Hunan Daxue Xuebao/Journal of Hunan University Natural Sciences
ISSN：1674-2974 | CN 43-1061 / N

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

METEOROLOGICAL DROUGHT'S INFLUENCE ON WATER SECURITY AND ITS CONTRIBUTION TO ATTAINING SUSTAINABLE DEVELOPMENT GOALS (SDGs)

TALA H. QTAISHAT*
Department of Agricultural Economics and Agribusiness Management, School of Agriculture, The University of Jordan, Amman 11942, Jordan.
The Research was conducted during my sabbatical year at Department of Management, College of Business Administration, University of Northern Iowa, Cedar Falls, USA.
*Corresponding Author Email: t.qtaishat@ju.edu.jo

DAN P. BUMBLAUSKAS
Dean and Professor, Breech School of Business, Drury University. Email: dbumblauskas@drury.edu

Abstract

Jordan is an arid to semi-arid country, with a population of 10.8 million people as of 2020. Jordan's water sources include surface water (59%), groundwater (27%), desalinated brackish water, and treated wastewater (14%). The main objective for this research was to evaluate the effect of meteorological drought on water security, food security, and the contribution to attain the sustainable development goals (SDGs) in Jordan. The annual rainfall volume fluctuated during the study period from 1970-2020. The conceptual model for a meteorological drought's effect on water security and its contribution for attaining the SDGs is composed of three parts: 1) The first one is the cause of the drought's occurrence. 2) The second item to consider is the causes of the water security, water affordability, water suitability, and accessibility. 3) The third part consists of the water's contribution for attaining the sustainable development goals (SDGs). Path analysis, which is a form of multiple-regression statistical analysis that is used to evaluate causal models by examining the relationships between a dependent variable and two or more independent variables, was utilized for this study. The results showed that climate changes have a significant effect on water security, food security, food hunger, and improved water and sanitation services for all communities in Jordan.

***Indexed Terms**: Climatological Drought, Water Security, Sustainable Development Goals (SDGs), Standardized Precipitation Index (SPI), Rainfall Index, water Security, and Jordan.*

1. INTRODUCTION

The country of Jordan has a total land area of 89,318 km^2, with around 12% of that land being classified as agricultural land, 2% being crop land, 2% being land with temporary crops, and only 1% being land with permanent crops [1]. Jordan's principal water sources include surface water (59%), groundwater (27%), desalinated brackish water, and treated wastewater (14%). There are 14 dam reservoirs in Jordan; most of them are used to irrigate lands in the Jordan Rift Valley (JRV). The second-largest one is the King Talal Dam, with a total height of 106 meters. The dam's main purpose is to store winter rains and treated wastewater from Amman and Zarqa treated wastewater station in As Samra Plant for irrigation in the Jordan Valley [2]. The dam irrigates about 17,000 hectares. The annual rainfall volume fluctuated during the period from 1970-2020, but the average annual amount during this period was about 127 million cubic meters (MCM). The lowest season was during 1999 (about 3 MCM), and the highest was in 1988.

Meanwhile, agriculture is a major source of revenue in Jordan, and treated wastewater might be a useful source of irrigation for the country's farmers. The wastewater reuse index (WRI) measures the

ISSN：1674-2974 | CN 43-1061 / N

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

percentage of wastewater that is reused from the total wastewater generated. Water reclamation, stewardship, etc. is an important part of modern water management for agricultural irrigation and production as well as for specific industries [3]. Jordan's WRI has progressively increased from 30% in 2004 to 38% in 2007, with room for more growth [4].

Jordan is a water-scarce country due to the lack of water availability. Jordan's yearly per-capita water use is less than 130 cubic meters. Renewable water supplies only provide about half of the country's total water use, resulting in frequent outages [5].

Jordan's development is threatened by a lack of water. The northwestern region receives between 250 and 450 mm (10 to 18 inches) of annual rainfall while the rest of the country, including the south-central Jordan Valley as well as vast areas of the northeast and southeast, which are offshoots of the Syrian and Arabian deserts, receives less than 100 mm (4 inches) per year. As a result, the majority of the country is desert, but the northwestern region is semi-desert, with some areas above 1,000 meters (3,300 feet) being relatively green. Rains that are more powerful than the typical precipitation and concentrated in time can occur from November to March [6].

The main objective of this research was to evaluate the effect of meteorological drought on water security, food security, and the contribution to attaining sustainable development goals (SDGs) in Jordan. To achieve these objectives, a statistical model was built to depict the influence of meteorological drought on water security and their contribution to attaining the SDGs in Jordan.

2. BACKGROUND

The Synthesis Report of the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report clearly stated that, in the 21st century, climate change is projected to significantly reduce renewable surface water and groundwater resources in driest, subtropical regions, intensifying the competition for water among the sectors. In many regions, changing precipitation or melting the perennial snow and ice are altering hydrological systems, affecting the quantity and quality of water resources [7].

The United Nations and the World Bank define "water stress" as having yearly available resources per capita of less than or equal to 2,000 cubic meters and "water scarcity" as having annual available resources of less than or equal to 1,000 cubic meters. A country is considered to be water scarce if its score falls below 500. These estimates cover both home and industrial water consumption [8].

"Water security is defined as the capacity of a population to safeguard access to adequate quantities of water (water availability) that has an acceptable quality for sustaining human and ecosystem health on a watershed basis, and to ensure efficient protection of life and property against water-related hazards such as floods, landslides, land subsidence, and droughts" [9].

Water availability must be sustainable; it must be accessible over time, even in the case of change and variability as well as other socioeconomic, environmental, and political factors.

Water security is critical in the following six areas [10]:

1) Human survival is dependent on water: We can't keep ourselves hydrated and clean, let alone provide sanitation services, if we don't have enough clean water.
2) Water is not only necessary for life, but it is also necessary for the provision of fundamental necessities: Agriculture, energy production, transportation, and a variety of other activities rely on water to keep humans alive.

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

3) Productive economies: When individual households are unable to meet their basic needs, society as a whole cannot attain economic stability, let alone flourish.
4) Ecosystems: When it comes to water security, human requirements are simply an important component to consider. Ecosystems also rely on water, and without it, they quickly deteriorate, putting the many livelihoods and resources that they offer in jeopardy. Groundwater-dependent ecosystems (GDEs) can be found across a variety of natural phenomena from high mountain valleys to the ocean floor to deserts. It consists of plants, animals, and fungi that depend on groundwater flow, temperature, or chemical properties. Groundwater drainage supports the base flows of streams and rivers, and is an important source of water that determines its risk of drying out during droughts [11].
5) Disaster risk reduction: Effective water management can mitigate the effects of predicted stressors (long-term trends such as climate change and variability, population increases, and urbanization) as well as unexpected shocks (sudden events, from floods and oil spills to political conflicts).
6) There is an increase in water-related risks as the number of flood disasters recorded since 2000 increased by 134% compared to the previous two decades, while the number of drought events increased by 29% over the same period. The effects of extreme weather events and water stress place a heavy burden on businesses as well as on people's health, security and productivity [12].

3. FACTORS THAT AFFECT WATER SECURITY

Numerous factors affect water security, including:

1) Lessening the danger of potential disputes about water resources between sectors and between water consumers or states, water security involves collaboration across sectors, communities, disciplines, and political borders.
2) Good governance means that there are enough legal frameworks, institutions, infrastructure, and capacity in place.
3) Sovereign governments negotiate and coordinate their actions in order to meet the diverse and often-competing interests for mutual gain.
4) Financing: Innovative sources of financing complement funding from the public sector, including investments from the private sector and micro-financing schemes.
5) Climate change causes more severe droughts and floods. Temperatures are one of the main contributors to droughts and floods. Climate change affects when, where, and how much precipitation falls. The changes also lead to more severe weather events over time. Increasing global temperatures cause water to evaporate in larger amounts, which will lead to higher levels of atmospheric water vapor as well as more frequent, heavy, and intense rains in future years [13].
6) Climate change may influence water quality, water shortages, intense rain, and severe temperatures; these instances are a few examples of weather-related shocks. Climate change can have a variety of effects on water resources. Freshwater supplies might fluctuate overall, for instance, because of dry spells or droughts. Water quality may be affected by flooding and heavy precipitation increases surface runoff has the potential to introduce pollutants into the water bodies. Additionally, because warm water contains fewer contaminants, higher temperatures immediately worsen the water’s quality.

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

Precipitation occurs during Jordan's short, cool winters, decreasing from 400 millimeters (mm) annually in the northwest near the Jordan River to less than 100 mm in the south. In the uplands east of the Jordan River, the annual total is about 355 mm. The valley itself has a yearly average of 200 mm, and the desert regions receive less than 50 mm annually. Occasional snow and frost occur in the uplands but are rare in the Rift Valley. As the population increases, water shortages in the major towns are becoming one of Jordan's crucial problems impacting many aspects of life including agricultural production [14].

4. THE WATER SITUATION IN JORDAN

In 2020, the total land area was 8931.8 thousand ha, the agricultural land was and the arable land was 206 thousand ha. Land area equipped for irrigation in 2020 was thousand 107ha, while agriculture area actually irrigated land was 83.32 thousand ha (Table 1; [15].

Table 1: Land Use in Jordan -2020 (1000 ha)

Item	Area
Country area	8931.8
Land area	8931.8
Agriculture	1029
Cropland	287
Arable land	206
Land under temporary crops	115.1
Land under temp. meadows and pastures	0.4
Land with temporary fallow	90.5
Land under permanent crops	80.6
Land under perm. meadows and pastures	742
Perm. meadows & pastures - Nat. growing	742
Forest land	97.5
Naturally regenerating forest	50.6
Planted Forest	46.9
Other land	7752.9
Land area equipped for irrigation	107
Agriculture area actually irrigated	83.32
Cropland area actually irrigated	83.32

Surface water and groundwater, desalinated brackish water, and treated wastewater are Jordan's principal water sources (Figure 1; [16]). The problem is exacerbated by the uneven distribution of water supplies across the four consuming sectors: agriculture, municipalities, tourism, and industry. The agriculture sector consumes 65% of all available water. Jordan has three types of water resources [16]; [17]; Figure 1.

1. Surface water: Two major rivers in Jordan are the Jordan River and the Yarmouk River. They are shared with Israel and Syria (Figure 2).
2. Groundwater: Whether it is renewable or not, groundwater is largely overused (Figure 3; [16]),
3. Recycled water (mainly treated wastewater/to a lesser extent, desalted brackish water): To cover the overuse of water resources, Jordan's strategy relies on increasing the use of recycled water, especially for agriculture; however, the plan prioritizes desalinization, which is costly.

Hunan Daxue Xuebao/Journal of Hunan University Natural Sciences
ISSN：1674-2974 | CN 43-1061 / N

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

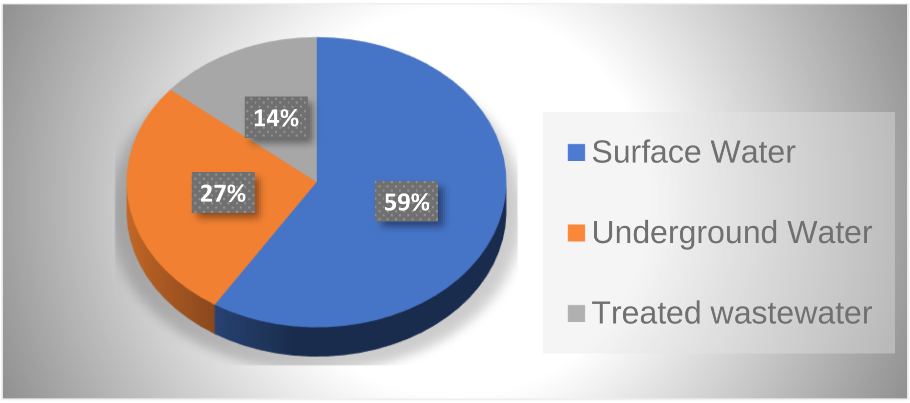

Fig 1: Jordan's Water Sources in 2017

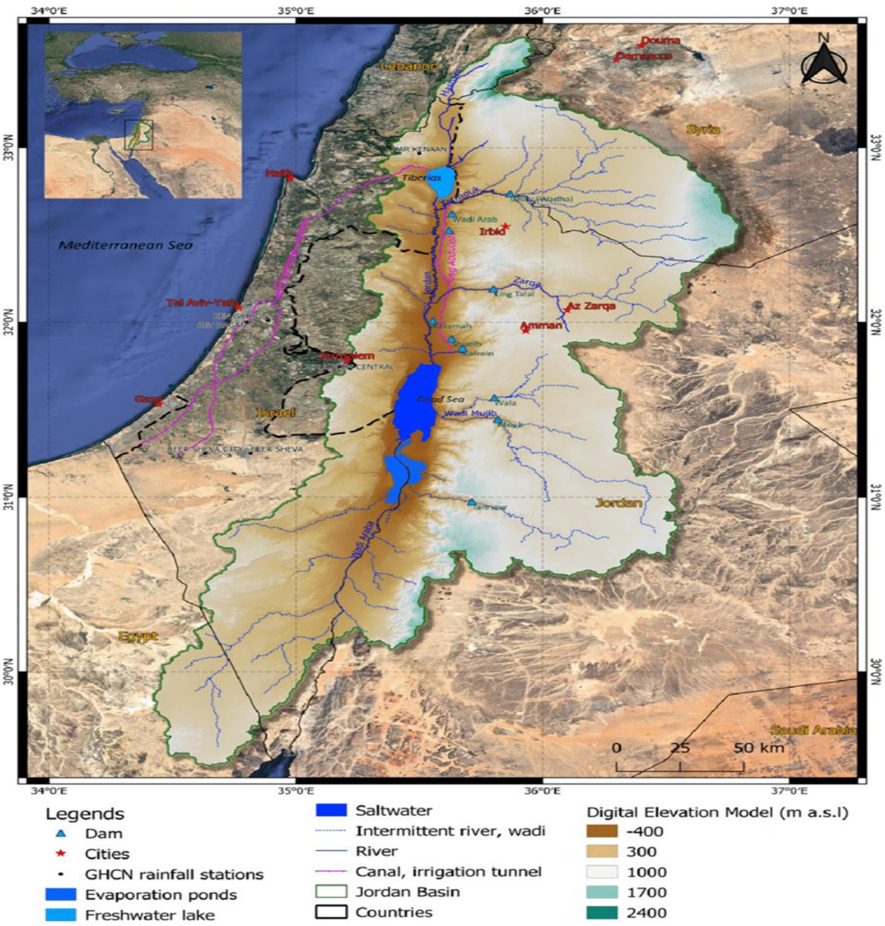

Fig 2: Surface Water resources in Jordan

The year 2021 was one of the most critical in Jordan because climate change was concretely affecting the lives of people who live in the country. That year, there was a 60% decrease in rainfall, which resulted in Jordan's 14 dam reservoirs drying up. Some of the most important dams in Jordan, such as the King Talal Dam, the Al-Walah Dam, and the Al- Mujib Dam, lost an estimated 150 million cubic meters of water. With the King Talal Dam reaching the slit stage, 330 thousand acres of agricultural lands that are fully dependent on the dam for irrigation have dried up, in addition to a major depletion of fisheries, and there are health hazards caused by the remaining still water at the bottom of the dam [18].

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

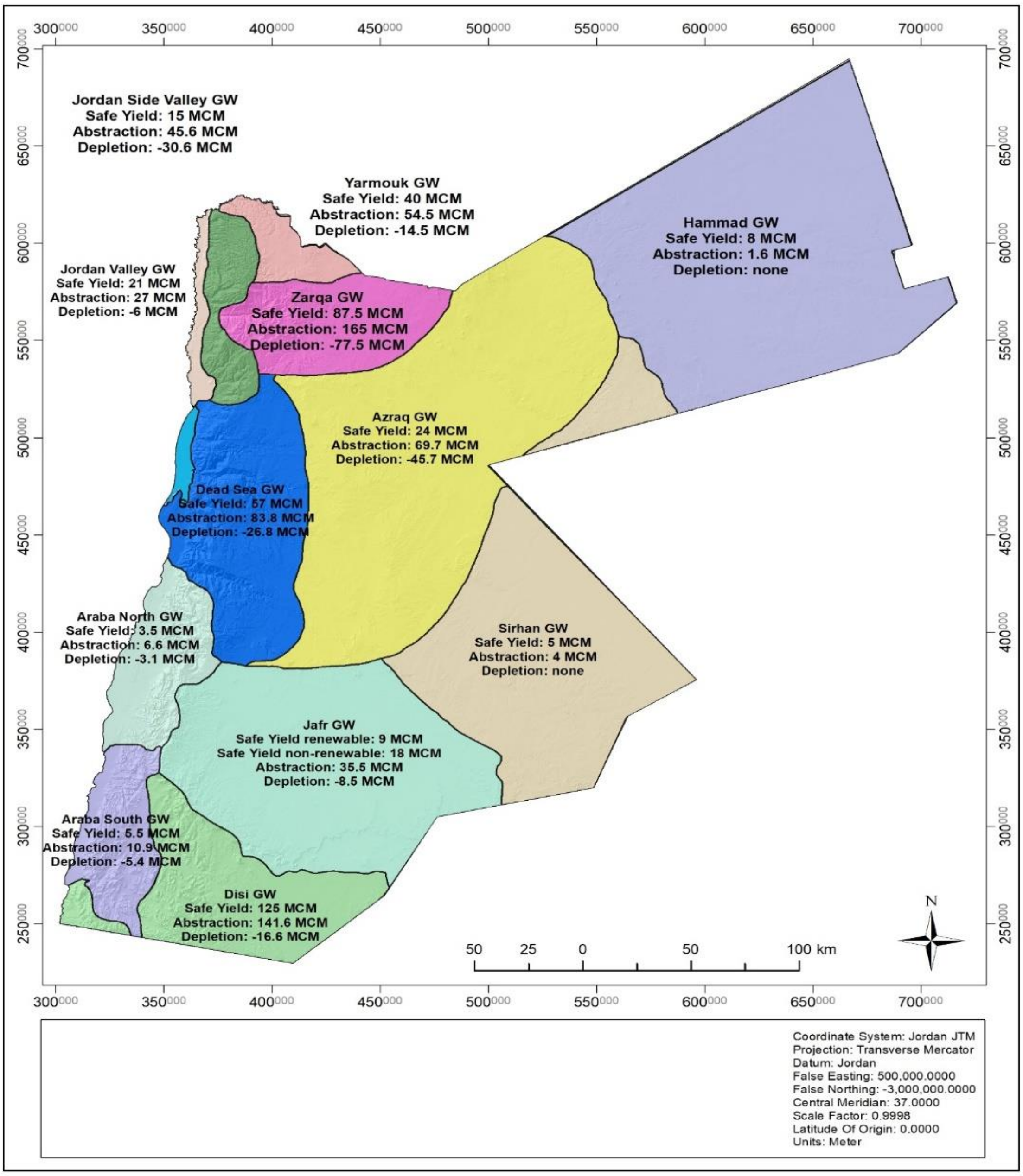

Fig 3: Jordan's Groundwater Spatial Map and Status for 2017 [modified by the researchers]

The King Talal Dam is located in the hills of northern Jordan, across the Zarqa River. The original construction was completed in 1978 with a height of 92.5 meters. In 1984, work began to raise the dam to a height of 106 meters, and the project was completed in 1988. The dam's main purpose is to store winter rains and treated wastewater from Amman and Zarqa for use with irrigation in the Jordan Valley. The dam irrigates about 17,000 hectares and supports the livelihood of about 120,000 people.

The annual rainfall volume fluctuated during the period from 1970-2020, but the average annual amount was about 127 million cubic meters (MCM). The lowest season was during 1999 (about 3 MCM), and the highest was in 1988 (about 12.3 MCM; Figure 4; [18]). In 2021, rainfall volume was 88.95 MCM [19].

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

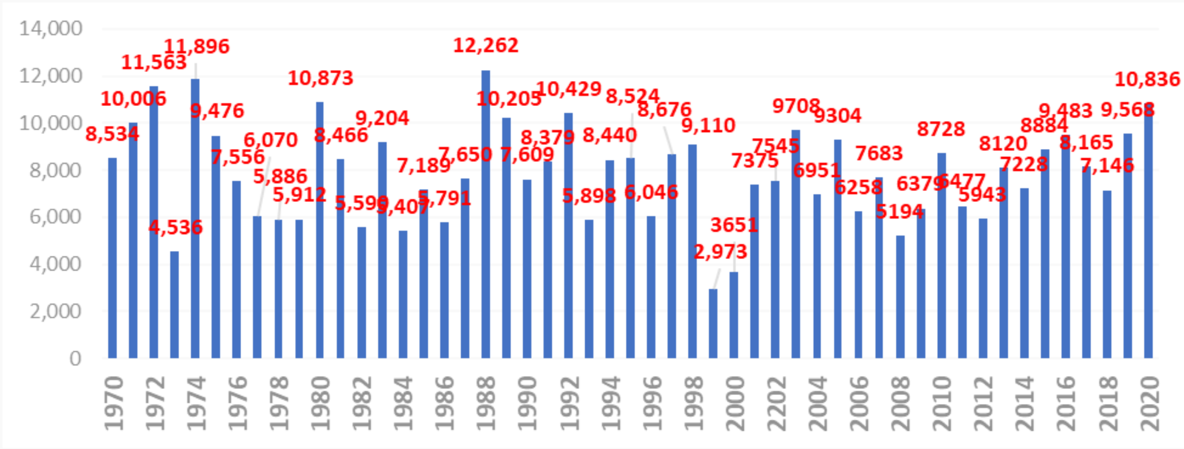

Fig 4: Annual Precipitation Volume (1970-2020)

The change in groundwater levels between 1995 and 2017 was found to be dramatic: large declines were recorded all over the country, reaching more than 100 mm in some areas. The most-affected areas had large-scale, groundwater-irrigated agriculture, but areas that were only used for the public's water supply were also affected. The decreased groundwater levels and saturated thickness pose a growing threat to the drinking-water supply, and the demand has to be met with increasingly deeper and more remote sources, causing higher costs for drilling and extraction. Groundwater-level contour lines show that the groundwater's flow direction has completely reversed in some parts of the main aquifer. Consequently, previously established conceptual models, such as the idea of 12 "groundwater basins," that are often used in Jordan should be revised or replaced. Additionally, hydraulic conditions are changing from confined to unconfined which is most likely a major driver for geogenic pollution with heavy metals through leakage from the overlying bituminous aquitard. Three exemplary case studies are presented to illustrate and to discuss the main causes for the water tables' decline (agriculture and population growth) as well as to show how the results of this assessment can be used on a regional scale [20].

Over the last 3 years, the Ministry of Water and Irrigation has invested $56 million for 29 desalination plants, which have generated 3,500 cubic meters of water every hour. The initiatives include the construction of new desalination facilities as well as the restoration of existing ones. Jordan's first seawater desalination plant opened in Aqaba in March 2017. The project produces 500 cubic meters per hour and is running in affiliation with KEMAPCO Arab Fertilizers and Chemicals Industries, one of the companies under the Arab Potash Company's umbrella [21]. Due to Jordan's severe water scarcity, the demand for marginal water for agriculture has increased drastically. This demand need was compensated with treated wastewater.

Until 1917, farmers in the Jordan Valley erected more than 52 privately owned brackish-water desalinization plants for irrigation purposes. All the plants used reverse-osmosis technology. The plants' capacity ranged from 360 to 2,400 m3/d. The entire amount of water abstracted was around 11.7 MCM, while the total desalinated amount was approximately 7.7 MCM, and the brine discharge was approximately 4.1 MCM. The available brackish water salinity ranges from 1,300 to 7,000 parts per million, with an average of 3,150 parts per million. The salinity of desalinated water ranged from 50 to 800 parts per million, with an average of 195 parts per million [22].

The change in the groundwater levels between 1995 and 2017 was found to be dramatic; significant declines were recorded nationwide, reaching more than 100 meters in some areas. The worst-affected areas were ones with large amounts of groundwater irrigation, but areas used for the public's water supply were also affected. Decreased groundwater levels and saturated congestion pose a growing

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

threat to the drinking-water supply as well as the need being met with deep and remote sources, resulting in higher drilling and extraction costs. Groundwater-level lines indicated that the groundwater flow was completely reversed in some parts of the main aquifer. Therefore, previously developed models, such as the concept of the 12 “basins of water,” commonly used in Jordan should be reviewed or modified. Additionally, hydraulic conditions change from confinement to non-closed which are probably considered the main driver of geogenic pollution from heavy metals leaking into the bituminous aquitard [21].

Low water-resource reliability and availability are exacerbated by irregular and low rainfall, high evaporation rates, and droughts. Table 2 shows that the average rainfall volume during 2005-2015 was about 7.3 million cubic meters, of which about 93.3 MCM evaporated; the floods and groundwater recharges were 177 and 313 MCM, respectively [23].

Table 2: Surface Water Budget in Million Cubic Meters (MCM) During 2000-2016

Year	Rainfall	Evaporation	Evaporation Percentage	Floods	Groundwater Recharge
2000	3651	3474	95.2	75	102
2001	7375	7063	95.8	148	164
2202	7545	7012	92.9	162	371
2003	9708	9026	93.0	275	406
2004	6951	6551	94.2	134	266
2005	9304	8671	93.2	270	364
2006	6258	5813	92.9	157	289
2007	7683	7201	93.7	195	288
2008	5194	4869	93.7	115	209
2009	6379	5903	92.5	127	349
2010	8728	8092	92.7	210	425
2011	6477	6073	93.8	119	285
2012	5943	5535	93.1	139	269
2013	8120	7689	94.7	187	244
2014	7228	6817	94.3	180	231
2015	8884	8154	91.8	245	485
2016	9482	8772	92.5	266	445
Average	7348	6866	93.5	177	305

Jordan’s water crisis is due not only to a scarcity of existing water resources, such as wadis (valleys), rivers, and underground water bodies, all of which are dependent on winter rainfall, but also to one of the world’s fastest-growing populations and, in some cases, poor water management [24].

Several variables influence water-resource management, including climate change, population increases, economic development, and urbanization [25]. Furthermore, many bio-systems have become unbalanced as a result of climate change. Bio-systems have been severely affected by climate change. It causes a disruption in the water cycle. Moreover, accessing good-quality water has become the major concern of mankind. Water security, being one of the seven components of human security, has a direct influence on human life. Experts predict that climate change will result in summer temperatures in the Mediterranean region rising between 2.2 °C and 2.5 °C, accompanied by a 4-27% decrease in annual precipitation, which will increase the risk of droughts. More evaporation and a reduction in the soil’s moisture will reduce the surface and groundwater recharge [26]. This drought factor will, in turn, lead to an increased need for crop irrigation. Climate change is also expected to raise the number of extreme weather events, such as rain and snowstorms, which can result in flooding. It will also cause greater variability with the annual temperature extremes.

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

This study's main purpose is to evaluate the effect of meteorological drought on water security and its contribution to attaining the SDGs in Jordan.

5. MATERIALS AND METHODS

5.1. The Conceptual Model for a Meteorological Drought's Effect on Water Security and its Contribution to Attaining the Sustainable Development Goals (SDGs)

Figure 5 shows the conceptual model for a meteorological drought's effect on water security and its contribution to attaining the SDGs. The first part consists of the cause of the meteorological drought occurrence. The causes of meteorological droughts are precipitation deficiency (amount, intensity, and timing), which causes reduced infiltration, run off, deep percolation, and groundwater recharge; high temperatures; high winds; lower relative humidity; greater sunshine; and less cloud cover, which causes increased evaporation and transpiration.

The second part of the figure 5 illustrates the causes of water security, water affordability, water suitability, and accessibility. The third part consists of the water's contribution to attaining the sustainable development goals (SDGs).

Resilient agricultural systems, which rely on stable and long-term freshwater supplies, whether from rainfall or irrigation, are required for food and nutritional security. It's an often-overlooked reliance that could compromise the ability to meet future food demands while also protecting the ecosystems on which all animals rely [27].

Water contamination is generally caused by pesticides and fertilizers that wash away from fields, untreated human wastewater, and industrial waste. Groundwater is not immune to pollution because many toxins can seep into the underground aquifers. Some of the effects are immediate, such as when the bacteria from human waste contaminate water, making the water dangerous to swim in or drink. It can take years for the consequences of the toxic substances emitted during industrial processes to be fully manifested in the environment and the food chain.

The values of relationships between the different components of the model were evaluated by calculating the regression equations, and taking the standardized coefficient.

5.1.1. Meteorological Droughts in Jordan

During 1999-2000, Jordan confronted the driest winter on record, and the farming area was seriously hurt by this unforgiving situation. The downpours were two months late, inadequately circulated, and finished early. Generally speaking, precipitation decreased by 70% all through the country [28].

There are two approaches for a drought. First, reactive methodologies depend on the execution of activities after a dry season. Second, proactive, or preventive, methodologies are portrayed as activities that are planned ahead of time, with proper instruments, and that incorporate partner support, giving both short- and long-haul instruments and incorporates early admonition systems. Additionally, the proactive methods incorporate an alternate course of action for crises [29].

Jordan's stormy season stretches from October to April; however, the most extreme downpours used to occur from January to March. During this period, the concerned government committee's follow and analyze the downpour amounts, anticipating the precipitation's effect on agribusinesses and horticulture. If, as expected, there is an unmistakable precipitation inadequacy (particularly before the end of February) with an adverse consequence for agribusinesses, the accompanying actions could be taken: Examine the measured precipitation step by step, and by contrasting these figures with the typical conditions, carry out a study about the precipitation's variance on agribusinesses and financial conditions. If there is a normal, adverse consequence for the horticulture area, the Drought

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

Compensation Committee talks about the issue and tells the bureau to pronounce the dry spell's status. The dry-spell statement comes from the bureau with actions to be taken, for example, food accessibility for the small ranchers as well as feed and water accessibility for the animals. The water will be free, and the feed will be had sponsored costs. Immunizations and medications will be available for the animals, and pesticides will be accessible.

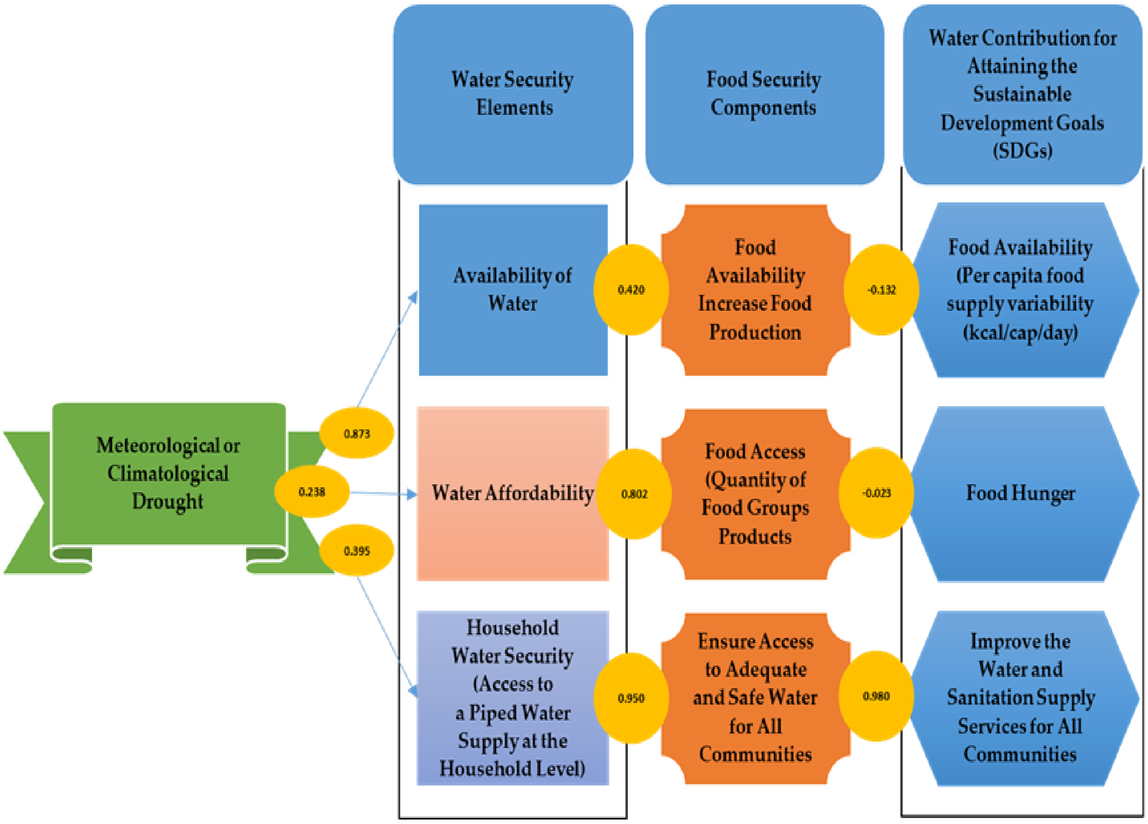

Fig 5: The Conceptual Model for a Metrological Drought's Effect on Water Security and its Contribution to attaining the sustainable Development Goals (SDG)

5.2. Meteorological or Climatological Drought

In this research, meteorological or climatological drought is measured by evaluating the Standardized Precipitation Index (SPI), which uses historical precipitation records for any Jordanian location to develop the probability for precipitation that will be computed for the period of 2000-2019. The SPI is a widely accepted and utilized index for meteorological drought monitoring [30]. This index focuses on precipitation as the major element of the water cycle. The index looks at precipitation as the most-effective parameter to calculate the drought's severity.

Twenty years after its launch, SPI is now in extensive use in both basic studies and applied practice. It is adopted by many hydrological studies and meteorological services, as a global aridity indicator [31].

The Standard Precipitation Index (SPI) is a widely used as indicator for describing drought over a large number of time periods. Over a short time, this precipitation index is closely related to soil moisture, while in longer time periods, the SPI can be associated with groundwater and water storage in dams. The SPI can also be compared across regions with remarkably different climates. SPI values can be interpreted as the number of standard deviations by which the observed anomaly deviates from the long-term average, as the SPI can be generated for different periods from 1 to 36 months, using the

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

monthly input data. The SPI has been recognized as the standard indicator that should be available worldwide for estimating and reporting atmospheric drought [32].

Drought pattern assessment is very important for risk management and climate change for adaptation planning, especially in arid and semi-arid lands where there is scarcity of water. Droughts are mostly caused by lower-than-average precipitation for a longtime

The precipitation index (SPI) is the basis for drought indices and is used to measure the deviation of precipitation values from the long-term average over a specific period of time [33].

This study used the Standardized Precipitation Index (SPI) to evaluate the metrological drought occurrences during the period of 2000-2019. Measurements were taken at the Amman Airport Meteorological (AAM) Climatology Station; it was the first station established in Jordan in 1922. The AAM station gets special attention because of its moderate record length, reliability, and its location with respect to Jordan and the Middle East. The station is in the eastern part of the capital city (Amman). The station's elevation is 780 m, with a latitude of N 31º 59` and a longitude of E 35º 59`.The mean annual rainfall and temperature are 275 mm and 12.3 oC, respectively, while the monthly evaporation mean is 51 mm [34].

The index values are the normalized deviations of the changed precipitation aggregates from the mean:

$$SPI= (X_i-\mu_i)/\sigma \qquad (1)$$

where

X_i is the surface-water budget (in million cubic meters) at the Amman rain-gauge station,

μ_i is the drawn-out occasional mean, and

σ is the standard deviation.

Positive SPI values demonstrate a more prominent than median level of precipitation while negative quantities show less than the median precipitation. If SPI =<-1, a dry season happens. Drought severity follows seven classes: extremely wet (SPI>2), very wet (1.5 to 1.99), moderately wet (1.0 to 1.49), near normal (-0.99 to 0.99), moderate drought (-1.49 to -1), severe drought (-1.99 to -1.5), and extreme drought (SPI < -2; [35].

The rainfall index was used in this study to explain the meteorological or climatological drought's occurrence. This value is calculated by dividing the annual precipitation for each year by the long-term average for the precipitation from 1970-2020.

5.3. Water-Security Dimensions and Elements

A study reviewed the available information about the concepts, dimensions, and elements of water security. Many studies alleged that there were five key dimensions of water security for a country [36].

Our study concentrates on one economic water-security element: agricultural water security. The other elements of economic water security are household water security, urban water security, environmental water security, and resilience to water-security disasters.

On the other hand, irrigation-water insecurity is defined as the lack of a reliable source of water, of an appropriate quality and quantity, to meet the needs of the local human population and the environment. The causes of water insecurity are physical (climate variability, salt water, and water pollution) as well as human (overuse from rivers, lakes, and groundwater aquifers).

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

The main elements of water security are follows:

1) Agricultural water security (water availability), which is measured by the annual rainfall surface-water budget from 2000-2020.
2) Water affordability (continuous supply), which is measured by water utilization in agriculture.
3) Household water security, which is measured by the amount of the population that has access to a piped-water supply.

5.4. Food-Security

Food security elements are:

1) **Food availability is measured by "the quantity of food groups products."**
2) Ensure access to adequate and safe water for all communities. This item is measured by the gross domestic product (GDP) at constant prices.

5.5. Water's Contribution to Attaining the Sustainable Development Goals (SDGs)

The Sustainable Development Goals (SDGs) include:

1) Food hunger i.e. ending hunger and ensuring food access for all people, this item is measured by calculating the per-capita food supply's variability (kcal/cap/day).
2) Improve the water supply and sanitation services for all communities. This item is measured by the amount of the population with access to sanitation services.

5.6. Path Analysis

Path analysis is a form of multiple-regression statistical analysis that is used to evaluate causal models by examining the relationships between a dependent variable and two or more independent variables. The path analysis starts by specifying relationships among all of the independent variables and the dependent variable because the independent variables provide both direct and indirect effects on a dependent variable. The analysis begins with constructing a diagram where the relationships between all variables and the causal direction between the variables are specifically shown.

The correlation between two variables is equal to the sum of the contribution for all the pathways through which the two variables are connected. The strength of each contributing pathway is calculated as the product of the path coefficients along that rout. The path coefficients are estimated with a simple regression between each consecutive variable in the path; then, the coefficients are standardized. If the values of error terms are required, they are calculated as the square root of ($1-R^2$) from the regression equation for the corresponding dependent variable.

6. RESULTS AND DISCUSSION

6.1. Drought Occurrences in Jordan

The SPI results revealed that there were eight wet years. There were 3 moderate drought years during the selected period. The highest severe-drought magnitude for the SPI (-2.28) was in 1999, followed by -1.95 in 2000, while the most-wet year was in 1988 (2.17). From Table 3 and Figure 6, we can conclude that about 73% (37 years) of the last 51 years were characterized by near-normal conditions. There were 4 extremely wet years and 4 moderately wet years.

ISSN：1674-2974 | CN 43-1061 / N

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

Table 3: Drought Level during the Period from 1970-2020

Level of Drought	SPI Range	No. of Occurrences	%
Extremely Wet	1.5 to 1.99	4	8
Moderately Wet	1 to 1.49	4	8
Near Normal	-0.99 to 0.99	37	73
Moderate Drought	-1.49 to -1	3	6
Severe Drought	-1.99 to -1.5	2	4
Extreme Drought	<-2	1	2
Total		51	100

Source: Calculated by the researcher based on Figure 4.

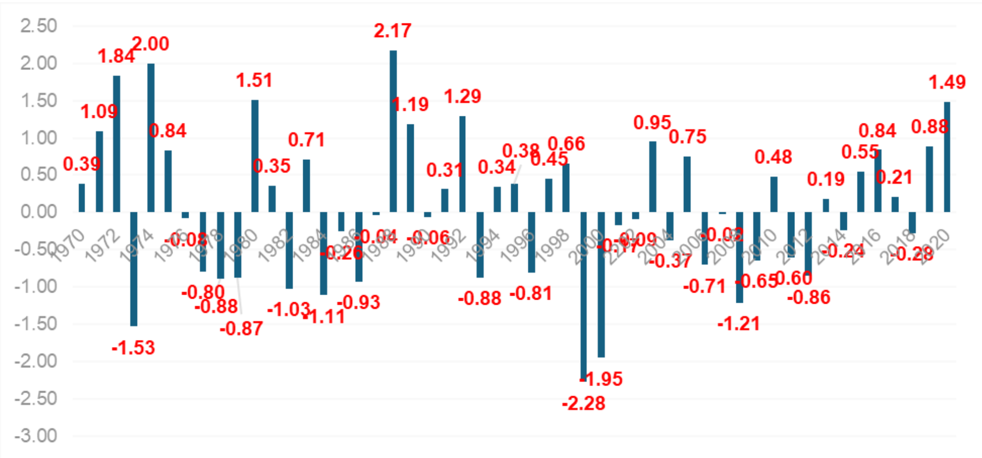

Fig 6: Annual SPI in Amman, Jordan, from 1970-2020

Source: Calculated by the researcher.

6.2. The Model's Path Analysis

The model contains three paths. They are as follows:

1) Meteorological or Climatological Drought ⟹ Availability of Water ⟹ Food Availability ⟹ Food Hunger
2) Meteorological or Climatological Drought ⟹ Water Affordability ⟹ Food Access ⟹ Food Hunger
3) Meteorological or Climatological Drought ⟹ Ensure Access to Adequate and Safe Water for All Communities ⟹ Improve Water and Sanitation Services for All Communities

6.2.1. Path One's Standardized Coefficients

The first component's coefficient is 0.873 (Table 4), which means that an increase of 1% for the rain index will cause an increase of 0.873 standard deviations for the available-water variable that is measured by the surface water's budget.

Table 4: Dependent Variable: Availability of Water

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	496.694	18.822		26.389	.000
	Availability of Water	154.537	23.961	.873	6.450	.000

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

The second component's coefficient is 0.426 (Table 5), which means that an increase of 1% for the water availability, as measured by surface water's budget, will cause an increase of 0.426 standard deviations for the percentage of food access, as measured by the Gross Domestic Product's Value-Constant in 2017 (Billion US$).

Table 5: Dependent Variable: Quantity of Food Groups Products

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2140336.323	1661238.391		-1.288	.214
	Surface Water Budget	433.997	217.253	.426	1.998	.061

The third component's coefficient is -0.132 (Table 6), which means that an increase of 1% for the quantity of food groups product variable will cause a decrease of 0.132 standard deviations for food hunger, as measured by the number of undernourished people (in millions).

Table 6: Dependent Variable: Undernourished People (Millions)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.549	.059		9.310	.000
	Quantity of Food Groups Products	-1.729E-8	.000	-.132	-.564	.580

The total effect of the first path (Availability of Water*Availability of Food* Food Hunger) is as follows:

0.873*0.426*-.132 = -0.049, meaning that an increase of 1% for the rain index will cause a decrease of 0.0.49 standard deviations for food hunger, as measured by the number of undernourished people (in millions).

6.2.2. Path Two's Standardized Coefficients

The first component's coefficient is 0.238 (Table 7), which means that an increase of 1% for the rain index will cause an increase of 0.238 standard deviations for the available-water variable, as measured by the 1% of water utilization in agriculture.

Table 7: Dependent Variable: Water Utilization in Agriculture (%)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	83.316	26.864		3.101	.006
	Rainfall Index (RI)	.287	.276	.238	1.041	.312

The second component's coefficient is 0.802 (Table 8), which means that an increase of 1% for the water affordability, as measured by the percentage of water utilization in agriculture, will cause an increase of 0.802 standard deviations for the percentage of food access, as measured by the Gross Domestic Product's Value-Constant in 2017, (Billion US$).

Table 8: Dependent Variable: The Gross Domestic Product's Value-Constant In 2017, (Billion US$)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7.041	12.466		.565	.579
	Water Utilization in Agriculture (%)	.626	.110	.802	5.689	.000

Hunan Daxue Xuebao/Journal of Hunan University Natural Sciences
ISSN：1674-2974 | CN 43-1061 / N

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

The third component's coefficient is - 0.889 (Table 9), which means that an increase of 1% for the water-utilization-in-agriculture variable will cause a decrease of 0.889 standard deviations for food hunger, as measured by the number of undernourished people (in millions).

Table 9: Dependent Variable: Water Utilization in Agriculture

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	.754	.047		16.040	.000
	Food Hunger	-.765	.131	-.889	-5.827	.000

The total effect of the second path is achieved with multiplying Water Affordability Food coefficient Access coefficient and Food Hunger as follows:

0.238*0.802*-890= -0.170, meaning that an increase of 1% for the rain index will cause a decrease of 0.17 standard deviations for food hunger, as measured by the number of undernourished people (in millions).

The total effect of the Meteorological or Climatological Drought on Hunger is the sum of the effects of the first two paths, which is equal to the following equation:

(-0.049) + (-0.170) = -0.219, meaning that an increase of 1% for the rain index will cause a total decrease 0.219 standard deviations for food hunger, as measured by the number of undernourished people (in millions).

6.2.3. Path Three's Standardized Coefficients

The first component's coefficient is 0.395 (Table 10), which means that an increase of 1% for the rain index will cause an increase of 0.395 standard deviations for the available-water variable, as measured by the number of Jordanian people who have access to piped, clean water.

Table 10: Dependent Variable: No Water Access for the Population

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3987.088	1722.189		2.315	.033
	Rainfall Index (RI)	32.234	17.696	.395	1.822	.085

The second component's coefficient is 0.953 (Table 11), which means that an increase of 1% for the household water security, as measured by the number of Jordanian people who have access to piped, clean water, will cause an increase of 0.953 standard deviations for the available-water variable, as measured by an increase of 1% of the population using safely managed drinking-water services.

Table 11: Dependent Variable: Percentage of the Population Using Safely Managed Drinking-Water Services

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	19.641	3.569		5.503	.000
	NUMBER OF POPULATION WATER ACCESS	.007	.000	.953	13.349	.000

The third component's coefficient is 0.534 (Table 12), which means that an increase of 1% for the access to piped, clean water will cause an improved supply of water and sanitation services by 0.534 standard deviations.

ISSN：1674-2974 | CN 43-1061 / N

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

Table 12: Dependent Variable: Percentage of The Population Using at Least Basic Sanitation Services

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	92.682	1.947		47.602	.000
	Access to Clean Water	.053	.020	.534	2.680	.015

The total effect of the third path (Household Water Security*Access to Adequate Safe water for all Communities* improved supply water and Sanitation services) is as follows:

0.395 * 0.953 * 0.534= 0.201, meaning that an increase of 1% for the rain index will cause an increase of 0.201 standard deviations for an improved supply of water and sanitation services.

From the above discussion, we can conclude that climate changes cause a significant effect on water security, food security, food hunger, and improved water and sanitation services for all communities in Jordan.

7. CONCLUSIONS AND FUTURE WORK

The path-analysis technique was used to evaluate the standardized betas of the variables' coefficients for the model's three paths:

1) The total effect of the Meteorological or Climatological Drought on Hunger is the sum of the effects for the first two paths. Meteorological or Climatological Drought influences the Availability of Water, which affects Food Availability and Food Hunger. Numerically, it is equal to (0.238) * (0.802) * (-0.023) = (-0.0044), meaning that an increase of 1% for the rain index will cause a total decrease of 0.0044 standard deviations for the Food Hunger, as measured by the number of undernourished people (in millions).
2) Meteorological or Climatological Drought Influences Water Affordability, which affects Food Access then Food Hunger, which is equal to (-0.049) + (-0.170) = -0.219 standard deviations.
3) Meteorological or Climatological Drought Affects Household Water Security and ensures Access to Adequate and Safe Water for All Communities, leading to the Improvement of Water and Sanitation Supply Services for All Communities, which is equal to (0.395) * (953) * (0.980) = 0.369.

7.1. Future Work

There is an urgent need for an official drought policy that is linked with Jordan's SDGs. There is a major opportunity and requirement for drought-management planning to occur in a participatory and collaborative fashion. Finally, a range of research is needed to develop opportunities to support the implementation of the drought management and to reduce Jordan's vulnerability to the primary drought effects. We recommend conducting the same analysis in the governorates that have a high level of poverty i.e., Jordan's Tafeelah and Ma'an governorates.

Author Contributions

T. H. Q.; methodology, writing, investigation and data curation, D.P.B.; formal analysis, validation, and review and editing. All authors have read and agreed to the published version of the manuscript.

Funding

This research was funded by Fulbright- T.H.Q. granted a Post-Doctoral Jordanian Fulbright Visiting Scholar Research Award 2022/2023. T.H.Q. conducted a Post-Doctoral, collaborative research at University of Northern Iowa with D.P.B.

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgments

The Researchers would like to acknowledge the Fulbright office for the funds, the Ministry of Agriculture, Department of Statistics, and the Ministry of Water and Irrigation in Jordan for providing us with the most data regarding the drought, production, and water availability.

References

1) Department of Statistics. Population yearbook. 2021. Available online: http://dosweb.dos.gov.jo/population/population-2/ (accessed on 4/ July/ 2022).

2) Qtaishat, T. H., El-Habbab, M. S., & Bumblauskas, D. P. Welfare Economic Analysis Of Lifting Water Subsidies For Banana Farms In Jordan. Sustainability 2019, 11(18), 5118.

3) Bumblauskas, D. P. Sustainable Operations Management and Benchmarking In Brewing: A Factor Weighting Approach. Journal of Operations and Supply Chain Management 2017, 10(1), 55-67.

4) Abdulla, F., Alfarra, A., Abu Qdais, H., & Sonneveld, B. Evaluation Of Wastewater Treatment Plants In Jordan And Suitability For ReusE. Academia Journal of Environmental Science 2016, 4(7), 111-117. doi: 10.15413/ajes.2016.0305

5) Al-Ansari, N., Alibrahiem, N., Alsaman, M., and Knutsson, S. Water Demand Management in Jordan. Engineering 2014, 6, 19-26 Published Online January 2014 (http://www.scirp.org/journal/eng) http://dx.doi.org/10.4236/eng.2014.61004

6) World Bank. World climate guide. 2014. Available online: https://climateknowledgeportal.worldbank.org/country/jordan/climate-data-historical#:~:text=Jordan's%20climate%20ranges%20between%20a,from%2019%2D22%C2%B0C. (Accessed on 4/ July/ 2022).

7) Dogse, P. Climate Change and Water Security. 2021. Unisco, water cop21.

8) Nathalie R. The Impact of Climate Change, Water Security and the Implications for Agriculture. China Perspectives 2007, Available online: URL: http://journals.openedition.org/chinaperspectives/1213; DOI: https://doi.org/ 10.4000/chinaperspectives.1213

9) Mishra, B. K., Kumar, P., Saraswat, C., Chakraborty, S., & Gautam, A. Water Security in a Changing Environment: Concept, Challenges and Solutions. Water 2021, 13(490), https://doi.org/10.3390/ w13040490

10) United Nations. UN-Water Annual Report. 2013. Available online: https://www.unwater.org/sites/default/files/app/uploads/2017/05/UN_Water_Annual_Report_2013.pdf. (Accessed on 12/ July/ 2022).

11) UNESCO. 2022. Un World water development Report 2022.

12) Samel, M. 2022. GLOBAL WATER AGENDA: What to expect in 2022.

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

13) National Geographic Society. How climate change impacts water access. 2022. Available online: https://education.nationalgeographic.org/resource/how-climate-change-impacts-water-access. (Accessed on 4/ July/ 2022).

14) Qtaishat, T., El-Habbab, M. S., Bumblauskas, D. P., & Tabieh, M. Fresh Tomatoes are in Demand: a Marketing and Sustainable Competitiveness Analysis of Tomato Exports from Jordan. Journal of Management Information & Decision Sciences 2022a, 25(5).

15) Food and Agricultural Organization (FAO). 2023. Sustainable development goals. Food and Agricultural Organization (FAO).

16) Ministry of Water and Irrigation. Jordan water sector facts and figures. 2017. Available online: https://jordankmportal.com/resources/jordan-water-sector-facts-and-figures-1. (Accessed on 4/ July/ 2022).

17) Qtaishat, T., El-Habbab, M. S., Bumblauskas, D. P., & Tabieh, M. The Impact of Drought on Food Security and Sustainability in Jordan. GeoJournal 2022b, 1-12.

18) Al-Kharabsheh, A. Challenges To Sustainable Water Management in Jordan. Jordan Journal of Earth and Environmental Sciences 2020, 11(1), 38-48.

19) Trading Economics. Jordan Average Precipitation Report. 2023. Available online: https://tradingeconomics.com/jordan/precipitation (accessed on 4/ September/ 2022).

20) Brückner, F., Bahls, R., Alqadi, M., Lindenmaier, F., Hamdan, I., Alhiyari, M., & Atieh, A. Causes and Consequences of Long-Term Groundwater Over Abstraction in Jordan. Hydrology Journal 2021, 29, 2789-2802. https://doi.org/10.1007/s10040-021-02404-1

21) International Union for Conservative of Nature (IUCN). Water, Energy and Food Security Nexus in Jordan, Lebanon and Tunisia. 2019. Assessment of current policies and regulatory and legal framework. Amman, Jordan: IUCN.

22) Qtaishat, T. H., Al-Karablieh, E. K., Salman, A. Z., Tabieh, M. A., Al-Qudah, H. F., & Seder, N. Economic Analysis Of Brackish-Water Desalination Used For Irrigation In The Jordan Valley. Desalination and Water Treatment 2017, 72, 13-21. doi:10.5004/dwt.2017.20435

23) Ministry of Water and Irrigation. Jordan water sector, facts and figures. 2018. Available online: http://www.mwi.gov.jo/ebv4.0/root_storage/ar/eb-2015.pdf. (Accessed on 4/ July/ 2022).

24) Garthwaite, J. 2021. Study reveals a deepening water crisis in Jordan – and a way forward. PHIZ-ORG

25) Brekke, L., Kiang, J., Olsen, R., Pulwarty, R., Raff, D., Turnipseed, D., Webb, R., & White, K. Climate Change and Water Resources Management: A federal perspective 2009. Reston, VA: U.S. Geological Survey.

26) Hussein, H. A Critique of Water Scarcity Discourses in Educational Policy and Textbooks in Jordan, the Journal of Environmental Education 2018, 49(3), 260-271. DOI: 10.1080/00958964.2017.1373620

27) Rosa, R. Adapting Agriculture to Climate Change via Sustainable Irrigation: Biophysical Potentials and Feedbacks. Environmental Research Letters 2022, 17(2022) 063008. doi:10.1088/1748-9326/ac7408

28) Fragaszy, S.; Fraj, M. B.; McKee, M.; Jobbins, G.; Al-Karablieh, E.; Bergaoui, K.; Ghanim, A.; Lawrenson, L.; McDonnell, R. Mena Drought Synthesis Of Drought Vulnerability In Jordan: 2022. Final report. Project report prepared by the International Water Management Institute (IWMI) for the Bureau for the Middle East of the United States Agency for International Development (USAID). Washington, DC, USA: USAID; Colombo, Sri Lanka: International Water Management Institute (IWMI). 93p. doi: https://doi.org/10.5337/2021.231

29) Gabiña, D. Drought Management Guidelines in the Mediterranean Region. zaragoza, 2013. Spain: Instituto Agronómico Mediterráneo de Zaragoza, CIHEAM.

30) Shamsnia, S. A., Amiri, S. N., & Pirmoradian, N. Drought Simulation in Fars Province Using Standardized Precipitation Index and Time Series Analysis (ARIMA MODEL). International Journal of Applied Mathematics 2009, 22(6), 869-878.

DOI: 10.5281/zenodo.14677419
Vol: 62 | Issue: 01 | 2025

31) Cheval, Sorin. 2015. The Standardized Precipitation Index – An Overview Sorin Cheval. Romanian Journal of Meteorology. Volume 12, issue 1-2

32) NCAR. 2018. Actionable Insights on Climate Data from Climate Experts. Available online: https://www.meted.ucar.edu/training_module.php?id=1226 (accessed on 22/ September/ 2022).

33) Bobadoye, A., Adewoye, R., Adio. A and Adewoye R. Assessment of Meteorological Drought Using Standardized Precipitation Index (SPI). Journal of Forestry Research and Management 2019, Vol. 16(1). 154-163; 2019, ISSN 0189-8418.ww.jfrm.org.ng

34) Smadi, M., & Zghoul, A. A Sudden Change in Rainfall Characteristics in Amman, Jordan during the Mid-1950S. American Journal of Environmental Sciences 2006, 2(3), 84-91. doi:10.3844/ajessp.2006.84.91

35) McKee, T. B., Doesken, N. J., & Kleist, J. The relationship of drought frequency and duration to timescales. In Proceedings of the 8th Conference on Applied Climatology 1993, 17(22), 179-183. Boston, MA: American Meteorological Society.

36) Chamhuri, A., & Ferdoushi, a. Concepts, dimensions, and elements of water security. Journal of Nutrition 2014, 13(5), 281-286.