Factors Influencing Groundwater Resources In Water Stress Countries

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CERTIFICATE

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List of Abbreviations

ADB= Asian Development Bank

CO2= Corban Dioxide

GHG= Greenhouses Gas Emissions

IPCCC= The Intergovernmental Panel on Climate Change

TGWR= Total Groundwater Resources

TDC= Total Dam Capacity

POP= Population

TEMP= Temperature

PREC= Precipitation/ Rainfall

TAA= Total Agriculture area

FOF= Frequency of Floods

OLS= Ordinary least square

ABSTRACT

This study is examining the effects of different influencing factors on Groundwater resources in the water stressed countries during the time period 1987-2016 using Panel data econometric techniques namely the Hausman test was conducted to identify the best model between Random effect and fixed effect models. The results show that Precipitation, dam capacity, temperature and frequency of floods have positive and statistically significant impact on Groundwater resources in water stressed countries. Whereas, population and total agriculture area have negative impact on groundwater resources. On the basis of the current study it is recommended that to save the flood water, snow melting water, and surface water by building the dams and reservoir which helps to increase the groundwater recharge. Artificial Aquifers recharge from floods and rainwater can increase the groundwater availability.

Chapter 1

1.1 Introduction

Water is one of the important natural resource in the natural environment. Water is classified into three major categories: Solid, liquid and invisible vapor. Water always dominating other natural resources existing in the environment because it is equally important for all the living things. Water molecules run through water cycle in different stages i.e. in the atmosphere through clouds and rain, through Surface water to subsurface or groundwater (Alcamo et al., 2003)

It is extremely related to the survival of human being and sustainable development of any society. More than 2billion people consuming groundwater resources for their daily use. A sizeable amount of industrial and agriculture requirement of water supplied by the government through groundwater resources (Wada et al., 2010). There is a predetermined quantity of water on our earth, only 3% of the total water in our planet is freshwater and less than 1% is easily usable by humans.

Total global water availability 97.5% is oceanic or salt water, 2.24% water is in polar icecap Antarctica and Greenland glaciers deep ground water, only 0.26% of water is accessible and available in lakes, reservoir and river channels (Gleick, 1993; Johnson, 2012) Glaciers and permanent snow cover 68.7%, Groundwater 30.1%, Freshwater lakes 0.26%, Rivers 0.006%, Atmosphere 0.004%, Biosphere 0.003% of the total amount of fresh water resources on earth (Stefan, 2009). In various countries, people extracting more than half of the groundwater for domestic water uses, which is the proportion of 25%–40% of the total world's drinking water (ADB, 2016)

This issue has got significant place after international economic development and environmental policies since after some significance meetings i.e. the first world water forum (WWF) in 1997 and 2000 and world summit on sustainable development (Information, 2003).

Various studies are conducted to investigate the water securities around the world. The current issue of water security is much more related to the water management rather to water stress and water security (Brown et al., 2015) . The water security is the environmental problem intensified by the lack of socio-economic development (Gleick, 1993). The strengthening and complication of the water stress and scarcity is because of increasing demand with increasing population and urbanization, inadequate management with unsystematic approach which cannot estimate the water security effectively.

We have to adopt systematic, predictive and cohesive methods for the identification and estimation of the Water Resource (José Galizia Tundisi, 2008; Somlyódy, 2000; Varis, Biswas, Tortajada, & Lundqvist, 2006) Water security is because of socio-economic development, intensifying pollution of water resources and increasing urbanization leads to increasing demand for water and water resource depletion in water scare countries (Tundisi, 2008)

Rising demand for food is increasing demand for agricultural production and, consequently, the demand for groundwater for irrigation process will increase. Globally, the agriculture water demand is projected to increase through 2050 (Johnson, 2012). The industrial sector demand will also increase by 2050 but not as much as in agriculture sector. Mostly middle east countries are water stress because of his ecological and geographical issues, mismanagement and water demand for Agriculture and Political-economic instability (El-Fadel & Bou-Zeid, 2001)

1.2 Situation in the Water Stress Countries

Groundwater situations in middle east and Asia are getting worse. Recent WB memorandum on water management has signaled that the increasing aquifers discharge will severely affect the human wellbeing of Yemeni society. The aquifers discharge is estimated increase by 400% in next 10 years (Mulholland, 2011). The condition of groundwater in the Asian countries is not better. Especially in Pakistan and India where recently more than a million of well have got added for irrigation purposes, the groundwater recharge exceeds the aquifers recharge rate in the most regions. The consequences of this rapid process have been visible in the Punjab and Haryana state of India in the form of salinity, water contamination and Increasing cost of water pumping in the mountain areas (Khan, 1994). In coastal areas, the dangerous consequence of increase in extracting of groundwater for agriculture turns the aquifers into saline water. All these challenges will weaken the region's ability to feed its increasing population. Unplanned groundwater extraction can create disturbance on fragile ecosystems for example wetlands. In Pakistan, rising groundwater salinity and water tables are amongst the most critical issues in the Indus Basin. Aquifer contamination from both point and non-point resources is becoming bigger worldwide. Non-point pollutants in the basin Anatolia and Gediz is generally polluted by agrochemicals,which badly affect the groundwater and downstream cities i-e Izmir and Menomin where strawberry fields owner would rather extract groundwater than use the river water. Middle East touches the continents of Asia, Africa, and Europe. With Extremely arid and semi-arid climatic regions and environmental variations. Most Arid regions are concentrated in the middles east and North African regions. Most of the middle east countries are water stressed. Overpopulation, climatic variability, geographical and physical aspects, political and regional disputes are the major responsible factors behind the groundwater resource depletion in this region. (El-Fadel & Bou-Zeid, 2001)

Overexploitation of groundwater resources seems to be general in most of irrigated areas of Greece. The northern part of the country has observed clay layers and flood situations, Along with lowering land surface because of wetland's drainage and groundwater extraction from shallow aquifers extraction. In the central part of the country intense agriculture practices consists of water demanding crops such as wheat, corn, Alfalfa and cotton. With the maximum subsidence rate in this part approximately 25mm/ year, damage the groundwater tables as well as roads, buildings and public infrastructure have also appeared recently. These damages are the outcomes of extensive wetlands drainage practices from 1920s to 1960s to overcome malaria and flooding and to expand the agriculture land. This policy increased the impermeable land surface and subsidence, which is a serious threat for the infrastructure and groundwater resource channels (Paleologos & Mertikas, 2013).

The main challenge in Middle East and North Africa affecting the groundwater resources is the scattered and countless amount of groundwater users. Like most other countries, Morocco has many wells. Lebanon has officially around 3000 wells, but in the literature the amount has been underestimated. Lebanon, Morocco and Yemen have uncontrollable and countless amount of groundwater users. Thus, enforcing and regulating policies are extremely difficult and resource consuming. Major consumer is agriculture sector which consume 90% about 9% of water is potable and 1% of water is combinedly used by the industry and tourism sector. It is generally used to decrease dust on streets and roads near operation sites, to transfer and wash the phosphate, to transfer heat, to cool sulfuric acid and to make phosphoric acid (Mayr et al., 2007).

In Afghanistan, Inefficient land-use practices and deforestation are responsible for long-term reduction of groundwater resources. With increasing pumping, the water table drawdown near the major urban centers i-e Kabul river and Helmand river. Another crucial problem is the water quality impacting the major urban zones and towns. Because of poor drainage, point and non-point waste water discharge and chemical discharge in water bodies. With increasing population in the major urban areas, the groundwater extraction increases with lowering the water tables, extraction from shallow aquifers and hand dug wells are the main reasons for decline water level in Helmand and Kabul River. Despite these cities, Kandahar and other cities are merely depend on groundwater for clean drinking water and irrigation purposes. Climate change also playing a vital role in the groundwater depletion in Afghanistan, but these problems can be handled with skillful management and adequate irrigation practices (Jyrkama, 2003).

Approximately 80% of the water is used for the irrigation purposes in Libya, Oman, Egypt, Saudi Arabia, Morocco, UAE and Syria while Yemen and Iran are using 90% of their water for irrigation which is higher than the world average 70%. Population is the main driving force behind the water scarcity.

As the people get richer the demand for water also increase due to changes in different nutritional preferences. The water demand will increase from 28Km^3 now to 88km^3 in 2040-2050 with doubled increase will be seen in the industrial water demand. Turkey has the capacity to manipulate the water flow of its downstream Regions. the downstream neighbors have no privilege to intervene in Turkish internal water policy which creates tension and scarcity in downstream Riparian (Dolatyar & Gray, 1999)

Agriculture is the important sector in Syria’s economy but it depends on groundwater, river and springs water resources. Its population is rapidly increasing with the increasing demand for water supply. The southern areas are water secure and it is effectively supplying water to the drier areas of Syria (Woodbury & Ulrych, 2000).

In 1975, Iraq sent platoon to the Syrian border when the flow of the Euphrates reduced from 28 to 21 billion cubic meters. Iraq frightened to blast Tabqa Dam if more water was not released. The Saudi Arabia and Soviets interfered and helped to negotiate the dispute. Syria decided to release more water to Iraq regardless any diplomacy and dispute.

Israel has strictly restrained the Arab population from retrieving new water sources. Palestinian antipathy lasts to grow as Israelis overdraw domestic aquifers. Palestinian's are consuming 130 mcm of the total estimated 560 to 710 mcm per annum, which correspond to only 20 % of the renewable groundwater resources of the West Bank (Dolatyar & Gray, 1999) Those who are living around the west bank the illegal water boring to meet water demand. Over exploitation has depressed the water table and has turn the freshwater to the saline water. These unsustainable approaches have persisted for 30 years in Palestine. A rising water scarcity is indicating that the Gaza must have to import water or in some way cope with the expense of constructing purification services (Dolatyar & Gray, 1999).

With growing urbanization and demand for domestic food and water, the Israel water system permitted the country to rise the agriculture output from 30,000 Ha in 1950 to 200,000 Ha in 1980's. The amount of water extraction had been doubled with increasing discharge and decreasing rate of recharge. Water resources of Israel are mostly situated in the north while 65% of its urban and agriculture Hubs are in the southern areas. This uneven distribution and growing demand intensifying the water scarcity.

Jordan is suffering from increasing population, climate vulnerability and a meager share of the Jordan Basin. With a population of 6.5 million (Davis, 2010) geographically, Syria and Israel have the advantage over it, because Jordan is the downstream riparian. It relies on surface water because of lower precipitation infiltration amount with an uneven and minimum of 300 mm rainfall per annum. Compared to its neighbor countries i.e. Israel and Syria, Jordan has suffering more by its physical and climatic attributes.

After deep insight of situation in water stress countries, the situation of middle east is different from south Asian and African countries. Apart from demographic and climatic conditions it is facing regional conflicts, institutional deficiency, geographical and political challenges (Dolatyar & Gray, 1999). While most of the Asian and African countries are facing the same situation but with the sever changes in climate and rapid increase in the population which increase the demand and decrease the water resources in the mentioned continents.

1.3 Significance of the study:

Various studies have been conducted to estimate the groundwater availability in future i.e. (Alcamo et al., 2003; Alcamo, Döll, Kaspar, & Siebert, 1997; Gedney et al., 2006; Shiklomanov & Rodda, 2004) These studies were based on WaterGAP model given by IPCC scenario A1, A2, B1, B2 for estimating the groundwater resources availability in future. Some studies estimated the impacts of climate change on groundwater resources regionally and socio-economic factors influencing groundwater resources (Singh & Kumar, 2015; Toure, Diekkrüger, Mariko, & Cissé, 2017). Studies attempted to estimate influencing factors of the groundwater resources such as climate change, socio-economic and demographic factors separately. But as per our knowledge, no specific research has been conducted to estimate the impact of climatic and non-climatic factors influencing the groundwater resources particularly in the water stressed countries. This study aims to estimate how each of the influencing factor affect the groundwater resources in the sampled water stressed countries.

Research Questions:

1. Are the groundwater resources depleting over the time?
2. What are the main factors influencing groundwater resources?

Research objectives:

This study aims to:

1. Estimate the trends of Groundwater resources in the water stress countries.
2. Estimate the impact of each influencing factor on the groundwater resources in the water stress countries.

Chapter 2

Review of literature

2.1 Socio-Economic Factors affecting groundwater resources:

Demand for agriculture irrigation is the most significant and common feature. However, mostly the under developing nations are vulnerable because of their socioeconomic problems, including the North Africa, China and Indian regions (Alcamo et al., 2003; Alcamo & Henrichs, 2002; Pimentel et al., 1997) used the Global assessment and prognosis (GAP) model assumed three scenarios for current water stress situations estimated for 2025. The *business as usual* (BAU) scenario was threaten situation where the under developing and agricultural countries are mostly vulnerable because of increasing population, Urbanization, Change in lifestyle and economic development. Another scenario was *technology economics and private sector* (TEC) setup where the technological efficiency which can reduce the impact and cost of converting saltwater into freshwater to meet the domestic demand. Another scenario was *values and lifestyle* (VAL) emphasize on the water conservation, water use, awareness about water security and water management the TEC and VAL can help to conserve and manage the water resources efficiently in under developing countries till 2050. To adopt the overall policies in the model can reduce the water stress in all the regions specially the affected regions of Sub-Saharan Africa and South and East Asian countries.

The consumer oriented society and strong western influence on Saudi Arabian society increase the demand for pure drinking water and irrigation significantly affect the renewable fresh water resources (El-Fadel & Bou-Zeid, 2001) Increase in the population increase the demand for water by household and agriculture sector, most of the Arabian countries has the desalination technologies which replaced the sea water to the clean water resources are All failed to meet the increasing demand by Arabian. Both water supply and demand changing over time, usually the water demand for irrigation is higher during dry summer when the water availability is least. Burning of fossil fuels resulting acid raining, Water withdrawal for irrigation, groundwater extraction in semi-arid[1] and coastal areas that generates groundwater pollution and salinization, Furthermore, increasing deforestation, restricting rivers for domestic uses, and wetland destruction also significantly affect the groundwater resources in many region of the world (Meybeck, 2006; Pimentel et al., 1997) the world's population will increase from current 6 billion to 8billion in 2032, which will increase the global water withdrawal from 3.500 km^3 in 1995 to 4900 km^3 by 2032 (Alcamo & Henrichs, 2002)

Building new constructions reduce the open areas i-e playgrounds and parks. Lying of concrete on roads and buildings reduce the amount of seepage of rainwater into the groundwater, groundwater is mostly use for the construction purposes. The water consumption trends around the world were not similar, its remain stable in south America and Southern Africa. Its become worse in the middle east as compare to other regions since 1950's. per capital consumption in Australia and pacific were increased six times compared to the 1900's. the Central Asia and Eastern Europe were also faced the increasing per capita consumption until 1990's. In the study periods the major water consumer was irrigation, by consuming the 90-94% of global water. south Asia were among the top regions by consuming 97% of its total water for massive rice farming, middle east used 98% of its total water for the irrigation due to the arid Conditions (Shah, Molden, Sakthivadivel, & Seckler, 2000)

Globally The irrigation water consumption is currently about 70%, After that industry consumes 20% and 10% for domestic use. The efforts are made to decrease the water consumption in the industry and household but the use and efficiency in the irrigation system remains the same. The proportion of water using in these sectors are varied region to region according to the development and conditions of the countries. North America and Europe

[1]less than 20 inches of rain each year (Wikipedia)

water is mostly used for industry, while in Africa and Asia the agriculture sector is the primary consumer. Therefore, more than 30% of groundwater resources are extracting for irrigation in many Arid and Semi-Arid regions of these continents. (Aydogdu, 2016)

Insensitive anthropogenic activities can affect the quantity as well as the quality of groundwater resources i-e intensive Groundwater extraction by the society and individual may lead the generation to face the serious situations of Security. Such extraction can reduce the evaporation from the water table by decreasing the water level and recharge rates. Practicing and use of mineral deposits in many cases decreasing the drainage and water level mutually.

Constructions and industrial factors has influence on groundwater resources and quality such as wastes flow from the machinery, Contaminated water, infiltration of irrigated water, concentration of moistures beneath the building structures and tarmac, construction of water reservoirs and pools for watering the buildings and pumping groundwater for the construction purposes. (Brown et al., 2015)

Rural development and construction sometimes disturb the groundwater lenses and percolation process, which influence the quality and quantity of groundwater resources. rising water level increasing evaporation of groundwater, Horizontal and vertical extraction practices of groundwater, Massive use f fertilizers and chemical directly deposited in the aquifers, different manures, poultry plants, cattle-breeding farms release wastes and water is also directly deposited into the aquifers. Nitrogen and iron, pesticides and fecal coliform are the major compounds polluting water. Other factors such as irrigation, pasture watering, Oil and gas development plants, mining for mineral deposits also affect the water lenses and groundwater channels. Which causes changes in outflow and inflow balance, Recharge and discharge process of groundwater and influence the quality of groundwater by infiltrating contaminations. (Arnell et al., 2004)

(Lerner, 2003) studied the factor analysis techniques and correlation co-efficient a group of parameters which discharge from common sources were obtained but also affected by anthropogenic activities. Accordingly, poor sanitation conditions and waste generation with increasing urbanization together with the lack of adequate waste disposal techniques contributed to the various effects of pollution was witnessed in the shallow well, which are the results of anthropogenic effects on groundwater of the region. these affects vary with the time and place depending on the geographical and climatic conditions.

Growing population, continuous economic development, inadequate water management and land use change will worsen groundwater shortage by growing water demand. The natural renewable water supply volume has been exceeded by the groundwater extraction in large numbers of aquifer in most of middle east water stress countries. Some forced migration in Iran has been witnessed after excessive use of groundwater and surface water in the irrigation, the farmer communities shifted from droughted area to the water rich areas. Such Environmental migration put Burdon on natural resources especially on water resources. As a result, the current level of Lake Urmia is approximately one-tenth of its original size, creating one of the serious water and environmental disasters in the middle East. Intensive Groundwater extraction directed to some serious changes in the water management exercises to deal with water scarcity by means of putting pressure on the inadequate and uncontrollable water users. (Shah, Roy, Qureshi, & Wang, 2003)

Groundwater is intensively using in the irrigation nowadays in the Bangladesh, India and Pakistan's Punjab and Sindh region. surface water has been used traditionally from rivers and ponds for irrigation and drinking purposes in south Asia including Pakistan and Afghanistan. Though, the groundwater has generally replaced by the surface water in the most south Asian countries. (Mall, Gupta, Singh, Singh, & Rathore, 2006)

Pakistan is using 35% of its groundwater resources for irrigation, A large quantity of this groundwater is consumed to produce rice, the main food of South Asia. study shows that the amount of groundwater resources is rapidly decreasing in various parts of Pakistan, the reason is groundwater is not discharge exceeds its recharge rate. Unsustainable and Intensive extraction of groundwater for domestic and irrigation use has headed towards rapid decrease in the capacity of aquifers.

According to (Konikow & Kendy, 2005) There is a significant relationship between the human activities and soil degradation quality, they found that extreme rainfall and climate change has stronger impact on soil degradation than agriculture activities such as grazing, Reduced the groundwater resources also.

Intensive groundwater withdrawal is a general circumstance in urban Areas, particularly in developing cities. As cities developed, areas extended, populations intensified, and industries prospered. To meet the increasing demand for water, people mostly over exploited the groundwater, which leads to decline the quality and quantity of groundwater resources. The shallow aquifers commonly polluted during the early stages of urban development, because of direct discharge of waste water into the surface and groundwater resources. Extraction of groundwater from deep aquifers to get clean drinking water, which creates different new channels and gradient downward, which brings the polluted water from shallow aquifers to deep aquifers. (Mayr et al., 2007)

The groundwater falls with the increasing demand of water during the rapid industrial development in the developed cities such as Birmingham and London.

But then, when heavy industry departed from these cities, the water demand has declined with decreasing groundwater extraction. The extraction was decreased further with water saving technologies in some places. (Abu-Rizaiza, 1999)

There are three components of evapotranspiration: evaporation from water forms, vegetation surfaces and bare soil; transpiration is the process of evaporation from plant's leaves. In the process of urban development, large amount of lands change to the public building, roads, parks, industrial, residential and commercial areas etc. evaporation process has been changed greatly with deforestation and impermeable surface structure. Evapotranspiration status may reduce by 33% in a location if relocating from a pre-urban area to a mainstream urban context with 50% impervious land area. (Mall et al., 2006)

Pakistan acquired the oldest and prevalent uninterrupted canal system for irrigation, the Indus basin provide approximately 16 Million hectors currently. The groundwater provides nearly 40% of the total crop water to the highly populated Punjab region, which produces approximately 90% of country's food. According to (Shah et al., 2003) more than 70% of the farmers got 80 to 100% of their irrigation water from tube-wells and wells. Pakistan has total 0.5 million tube-wells, far lesser than India which is approximately 21 million. The average output of wells is nearly 100 m^3/h in Pakistan, while in India the average output of wells is far lower than the Pakistan which is nearly 25-27 100 m^3/h, Even with the higher average output in south Asia (Shah et al., 2000)

2.2 Environmental Factors affecting groundwater resources:

The anticipated climate change will result in increases the average global temperatures 1.4 to 5.8C by 2100 (Gedney et al., 2006) and precipitation levels. Although, the magnitude and impacts of these changes will be varying regionally. These changes will significantly affect the quality and quantity of ground water resources. Hydrological cycle is closely connected with climate change, and specially with GHG's in the earth's atmosphere linked with global warming i.e. seasonal variation and distribution of precipitation, increase precipitation intensity mostly in unwanted seasons, extreme weather events with severe increase in the temperature, reordered balance between the snow and rain fall, increase in evapotranspiration[2] and decreasing the soil moisture level, sea level rise in coastal areas increase the salt water quantity. (Tian, Hu, & Zhang, 2017) these variations have some reverse feedback on water security because greater evapotranspiration with increasing temperature, rise demand for irrigation, and lower runoff, although increase in precipitation leads to lower demand for irrigation use and higher runoff.

Generally, the effects of precipitation are more significant as compared to temperature impacts on water stress. Evapotranspiration will increase but not as much as precipitation, because concentration of increasing CO_2 brings stomata closure and reduce the process of transpiration[3] (Gedney et al., 2006) Additionally, the irregular and intensifying precipitation, draughts and floods risks will increase globally.

Precipitation is the important factor in the process of groundwater recharge. The man hydrological cycle factor which is providing water that is recharge groundwater Resources. Climatic factors for instance temperature and wind affect the precipitation with imbalanced and dynamic distribution. temperature variation makes the precipitation events more

[2]The mutual activity of water evaporation from the Earth's surface and transpiration from plants.
[3]The emission of water vapor from the leaves of plants Absorbs by its roots from soil.

unpredictable, extreme temperature can increase the storm events with more intensity, velocity and duration; while decreasing temperature can cause snowfall and mixed rainfall. Evaporation is the dominating factor that control the water balance in the Arid and Semi-Arid areas, while the recharge rate is regulated by the extreme climatic events.

The storm has significantly affect the rainfall variation and hydrographic situations according to its velocity and direction, its resulting extreme rainfall. On the other hand, low precipitation decreases the recharge rate due to high evapotranspiration rate, in such situation high amount of rainfall with shorter time may be enough for groundwater recharge {Lerner et a l, 1990).

increasing rainfall is the main factor that increases the evaporation, transpiration, surface water runoff, and groundwater recharge. Global warming and extreme temperature will diminish the surface water flow in colder climate by reducing ground frostiness and transferring the spring melt to the winter months. The intensification in greenhouse gases by decrease in the incoming radioactivity, will bring minor changes to the groundwater resources and hydrological process (Mikko Ilmari Jyrkama 2003)

Literature Gap:

Most of the studies were focused to estimate the global groundwater scarcity and its availability in the future. some studies were conducted to estimate the Impact of Climate change or Anthropogenic factors on groundwater resources independently. Literature gap shows that no specific study was conducted on Climatic and Anthropogenic factors that influencing groundwater resources in the Water stress Countries.

CHAPTER 3

Data and Methodology

3 Data and Methodology:

The study uses panel data taking time period of 1987 to 2016 while cross sections of 25 water stressed countries. The main and common factors between the sample countries is that the agriculture is the major consumer. South Asia Using more than 90%, Africa 82% and Asia using its 80% of its total water for irrigation purposes (FAO, 2017). the data on the water variables are generally available with gap of five years each, so this study also uses the same data having gap of five years. The details on the data and sources of data are given in table 1.

3.1 Variables, Data Unit and sources:

Abbreviation	Variables	Unit	Source
TGWR	Total groundwater resources	10^9 m3/year	SESRIC AQUASTAT
POP	Population	In million	-do-
PREC	Precipitation	(mm/year)	-do-
TDS	Total Dam Storage	km3	-do-
TAA	Agriculture Area	Thousand hectares	-do-
TEMP	Temperature	Degree Celsius	World bank
FOF	Frequency of floods	Flood occurrence	The emergency event database EM-DAT

Note: SESRIC is the data source for Muslim countries, for non-Muslim countries we collected the data from AQUASTAT.[4]

[4] See the appendix for Descriptive Statistics

3.1 Methodology:

For estimating the impact of each influencing factor on the ground water resources, the panel data techniques is used. Suitable regression among the panel data models was applied to decide the regression to be either pooled OLS, Fixed or Random effect.

$TGWR_{it} = \beta_0 + \beta_1 POP_{it} + \beta_2 FOF_{it} + \beta_3 TDS_{it} + \beta_4 TAA_{it} + \beta_5 TEMP_{it} + \beta_6 PREC_{it} + \mu_{it}$[5]

Dependent Variable= TGWR

Independent Variables

POP = population

FOF = frequency of floods

TDS= total Dam storage

TAA= Total Agriculture Area

TEMP= Temperature

PREC= Precipitation

μ= Error term

t= Time

i = Country

β_0 = Intercept

β_1, β_2, β_3, β_4, β_5, β_6, β_7 = Slope terms

3.2 Construction/Theoretical justification of variables:

A brief discussion on the relationship between explanatory and dependent variables in above mention model is given below:

[5] See 4.3.2 for the rest of model (Fixed effect model)

Dependent Variables:

Total Groundwater resources:

Groundwater is the source of recharging wetlands, lakes and rivers. Groundwater provides water to 50% of the total population including 99% of rural and 64% to irrigation. The surface and groundwater resources are interconnected with each other; depletion of groundwater resources can diminish the surface water as well. Groundwater is stored in saturated and unsaturated zones below the earth surface can be withdrawal for various purposes by pumping and extraction of wells (Vörösmarty, Green, Salisbury, & Lammers, 2000). It's also discharge by springs and seeps and wetlands. Its recharge by the hydrological cycle[6] i.e. precipitations, Evaporation, Infiltration, Transpiration, Run-off surface water, condensation and reservoir movement (lake to lake, Ocean to lake). These are the major natural factors responsible for recharge and discharge of groundwater resources. The main two components of groundwater resources are renewable[7] and non-renewable[8] resources.

Independent Variables:

The introduction of the explanatory variables followed by their theoretical justification is given as under:

Population (POP):

Population is one of the main factors influencing the groundwater resources and many studies (Arnell et al., 2004; Johnson, 2012; Vörösmarty et al., 2000) argued that the groundwater resources are decreasing due to increasing population. The per capita consumption and water withdrawal intensifying the water demand and diminish the water resources. Groundwater

[6] A continuous progress of water between the environment, atmosphere, hydrosphere and lithosphere
[7]Long-term average annual flow of rivers surface water and groundwater.
[8] Non-renewable water resources are deep groundwater resources existing in deep aquifers and rocks for long time.

recharge as well as storage capacity in the reservoir decreasing due to the socio-economic development and rapid population growth (Toure et al., 2017). This shows that the population is expected to have negative impact on groundwater resource.

Frequency of floods (FOF):

Climate change increase the frequency of flooding and storm. Floods fill the reservoirs and dams which increase the surface as well as the groundwater resources by flow of water through infiltration recharge the aquifers and increase the groundwater availability (Council, 1982; De Giglio et al., 2015). Increasing the frequency of floods will Increase the availability of water and expected to have positive impact on the groundwater resources.

Total Dam Capacity (TDC):

Dams and reservoir are built to conserve water for flood control and supply in dry seasons and summer. However, these reservoirs have also some environmental and hydrological impacts. It recharges the aquifers and enhance the groundwater capacity depending on the geographical location. The countries having more dam capacity will have less pressure on their ground water resources. So, the dam capacity is expected to have positive impact on the ground water resources.

Total Agriculture Area (TAA):

Extraction of water for irrigation purposes reduces the availability of water for other users and usages. Increasing population with the passage of time increase the demand for food and land use. Large amount of groundwater withdrawals affects the underground aquifers and intensification of pumping groundwater for irrigation in aquifers becomes a common practice. So, the increase in the agriculture area is expected to have negative impact on the groundwater resources.

Temperature (TEMP):

Increasing temperature is responsible for snow melting and increasing the run-off surface water resources, which also recharge the underground aquifers and water tables[9]. These studies suggest the positive correlation between increasing groundwater resource increasing with temperature increase (Singh & Kumar, 2015; Vörösmarty et al., 2000). While some of the studies estimated negative correlation between both the variables by stating that with increasing temperature the evaporation will increase which causes the water discharge to become more intense.(Oki et al., 2001; Tian et al., 2017)

Precipitation (PREC):

Groundwater resources increase by effective Precipitation, lakes and rivers, and indirectly through the recharge process in aquifers. The direct impacts of precipitation on groundwater resources determined by the variation in the amount and circulation of groundwater recharge. It's also increase the rate of infiltration[10] and surface run-off. Therefore, increase in the intensity of precipitation will positively increase the groundwater resources. (Alcamo et al., 2003; Tian et al., 2017; Vörösmarty et al., 2000)

[9]Water table, also called Groundwater Table, top point of an underground surface in which the rock or soil are strongly saturated with water
[10] Soil absorb water with the help of vegetation especially when rain hits the ground surface.

CHAPTER 4
RESULTS AND IMPLICATIONS

In this chapter first, we discuss the descriptive statistics analysis of all samples and then descriptive statistics region wise.

4.1 Descriptive statistics

Table 4.1 Descriptive statistics of Overall samples (1987-2016)

Variables	Mean	Median	Std. Dev.	Minimum	Maximum	Obs.
TGWR (10^9 m3)	11.630	3.28	18.535	0.022	67.81	150
PREC (mm)	271.211	260.55	188.177	0.004	775.43	150
TDC (km3)	24.601	5.55	42.231	0	157.32	150
POP (in million)	21.638	9.055	32.736	0.49	188.925	150
TAA (Thousand hectors)	29381.91	10594.12	50957.52	8.26	221463	150
TEMP (C°)	18.365	18.813	6.693	3.782	28.413	150
FOF (Occurrence)	2.24	0	4.706	0	33	150

Source: Author's estimations
Note: Frequency of flood is the Average of flood occurrence in each five years of break.

The descriptive statistics of the overall samples shows that the average total groundwater resources (TGWR) in water stress countries is about (11.630)10^9m^3, Kuwait has the minimum amount of groundwater resources (0.02)10^9m^3 while Turkey has the maximum resources of groundwater (67.8) 10^9m^3. The average population of 25 countries is approximately 21.64 million, Followed by the average agriculture area (TAA) of 29 million with in Kazakhstan and total minimum in Bahrain values. The average precipitation is (271.211) mm, Pakistan has received maximum rainfall of about 775.4 mm while Bahrain with minimum rainfall 0.004mm. The average dam capacity (TDC) is (24.601) km^3. Turkey has the maximum dam capacity among all the water stress countries (157.3) km^3 . while Qatar, Kuwait and Bahrain have maintained no or zero dam capacity. The average temperature is about (18.37) C°, with minimum temperature in Kyrgyzstan (3.78) C° while maximum temperature in Qatar (28.413) C°. Average flood occurrence is 2.24 times. while Afghanistan faced maximum floods 33 at some period with overall 76 floods in the study period. Pakistan is second to Afghanistan with total 75 floods. Armenia, Bahrain, Oman, Qatar and UAE experienced no floods during the study period.

4.2 Region wise Descriptive statistics:

Table 4.2 : Descriptive statistics of South Asian Countries

Var	Mean	Median	Std. Dev	Minimum	Maximum	Obs
TGWR (10^9 m3)	32.83	32.83	23.16	10.65	55.00	12
PREC (mm)	421.58	346.25	190.03	185.00	775.40	12
TDC (km3)	14.89	14.85	13.45	2.01	27.81	12
POP (Million)	82.97	68.64	66.97	12.01	185.55	12
TAA (Thousand hectors)	36973.84	37294.90	1020.03	35412.60	38036.00	12
TEMP (C°)	14.14	14.17	6.60	6.69	20.82	12
FOF (Occurrence)	12.58	10.00	8.60	5.00	33.00	12

Note: The South Asian Countries include Afghanistan and Pakistan only due to non-Availability of Data

Table 4.2 shows that the average groundwater resources in Afghanistan and Pakistan is 32.83 10^9km^3. Pakistan has the higher dam capacity than Afghanistan. Average population of 82.97 million of both countries. Average temperature is 14.14 C° and This region has the highest flood occurrence ratio as compare to other all regions.

Middle East:

Table 4.2: Middle East Countries:

Var	Mean	Median	Std. Dev	Minimum	Maximum	Obs.
TGWR (10^9 m3)	9.40	1.50	19.76	0.02	67.80	90
PREC (mm)	232.94	180.45	192.41	0.00	745.10	90
TDC (km3)	27.10	0.42	51.53	0.00	157.30	90
POP (Million)	15.67	5.47	21.53	0.46	78.39	90
TAA (Thousand hectors)	20841.36	1161.20	42393.07	8.20	173787.80	90
TEMP (C°)	21.56	22.52	5.18	10.27	28.41	90
FOF (Occurrence)	1.71	0.00	3.36	0.00	17.00	90

Note: Middle East countries including Middle East countries are Syria, Israel, Iran, Turkey, Saudi Arab, United Arab Emirates, Iraq, Lebanon, Qatar, Jordan, Yemen, Bahrain, Oman and Kuwait.

Table 4.2.2 shows that the average groundwater resources is $(9.40)10^9Km^3$. Kuwait has the minimum amount of groundwater resources $(0.02)10^9m^3$ and Turkey has the maximum resources of groundwater $(67.8)\ 10^9m^3$. The average population in the region is 15 million, highest temperature has been observed in this region compare the other regions.

African Countries:

Table 4.2: African Countries:

Var	Mean	Median	Std. Dev	Minimum	Maximum	Obs.
TGWR (10^9 m3)	5.30	5.30	4.91	0.60	10.00	12
PREC (mm)	228.79	230.85	78.02	140.60	331.00	12
TDC (km3)	7.82	5.69	8.05	0.39	17.96	12
POP (Million)	17.38	15.32	12.74	4.33	34.31	12
TAA (Thousand hectors)	22925.11	22826.57	7832.02	15351.67	30857.00	12
TEMP (C°)	20.69	20.51	2.13	17.78	23.10	12
FOF (Occurrence)	0.25	0.00	0.45	0.00	1.00	12

Note: African countries Including Libya and Morocco

Table 4.2.3 shows that the average groundwater resources is 5.30 10^9 m^3 with which is the lowest amount compare to other regions. Libya has the lower amount of dam capacity and it is just 0.39km^3. Average population is 17.38 million with The average temperature of 20.69 C°.

Central Asian:

Table 4.2: Central Asian Countries

Var	Mean	Median	Std. Dev	Minimum	Maximum	Obs.
TGWR (10^9 m3)	12.65	8.80	11.62	0.41	33.85	30
PREC (mm)	280.39	271.35	130.89	71.38	540.20	30
TDC (km3)	30.27	21.83	26.08	4.97	79.95	30
POP (Million)	11.79	8.15	8.17	3.59	30.78	30
TAA (Thousand hectors)	58715.61	27022.10	80962.59	4446.20	221463.00	30
TEMP (C°)	10.37	11.88	4.32	3.78	16.41	30
FOF (Occurrence)	0.83	0.50	1.21	0.00	5.00	30

Note: Central Asian countries Including Uzbekistan, Turkmenistan, Kyrgyzstan, Kazakhstan and Armenia

Table 4.2.4 shows that the average groundwater resources is 12.65 $10^9$$Km^3$. Kirghizstan has the maximum groundwater amount 33.85 $10^9$$m^3$. The Average population is about 11.8million. Average temperature is about 10.37 C°.

4.3.1 Trends of Groundwater Resources in Water Stressed Countries:[11]

Groundwater resources in the sampled countries are decreasing over the time. The available data on the groundwater resources shows constant trends with the given data, but compare it to the total food production and population it should be decrease over the time with the increasing in the total population increase the demand for food to meet the demand

[11] See the appendix

its put pressure on the agriculture and water requirement in other sectors. The reasons behind the ths in the sampled countries are observed that the Middle East and North Africa the groundwater resources affecting by the scattered and countless amount of groundwater users following Lebanon, Morocco and Yemen. Thus, enforcing and regulating policies are extremely difficult and resource consuming. In Pakistan, rising groundwater salinity and water tables are amongst the most critical issues in the Indus Basin. Most Arid regions are concentrated in the middles east and North African regions. Most of the middle east countries are water stressed. Overpopulation, climatic variability, geographical and physical aspects, political and regional disputes are the major responsible factors behind the groundwater resource depletion in this region. (El-Fadel & Bou-Zeid, 2001). In Afghanistan, Inefficient land-use practices and deforestation are responsible for long-term reduction of groundwater resources. Another crucial problem is the water quality impacting the major urban zones and towns. Because of poor drainage, point and non-point waste water discharge and chemical discharge in water bodies. Jordan is suffering from increasing population, climate vulnerability and a meager share of the Jordan Basin. With a population of 6.5 million. Most of the Gulf Countries are suffering from the extreme climate and urbanization development that resulted decreasing trend in the groundwater resources (Davis, 2010).

Central Asian Countries are mostly agrarian countries about 89% of water withdrawn by agriculture, which is higher than the value for global agricultural water withdrawal 69%. Except Kazakhstan's 66% water consumption in irrigation, the rest of the central Asian countries using 90% of water for agriculture sector. (Mulholland, 2011). We used the data of Food production index[12] for food productivity.

[12] The relative level of the aggregate volume of agricultural productivity in comparison with the base period 1999-2001. It is constructed on the sum of price-weighted quantities of agricultural products produced after deductions of quantities used as seed and feed weighted.

4.3.2 Hausman Test- Fixed Effects versus Random Effects

Before the regression estimation we checked which model out of Random effect or Fixed effect is appropriate for estimation. According to cheng Hsiao (2014) there is no difference between the both model in large time period, in such situation the least square dummy variables (LSDV) and generalized least square (GLS) become the same. The researcher widely used the "Hausman Test" in this situation, (Hausman, 1978) formulated the test to make a distinction between the Fixed Effects Model and Random Effects Model.

If the effects of cross section specifically corelated with independent variables, then the fixed effect model is a suitable option. If the individual effects are independently and randomly distributed of the independent variables, then the random effect model is an appropriate choice. The null hypothesis shows there is no significant relationship between the random Effect and Fixed Effect estimators. If there is any significant difference, then we choose the fixed effect model over Random affect. We are using the Chi-square method to test our null hypothesis.

According to the Hausman test results the Hausman probability > Chi^2 value, hence we reject our null hypothesis and accept our alternative hypothesis. Rejecting null hypothesis means that individual factors are correlated with the independent variables. Which means the fixed effect model is appropriate for our estimate.

Table 4.4 : Regression Results of the Determinants of Groundwater Resources Using Fixed Effect Model

Explanatory Variables	Coefficients	Std Error	t- Values	P-Values
PREC	0.337	0.067	4.970	0.000
TDC	0.153	0.025	6.170	0.000
POP	-0.406	0.175	-2.310	0.002
TAA	-0.211	0.057	-3.700	0.001
TEMP	0.035	0.170	2.170	0.003
FOF	0.475	0.223	2.020	0.004
Constant	-7.349	4.880	-1.510	0.134
Ho: Difference in coefficients not systematic				
Chi^2	1.19			
Probability	0.945			

$R^2 = 0.6215$

The regression results shows that 1 mm average increase in Precipitation will increase the total groundwater resources (TGWR) by 0.33 10^9 m^3. The precipitation has strong correlation with TGWR, because it increases the amount of surface water and infiltration volume and then recharge the aquifers. The co-efficient is also statistically significant.

Looking to the Total Dam Capacity (TDC), 1 km^3 increase in the TDC will increase the TGWR by 0.153 10^9 m^3. Because Dams and reservoir recharges the aquifers and enhance the groundwater capacity; Literature shows that countries having more dam capacity will have less pressure on their ground water resources (Oki et al., 2001). The co-efficient value is statistically significant

Population (POP) strongly impact on TGWR. 1 million increase in the POP will decrease the TGWR by 0.41 10^9 m^3. It is because increasing population increases water withdrawal for domestic, industrial and agriculture purposes. Increase in population put pressure on Groundwater resources and its recharge as well. It is also significant. The total agriculture area (TAA) is negatively correlated with TGWR, A thousand Hector increase in the TAA will decrease the TGWR by 0.211 10^9 m^3. Groundwater is mostly using for the irrigation purposes pumping. Extraction of groundwater for irrigation purposes reduces the availability of groundwater. It is also significant

Temperature (TEMP) is positively correlated with the groundwater resources it shows that 1C Average increase in the TEMP increases the groundwater resources by 0.035 10^9 m^3. Because Increasing temperature is responsible for snow melting and increasing the run-off surface water resources, which also recharge the underground aquifers and water tables. These studies suggest the positive correlation between increasing groundwater resource increasing with temperature increase (Singh & Kumar, 2015; Vörösmarty et al., 2000). It is significant.

Frequency of Floods (FOF) is positively correlated with the TGWR, with an Average single flood increase in the FOF increase the groundwater resources by 0.47 10^9m^3. Because floods recharge the groundwater and increasing the surface water flow. Sometimes floods reach to the places where surface water are lower or no surface water available there, therefore, it recharges the groundwater aquifers. We reported the results of fixed effect model only suggested by the Hausman test.

CHAPTER 5

CONCLUSION

This study analyze the factors affecting the groundwater resources in the water stress countries through panel data has including 25 water stress countries during the time period 1987-2016. The data for total groundwater resources in the sampled countries were constant over time with non-variation trends. So we took total population and food production index and compared both with total Groundwater resources. Generally, increase in the population and food productivity put more pressure on groundwater which increase the water extraction and decrease the aquifer's capacity. The results of estimated trends shows that the groundwater should be decrease in the sampled countries because we have seen the consistent increase in the FPI and POP which means that the groundwater resources are depleting over the time in these water stress countries.

The study has employed the Hausman test to check the appropriate model out of the fixed and random effect models. The fixed effect model was found appropriate. The results show that increase in the precipitation will increase the groundwater resources because precipitation recharges the groundwater resources and aquifers. Total Dam Capacity is positively related with TGWR, increase in the water storage increase the surface water availability and recharge the groundwater resources by more availability, on the other hand it also decrease the groundwater extraction due to more availability of surface water. People will extract minimum water when the surface water is available in more volume and vice versa.

Population (POP) shows negative correlation because increasing population, increases water withdrawal for domestic, industrial and agriculture purposes. The total agriculture area (TAA) is negatively related with TGWR because groundwater is using for the irrigation purposes pumping, over extraction and mismanagement in irrigation make the situation worse.

Temperature (TEMP) is positively correlated with TGWR because Increasing temperature is responsible for snow melting and increasing the run-off surface water resources, which also recharge the underground aquifers and water tables.

Frequency of Floods (FOF) is positively related with the TGWR because floods recharge the groundwater by increasing the surface water flow. Rapid changes in the climate change increasing the catastrophes like Non-seasonal rainfall and flash floods, so we need to take some adaptive techniques by turning the flood water into groundwater storage.

POLICY RECOMENDATIONS

- Countries without less reservoir and dams facing the worse situation of water security. We can save the flood water, snow melting water, and surface water by building the dams and reservoir which helps to increase the groundwater recharge.
- Artificial Aquifers recharge from floods and rainwater can increase the groundwater availability.
- Improve technology and use low water consuming crops to reduce the groundwater extraction.

Limitation of the study:

1. We used the data with five years gap, The result would be more realistic to generate annual or monthly data
2. The data of infiltration and evaporation can strengthen the results for further studies. But data on aforementioned variable is not available.

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Appendix-A

Water stress countries list with Ranking:

S. No	Ranking	Country Name	Region
1	1	Bahrain	Middle East
2	1	Kuwait	
3	1	Qatar	
4	1	UAE	
5	7	Saudi Arabia	
6	8	Israel	
7	9	Oman	
8	10	Yemen	
9	13	Iran	
10	14	Jordan	
11	15	Lebanon	
12	18	Iraq	
13	19	Syria	
14	26	Turkey	
15	21	Armenia	
16	22	Turkmenistan	Central Asia
17	16	Kazakhstan	
18	22	Turkmenistan	
19	11	Kyrgyzstan	
20	24	Uzbekistan	
21	25	Afghanistan	South Asia
22	17	Pakistan	
23	20	Morocco	Africa
24	12	Libya	
25	27	Greece	Europe

Source: World resource Institute (WRI)

Appendix-B

Brief of the Types of Water resources

Groundwater total renewable (TGWR):

Groundwater renewable resources is computed on the based on hydrological cycle representing long-term average natural flow of river of rivers and recharge of aquifers produced from precipitation including surface water resources.

Total External Renewable water resources (TERWR):

The External Renewable Water Resources are sum of the average annual flow of rivers and groundwater inflow in a country from neighboring countries. It can be described as follow:

$ERWR = SW_{IN} + SW_{BR} + SW_{PL} + GW_{IN}$

It is the combination of surface water inflow (SW_{IN}), estimated surface water flow of border rivers (SW_{BR}), estimated surface water part of shared lakes (SW_{PL}) and Groundwater inflow (GW_{IN})

Total Internal Renewable water resources (TIRWR):

Total internal renewable water resources are corresponding to the volume of average annual flow of groundwater and total surface water generated from precipitation within the country (FAO. 2003)

Define as follow:

$IRWR = SR + GR - (F_{OUT} - F_{IN})$

SR= Surface Runoff

GR= Groundwater recharge

F_{OUT} = Groundwater drainage into rivers

$F_{IN=}$ Flow from rivers into Aquifers.

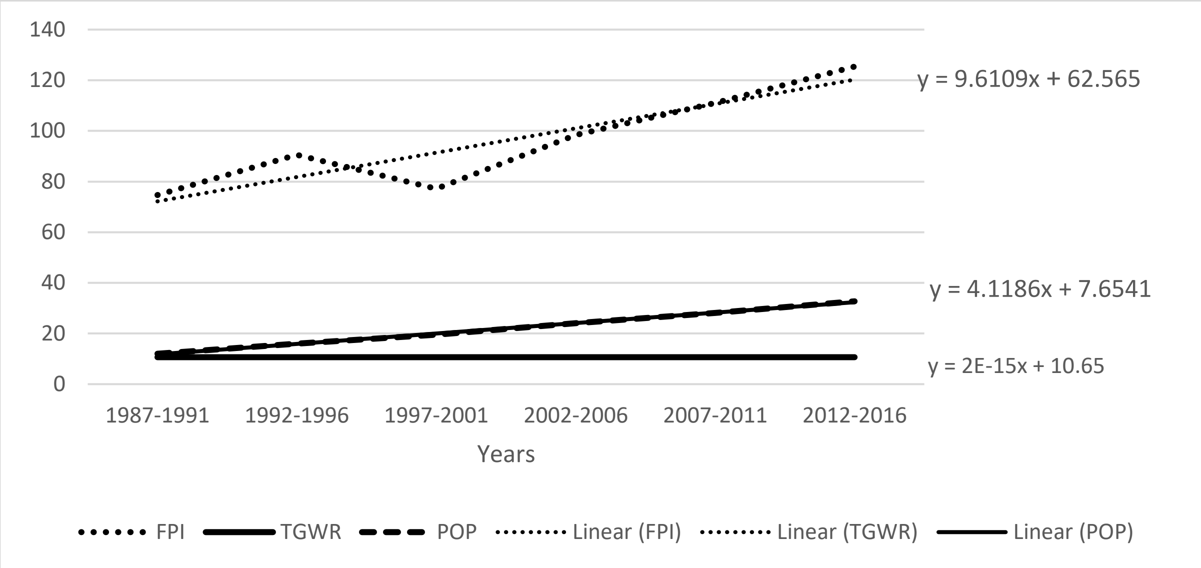
Water withdrawal per capita (WW_PC):

The extraction of ground and surface water per capital also shows us the availability and supply of water resources per capital.

Water withdrawal Total (WWT):

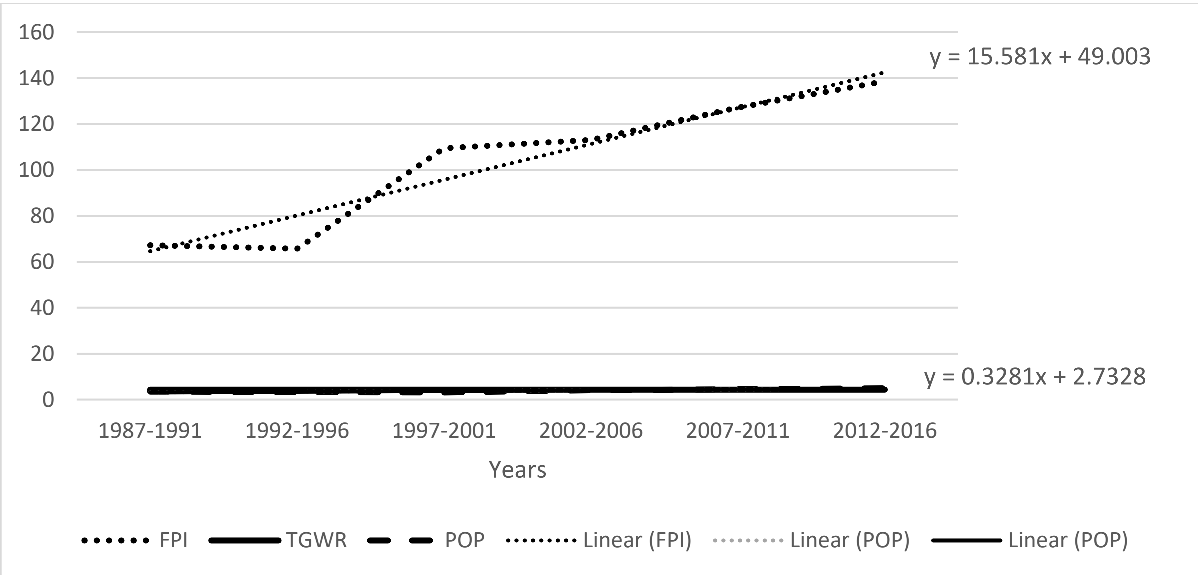
Total withdrawal tells us that how much ground and surface water are extracted in the specific period. Total water withdrawal increases with the time and reduce the water resources.

Appendix-C: Trends of Groundwater resources in the sampled countries



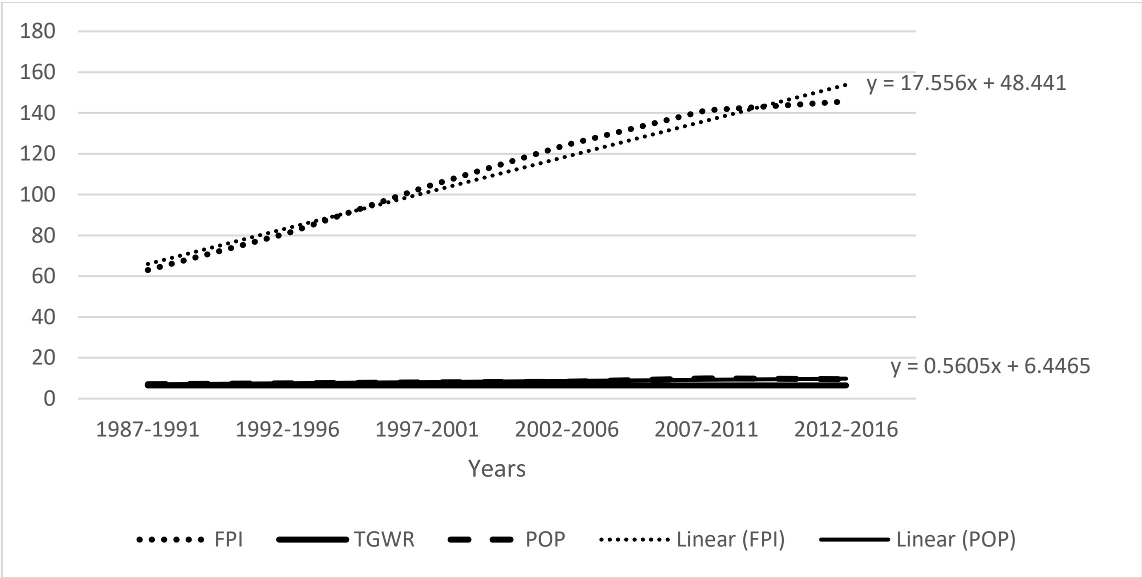
Appendix C.1: Trend of groundwater resources in Afghanistan

Appendix C.2: Trend of groundwater resources in Armenia

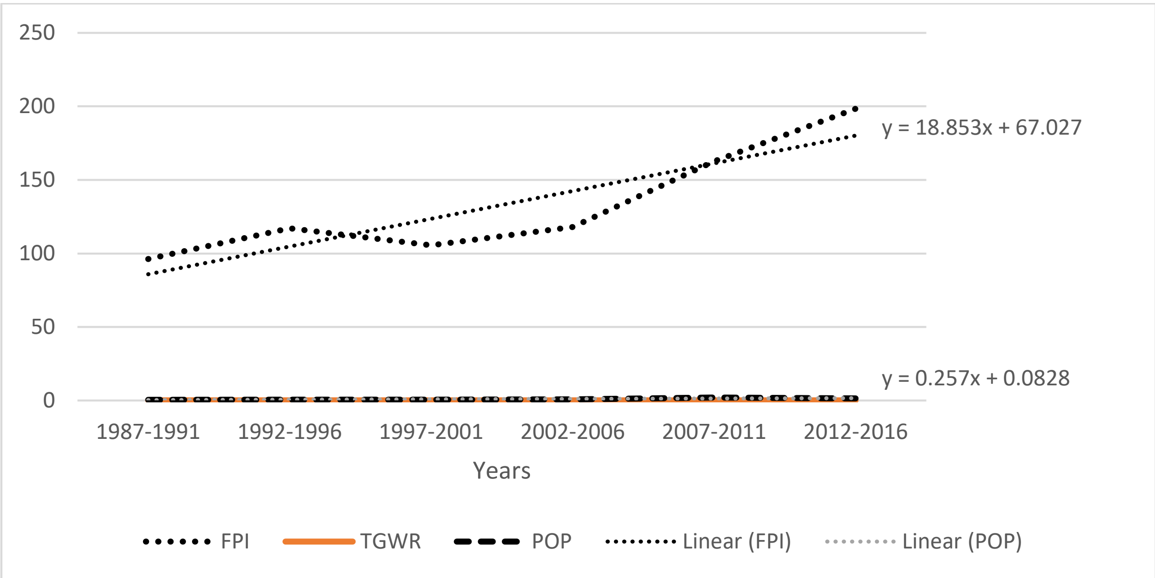


Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix C.3: Trend of groundwater resources in Azerbaijan

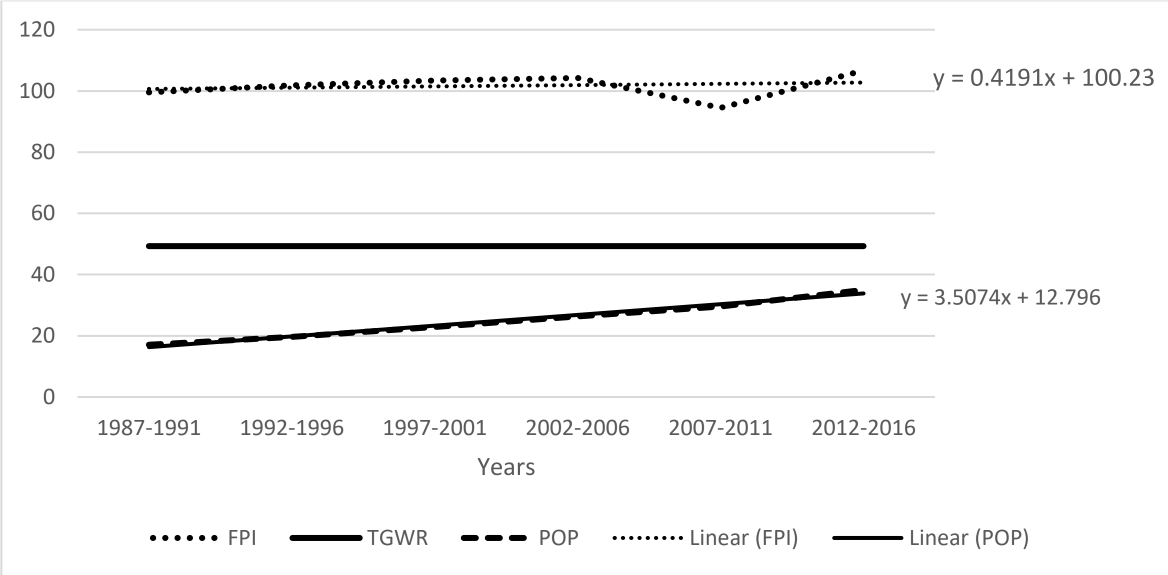


Appendix C.4: Trend of groundwater resources in Bahrain

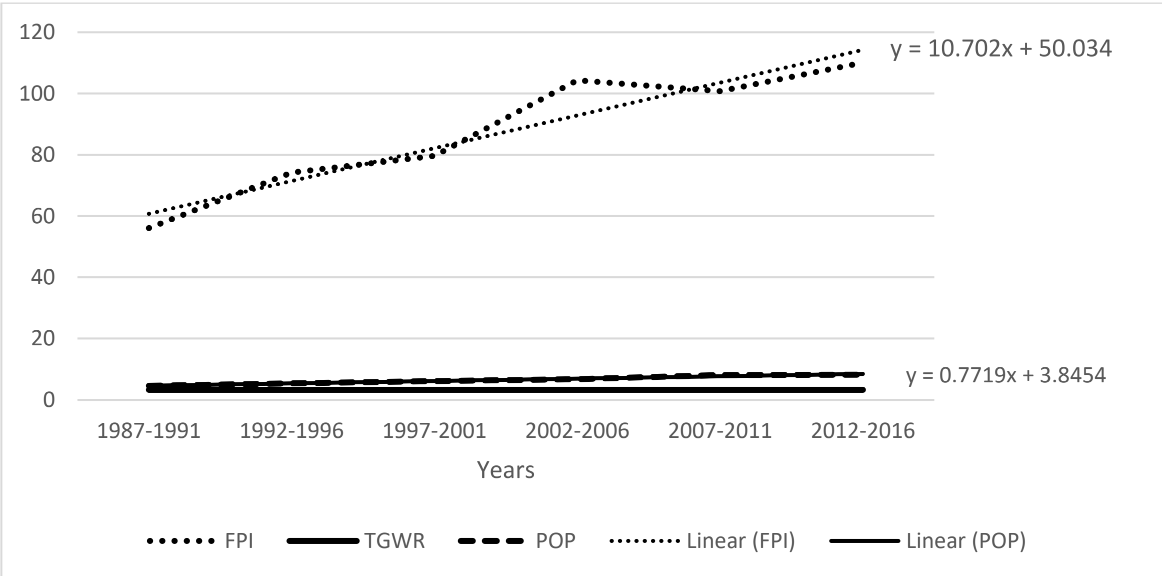


Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix C.5: Trend of groundwater resources in Greece

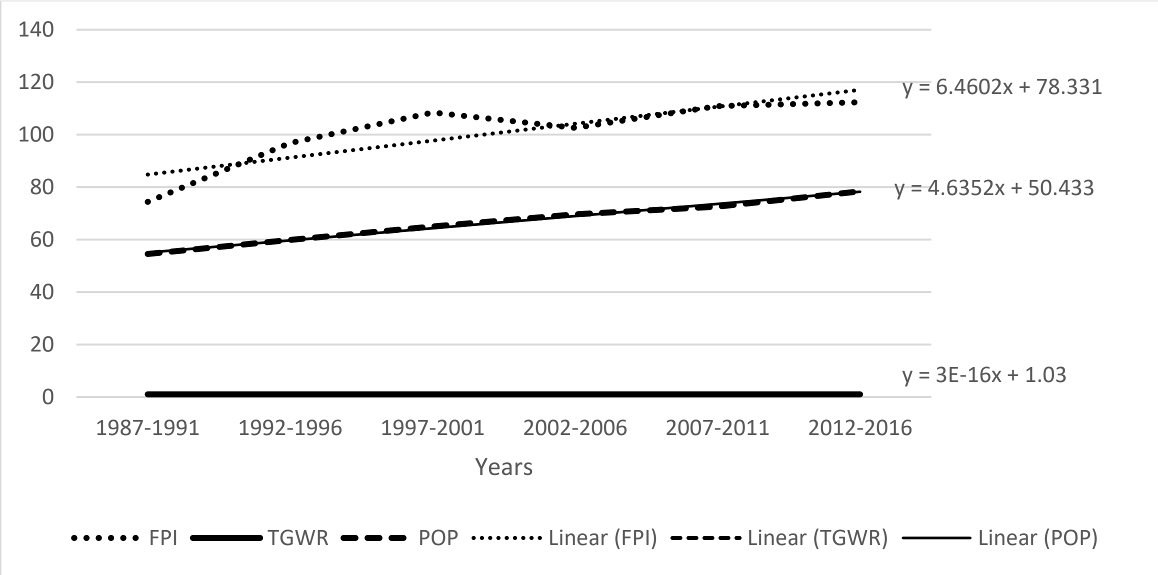


Appendix C.6: Trend of groundwater resources in Iran

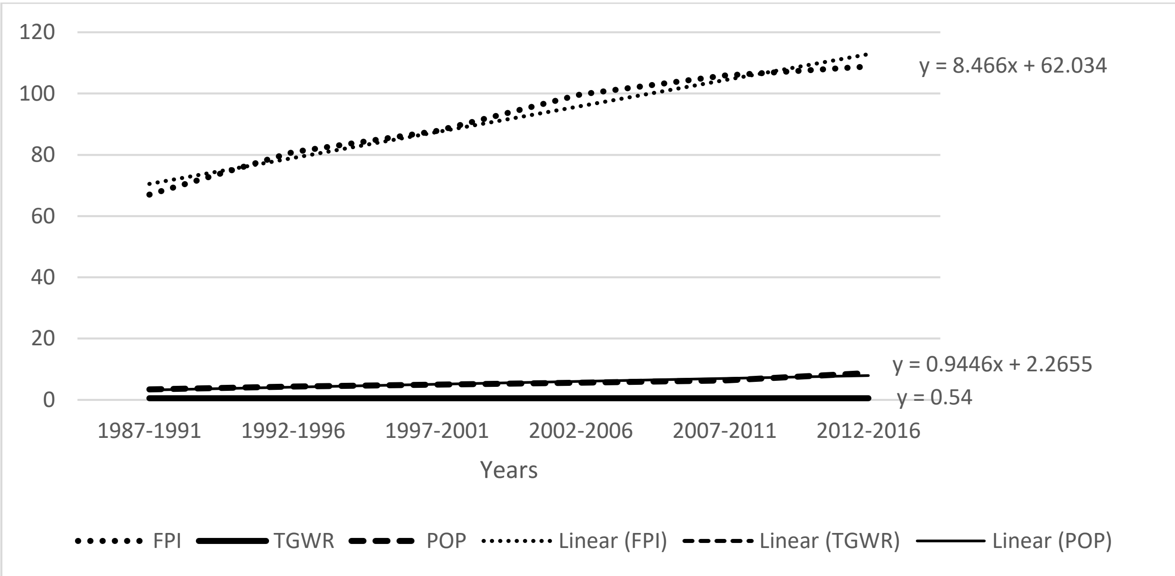


Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix C.7: Trend of groundwater resources in Iraq

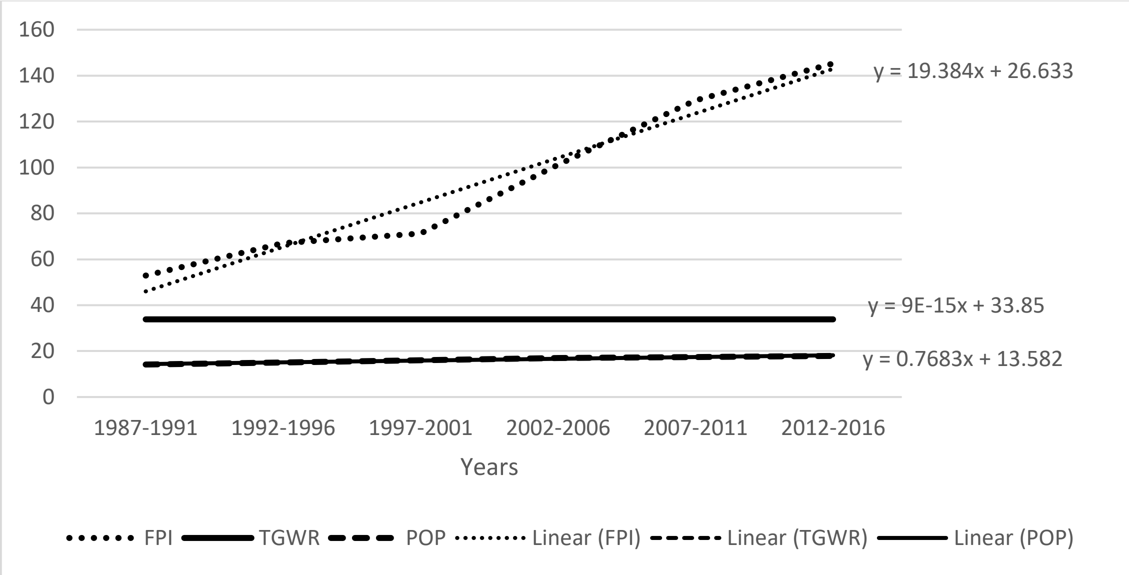


Appendix C.8: Trend of groundwater resources in Israel

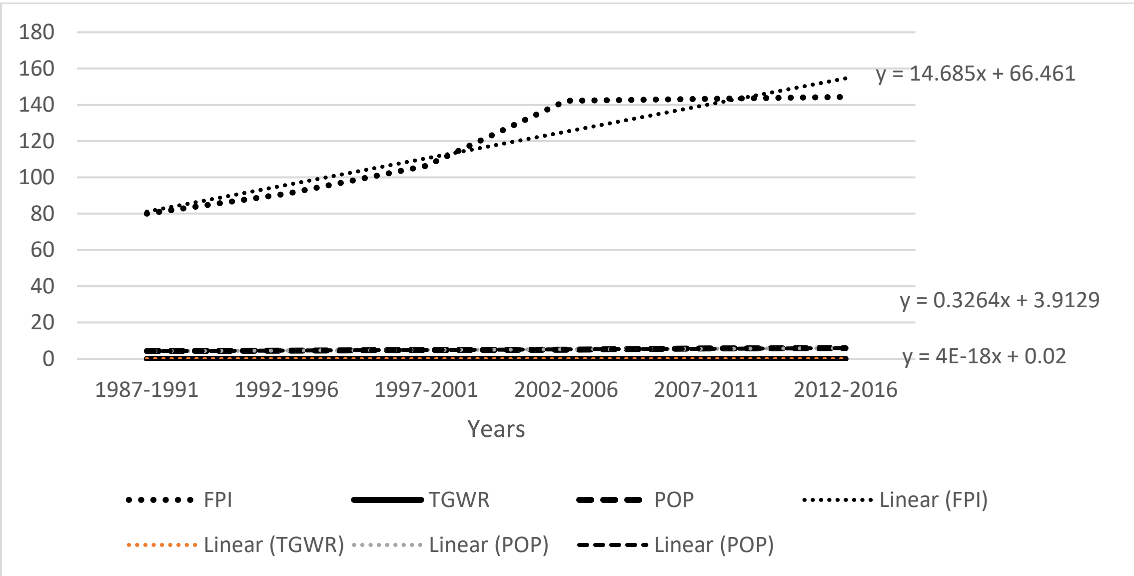


Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix C.9: Trend of groundwater resources in Jordan

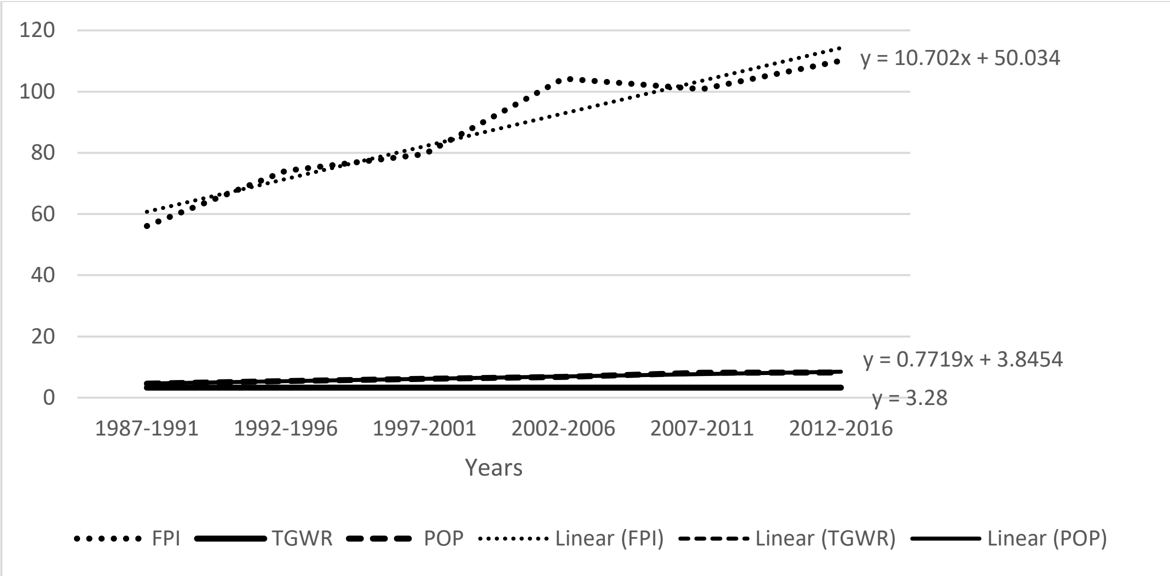


Appendix C.10: Trend of groundwater resources in Kazakhstan

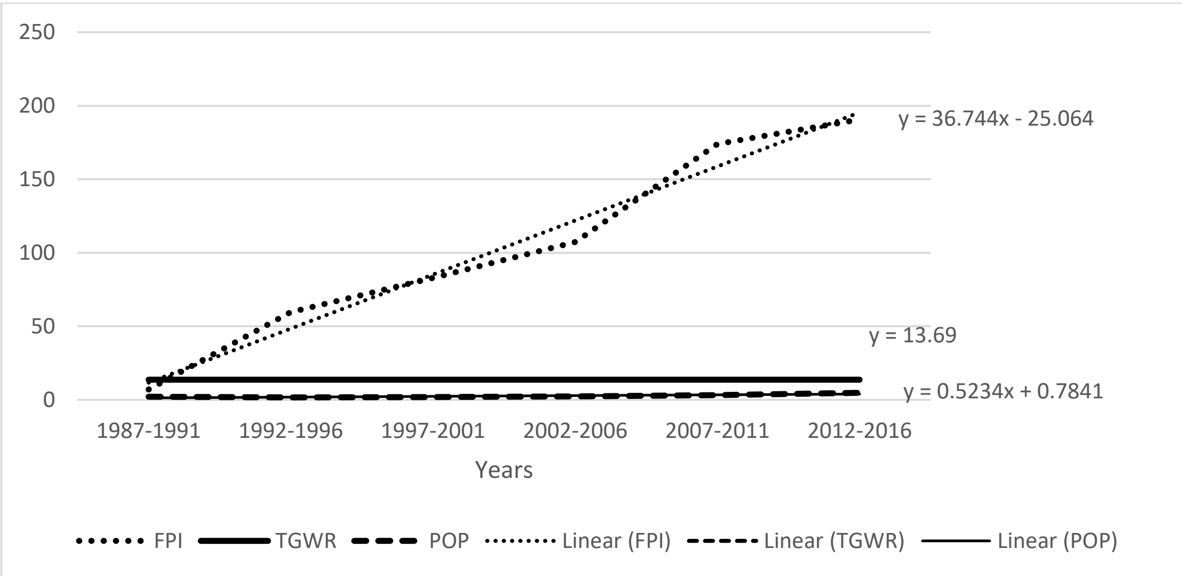


Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix C.11: Trend of groundwater resources in Kyrgyzstan

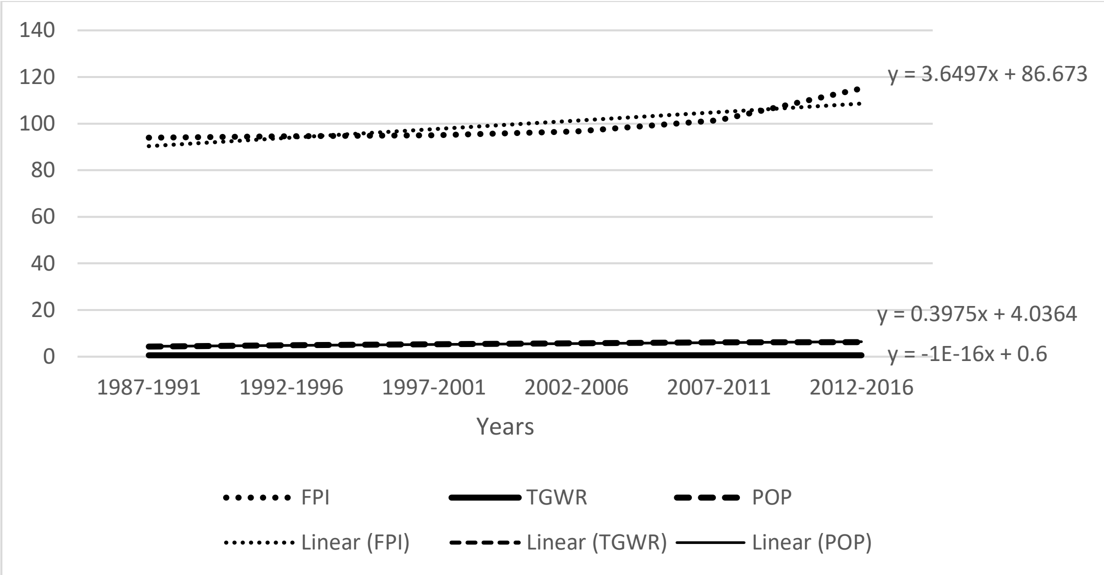


Appendix C.12: Trend of groundwater resources in Kuwait

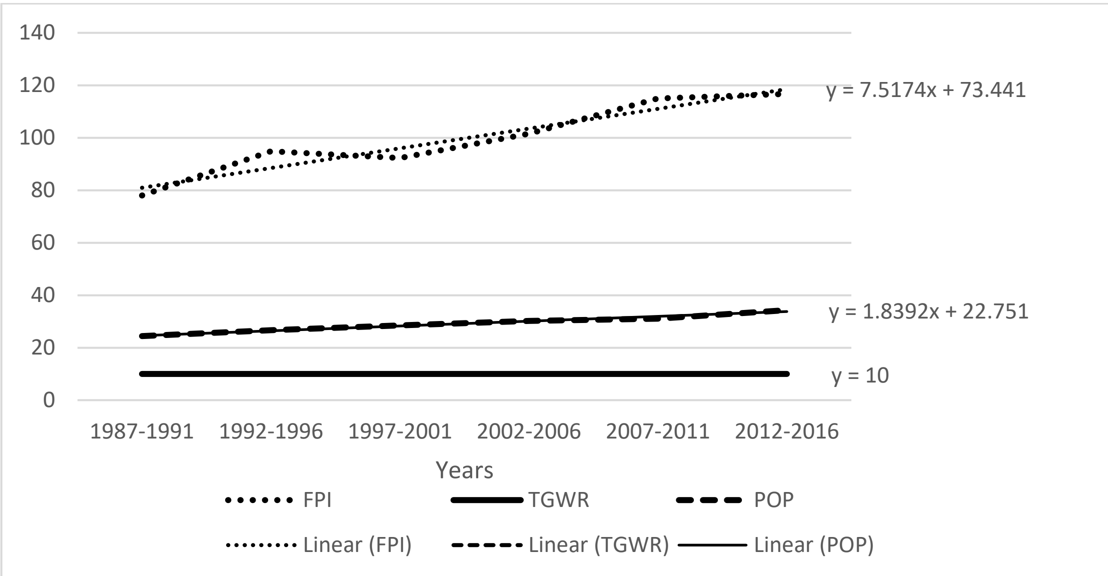


Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix C.13: Trend of groundwater resources in Lebanon

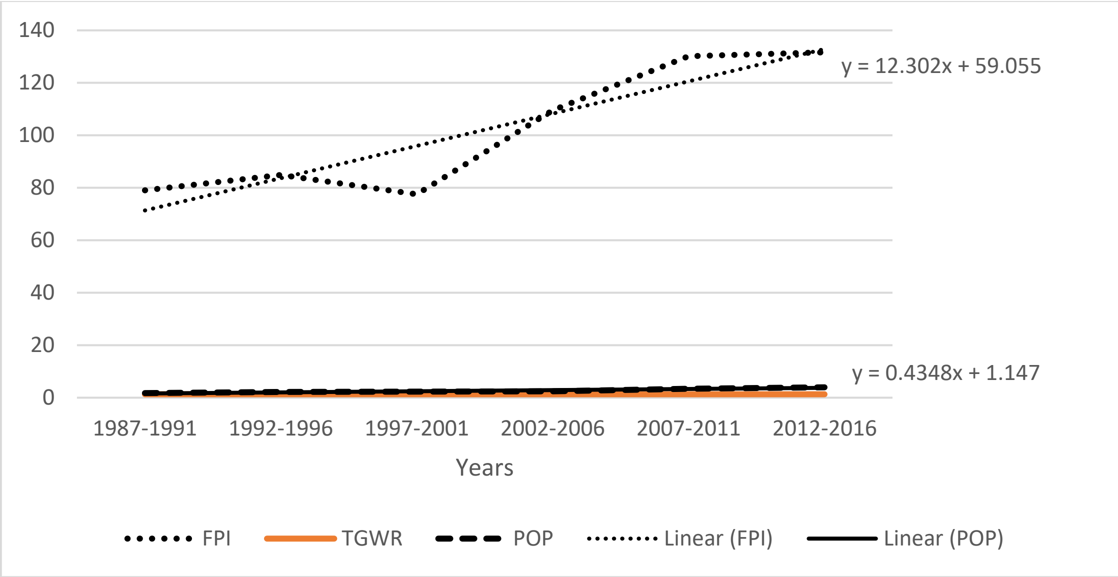


Appendix C.14: Trend of groundwater resources in Libya

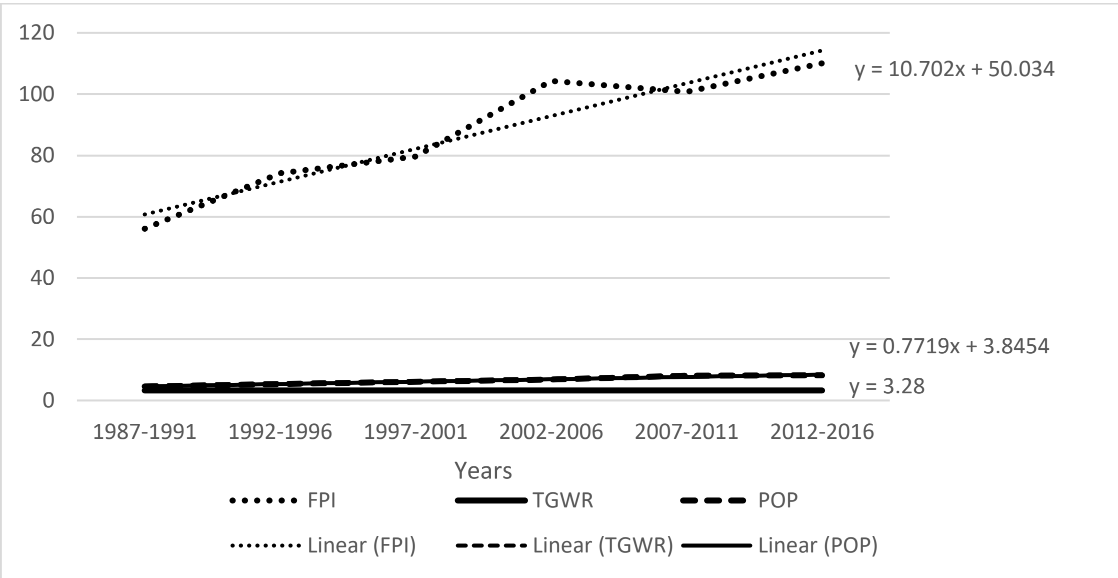


Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix C.15: Trend of groundwater resources in Morocco

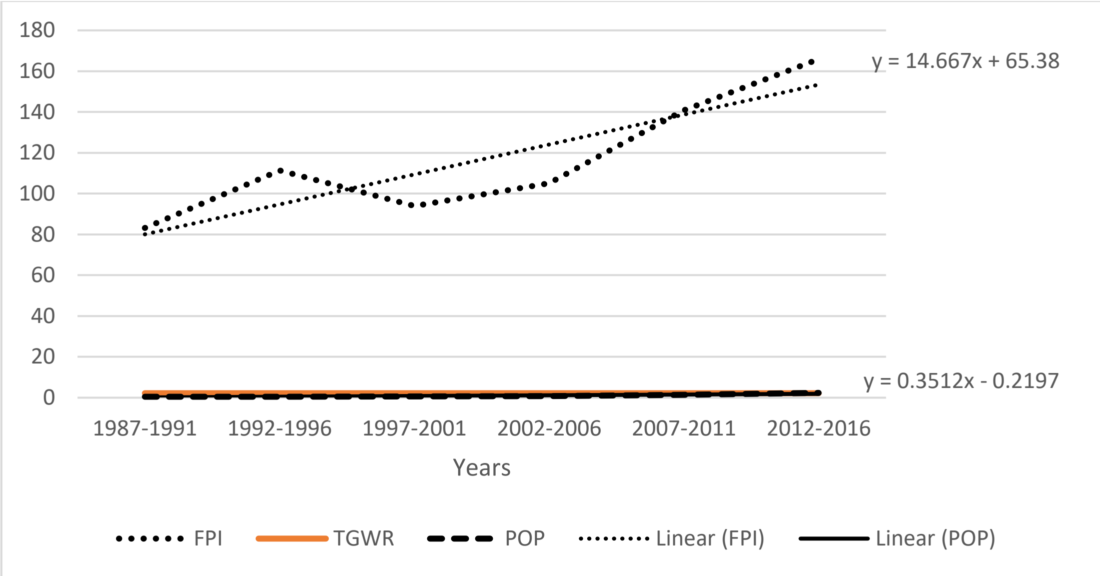


Appendix C.16: Trend of groundwater resources in Oman

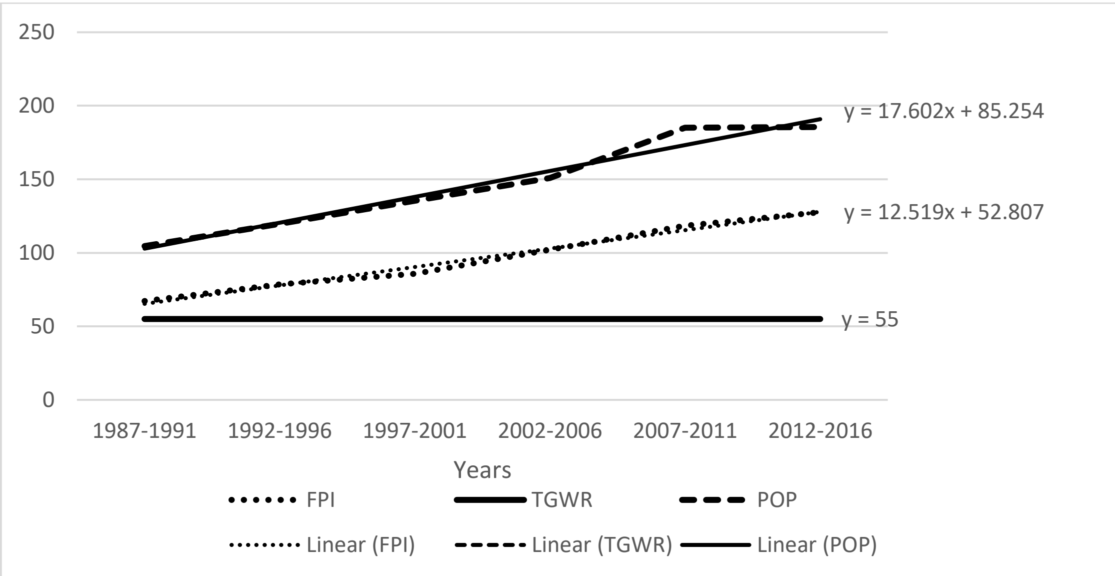


Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix C.17: Trend of groundwater resources in Qatar

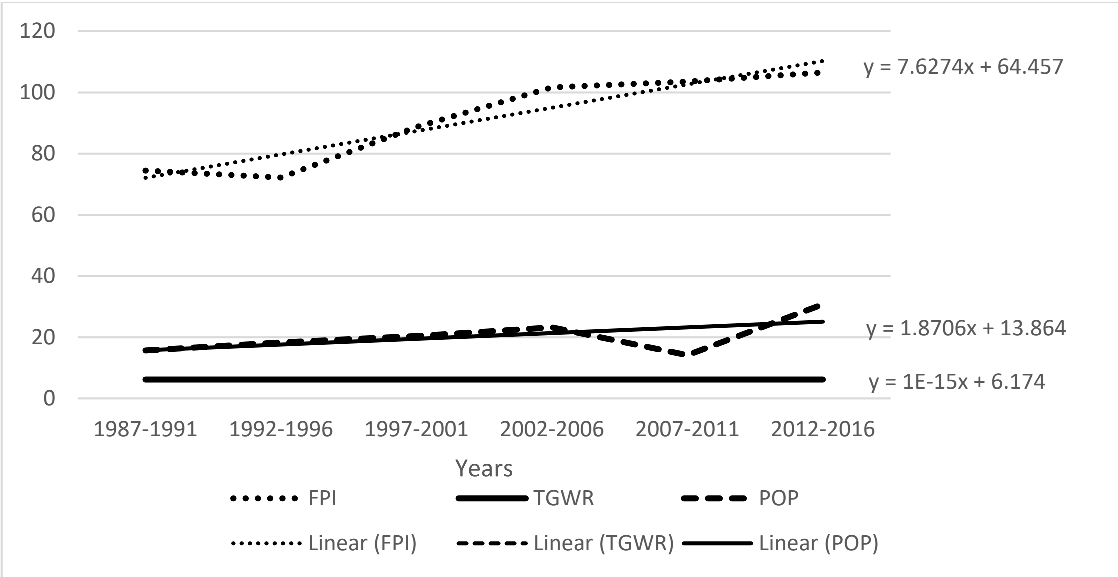


Appendix C.18: Trend of groundwater resources in Pakistan

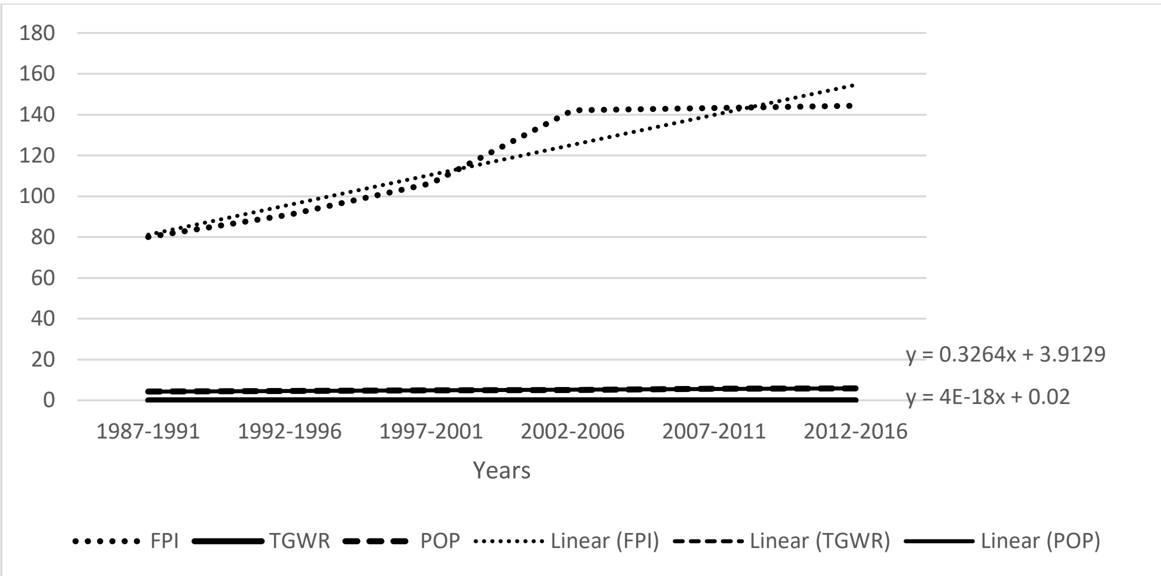


Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix C.19: Trend of groundwater resources in Saudi Arabia

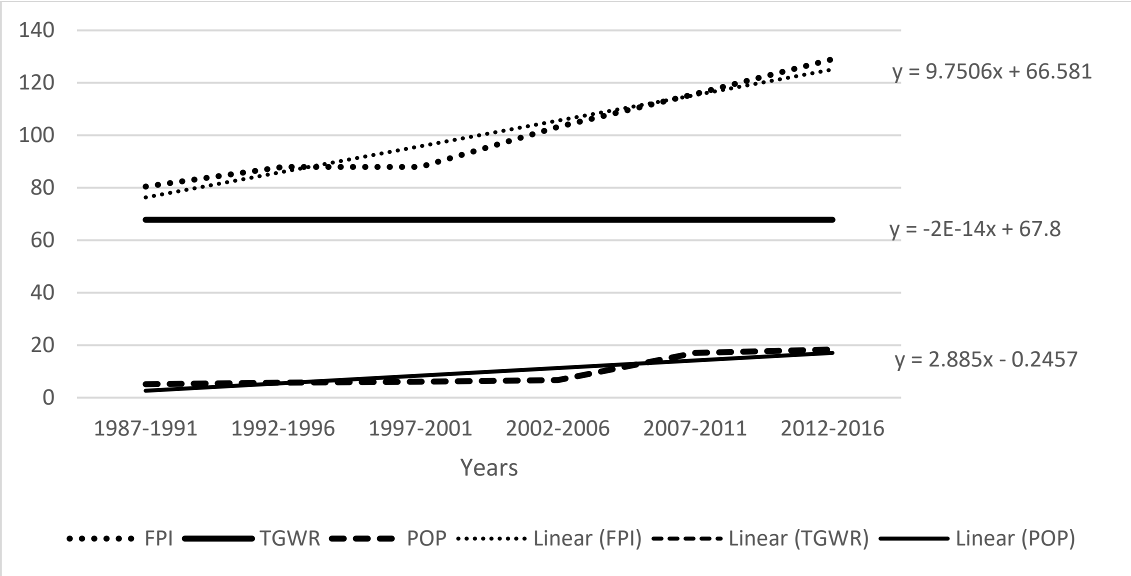


Appendix C.20: Trend of groundwater resources in Syria

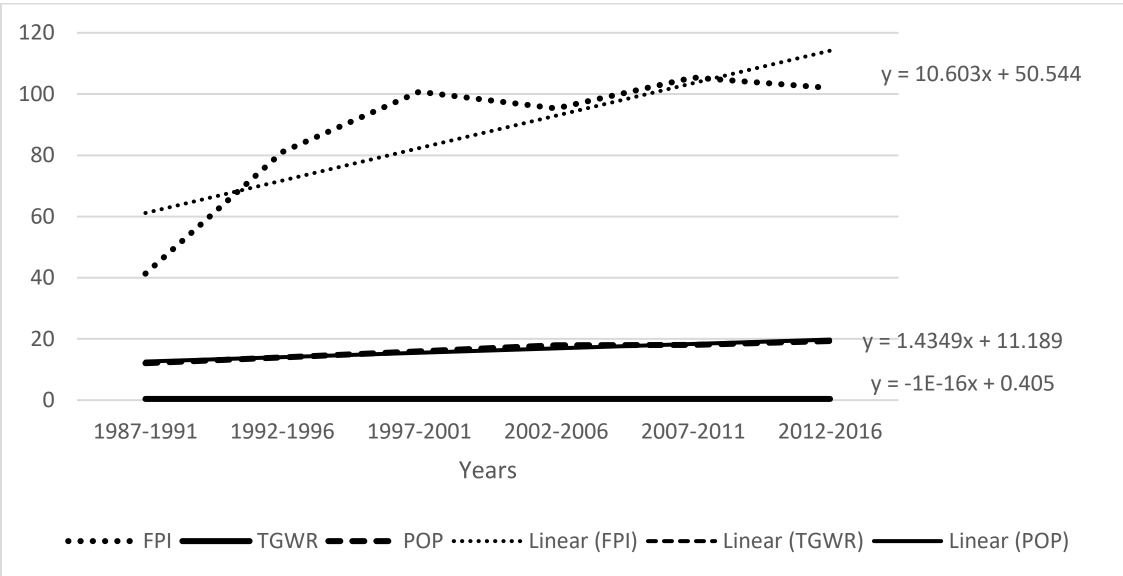


Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix C.21: Trend of groundwater resources in Turkey

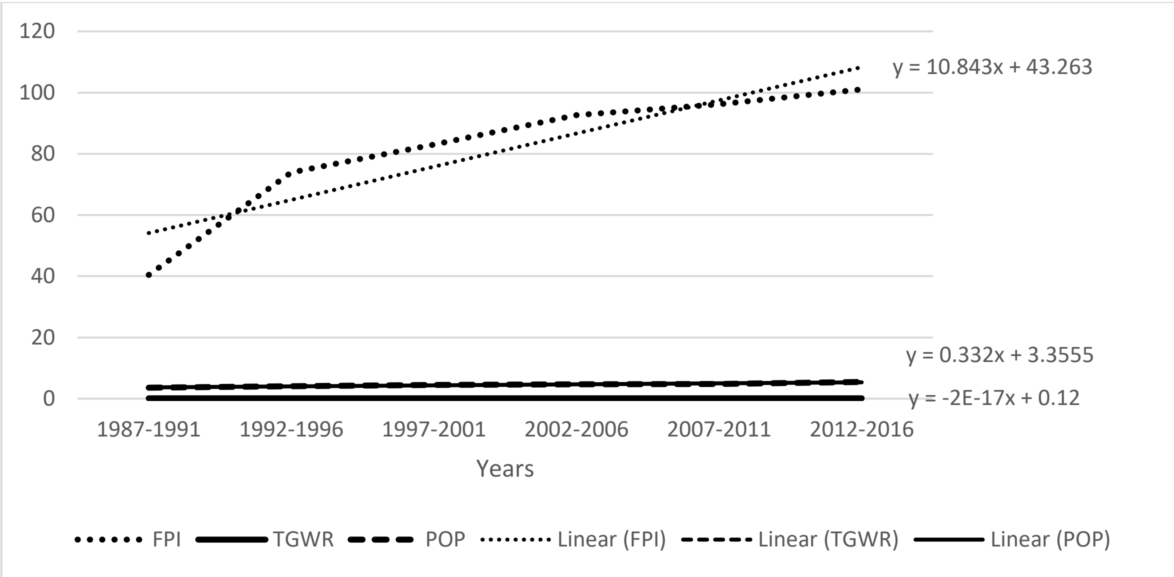


Appendix C.22: Trend of groundwater resources in Turkmenistan

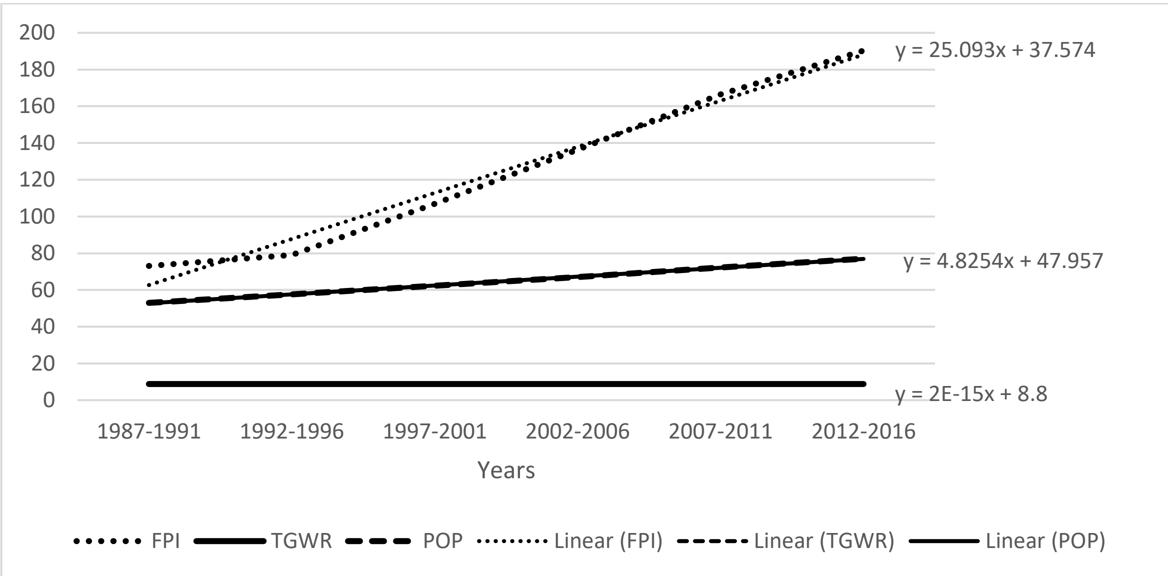


Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix C.23: Trend of groundwater resources in UAE

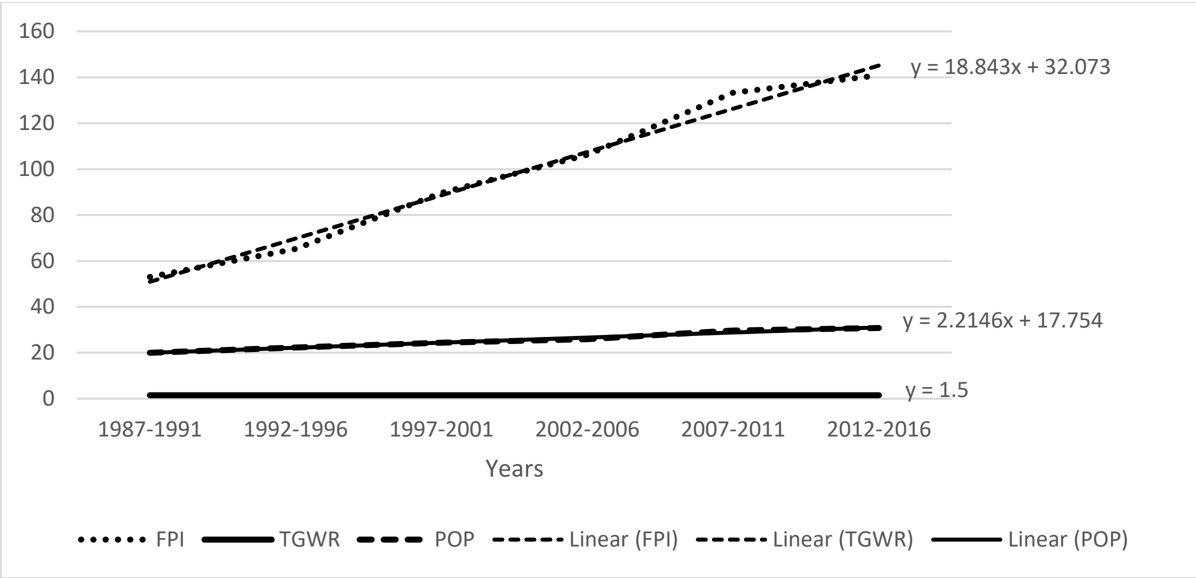


Appendix C.24: Trend of groundwater resources in Uzbekistan



Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix C.25: Trend of groundwater resources in Yemen



Note: Food Production index (FPI) is in US$, Total Groundwater Resources (TGWR) is in Billion Cubic Meters and Population (POP) is in Million.

Appendix-D

Descriptive statistics of individual sample Countries

Afghanistan							
Statistics	TGWR	PREC	TDC	POP	TAA	TEMP	FOF
Mean	10.65	269.6833	2.009	22.0693	37891.77	7.836988	12.66667
Median	10.65	297.75	2.009	21.78375	37910.1	7.999874	9
Mode	10.65	#N/A	2.009	#N/A	37910.2	#N/A	6
Minimum	10.65	185	2.009	12.01281	37775.8	6.694063	5
Maximum	10.65	336.9	2.009	32.71584	38036	8.516804	33
Armenia							
Mean	4.311	377.9	1.3875	5.214432	1462.629	13.67109	0.166667
Median	4.311	370.35	1.3865	3.192616	1475.53	13.96972	0
Mode	4.311	#N/A	1.386	#N/A	#N/A	#N/A	0
Minimum	4.311	328	1.38	2.904683	1170	12.88696	0
Maximum	4.311	437.7	1.399	15.49097	1722.24	14.17259	1
Azerbaijan							
Mean	6.51	452.5	21.43833	9.408354	4661.008	11.69075	1.166667
Median	6.51	452.45	21.5	8.148275	4738.6	11.87949	1
Mode	6.51	#N/A	21.5	#N/A	#N/A	#N/A	1
Minimum	6.51	388.5	21.25	7.092085	4446.2	10.74123	0
Maximum	6.51	540.2	21.5	15.94613	4769.767	12.2708	4
Bahrain							
Mean	0.116	0.004	0	0.982286	8.707	27.64908	0
Median	0.116	0.004	0	0.739863	8.625	27.91497	0
Mode	0.116	0.004	0	#N/A	#N/A	#N/A	0
Minimum	0.116	0.004	0	0.480192	8.2	26.3439	0
Maximum	0.116	0.004	0	2.033739	9.32	28.2771	0
Greece							
Mean	10.3	583.45	11.81	9.898269	8551.167	14.25354	0.5
Median	10.3	593.15	12.14	10.63548	8459.2	14.44142	0
Mode	10.3	#N/A	12.32	#N/A	#N/A	#N/A	0
Minimum	10.3	517.4	10.87	6.131421	7885	13.28055	0
Maximum	10.3	626.3	12.32	10.95858	9189.4	14.86385	2
Iran							
Mean	49.3	281.9333	25.41	23.5719	56224.09	17.79386	10
Median	49.3	294.35	26.06	21.70677	58416.2	18.00895	9
Mode	49.3	#N/A	32.24	#N/A	#N/A	#N/A	9
Minimum	49.3	207.1	17.34	17.07877	46002.13	16.7004	3
Maximum	49.3	314.9	32.24	34.9968	64155.2	18.36405	17

Iraq							
	TGWR	PREC	TDC	POP	TAA	TEMP	FOF
Mean	3.28	293.6167	151.8	8.313579	8969.228	22.30599	1.5
Median	3.28	298.6	151.8	6.47125	9098	22.51976	1
Mode	3.28	#N/A	151.8	#N/A	#N/A	#N/A	0
Minimum	3.28	225	151.8	4.5876	8271.7	21.14565	0
Maximum	3.28	330.1	151.8	18.72502	9434	22.76832	4
Israel							
Mean	1.03	50.75667	57.87	61.32281	546.5656	20.22141	0.5
Median	1.03	54.815	57.87	62.40379	546.4167	20.47688	0
Mode	1.03	#N/A	57.87	#N/A	#N/A	#N/A	0
Minimum	1.03	30.56	57.87	40.59872	517.18	19.00796	0
Maximum	1.03	65.99	57.87	78.38759	577	20.94295	2
Jordan							
Mean	0.54	186.3667	0.18925	11.23817	1050.068	19.20379	0.333333
Median	0.54	180.45	0.19125	5.293989	1054.433	19.44299	0
Mode	0.54	#N/A	0.1016	#N/A	#N/A	#N/A	0
Minimum	0.54	148.8	0.1016	3.417925	1007.26	18.04785	0
Maximum	0.54	241.8	0.2749	40.28848	1097.22	19.89285	1
Kazakhstan							
Mean	33.85	270.1833	79.95	15.16835	216394.9	6.711304	2
Median	33.85	271.35	79.95	15.54943	215871.6	6.775543	1.5
Mode	33.85	#N/A	79.95	#N/A	#N/A	#N/A	1
Minimum	33.85	245.2	79.95	11.43915	212254	6.02689	1
Maximum	33.85	299.3	79.95	17.29056	221463	7.200587	5
Kuwait							
Mean	0.02	92.13667	0	5.888683	147.45	26.04705	0.166667
Median	0.02	93.25	0	4.9669	148.9	26.23637	0
Mode	0.02	#N/A	0	#N/A	#N/A	#N/A	0
Minimum	0.02	67.35	0	4.30506	141	25.0498	0
Maximum	0.02	115	0	10.7063	151.8	26.73375	1
Kyrgyzstan							
Mean	13.69	378.4	22.41667	2.615887	10537.06	4.409108	0.666667
Median	13.69	376.9	22.5	2.138867	10594.1	4.654791	0.5
Mode	13.69	#N/A	23	#N/A	#N/A	#N/A	0
Minimum	13.69	366.2	21	1.621196	10088	3.782184	0
Maximum	13.69	397.4	23.5	4.109672	10762.94	4.796293	2
Lebanon							
	TGWR	PREC	TDC	POP	TAA	TEMP	FOF
Mean	3.2	598.1	0.222667	3.625125	631.4633	16.2661	0.166667
Median	3.2	566.75	0.22	3.369349	633.64	16.34504	0
Mode	3.2	#N/A	0.22	#N/A	#N/A	#N/A	0
Minimum	3.2	500	0.22	2.694568	603.5	15.27506	0
Maximum	3.2	745.1	0.228	5.530786	658	16.85158	1

Libya							
Mean	0.6	156.55	0.3899	1.446417	15429.24	22.67636	0.333333
Median	0.6	149.9	0.3899	1.553	15424	22.83814	0
Mode	0.6	#N/A	0.3899	#N/A	#N/A	#N/A	0
Minimum	0.6	140.6	0.3899	0.3825	15351.67	21.90383	0
Maximum	0.6	193.9	0.3899	2.506	15557.4	23.10345	1
Morocco							
Mean	10	301.0333	15.25833	27.18843	30420.97	18.69481	0.166667
Median	10	301.05	16.63	27.57792	30407.95	18.89524	0
Mode	10	#N/A	#N/A	#N/A	#N/A	#N/A	0
Minimum	10	267.8	11	19.05882	30095.74	17.78081	0
Maximum	10	331	17.96	34.31135	30857	19.11458	1
Oman							
Mean	1.3	51.82	0.075683	5.002054	1281.83	25.94494	0.166667
Median	1.3	45.29	0.0819	2.35779	1300	26.0867	0
Mode	1.3	#N/A	0.0884	#N/A	#N/A	#N/A	0
Minimum	1.3	23.44	0.0382	1.749014	1071.2	25.42359	0
Maximum	1.3	112.5	0.0884	17.46645	1472.48	26.18319	1
Pakistan							
Mean	55	573.4833	27.76333	146.8603	36055.92	20.44122	12.5
Median	55	551.4	27.76	143.1012	36140.7	20.63464	11
Mode	55	#N/A	27.74	#N/A	#N/A	#N/A	#N/A
Minimum	55	355.6	27.7	104.566	35412.6	19.82768	5
Maximum	55	775.4	27.81	185.5509	36814	20.81584	23
Qatar							
Mean	0.058	63.21667	0	14.84287	64.80767	27.75866	0
Median	0.058	55.65	0	0.683198	65.433	27.98439	0
Mode	0.058	#N/A	0	#N/A	#N/A	#N/A	0
Minimum	0.058	36	0	0.458388	61.4	26.55378	0
Maximum	0.058	99	0	84.36731	65.9	28.41336	0
Saudi Arabia							
	TGWR	PREC	TDC	POP	TAA	TEMP	FOF
Mean	2.2	145.95	0.865467	20.41083	164785	25.35526	3
Median	2.2	141.35	0.974	19.31674	173622.2	25.60168	2.5
Mode	2.2	#N/A	1.004	#N/A	#N/A	#N/A	0
Minimum	2.2	126.5	0.6184	14.142	120463.8	24.35792	0
Maximum	2.2	175.5	1.004	30.72808	173787.8	25.8299	7
Syria							
Mean	6.174	406.5833	16.65667	9.851718	13794.83	18.30541	0.166667
Median	6.174	411.5	17.03	6.420633	13813.1	18.49245	0
Mode	6.174	#N/A	#N/A	#N/A	#N/A	#N/A	0
Minimum	6.174	345	12.5	5.135861	13569	17.19456	0
Maximum	6.174	454.7	20.21	18.36384	13921	18.8188	1

Turkey							
Mean	67.8	596.8	151.4833	15.5448	39638.57	11.53503	5.166667
Median	67.8	616	156.65	15.00027	39696.9	11.7582	5
Mode	67.8	#N/A	157.3	#N/A	#N/A	#N/A	#N/A
Minimum	67.8	500	133.7	12.08435	38510	10.26904	0
Maximum	67.8	645.5	157.3	19.31967	40615	12.18102	11
Turkmenistan							
Mean	67.8	596.8	151.4833	5.850957	39638.57	11.53503	5.166667
Median	67.8	616	156.65	4.584882	39696.9	11.7582	5
Mode	67.8	#N/A	157.3	#N/A	#N/A	#N/A	#N/A
Minimum	67.8	500	133.7	3.592046	38510	10.26904	0
Maximum	67.8	645.5	157.3	12.77411	40615	12.18102	11
UAE							
Mean	0.12	73	0.048017	59.17919	423.69	27.46951	0
Median	0.12	57.905	0.05445	59.92973	402.15	27.74057	0
Mode	0.12	#N/A	0.0611	#N/A	#N/A	#N/A	0
Minimum	0.12	45.41	0.016	38.2188	282.4	26.49945	0
Maximum	0.12	136.6	0.0611	77.03435	552.24	27.9061	0
Uzbekistan							
Mean	8.8	206	21.98333	28.83842	27140.67	13.08775	0.166667
Median	8.8	206	22.16	25.10036	27022.1	13.28157	0
Mode	8.8	206	22.16	#N/A	26770	#N/A	0
Minimum	8.8	206	21.6	19.99445	26662	12.44574	0
Maximum	8.8	206	22.16	49.69529	27724	13.51101	1
Yemen							
	TGWR	PREC	TDC	POP	TAA	TEMP	FOF
Mean	1.5	275.9333	0.426617	19.22938	23591.37	23.85931	4.333333
Median	1.5	270.85	0.41555	18.70899	23555.9	23.96068	3
Mode	1.5	#N/A	#N/A	#N/A	#N/A	#N/A	3
Minimum	1.5	232.7	0.4063	11.5844	23510	23.38062	1
Maximum	1.5	324.2	0.4625	26.24661	23733.2	24.11514	8

Author's Own estimations.