor refers to stability which in turns has effect on three physical elements: availability, accessibility and utilization. The availability refers to the physical existence of food whether it is the production from the cultivated lands or an availability of food in the markets. On national levels, food availability is the combination of domestic food supplies, production and, commercial imports, food stocks and food aid. The term food availability is applied to both household and national or aggregate levels (Riely et al 1995). Access to food refers to a situation when all households and all individuals within those households have sufficient resources to obtain a nutritious diet (Riely et al. 1995). It has its own determinants. These determinants influence the accessibility and it is dependent on these determinants which may include household labor, capital, property and knowledge. Moreover, price and ability of household to generate income with production are considered to be the most important determinants of food access. Food access is also dependent on certain conditions such as politics, policy social environment and physical environment. Drastic and abrupt changes in these conditions during drought, conflict, war and chaos leads to a higher risk to food access of the affected households (Riely et al. 1999, 22). The third element Food utilization refers to the socio-economic aspect of household food security. It also incorporates the biological utilization of the food which is defined as an ability of the human body to take food and convert into energy. The conversion of food into energy helps human perform daily tasks and it is dependent on the adequate diet, healthy physical environment, access to safe drinking water and adequate sanitary facilities (Garter 2000). The decision for allocation of the food is crucial because it may affect the nutrition of food for each individual which may be balanced or unbalanced.

Much of the food security literature makes a distinction between food security and food insecurity. Two types of food insecurity are used in the literature: (a) chronic food insecurity and (b) transitory food insecurity. The inability to meet food need on an ongoing basis is known as chronic food insecurity and the inability to meet food needs on a temporary basis is called the transitory food insecurity which is further divided into two subcategories cyclical and temporary. The cyclical food insecurity occurs where there is a regular pattern of food insecurity for stance during the lean season, hungry season and before the harvest. Whereas the temporary subcategory of food insecurity occurs where there short term exogenous shock like flood and drought (Maxwell and Frankenberg 1992). Both cyclical and temporary food insecurity has negative Impact on food security for a longer period of time (Garteir, 2000).

The conceptual framework of food security establishes a strong connection between the categorical elements (food absorption/ food utilization, food accessibility, food availability) with the operative levels of social and administrative organizations. There are three operative levels of food security: (a) micro; (b) meso (c) macro. The micro level refers to food security at individual and household level. The meso level refers to food security at districts and province level. The macro level refers to food security at overall at national and global levels (Gartier, 2002). The interaction of the categorical elements of food security differs in nature, cause and effects on micro, meso and macro level respectively. For stance, measure to assess the food availability at macro level is different from meso or micro levels. At the macro level, food is available in Pakistan but not in certain disadvantaged districts of Baluchistan. Similarly at national level, the caloric supply might be high but at individual and household level the calorie levels might be very low for the poor and marginalized population. Therefore, a holistic approach is used in the conceptual framework of FNS (Billing, 2002)

The conceptual framework of FNS also integrates the food security and the malnutrition framework. Although each starts from a different conceptual perspective, but both arrive at the same programs designed by using common instruments and processes (Gartier, 2000) .The conceptual framework under the holistic approach also incorporates immediate causes of malnutrition which occurs at the level of individual human beings. These are dietary intake and health status (Smith and Haddad 1999); inadequate mother care, inadequate health service, lack of access to the safe drinking water, (Billig, 1999), low income and a hike in food price ( Smith and Haddad 1999 ). According to the health experts, dietary intake must be adequate quantity and quality. The nutrition of food consumed must be absorbed in the human body and should provide the required energy. Since a strong relationship between health status and nutritional status exists, for the reason, a sick person is likely to loose appetite, eating a poor diet and the poor digestion of food cause infections. These infections foster the infliction of malnutrition. In developing countries, infectious diseases, such as diarrheal diseases (DD), and acute respiratory infections (ARI), are the most important nutrition related health problems (WHO, 2002).

Food Security Analysis (FSA) of Pakistan conducted by the Sustainable Development Policy Institute (SDPI) and United Nations' World Food Program (WFP) presents the comprehensive picture of food security in Pakistan. This analysis is not in not in conformity with a common perception: "Pakistan is not a food insecure country". The findings of SDPI (2003, 2009) support the argument that food insecurity is more pronounced in Pakistan. According to the FSA of SDPI, Out of 120 districts in Pakistan, 74 (62percent) were found to be a food deficit in the context of food availability. This deficit varies ranging from low through high to an extreme degree. The shortage of wheat alone was estimated to be 3.8 million. Wheat is the most important staple because it fulfills around 48 percent of caloric needs in Pakistan. Food absorption was assessed on the basis of safe drinking water, immunization, infant mortality, hospitals and morbidity. In the context of food absorption, out of 120 only 45 districts experienced a low rate of food absorption while only 11 districts experienced the reasonable food absorption. Access to safe drinking water was found to be the major contributing factor for low rates of food utilization. Safe drinking water was only available to less than 50 percent population of all districts. The study also investigated the factors contributing to wide disparities in Pakistan. The contributory factors included gender disparity, income inequality, inequitable holdings of land and access to education and employment. These factors were found to have an adverse impact on women, labor, landless and small farmers in terms of access to food. The small landholding coupled with low reduced capacity of agriculture for gainful employment was also found to be a major factor. Further, the low income of 96 (80percent) districts out of 120 was found to exacerbate food excess from low to very low (SDPI, 2003).

**Implicit and Explicit linkages and relationships between water scarcity and food security**

Cline (2003) examined the impact of water scarcity on food production. The study concluded the water scarcity could cut food production and would adversely impact food security. The study proposed that self-sufficiency in food grain production can be achieved through expansion of existing irrigation infrastructure, control of the 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, which came up with a conclusion that it is not lack of arable land which will worsen the food security and cut the food production. It is the water scarcity which will risk the food security and will bar the increased food production in the coming decades (UNDP, 2007).

Whilst examining the impact of water scarcity of future food security Hanjra and Qureshi (2010) has analyzed that the future food security is being threatened by a constant decline in the water resources, climate change, and energy shortfalls. The study suggested the policy measures to cope with the worsening situation of water and food security. These measures are critical for eradicating poverty and hunger. Besides, the study brought to close that the water scarcity coupled with population growth, is defining the future of food security. Therefore investments in water conservation, modernization of irrigation infrastructure, preservation of land, and tackling climate change are direly needed. Further the transfer of water from agriculture put pressure on irrigation water demand and risks the food security due to its shortage for agriculture. Therefore water is a critical natural resource for food security (Fedroff, 2010).

The gaps between food supply and food demand in relation with water demand and water supply were found to be widening in Pakistan. A study conducted by the International Water Management Institute (IWMI) projected future cereal demand and supply in Pakistan. The model used 1995 data as default and makes a projection for 2025. The cereal production will rise to 36.25 MMT in 2025. Correspondingly, the domestic consumption will mount to 40.82 MMT, showing a gap of 4.47 MMT in demand and supply of cereals. Whereas physical water availability will remain 199 cubic kilometers till 2025 experiencing no change as it was 199 cubic kilometers in 1992. The study estimated that 40percent more food would be required by the year 2025 to feed the increasing population. The study provided a comprehensive projection with an analytical judgment that the annual growth rates of food production are far lesser that population growth rate during this period. Whereas for sustainability and self-sufficiency in food grain, the growth rate of in production would should be equal or greater than the population growth rate. Therefore, food security will face risks as water supplies are static over the same period of time (IWMI, 2001).

Hanjra and Gichuki, (2008) identified the factors posing major challenges to the water scarcity and food security. These challenges included increasing costs of developing new water resources, land degradation in the irrigated areas, groundwater depletion, water pollution and ecosystem degradation, current water utilization practices and fast growing population. The impact of these factors on densely populated regions of the world such as the Mediterranean, the Middle East, India, China, and Pakistan is analyzed which reveals the growing water scarcity has implications for poverty, hunger, ecosystem degradation, climate change and even world peace and security.

The similar challenges identified in Vision 2030, GOP (2008) listed the factors such as increasing water scarcity, climate change, degradation of land resources, inefficient use of agricultural inputs, ineffective transfer of technology to the farmers, lack of coordination between research and extension, post-harvest losses and marketing infrastructure and declared theses factors as challenges for Pakistan. These challenges together with looming water shortages are researched as posing a great threat to food security risks in Pakistan.

Pakistan’s 50-year period of glacial retreat and glacial reservoirs emptied are likely to decrease the river flows by about 40percent in Indus basin. The flows of Indus basin are already under the pressure of water competition between sectors and provinces. The decrease in the flows is likely to pose a great threat for agriculture and food security in Pakistan (WB, 2005). Another finding brought out by UNDP (2008) synthesized that progress in human development achieved over the last decade may be slowed down or even reversed by climate change, as new threats emerge to water and food security, agricultural production and access, and nutrition and public health. The impacts of climate change--- sea level rise, droughts, heat waves, floods and rainfall variation--- could, by 2080, push another 600 million people into malnutrition and increase the number of people facing water scarcity by 1.8 billion.

The analysis of all previous studies regarding climate change and water scarcity as cited by different sources has made final underpinnings about the disastrous impact of water scarcity and climate change. Parry et al., (2001) made a comprehensive assessment of the impact of climate change on food security and water resources. The conclusion of the study showed the disastrous impact of climate change on food production: causing food shortages, disruption in access to water, an increase in the number of people at risk of hunger and increase in poverty levels. The study suggested the mitigation of climate change can have significant positive effects on agricultural productivity and food security. The same findings about the negative impact of climate change on food security were shown by Spash, (2008).

Water productivity is a driver of water scarcity as enhanced water productivity impacts food security by increasing agricultural food production and mitigates the water scarcity (Cain and Rosegrant, 2003). Likewise the water price mechanism is also an effective tool in addressing the water scarcity (Johnson, 2003). Pretty (2001) suggested that effective in increasing the food production. The same findings were confirmed by (CLI, 2002). The study concluded that modern irrigation techniques can produce higher yields of good quality. In a report captioned" Pakistan's food and agriculture systems" USAID (2009) noticed the water productivity per cubic meter. It was found to be very low in Pakistan as compared to the international benchmark.

Molden, (2007) analyzed the links between food security, water entitlements, inequitable food distribution and poverty. The study found that the lack of water entitlements exacerbated the food security. The widening gap between poor and rich under scarce water scenario will pose risks to food security. In Pakistan more than 80percent people are living below the international poverty line of 2$ and about 70 percent people are found to be food insecure (Oxfam, 2007) whereas Gini index is medium but closer to high in Pakistan (Todaro, 2008). Therefore poverty amid growing water scarcity, decreasing yields, outmoded irrigation system and worsening food security is further exacerbating the food insecurity and water scarcity in all dimensions. In the same way institutional and political negligence is giving rise to the inequality in terms of water and food access. This situation is prevalent among all the countries of the world as well. A study by Hussain and Hanjra (2003) analyzed the impact of increased inequality. The study found that increased inequality in access to water is perpetuating poverty and widening the inequalities in access to water for food. Water scarcity was found to gear the competition for water resources among sectors, regions, and countries, and associated human activities. In connection with inequalities and competition for water the study estimated the total percentage of world population living in the region that directly compete for shared trans-boundary resources.

In the sum, literature cited above has regarded water scarcity an important determinant of food security. The constant decline in water resources will have an adverse impact on food security. More to the point, environmental, demographic, social and political factors are further exacerbating the water scarcity which in turn is posing major risks to food security and livelihood.

## Material and Methodology

### Data

Data on food security is collected from the report captioned "Food Insecurity in Pakistan 2009' which is a follow up of the "Food Security Analysis of Rural Pakistan 2003 (FSA 2003). The report ranks the districts of Pakistan on the basis of food security and gives a comparison of the current food security situation with the year 2003. In addition, some data have been obtained from Food Insecurity and Vulnerability Information Mapping system (FIVIMS), UN and Government of Pakistan. The information generated through FIVIMS is useful for policy makers; Government officials, civil society including NGOs, District Governments, Donor Community including UN agencies, bilateral donors, researchers, academia and training institutions. National FIVIMS program of Pakistan included the followings: National Nutrition Surveys, Agriculture Statistics of Pakistan (yearly)/Food Vulnerability, Economic Surveys of Pakistan (Yearly), Household Integrated Economic Survey, Household Income and Expenditure Survey, Food Balance Sheets, Health Statistics, National Data from International Agencies/NGOs, Provincial Surveys and Population Surveys/Census/Population Welfare. Water data were obtained partially from the report, Titled “Pakistan is running empty”. This report was released by the Wilson center for scholar in the USA and the remaining data were taken from, planning commission, International Water management institute, Reports of International agencies/NGOs and Research papers.

**Econometric Methodology**

A series of models is being used to assess the impact of water scarcity on food security in Pakistan. All models differ in their nature, functional form, operational definition and estimation methodology. Simultaneous equations have been given a proper structural and reduced form and the causal relationship of structural equations is in conformity with the conceptual framework of food security. The structural equations indeed catch the effect of causation of one variable for the other in a system of joint determination. For simultaneous equations 2SLS estimation method has been used and for simple equations OLS estimation has been used. .

**Meso Model**

In this model, the analysis is being made on the data at Meso level (Districts). The data set has been transferred into a new set of variables. The categorical elements of food security: food utilization , food access and food availability has been assigned five incremental values ranging from 1 to 5 showing the district is extremely low deficit, very low deficit, low deficit and surplus production in the context of categorical elements of food security. This model is also divided into two models: Model 1 and model 2. Three Simultaneous equations for Food utilization, food access, food availability and water availability per capita on the basis of cubic meters have been employed in the model 1. For model 2 the simultaneous equations change, instead of three only two simultaneous equations have been employed.

**Model 1**

The simultaneous equations of this model are as:

Food Absorption = $\alpha_1 + \alpha_2$ (Food Access) + $\alpha_3$ (Caloric intake) + $\mu 1$
Food Access = $\beta_1 + \beta_2$ (Food Absorption) $+ \beta_3$ (Food Availability) $+ \mu_2$
Food Availability= $\gamma_1 + \gamma_2$ (Food Access) + $\gamma_3$ (Water scarcity Cubic meters) + $\mu_3$

**The structural model: Causal relationship**

$$FAB = \alpha_1 + \alpha_2\, FAC + \alpha_3\, (SDW) + \mu_1 \qquad (1)$$
$$FAC = \beta_1 + \beta_2\, FAB + \beta_3\, FAV + \mu_2 \qquad (2)$$
$$FAV = \gamma_1 + \gamma_2\, FAC + \gamma_3\, WSC + \mu_3 \qquad (3)$$

Structural parameters: $\alpha_1, \alpha_2, \alpha_3, \beta1, \beta2 \quad \beta_3, \gamma_1, \ \gamma_{2,} \gamma3$
Number of structural parameter (NSP): 9

**Reduced form equations**
In these equations endogenous variables are expressed as a function of exogenous (predetermined) variables and these variables are not correlated in error.
Reduced form parameters are obtained by replacing equations in one another. The procedure of obtaining reduced form parameters is given below.

$$FAB = \alpha_1 + \alpha_2 (\beta1 + \beta_2 FAB + \beta_3 FAV + \mu_2 + \alpha3\ SDW + \mu_1$$
$$FAB = \alpha_1 + \alpha_2\ \beta1 + \alpha_2\ \beta_2\ FAB + \alpha_2\ \beta_3 FAV + \alpha_2\mu_2 + \alpha3\ SDW + \mu_1$$
$$(1- \alpha_2\ \beta_2)\ FAB = \alpha_1 + \alpha_2\ \beta1 + \alpha_2\ \beta_3 FAV + \alpha3\ SDW + \alpha_2\mu_2 + \mu_1$$
$$FAB = \left(\frac{\alpha1 + \alpha2\ \beta1}{1-\alpha2\ \beta2}\right) + \left(\frac{\alpha2\ \beta3}{1-\alpha2\ \beta2}\right) FAV \left(\frac{\alpha3}{1-\alpha2\ \beta2}\right) SDW + \left(\frac{\alpha2\mu2+\mu1}{1-\alpha2\ \beta2}\right)$$

Equation now gives the reduced form parameters i.e.

$$a = \left(\frac{\alpha1 + \alpha2\ \beta1}{1-\alpha2\ \beta2}\right)$$
$$b = \left(\frac{\alpha2\ \beta3}{1-\alpha2\ \beta2}\right)$$
$$c = \left(\frac{\alpha3}{1-\alpha2\ \beta2}\right)$$
$$e_{1=} \left(\frac{\alpha2\mu2+\mu1}{1-\alpha2\ \beta2}\right)$$

So, the first reduced form equation with reduced form parameters can be written as following

$$FAB = a + bFAV + c\ SDW + e_1 \qquad (1)$$

By repeating the same procedure the other two reduced form equations with reduced form parameter are obtained and these equations are given below.

$$FAC = f + g\ FAV + h\ SDW + e_2 \qquad (2)$$
$$FAV_{=} I + J\ FAB + K\ WSC \ + e_3 \qquad (3)$$

**Reduced Form Parameters** = a, b, c, f, g, h, I, J, k
**Number of reduced form parameters** = 9
There is a relation between the reduced form parameters and the structural parameters.
Reduced form parameters give the full effect of a change in an exogenous variable. **Identification:**
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 rule for the identification are given in the table below

**Identification Rules**

| **Name** | **Number of Reduced and structural parameters** | **Estimation method** |
|---|---|---|
| Just identified | NRFP = NSP | 2SLS = ILS |
| Over identified | NRFP > NSP | 2SLS |
| Under identified NRFP | NRFP < NSP | NSP Cannot estimate |

NRFP: Number of reduced form parameters.
NSP: Number of structural parameters.

**2SLS an Estimation Method**

**Step 1**: Reduced-form equations are estimated in first step of 2SLS. Reduced-form equations can be estimated by OLS.

**Step 2** Structural equations are estimated in second step of 2SLS.

After performing the two steps, some results are obtained. These results are documented in the results and discussions. Operational definitions of variables are given in table (a)

Table (a) Operational definitions of variables of Model 1 at Meso Level

| Variables | Operational definitions |
|---|---|
| **FAB ( Food absorption)*** | Districts are extreme deficit =1;Districts are high deficit =2;Districts are low deficit=3; Districts are sufficient =4 ;Districts are surplus =5 |
| **FAV( Food Availability)**** | Districts are extreme deficit =1;Districts are high deficit =2;Districts are low deficit=3; Districts are sufficient =4 ;Districts are surplus =5 |
| **FAC ( Food Access) **** | Districts are extreme deficit =1;Districts are high deficit =2;Districts are low deficit=3; Districts are sufficient =4 ;Districts are surplus =5 |
| **WSC** | Water Scarcity on the basis of Water availability cubic meter per capita |
| **SDW** | Safe drinking water |

**Model 2**

Two Simultaneous equations for Food utilization, food access, food availability and water availability per capita on the basis of cubic meters have been employed in the model. These equations are given below.

Food Availability= $\alpha + \beta$ (Food Utilization) + $\theta$ (Water scarcity cubic meter) + $\varepsilon$ (1)

Food utilization = $\lambda + \Phi$ (Food Availability) + $\eta$ (Food Access) + $\mu$ (2)

No problem found in the equations. Therefore reduced form equations are being used in this model.

**The structural model: Causal relationship**

$$FAV = \alpha + \beta\, FUT + \theta\, WSC + \varepsilon$$

$$FUT = \lambda + \Phi\, FAV + \eta\, FAC + \mu$$

**Structural parameters**: $\alpha, \beta, \theta, \lambda, \Phi, \eta$

**Number of structural parameter (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.

$$FAV= \alpha + \beta\ FAB+ \theta\ WSC + \varepsilon \qquad (1)$$

$$FAB\ = \lambda+ \Phi\ FAV + \eta\ (FAC) + \mu \qquad (2)$$

Reduced form parameters are obtained by replacing equation 2 into 1. The procedure of obtaining reduced form parameters is given below.

$$FAV = \alpha +\beta\ (\lambda + \Phi FAV+ \eta FAC + \mu) + \theta WSC + \varepsilon$$

$$FAV= \alpha +\beta\ \lambda + \beta\ \Phi\ FAV +\beta\ \eta FAC + \theta WSC +\beta\ \mu + \varepsilon$$

$$(1- \beta\ \Phi)\ FAV= \alpha +\beta\ \lambda +\beta\ \eta FAC + \theta WSC +\beta\ \mu + \varepsilon \quad (3)$$

Dividing equation 3 by (1- β Φ) on both sides

$$FAV= (\alpha+\beta\lambda/1-\beta\Phi) + (\beta\eta/1- \beta\ \Phi)\ FAC + (\theta/1- \beta\ \Phi)\ WSC + (\beta\mu+ \varepsilon/1- \beta\ \Phi) \quad (4)$$

Reduced form parameter are obtained from equation 4 i.e

$$a= (\alpha+\beta\lambda/1-\beta\Phi)$$

$$b= (\beta\eta/1- \beta\ \Phi)$$

$$c= (\theta/1- \beta\ \Phi)$$

$$e= (\beta\mu+ \varepsilon/1- \beta\ \Phi)$$

By replacing a, b, c, and e in equation 4, the following equation is obtained

$$FAV= a+ bFAC+ c(WSC) + \varepsilon \qquad (5)$$

Similarly for equation 2:

$$FAB= (\lambda+\Phi\alpha/1-\beta\Phi) + (\eta/1-\beta\Phi)\ FAC + (\Phi\theta/1-\beta\Phi)\ WAS + (\Phi\ \varepsilon + \mu/1-\beta\Phi) \quad (6\ )$$

Again, reduced form parameters are obtained from the equation (6) i.e

$$d = (\lambda+\Phi\alpha/1-\beta\Phi)$$

$f = (\eta/1\text{-}\beta\Phi)$
$g= (\Phi\theta/1\text{-}\beta\Phi)$

And

$u= (\Phi\ \varepsilon + \mu/1\text{-}\beta\Phi)$
By replacing d, f, g and u the following equation is obtained

FAB= d+ f (FAC) + g( WSC) + u (7)

The equation (5) and (7) has equal number of reduced form parameters making a total of six reduced form parameters.
**Reduced form parameters**: a, b, c, d, f, g,
**Number of reduced form parameters** (NRFP) = 6
There is a relation between the reduced form parameters and the structural parameters.
Reduced form parameters give the full effect of a change in an exogenous variable.

$$FAV= \alpha + \beta\ FAB + \theta\ WAV + \varepsilon\ (1)$$

$$FUT = \lambda+ \Phi\ FAV + \eta\ FAC + \mu\ (2)$$

For example WSC increases by one unit then

FAV decreases by $\theta$
FUT decreases by $\Phi\theta$
FAV decreases by $\beta[\Phi\theta]$
FUT decreases by $\Phi[\Phi\theta]= \beta\Phi^2\theta$
FAV decrease b $\beta[\beta\Phi^2\theta]=\beta^2\Phi^3\theta$
FAV decreases by $\beta[\beta^2\Phi^3\theta]= \beta^3\Phi^3\theta$

Total effect on FAV:

$\theta + \beta\Phi\theta + (\beta\Phi)^2 + (\beta\ \Phi)^3\theta + \ldots\ldots\ldots\ldots\ldots\ldots = \Sigma\ (\beta\theta)^t\theta = \theta/1\text{-}\beta\theta$

Similarly, the total effect on FAB:

$\Phi\theta + \beta\ \Phi^2\ \theta + \beta\Phi^3\theta = \Phi\theta + (\beta\ \Phi)\ \Phi\theta + (\beta\Phi)^{2\Phi\theta} = \Sigma\ (\beta\Phi)^t\theta\Phi = \Phi\theta/1\text{-}\beta\theta$

**Identification:**

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 rule for the identification are given in the table below

| Name | Number of Reduced and structural parameters | Estimation method |
|---|---|---|
| Just identified | NRFP = NSP | 2SLS = ILS |
| Over identified | NRFP > NSP | 2SLS |
| Under identified NRFP | NRFP < NSP | NSP Cannot estimate |

**Step 1**: Reduced-form equations are estimated in first step of 2SLS.
**Step 2** Structural equations are estimated in second step of 2SLS.Reduced-form equations can be estimated by OLS
.After performing the two steps, some results are obtained. These results are given in the next chapter 4. Operational definition of variables is given in table (b).

Table (b) Operational definitions of Model 1

| Variables | Operational definitions |
|---|---|
| **FAB ( Food absorption)*** | Districts are extreme deficit =1;Districts are high deficit =2;Districts are low deficit=3; Districts are sufficient =4 ;Districts are surplus =5 |
| | |
| **FAV( Food Availability)**** | Districts are extreme deficit =1;Districts are high deficit =2;Districts are low deficit=3; Districts are sufficient =4 ;Districts are surplus =5 |
| **FAC ( Food Access) **** | Districts are extreme deficit =1;Districts are high deficit =2;Districts are low deficit=3; Districts are sufficient =4 ;Districts are surplus =5 |
| **WSC** | Water Scarcity on the basis of Water availability cubic meter per capita |

## Results and discussion of Meso Model

The analysis made at meso level is also showing the negative impact of water scarcity on all the components of food security. However, the decline in food utilization is must because it is absolutely dependent on food access and food availability in the system of equations. As shown by the results, food availability is associated with food utilization. The more the food availability is the more will be the food absorption. In the same way, food access is dependent on food availability. The higher the food availability is the higher will be the food access. This is why the simultaneous equation of joint determination is being used in this model. These results are based on the two stages. The results show that water scarcity is rendering and adverse impact on the food security at Meso level. The two components food availability and food absorption are decreasing with the increase in water scarcity. Conversely, food access is positively related to the water scarcity variable. The reason behind this negative relationship can be interpreted from the second stage in which food absorption is positively linked with the food access and food access is positively linked with the food availability and the food availability is negatively related to the water scarcity, thus, this thesis may deduce that the water scarcity has a negative relationship with food access. However, the food availability and food absorption are negatively related with water scarcity in the results. Much of the theory in its conceptual footings establishes only a negative link between the water scarcity and food availability only. This is why two models have been built at meso level i.e1 and model 2. Overall, the model is good and the output of the results is satisfactory and is in accord with the theoretical relationships. The results of this model are given in the table respectively.

### 4.2.1: Model 1

The results of Model 1 show negative impact of water scarcity on food availability. The food availability decreases as water scarcity increases. In joint determination, food absorption is positively related to food availability and food access. The more the food availability is the more will be the food access. The results confirm that food absorption increases with the increase of both food availability and food access. In other words , the prediction of model confirms that the absorption of food will shift from extreme to very low and from very low to low and from low to sufficient and from to sufficient to surplus when both food availability and food access increase. Therefore, thesis can easily jump to a conclusion that food absorption is positively related to food availability and food access---albeit the determinants of food absorption are different. These determinants may include hospitalization, access to safe drinking water, mother care, knowledge of healthcare, hygiene and sanitation. However, the impact of water scarcity on food availability is negative. As shown by the results, an increase in water scarcity is causing the food security of districts to shift from surplus production to sufficient production; from sufficient to low food secure; from low food secure to very low food secure and from low food secure to extreme food insecure. Results of model 1 at meso level are given in tables c, d, e, f, g and h respectively.

Table (C) OLS on reduced form equation 1

| Variables | Coefficient | t-statistics |
|---|---|---|
| **Constant** | - | 3.7325 |
| **SDW** | 0.232 | 2.1869 |
| **FAV** | 0.118 | 2.2321 |
| **Dependent Variable=FAB**<br>**Number of observations = 120**<br>**$R^2$ =0.745** | | |

Table (d) OLS on reduced form equation 2

| Variables | Coefficient | t-statistics |
|---|---|---|
| **Constant** | - | 3.7325 |
| **SDW** | 0.232 | 2.1869 |
| **FAV** | 0.118 | 2.2321 |
| **Dependent Variable=FAC**<br>**Number of observations = 120**<br>**$R^2$ =0.735** | | |

Table (e) OLS on Reduced form equation 3

| Variables | Coefficient | t-statistics |
|---|---|---|
| **Constant** | - | 3.7325 |
| **WSC** | 0.232 | 2.1869 |
| **FAB** | 0.118 | 2.2321 |
| **Dependent Variable=FAV**<br>**Number of observations = 120**<br>**$R^2$ =0.731** | | |

Table (f) estimated FAC HAT

| Variables | Coefficient | t-statistics |
|---|---|---|
| **Constant** | - | 2. 7861 |
| **SDW** | -2.376 | -3.1568 |
| **FAV** | 0.3243 | 2.0324 |
| **FAC HAT** | 0.165 | 2.7543 |
| **Dependent Variable= FAB** | | |

| | |
|---|---|
| **Number of observations = 120** <br> **$R^2$ =0.742** | |

Table (g) estimated FAB HAT

| Variables | Coefficient | t-statistics |
|---|---|---|
| **Constant** | - | 2.93876 |
| **WSC** | -2.234 | -3.3479 |
| **FAB(1)** | - | - |
| **FAB HAT** | 0.347 | 2.3422 |
| **Dependent Variable= FAV** <br> **Number of observations = 120** <br> **$R^2$ =0.753** | | |

Table (h) estimated FAV HAT

| Variables | Coefficient | t-statistics |
|---|---|---|
| **Constant** | - | 2. 7861 |
| **WSC** | -2.376 | -3.3435 |
| **FAB-1** | - | - |
| **FAV HAT** | 0.234 | 2.7543 |
| **Dependent Variable= FAB** <br> **Number of observations = 120** <br> **$R^2$ =0.742** | | |

### 4.2.2: Model 2

The results of Model 2 also show the negative impact of water scarcity on food availability. The food availability decreases as water scarcity increases. Likewise food absorption decrease when water scarcity increases which implies under water stress conditions the food security status of districts is shifting from surplus to sufficient; from sufficient to low; from low to very low and from very low to extreme low . Therefore, the findings of thesis are cogent enough to depict the negative impact of water scarcity on food security in Pakistan.

The water scarcity is a grave concern for all the components of food security. The water scarcity is not only causing the food availability to decline but also posing threats to the other two components of food security. As the results show that in joint determination, food absorption is positively related to food availability and food access. The more the food availability is the more will be the food access. The results confirm that food absorption increases with the increase of both food availability and food access. In other words , the prediction of model confirms that the absorption of food will shift from extreme to very low and from very low to low and from low to sufficient and from to sufficient to surplus ---when both food availability and food access increase. 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 2 are given in table I,j,k,l,m

Table ( I ) OLS on the reduced form equation 5

| Variables | Coefficient | t-statistics |
|---|---|---|
| **Constant** | - | 2.9623 |
| **WSC** | -0.264 | -3.1265 |
| **FAC** | 0.187 | 3.1354 |
| **Dependent Variable= FAV**<br>**Number of observations = 111**<br>**$R^2$ =0.798** | | |

Table (J) OLS on the Second Reduced form equation 7

| Variables | Coefficient | t-statistics |
|---|---|---|
| **Constant** | - | 2.8327 |
| **WSC** | -0.274 | -3.4569 |
| **FAC** | 0.156 | -2.7691 |
| **Dependent Variable=FAB**<br>**Number of observations = 111**<br>**$R^2$ =.743** | | |

Table (K) estimated FAB HAT

| Variables | Coefficient | t-statistics |
|---|---|---|
| **Constant** | - | 3.2732 |
| **WSC** | -0.287 | -3.3958 |
| **FAC** | 0.137 | 2.3985 |
| **FAB HAT** | 0.265 | 3.4284 |
| **Dependent Variable= FAV**<br>**Number of observations = 111**<br>**$R^2$ =0.734** | | |

Table (L) Estimated FAV HAT

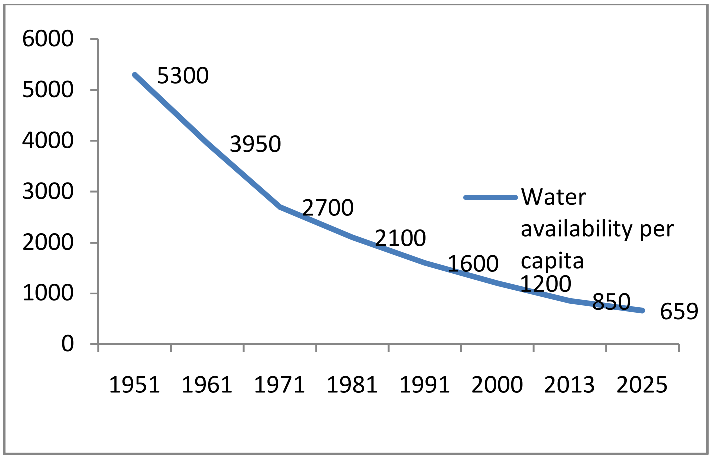
| Variables | Coefficient | t-statistics |
|---|---|---|
| **Constant** | - | 2.8436 |
| **WSC** | -0.218 | -3.0128 |
| **FAC** | 0.134 | 2.2854 |
| **FAV HAT** | 2.164 | 3.02163 |
| **Dependent Variable= FUB**<br>**Number of observations = 111**<br>**$R^2$ =.749** | | |

**Projection of future water and food**

As per literature review, the future food security of Pakistan will deteriorate under the scarce water situation. The results in this study also confirm the validity of past research (see UNDP). Some researchers presented the projections of future food security in comparison with the growing water scarcity in Pakistan. Their research presents many scenarios like best agricultural practices, advanced technology water management and draws the comparison of each scenario with water scarcity. In this study, only the data of PODIUM (Policy dialogue model) is being used for the graphical representation of the future food security under scarce water scenario.

Fig1 describes the trends of future water availability on the basis of cubic meter per capita per person. The figure shows water availability is in constant decline when compared with the previous years. In year 2025, the water scarcity will be around at the levels of absolute water scarcity**.** On the contrary, there is a constant increase in the future demands of water for irrigation, agriculture and livestock. While making a comparison of water availability with the demand of water for different sectors, it can be clearly observed that supply of water falls short.

Figure 1 Future water availability




The supply is low in comparison with the demand. The gaps of supply demand cannot be filled because water is a natural resource which can neither be produced nor can be generated. Under such a distressing state of affairs, the demand for food is also larger as compared to the supply of food. As it is clearly shown in the fig 2 and 3: amid rapid growth in population the supply of food will not be able to feed a big chunk of food. Consequently, the food security will deteriorate further and the stake of water scarcity would be high for the people of Pakistan-----hunger, famines, conflict, civil wars, extreme poverty, misery, diseases, and an utter helplessness for people and state as well.

Figure 2 Future Population

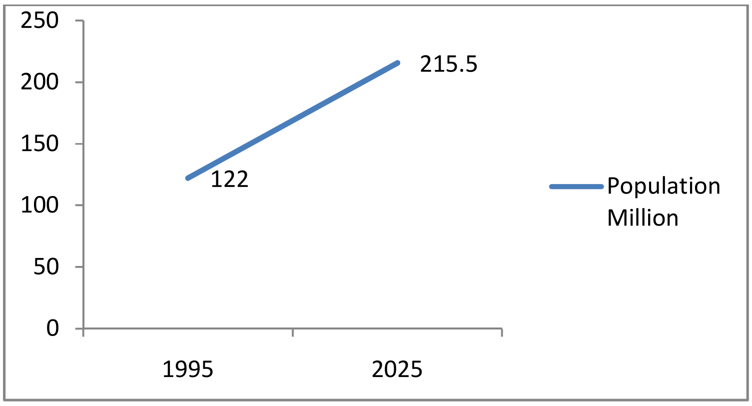
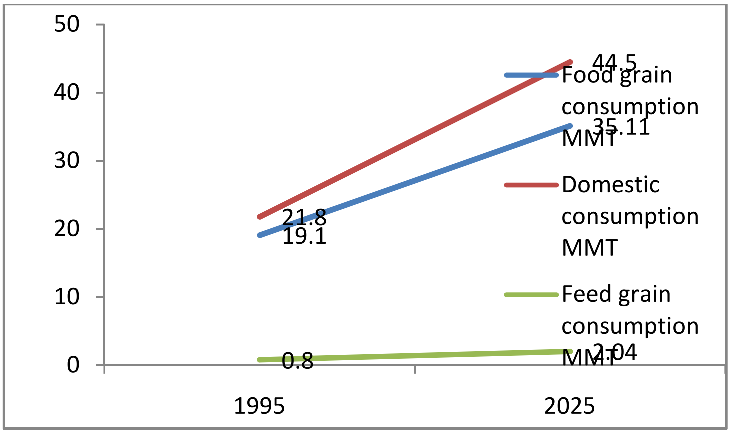



Figure 3 Future Cereal Requirement




## Conclusion and Policy

Water scarcity is posing great challenges to food security in Pakistan .A state with a big chunk of the population which is already food insecure will face the dire consequences of looming water scarcity: hunger, famines, conflict, diseases, helplessness and extreme poverty. The impact of water scarcity is acute on food security because climate change and population growth are the two factors that are simultaneously affecting water resources and agriculture. The rapid growth of population has exerted pressure on water resources as the excessive pumping of water with excessive and discriminatory use of water is causing the water tables to recede fast in the aquifer. In other words, aquifer is depleting. At the same time Pakistan will require more food supplies to feed its rapidly growing population. Whereas climate change is rendering negative impact on the agricultural yields and water resources are also being negatively impacted by the climate change. This scenario is distressing and has implications for Pakistan as a state and as a society. Furthermore, the results of the models employed show that water scarcity has negative impact on food security. The water scarcity is causing the entire population of Pakistan to become more food insecure as the water scarcity is making the population fall from the less food insecure status to the more food insecure status. In the same way, the food security is deteriorating for the provinces and districts. Owing to the impact of water scarcity, the districts which have been found moderate food secure in the data are becoming low food insecure; the districts which have been found low food secure are becoming very low food secure and the districts which are already food very low food insecure will become extreme food insecure. The same is true for the provinces. The food security of Baluchistan, Sind, Khyber Pakhtoon khawa and Punjab is negatively related to water scarcity in the results .For a household , the more the household is water scarce the more will be the household food insecure which has implications for water security as well . As far as the components of food security are concerned, their relationship with each other is also shown in the results. The more the food availability is the more will be the food access and food utilization. In the models, the food access is a function of poverty and income, the two crucial factors that bar the people to have food access and it's negatively related to poverty and income. The higher the level of the poverty is the higher will be the number of people being bared to have access to the food. Likewise, the higher the income is the higher will be the number of people accessing food. Food utilization is function of safe drinking water and poverty. In Pakistan, almost half of population has no access to the safe drinking water. Food utilization is negatively associated with the availability of safe drinking water in the results. The lesser the number of people accessing the safe drinking water, the more the number of food insecure people in the terms of food utilization or absorption. In nutshell, the water scarcity is rendering a negative impact on food security. The severity of impact can be lessened by the implementation of the policy guidelines. These policy guidelines are given in the followings:

1: 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.

2: The optimal use of water with a sustainable agriculture will lessen the adverse impact of water scarcity on food security in Pakistan.

3: Pakistan should build environmentally friendly water reservoirs.

4: There is a dire need to repair and to maintain the existing infrastructure.

5: More emphasis on drip irrigation must be placed.

6: Appropriate balance between centralized and decentralized water management must be achieved.

7: Water provision at local and individual level coupled with the empowerment of citizenry particularly gender must be emphasized in water policy of Pakistan.

8: Balance between urban water pressures and agriculture should be achieved.

9: Promotion of private sector for the management of water resources will be effective to alleviate the crisis.

10: Conservation of water must be prioritized and farmers should be provided with water conserving agriculture technologies.

11: There is a need to address the structural obstacles at national and policy level.

12: Success stories are good learning for overcoming the water scarcity in Pakistan and these successes should be followed in their true essence.

13: Effective and efficient use of water by government , businesses, farmers, private sector , communities and people must be considered as a moral duty .

14: Abatement technologies can help lessen the impact of climate change on water resources and agriculture. These abatement technologies should be made operative in all sectors.

15: Productivity enhancement of major crops is an urgent need.

16: Shifting dependence from staple food to other foods which require lesser water for production might be a good initiative.

17: Indiscriminate and excessive use of pesticides must be abolished.

18: Sustainable and efficient utilization of the natural resource needs to be prioritized at national and local level.

19: Proper application of physical inputs such as seeds, fertilizers, credit and pesticides should be adopted by the farmers.

20: Identification and targeting the food insecure people will enormously help to alleviate the food insecurity.

21: On- Farm and off-farm income generation activities should be diversified.

22: Stabilization of input and output prices needs to be achieved.

23 Inter-regional and urban-rural disparity must be removed.

24: Distribution of land and access to the resources should be emphasized equally for both small and large farmers.

24: Gender inequity needs to be addressed at national and local level.

25: Skill development and exposure to the development needs to be emphasized.

26: Improving the nutritional aspects of food will be beneficial for every individual of the society.

27: Vegetable and pulses production, rural poultry, inland fisheries and rearing of small ruminants must be adopted at household level.

28: Policy bias in macro framework against agriculture must be removed immediately.

29: Provision of rural infrastructure, human resource development, research and extension support services need to be given much higher priority.

The policy recommendations given above must be implemented at war footing basis, because absolute water scarcity is approaching fast and food insecurity is much higher in Pakistan. Climate change is adding fuel to the fire, a challenge being accepted superficially but in reality the greatest threat for both water scarcity and food security. It will not only exacerbate water scarcity and food insecurity but will also make poor and vulnerable wiped out from the face of the earth. The consequences of water scarcity and climate change in the view of this thesis will play havoc with life. These consequences are beyond--- famines, conflict, diseases, extreme powerlessness, utter helplessness and extreme poverty.

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