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RESEARCH ARTICLE

A LONG-TERM ESTIMATION AND MODELING OF DOMESTIC WATER RESOURCES IN THE YARMOUK RIVER BASIN-JORDAN

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ABSTRACT

This paper presents an assessment of the supply and demand of domestic water resources in the Yarmouk River Basin-Jordan over a twenty-year period and a long-term estimate of domestic water use for the coming years through 2030. The basin was selected because of water-related problems ranging from management to water scarcity and overpopulation. These problems have increased pressure on the domestic water supply, thus the population's demand for water far exceeds the water supply from internal wells, necessitating management actions to bridge the gap between domestic supply and demand. The method includes identifying the governorates, wells, cities, villages, and computing the population in the basin governorates. Domestic water demand was assessed on a per capita water basis in 1997 and 2017. An Autoregressive Integrated Moving Average (ARIMA) model was used to estimate usage behavior. The results showed an increase in the basin population from 0.64 to 1.53 million, more than doubling. Comparing the population demand with the internal water supply showed significant changes, as the increase in water use was remarkably high despite the decline in per capita water. ARIMA estimates a 2% increase in domestic use annually and 15% through 2030, challenging the future of water supplies. Water management actions will address this challenge, such as the inter-basins located outside the Yarmouk Basin, thus resolving supply shortage issues. These findings are important as a baseline for future studies, and can assist stakeholders in taking actions such as reviewing groundwater data, detecting illegal practices, water harvesting, and assessing non-revenue water.

KEYWORDS

Population growth; domestic supply-demand for water; modeling; water management actions; stakeholders

1. INTRODUCTION

Globally, the increase in water demand has outpaced the rapid population growth rate, with most regions currently exerting unprecedented pressure on water resources, resulting in unsustainable water supplies (Mongelli, et al. 2019). The world will face a forty percent shortfall between projected demand and available water supply by 2030. Moreover, water scarcity and hydrological changes are seen as the biggest challenge to the world's stability (The World Bank, 2017). One of which is that the freshwater resources are limited and their quality is getting worse, all with the need to maintain the supply and manage demands in river basins and their communities. Many people still lack the means to provide clean and adequate water resources, and there is a huge potential for achieving food security through optimal use of water supplies (Savenije and Van der Zaag, 2008; Adnan et al., 2019). In basins where domestic water demand has grown rapidly and water consumption has exceeded the available water supply, this has led to the deterioration of river basins (Fang et al., 2007).

The challenge of providing sustainable and sufficient quantities of water supply worldwide to meet the needs of millions of people is growing due to lack of water supply infrastructure, as well as lack of water supply versus water demand (Chung et al., 2009; Edokpayi et al., 2018). Therefore, water resources management stakeholders as governments, decision-makers, and institutions face enormous challenges in finding alternative sources of water and proposing water measures management that respond to population growth and their needs. They are experienced with current water demand, while estimating water supply and demand and predicting future water use through statistical analysis will help bridge the gap between supply and demand, as well as maintain the sustainability of river basins and their Environment, where statistical tools are useful in creating the right decision in many river basins areas (Demir et al., 2007; Chen et al., 2005). The autoregressive integrated moving average (ARIMA) model is one such analysis that can help decision makers manage water resources in the future (Du et al., 2020). ARIMA is widely used in the analysis and forecasting of water needs (Niknam et al., 2022). Studies have recently demonstrated the efficiency of the ARIMA model in predicting and planning water consumption to provide advice and meet water demand. The data used for prediction can be monthly or yearly and the results of the model help show when water consumption will increase (Bo et al., 2021; Enbeyle et al., 2022). The ARIMA model can be used in crowded areas where the demand for clean water rises sharply. Yalçıntaş et al. (2015) used the ARIMA model to predict the demand and supply of water between 2015 and 2018 and attempted to estimate the long-term feasibility of urban water management in Istanbul and the findings showed that the population's water demand is for nearly 80% of total water use. Also, they indicated that pipeline projects will be important in the near future due to the increasing demand for water. Rahaman and Kalra (2018) developed an ARIMA model to derive the

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monthly groundwater level over the Colorado River Basin. The results showed that the model can be used to predict groundwater trends and fluctuations in the coming years, which will help to develop a strategy for sustainable groundwater planning and management. Patle et al. (2015) select ARIMA as a suitable model for time series modeling and forecasting for the Karnal district of Haryana, and showed that the monsoon groundwater level will decline after the year 2050. Takafuji et al., (2018) also showed that best water management practices should include forecasting the availability of groundwater resources and the ARIMA model has proven its efficiency and accuracy in monitoring the aquifer at all periods.

In Jordan, the supply of water resources is inadequate and unable to meet the domestic demand, especially for drinking purposes. In 2016, Jordan's annual renewable resources is less than 100 m^3/capita and far below the global threshold for acute water scarcity; 500 m^3/capita (MWI, 2016). The increase in demand and decrease in supply adversely affected the balance of water resources (MWI, 2016). Most of the springs in Jordan are concentrated in the northern highlands (MWI, 2018), and there are fifteen surface water basins; the most important are the Yarmouk and Jordan rivers, whose waterways flow permanently, and the Jordan River gets 50% of its water from the Yarmouk River (Obeidat, 2019). Figure 1 shows the surface water basins, the Yarmouk Basin, and its governorates.

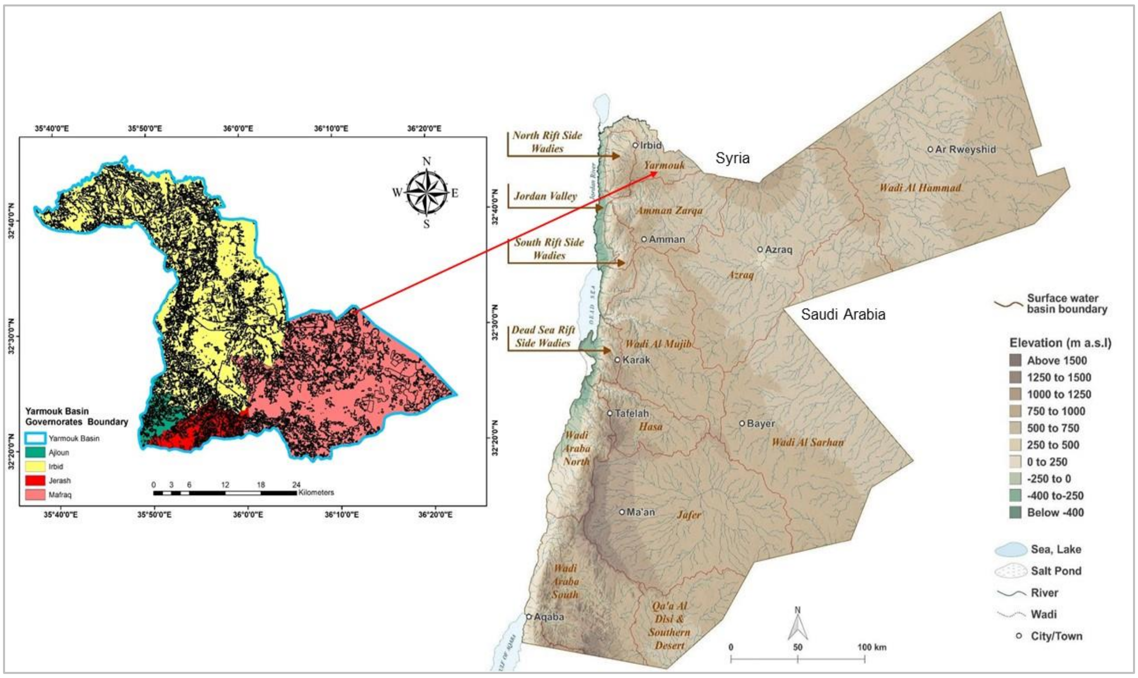


Figure 1: The surface water basins, the Yarmouk Basin, and its governorates.

The major issues in the water supply in the Yarmouk Basin stem from the truth that the water demand to meet human needs far exceeds the supply, leading to increased pressures on the domestic water supply (Shatanawi and Shammout, 2011; Shammout et al., 2013). The problem is exacerbated when water resources systems are cannot compensate for shocks caused by natural asymmetries such as drought and sudden overpopulation, as the influx of Syrian Refugees residing in the Yarmouk Basin governorates has put additional pressure on groundwater wells in order to meet the needs of the population (UNHCR, 2015; Shammout et al., 2023). Accordingly, the Jordanian government, planners, scientists, stakeholders, and relevant actors should take actions to manage domestic water demand affected by population growth to reduce the gap between domestic supply and demand and conserve the environment, as well as propose sustainable solutions to challenge future domestic needs in the Yarmouk River basin. For the aforementioned reasons, the Yarmouk River Basin was selected as a case study for the [WE/2/08/2017] project funded by the Scientific Research and Innovation Support Fund- Ministry of Higher Education and Scientific Research, Jordan.

Therefore, this study was conducted for the Yarmouk River Basin of Jordan and presents the findings of the funded project referred to above. The paper deals with a twenty-year assessment of the supply and demand of domestic water resources with long-term estimation and modeling of domestic water resources affected by population growth and domestic water demand. The main objectives of this study are: (1) To evaluate domestic water resources with population water demand on a per capita water basis over twenty years for 1997 and 2017, and (2) To estimate changes in domestic water use for basin wells up to 2030 using the ARIMA model, and (3) Highlight actions that can assist stakeholders in managing domestic water resources to deal with water shortages and population's needs and conserve the basin environment.

2. Methodology

2.1 Study Site

The Yarmouk River Basin is located in the northwestern part of Jordan. The basin in Jordan has an area of about 1,393 Km^2. Its elevation is ranged from about -200 m in the Jordan Valley to about 1150 m at the upper boundary of the watershed (Ras Munif). The Yarmouk River originates in Jordan and then it forms the border between Jordan and the Syrian Arab Republic (Avisse et al., 2020). The Yarmouk River Basin of Jordan is located within four Jordanian governorates, namely, Mafraq, Irbid, Jerash, and Ajloun governorates. The western part of the basin is densely populated and comprises the major cities Irbid and Ar Ramtha, but the eastern part is less densely populated.

The Yarmouk River is the main source of water for the King Abdullah Canal (KAC), the backbone of development in the Jordan Valley. KAC is also fed by the Zarqa River (ZR). ZR is one of the largest rivers in Jordan and one of the main tributaries of the Jordan river, it is controlled by King Talal Dam (KTD) (FAO, 2009; Abualhaija et al., 2019; Shammout and Shatanawi, 2021). The annual flow of the Yarmouk River has been evaluated at the confluence of the Lower Jordan River and was about 440 to 470 MCM /year for the period 1927–1954. The mean total annual usable recharge of the Yarmouk aquifer has been estimated at 125 MCM/yr, whereas the net recharge of the part of the Yarmouk basin located within Jordan is 35 to 40 MCM /yr. The side-wadi basin is annually replenished by 30-40 MCM/year (Courcier et al., 2005). Water Year Book of the Ministry of Water and Irrigation (MWI, 2018) shows that the flow varies between 11 m^3/sec (31.5 MCM) to Zero. Yarmouk River Basin discharges its water at the confluence of the Yarmouk River with the Jordan River at an elevation of about -200m. The stream flow of the Yarmouk River is impounded at Wehdah Dam, where the dam's water is used for irrigating different crops in the Jordan Valley.

There are several wadis draining in the Yarmouk Basin, such as Wadi al Harir and Wadi al Shalalah. The Basin includes five municipal wastewater treatment plants (WWTPs), which are Al Akaidar, Wadi al Shalalah, Mafraq, Wadi Hassan, and Ramtha. The amount of treated effluent from most wastewater treatment plants has increased over the years due to the increase in population growth and overuse of water resources (González, 2018), thus increasing the demand for domestic water and pressure on the available limited water resources in the basin.

2.2 Determination of Domestic Water Resources and Population Demand in the Basin

The water resources for domestic use and population were calculated and evaluated over twenty years period using the data of 1997 and 2017. These years were chosen because all the data required for this study are available. The data of the water resources records for the study period were obtained from the open files of the Ministry of Water and Irrigation (MWI) (MWI,1997; MWI,2017), as the water resources of the Yarmouk River Basin mainly consist of groundwater, which is the most important source for domestic use purposes. Hence, the wells of Yarmouk River Basin were identified in terms of uses, quantities and distribution across the entire basin by delineating the specific governorates associated with the basin boundaries using ArcMap 10.8.1. The domestic water supply from the basin wells was calculated over the target years.

The cities and villages of the specific (delineated) governorates of the Yarmouk Basin were identified by defining the boundaries of villages and cities within the boundaries of the basins based on the information provided by the Department of Lands and Survey in Jordan, then the population of the entire basin was computed based on the demographic records provided by the Department of Statistics (DoS, 1997; DoS, 2017). Information from the Department of Lands and Survey and the Jordanian DoS helped in calculating the required domestic demand for water in the entire basin within its boundaries, as the Jordanian government and water managers determined the per capita share of water for each governorate in Jordan, taking into account the geographical location of the governorates.

In this study, the total domestic water demand was compared with the population of basin and the internal supply of wells in order to assess supply versus demand within the basin, as well as to identify actions that could offset for the shortage in the supply of internal wells. Establishing water management actions to reduce pressure on basin's internal groundwater wells will help the water supply meet water demand and preserve the basin environment.

The total domestic water demand of the entire Yarmouk Basin was calculated by multiplying the per capita share of water by the population of the governorates within the basin, then summing the total domestic water demand for all basin governorates as shown in Table 1, in terms of the following:

Total Domestic Water Demand in the Yarmouk River Basin =
Mafraq Water Per Capita[Mafraq Population] +
Irbid Water Per Capita[Irbid Population] +
Jerash Water Per Capita[Jerash Population] +
Ajloun Water Per Capita[Ajloun Population]

2.3 Autoregressive Integrated Moving Average (ARIMA) Model For Estimating Usage Behavior

Statistical tools are essential to building a correct decision in many fields of study. Such analysis tools are developed to create a future vision that can help decision makers by providing an insight view of existing data. Since water usage (supply) at different stations in the Yarmouk Basin has been recorded based on time measures, an Autoregressive model based on time-series data was developed to make a future estimation of water supply at these stations.

According to the recorded data from 1997 to 2017, the model creates different average points based on time and tries to understand how such averages move concerning time (Moving Average). Such a method allows for a better understanding of future behavior and, ultimately, creates an estimation model to predict future estimates. Typical water supply associated with the type of domestic use from wells of the Yarmouk Basin wells was investigated to create the ARIMA model, in addition to a combination of domestic and irrigation uses was also investigated according to increasing demand.

Data models were developed, based on actual site data and appropriate assumptions. Such extensive analysis enhances the accuracy of the resulting estimations, therefore, minimizes the estimation error. For some specific uses, water use can vary significantly depending on development-specific factors such as demographics. To show how this water use behaves in different regions, ARIMA time series models have been developed. This type of analysis allows simulating and estimating the use for water in the near future accurately (Dimri et al., 2020). The models have been built on two levels. The first is the station level where every single station has its model. While the second level is the region level where water usage is estimated after aggregate data in each region. The general ARIMA model depends on three parameters: p, d, q (we denoted this model as ARIMA (p,d,q)) as shown in Eq. (1):

$$\hat{y}_t = \mu + \left[\oint_1 y_{t-1} + \cdots + \oint_p y_{t-p}\right] - \left[\theta_1 e_{t-1} - \cdots \theta_q e_{t-q}\right] \quad (1)$$

$\hat{y}_t$ is the estimation parameter; as a result of applying the model at time t.

y_t is the value of water usage at time t. μ is the mean value of the previous readings.

ϕi is the autoregressive coefficients i = 1,…,p, and θj is the moving average coefficients j = 1,…,q.

e_t is the estimated error at time t, and p is the number of autoregressive terms. d is the number of non-seasonal differences needed for stationarity. q is the number of lagged forecast errors in the prediction equation. while the different terms in the above model will be introduced for d> 0. For example, if d= 1 (means that the left-hand side of the model needs the reading from the previous period), the ARIMA model has the form, Eq. (2):

$$\hat{y}_t - y_{t-1} = \mu + \left[\oint_1 y_{t-1} + \cdots + \oint_p y_{t-p}\right] - \left[\theta_1 e_{t-1} - \cdots \theta_q e_{t-q}\right] \quad (2)$$

If d = 2 means that the model will depend on the previous two readings or the difference from 2 periods ago. Generally, to find the appropriate ARIMA model, the coefficients defined above need to be estimated. This can be achieved by implementing the data set via handy software.

3. Results and Discussion

3.1 Evaluation of Domestic Water Resources and Population Demand 1997 and 2017

The Ministry of Water and Irrigation (MWI, 2016) indicated that groundwater wells are the main supply of domestic water purposes, and prioritizing the use of drinking water is the central issue of the Jordanian government. Figure 2 shows the distribution of the wells and uses of the governorates of the Yarmouk River Basin. Most wells are concentrated in the Northern part of the Yarmouk Basin. Figure 3 shows the cities and villages in the Yarmouk River Basin governorates. Table 1 summarizes the population and domestic water demand in the Yarmouk River Basin for 1997 and 2017. In 1997, the total population of the basin was estimated at 0.64 million inhabitants, including the inhabitants of Mafraq 73,834 Irbid 515,590 Jerash 25,174 and Ajloun 25,394. Domestic water demand in 1997 was estimated at 27 MCM, and water use from domestic groundwater wells in the Yarmouk River Basin was about 11 MCM. In 2017, the total population of the Yarmouk Basin was estimated at 1.5 million inhabitants, including the inhabitants of Mafraq 180,458 Irbid 1,262,549 Jerash 35,576 and Ajloun 47,792 inhabitants. Irbid Governorate is the densely populated area in the basin followed by Mafraq Governorate, while Jerash Governorate is the least populated area due to its small area compared to the governorates of Irbid and Mafraq. The domestic demand for water in 2017 was estimated at 45 MCM, and water use from domestic groundwater wells in the basin was about 21.5 MCM. It is clear from the calculated data in this study that the demand for water exceeds the use of internal wells, and therefore a significant shortage of water supply internally.

The comparison of population with the demand for domestic water for the years 1997 and 2017 (Table 1) showed significant changes as evidenced by a noticeable increase in the population and a considerable increase in the demand for domestic water. An observed decrease in the per capita share of water between 1997 and 2017. For example, in 1997, the water per capita was about 256.7 liters per capita per day (lpcd) for Mafraq, and 97.6 lpcd for Irbid. In 2017, it reached 130 lpcd and 73.8 lpcd for Mafraq and Irbid respectively. The decline in per capita share of water will not offset the increase in demand caused by population growth, not to mention, recurrent droughts in the region which have also affected the quantities of domestic water sources and thus the water supply. Thus, the levels of groundwater wells have significantly decreased as a result of water withdrawal to compensate for the increase in the demand for domestic water. Besides the differences between the domestic water supply and the domestic water demand, the water loss in the distribution network is relatively high, which has led to a chronic shortage (Shatanawi and Shammout, 2011), and MWI (2018) reported that the loss of water from the water network is about 50% of the total drinking water network.

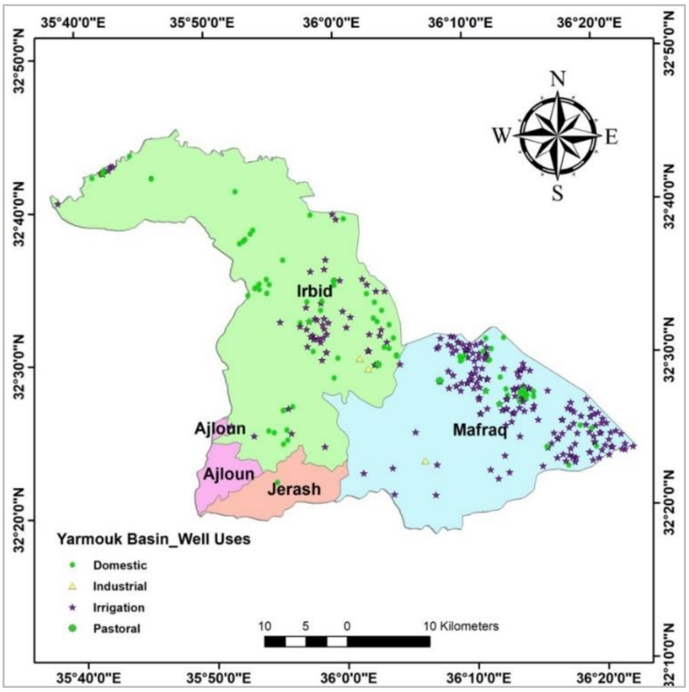


Figure 2: The wells distribution and uses of the governorates of the Yarmouk River Basin.

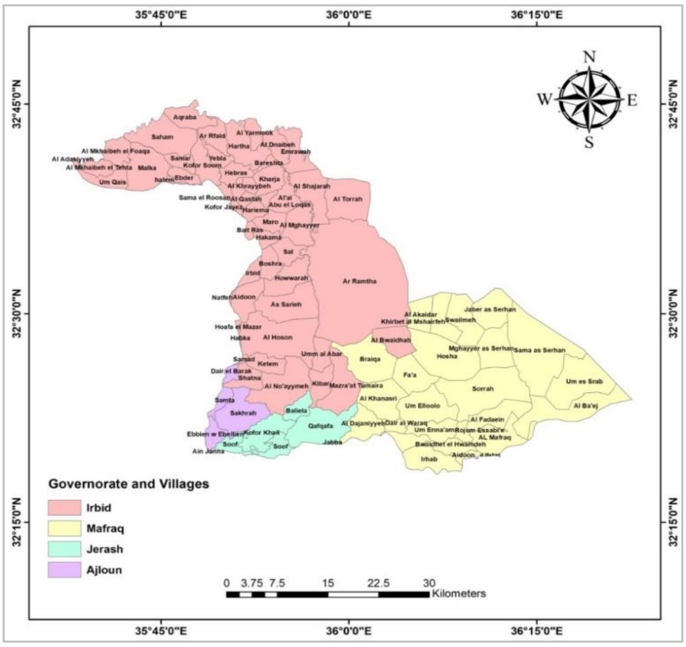


Figure 3: The cities and villages in the Yarmouk River Basin governorates.

Table 1: Population and Domestic Water Demand in the Yarmouk River Basin for 1997 And 2017.

Governorate	Per Capita Share of water 1997 Lpcd	Per Capita Share of water 2017 lpcd	Yarmouk Basin Population 1997	Yarmouk Basin Domestic Water Demand 1997 MCM	Yarmouk Basin Population 2017	Yarmouk Basin Domestic Water Demand 2017 MCM
Mafraq	256.7	129.9	73834	6.92	180458	8.56
Irbid	97.6	73.8	515590	18.37	1262549	34
Jerash	82.8	86.6	25174	0.761	35576	1.12
Ajloun	96.5	76.7	25394	0.89	47792	1.33
Total			639992	26.94	1526375	45

3.2 Estimating Changes In Domestic Water Resources Uses Until 2030

A model has been created using ARIMA estimation. To create an estimation model, basic parameters have to be induced from historical data (1997 to 2017) to develop a behavioral understanding of its usage patterns. Such analysis allows for estimating future behavior. A descriptive and deep statistical analysis has been performed for inducing ARIMA parameters as shown in Figure 4. Table 2 shows the estimation of future domestic use (MCM). This by inserting the parameters of ARIMA into the estimation formula as follows:

$$\hat{y}_t - y_{t-1} = 230.503 + .927\, y_{t-1} - 0.02\, y_{t-2} - 0.949\, e_{t-1}$$

By focusing on the domestic use from the groundwater wells in the Yarmouk Basin; we can notice the drop from the year 2011 to 2014 as shown in Figure 5, due to the significant increase in domestic water use from Yarmouk Basin wells. However, the model estimates an increase in domestic use by 2% every year and an accumulative amount of 15% through 2030. Such information should draw the attention of water resources management stakeholders as decision-makers to find sustainable solutions to the challenge of future domestic needs in this basin. The use of ARIMA in groundwater estimation has been found in other case studies such as the Brazil case study (Takafuji et al., 2018) that helps in understanding and monitoring the aquifer behaviour, and other studies related to the estimation of annual and daily water consumption such as in China (Bo et al., 2021; Du et al., 2020), and in Malaysia (Razali1 et al., 2018). ARIMA Predictions of future levels of groundwater wells are an important basins management measure, vital to water resource management, and help prevent overexploitation (Khosravi et al., 2022). Therefore, estimation of water uses is recommended because it has a certain fundamental value for annual planning of water use enterprises, long-term construction planning and the decision-making.

In addition to domestic water use from the wells of the entire basin (**Figure 5**), this study also estimates the use of domestic wells and the use of irrigation wells that comes from two major governorates (Mafraq and Irbid). **Figure 6** shows the water uses from wells in the Yarmouk Basin (existing and estimated): (**a**) Mafraq, and (b) Irbid.

The analysis of the usage patterns at Mafraq Governorate and Irbid as shown in Figure 6 reflects a combination of domestic and irrigation uses and is affected by the population increase and the ability of these governorates to attract crops production from irrigation uses. Therefore, it is expected to demand more water during the next decade. The increasing population and the ability of Mafraq Governorate to attract businesses in agriculture play a significant role in this estimation. On the other hand, Irbid Governorate is expected to demand a nearly fixed average of water during the next decade. Such estimation copes with the fact that people in Irbid are increasingly leaving work in agriculture, and thus the population's demand for water exceeds the demand for irrigation.

Based on the above findings, the Yarmouk River Basin is facing an acute water supply crisis (Avisse et al., 2020). Consequently, in the face of these challenges of basin water demand; the management of water resources is highly required to minimize the difference between domestic water supply and domestic water demand. This is a major and complex set of challenges facing ministries, stakeholders, and relevant actors in the water sector to secure more domestic water supply for a growing population with limited water resources.

ARIMA Model Parameters

					Estimate	SE	t	Sig.
Trans_amount-Model_1	Trans_amount	No Transformation	Constant		230.503	93.252	2.472	.014
			AR	Lag 1	.927	.120	7.757	.000
				Lag 2	-.020	.078	-.261	.794
			Difference		1			
			MA	Lag 1	.949	.096	9.929	.000

Figure 4: ARIMA parameter induction process using SPSS.

Table 2: Estimation of Future Domestic Use In MCM.									
Type	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Domestic	23.95	24.40	24.85	25.30	25.75	26.20	26.65	27.10	27.55

Figure 5 shows the behavior of domestic water use in m³ (existing and estimated). The behavior is during the years from 1997 to 2030 including 13 years of estimations after (1997-2017).

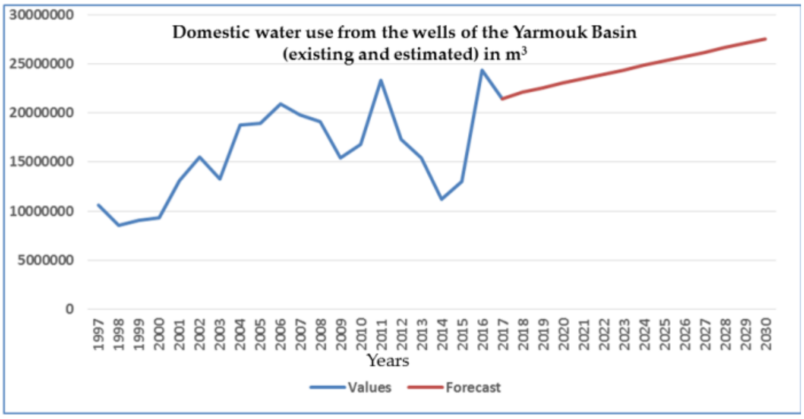
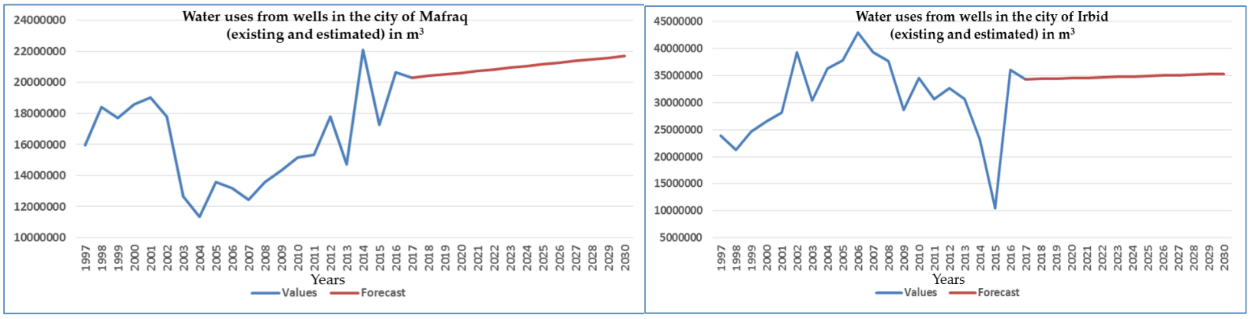


Figure 5: Behavior of domestic water use in m³ (existing and estimated).



(**a**) (**b**)

Figure 6: Water uses from wells in the Yarmouk Basin (existing & estimated): (**a**) Mafraq; (**b**) Irbid.

3.3 Managing The Domestic Demand for Water Under The Needs of The Population

The above-mentioned findings demonstrate that managing domestic water resources under the needs of the population is an issue of great importance for finding new sources of water supply as well as implementing actions that can compensate for the shortage in domestic water supply (MWI, 2016; MWI, 2018), where the driving force for the future challenge is likely to come from population growth and climate change (Weatherhead and Howden, 2009). The basin groundwater extraction exceeds the safe yield of 40 MCM and doesn't meet the required need. Therefore, management actions of water supply versus population demand needs must be adopted in terms of the following:

- Inter-basin water supply to offset water shortage in domestic water will aid in the sustainable management of water resources in the Yarmouk Basin, as well as to secure supply versus demand. The main management actions taken by the Jordanian government regarding inter-basin water supply is identified (Table 3). Table 3 shows the inter-basin water supplies to Yarmouk Basin for the year 2017. The inter-basin water supply is from the wells located outside the Yarmouk Basin to the pumping stations and reservoirs related to Yarmouk Water (YWC, 2019), namely: For Mafraq Governorate; Za'atari supplies Um Ellollo 150 m^3/h and Smayya 500 m^3/h with a total of 650 m^3/h. For Irbid Governorate; Kufr Assad wells supplies Kufr Assad 214 m^3/h, Wadi Al-Arab supplies Zabdah resrviour 2100 m^3/h, and Za'atari wells supply Hufa reservior 700 m^3/h. These quantities of pumping stations are under the management of water managers to main governorates in Mafraq and Irbid to compensate for the shortage in water needs for domestic purposes. The domestic water supply in the governorates of Jerash and Ajloun comes also from the inter-basins, which are: Zabdah and Um Ellollo Reservoirs. Zabdah Reservoir provides Hufa and Samad Stations, while the Um Elloolo Reservior provides Hufa to meet the domestic needs in the governorates of Jerash and Ajloun.

Changing water use intensity over time (MWI, 2020). This intensity is used to assess water needs versus consumption (Llop, 2019) This is by measuring the amount of water relative to the Gross Domestic Product (GDP) which is the optimal use of the water supply.

Table 3: Inter- Basin water supplies to Yarmouk River Basin for the year 2017.

Main Governorate	Yarmouk Basin Inter-Basin Wells Supply	Yarmouk Basin Pumping Stations/ Reservoirs	Yarmouk Basin Inter-Basin Water Supplies m^3/h
Mafraq	Za'atari	Um Ellollo and Smayya	650
Irbid	Kufr Assad	Kufr Assad	214
	Wadi Al-Arab	Zabdah	2100
	Za'atari	Hufa	700

- The Yarmouk River Basin lacked infrastructure as dams, with dams concentrated on the Syria side (Avisse et al., 2020). The construction of dams to collect and store harvested rainwater will address water scarcity and water demand in the basin governorates. But there is currently one dam in the Jordanian side and it is used for irrigation, and thus the construction of dams will secure additional water sources.
- Decreasing the level of non-revenue water (NRW). It is provided to water systems but is not billed to the residents. The NRW was 48% in 2017, which equates to about sixty-five (65) lpcd. The Jordanian government's goal is to decrease NRW to 25% (YWC, 2019).
- -Planners and decision-makers should audit the groundwater abstraction, reveal illegal practices of unlicensed wells, and incorrect measurement of irrigated water, and for an affected or partially filled aquifer, its abstraction must be completely stopped. Illegal drilling of private wells should be managed using law enforcement by closing illegal wells and penalties should be imposed to curb in domestic groundwater over-pumping.

4. Conclusions

The population growth of the Yarmouk River Basin places an unprecedented pressure on water resources, especially for domestic use. Understanding the state of the supply-demand of domestic water resources over a twenty-year period and the long-term estimate of domestic water use for the coming years up to 2030 provides information to relevant stakeholders and actors about managing and conserving basin water resourcse. Groundwater wells, cities, villages, and population were determined for the years 1997 and 2017, as well as per capita share of water. Changes on supply-demand were estimated using an autoregressive integrated moving average (ARIMA) model were estimated, and measures and action related to domestic water management were also adopted.

The results showed a significant growth in population. By comparing the population with the demand for domestic water for 1997 and 2017, there were also significant changes, in which the increase in demand is clearly observed and is remarkably large, despite the decrease in the water per capita water supply. The supply-demand changes, according to ARIMA-based estimation model are expected to continue through 2030, with ARIMA estimates a 2% increase in domestic use annually and an accumulative amount of 15% through 2030. Determining population growth in the basin showed an increase in domestic groundwater over pumping, as well as the impact of climate change on groundwater recharge. Under these circumstances, Jordanian government, and related actors are challenged to secure additional sources of domestic water, take water management actions such as, build dams, inter-basin water supply, change water intensity, reduce non-revenue water, and groundwater abstraction audit and law enforcement to drill illegal private wells.

The outcomes of this study will serve as a baseline for the future. It may assist stakeholders in dealing with the domestic demand for water versus the increasing population and needs. There is an urgent need for water resources conservation projects, and studies are highly recommended.

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References

Abualhaija, M.M., Shammout, M.W., Mohammad, A.H., Abu Hilal, A.H., 2019. Heavy metals in water and sediments of King Talal Dam the largest man-made water body in Jordan. Water and Energy International. 62r (5), 49-62.

Adnan, S., Iqbal, J., Maltamo, M., Bacha, M.S., Shahab, A., Valbuena, R., 2019. A Simple Approach of Groundwater Quality Analysis, Classification, and Mapping in Peshawar, Pakistan. Environments. 6, 123. https://doi.org/10.3390/environments6120123

Avisse, N., Tilmant, A., Rosenberg, D., Talozi, S., 2020. Quantitative Assessment of Contested Water Uses and Management in the Conflict-Torn Yarmouk River Basin. Journal of Water Resources Planning and Management. 146, 7. https://ascelibrary.org/doi/full/10.1061/%28ASCE%29WR.1943-5452.0001240

Bo, Z., Yezheng, L., Feifei, Z., 2021. Annual Water Consumption Forecast of Hefei Based on ARIMA Model. Academic Journal of Computing & Information Science. 4 (3), 88-93. https://doi.org/10.25236/AJCIS.2021.040314

Chen, Y., Zhang, D., Sun, Y., Liu, X.,Wang, N., Savenije, H.H.G., 2005. Water demand management: A case study of the Heihe River Basin in China. Physics and Chemistry of the Earth. Parts A/B/C, 30, Issues 6–7, 408-419. https://doi.org/10.1016/j.pce.2005.06.019

Chung, P.-L., Chung, C.-Y., Liao, S.-W., Miaw, C.-L., 2009. Assessment of the school drinking water supply and the water quality in Pingtung County, Taiwan. Environ. Monit. Assess. 159, 207.

Courcier, R., Venot, J.-P., Molle, F., 2005. Historical transformations of the lower Jordan River Basin (in Jordan): Changes in water use and projections (1950-2025). Colombo, SriLanka: International Water Management Institute. 91p. (Comprehensive Assessment of Water Management in Agriculture Research Report 9). https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers15-08/010039160.pdf

Demir, O., Yaçinkaya, M., Atasoy, M., Bayrak, T., Bryik, C., 2007. Evaluating sustainable land use for the Değirmendere valley: A case study from northeastern Turkey. International Journal of Sustainable Development & World Ecology. 14(6), 626-633. https://doi.org/10.1080/13504500709469760

Dimri, T., Ahmad, S., & Sharif, M., 2020. Time series analysis of climate variables using seasonal ARIMA approach. Journal of Earth System Science. 129(1), 1-16. https://doi.org/10.1007/s12040-020-01408-x

DoS, 1997. Department of Statistics-Open files, Hashemite Kingdom of Jordan, Amman, Jordan.

DoS, 2017. Department of Statistics-Open files, Hashemite Kingdom of Jordan, Amman, Jordan.

Du, H., Zhao, Z., Xue, H., 2020. ARIMA-M: A New Model for Daily Water Consumption Prediction Based on the Autoregressive Integrated Moving Average Model and the Markov Chain Error Correction. Water.12, 760. https://doi.org/10.3390/w12030760

Edokpayi, J.N., Rogawski, E.T., Kahler, D.M., Hill, C.L., Reynolds, C., Nyathi, E., Smith, J.A., Odiyo, J.O., Samie, A., Bessong, P., Dillingham, R., 2018. Challenges to Sustainable Safe Drinking Water: A Case Study of Water Quality and Use across Seasons in Rural Communities in Limpopo Province, South Africa. Water.10, 159. https://doi.org/10.3390/w10020159

Enbeyle, W., Hamad, A.A., Al-Obeidi, A.S., Abebaw, S., Belay, A., Markos, A., and Derebew, B., 2022. Trend analysis and prediction on water consumption in southwestern Ethiopia. Journal of Nanomaterials. 2022, Article ID 3294954. https://doi.org/10.1155/2022/3294954

Fang, C.L., Bao, C., Huang, J.C., 2007. Management implications to water resources constraint force on socioeconomic system in rapid urbanization: A case study of the Hexi Corridor, NW China. Water Resources Management. 21, 1613–1633. https://doi.org/10.1007/s11269-006-9117-0

FAO, 2009. AQUASTAT Transboundary River Basins Overview- Jordan. Food and Agriculture Organization of the United Nations (FAO) Reports. Rome, Italy. http://www.fao.org/3/CA2131EN/ca2131en.pdf

González, A.B., 2018. The Water-Energy-Agriculture nexus in Jordan–A case study on As-Samra wastewater treatment plant in the Lower Jordan River Basin. [Master of Science Thesis]: TRITA-ITM-EX: 588, Stockholm. Available online: http://www.divaportal.org/smash/get/diva2:1236635/FULLTEXT01.pdf (accessed on 15 October 2022).

Khosravi, K., Banadkooki, F.M., Ehteram, M., Ahmed, A.N., El-Shafie, A., 2022. Combining autoregressive integrated moving average with Long Short-Term Memory neural network and optimisation algorithms for predicting ground water level. Journal of Cleaner Production. 38, 131224. https://doi.org/10.1016/j.jclepro.2022.131224

Llop, M., 2019. Decomposing the Changes in Water Intensity in a Mediterranean Region. Water Resour Manage. 33, 3057–3069. https://doi.org/10.1007/s11269-019-02285-w

Mongelli, G., Argyraki, A., Lorenzo, M.L.G., Shammout, M.W., Paternoster, M., Simeone, V., 2019. Groundwater Quality in the Mediterranean Region. Geofluids. 2019, Article ID 7269304. https://doi.org/10.1155/2019/7269304

MWI, 1997. Ministry of Water and Irrigation-Open files, Hashemite Kingdom of Jordan, Amman, Jordan.

MWI, 2016. Ministry of Water and Irrigation, National Water Strategy of Jordan 2016 – 2025. Hashemite Kingdom of Jordan, Amman, Jordan. http://extwprlegs1.fao.org/docs/pdf/jor156264E.pdf

MWI, 2017. Ministry of Water and Irrigation-Open files, Hashemite Kingdom of Jordan, Amman, Jordan.

MWI, 2018. Ministry of Water and Irrigation 2016-2017. Water Year Book, Hydrological Year 2016-2017, Spring, Surface Water and Ground Water. Hashemite Kingdom of Jordan, Amman, Jordan. http://waterjo.mwi.gov.jo/Ar/DocLib/Water%20Yearbook%202016-2017.pdf

MWI, 2020. Ministry of Water and Irrigation, Water Sector Green Growth National Action Plan 2021-2025. Hashemite Kingdom of Jordan, Amman, Jordan

Niknam, A., Zare, H.K., Hosseininasab, H., Mostafaeipour, A., Herrera, M., 2022. A Critical Review of Short-Term Water Demand Forecasting Tools—What Method Should I Use?. Sustainability. 14, 5412. https://doi.org/10.3390/su1409541

Obeidat, M., Awawdeh, M., Lababneh, A., 2019. Assessment of land use/land cover change and its environmental impacts using remote sensing and GIS techniques, Yarmouk River Basin, north Jordan. Arab J Geosci. 12, 685. https://doi.org/10.1007/s12517-019-4905-z

Patle, G.T., Singh, D.K., Sarangi, A., Rai, A., Khanna, M., Sahoo, R.N., 2015. Time series analysis of groundwater levels and projection of of future trend. Journal of the Geological Society of India. 85, 232–242. https://doi.org/10.1007/s12594-015-0209-4

Rahaman, M.M., Kalra, A., 2018. ARIMA modeling of GRACE derived groundwater level in Colorado River Basin. In American Geophysical Union, Fall Meeting 2018, abstracts #H23J-2042. Bibcode: 2018AGUFM.H23J2042R

Razali1, S.N.A.M., Rusiman, M.S., Zawawi, N., Arbin, N., 2018. Forecasting of Water Consumptions Expenditure Using Holt Winter's and ARIMA. Journal of Physics: Conf. Ser. 995 012041. https://iopscience.iop.org/article/10.1088/1742-6596/995/1/012041

Savenije, H.H.G., Van der Zaag, P., 2008. Integrated water resources management: Concepts and issues. Physics and Chemistry of the Earth. 33(5), 290–297. https://doi.org/10.1016/j.pce.2008.02.003

Shammout, M.W., Shatanawi, K., Abualhaija, M.M., 2023. Influence of Population Growth on Supply, Demand, and Quality Issues of Water Resources in the Yarmouk River Basin in Jordan. Journal of Experimental Biology and Agricultural Sciences. 11(1), 171–178. https://doi.org/10.18006/2023.11(1).171.178

Shammout, M.W., Shatanawi, M., 2021. Water Supply–Demand Management and Cr(VI) Contamination: A Participatory Approach. Bull Environ Contam Toxicol. 106, 441–445. https://doi.org/10.1007/s00128-020-02958-y

Shammout, M.W., Shatanawi, M., Naber, S., 2013. Participatory Optimization Scenario for Water Resources Management: A Case from Jordan. Water Resour. Manag. 27, 1949-1962. https://doi.org/10.1007/s11269-013-0264-9

Shatanawi, M., Shammout, M.W., 2011. Supply-demand modeling of water resources in Zarqa river basin in Jordan. Int. J. Appl. Environ. Sci. 6, 261-278.

Takafuji, E.H.D, Rocha, M.M., Manzione, R. L., 2018. Groundwater Level Prediction/Forecasting and Assessment of Uncertainty Using SGS and ARIMA Models: A Case Study in the Bauru Aquifer System (Brazil). Natural Resources Research. 28(2), 487- 503. https://doi.org/10.1007/s11053-018-9403-6

The World Bank. 2017. Water Resources Management. https://www.worldbank.org/en/topic/waterresourcesmanagement#1

UNHCR. 2015. United Nations High Commissioner for Refugees, Factsheet-Mafraq Governorate. www.unhcr.org

Weatherhead, E.K., Howden, N.J.K., 2009. The relationship between land use and surface water resources in the UK. Land Use Policy. 26, Supplement 1, S243-S250. https://doi.org/10.1016/j.landusepol.2009.08.007

Yalçıntaş, M., Bulu, M., Küçükvar, M., Samadi, H., 2015. A Framework for Sustainable Urban Water Management through Demand and Supply Forecasting: The Case of Istanbul. Sustainability. 7(8), 11050-11067. https://doi.org/10.3390/su70811050

YWC, 2019.Yarmouk Water Company -Open files, Hashemite Kingdom of Jordan, Irbid, Jordan.