Agricultural water demand, water quality and crop suitability in Souk-Alkhamis Al-Khums, Libya

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Abstract. Water scarcity, unequal population distribution and agricultural activities increased in the coastal plains, and the probability of seawater intrusion with ground water. According to this, the quantitative and qualitative deterioration of underground water quality has become a potential for the occurrence, in addition to the decline in agricultural production in the study area. This paper aims to discover the use of ground water for irrigation in agriculture and their suitability and compatibility for agricultural. On the other hand, the quality is determined by the cultivated crops. 16 random samples of regular groundwater are collected and analyzed chemically. Questionnaires are also distributed randomly on regular basis to farmers.

1. Introduction

World over, agricultural water is used to grow fresh produce such as crops, fruits and vegetables as well as raising livestock for our diet. The United States Geological Survey (USGS) states that water used for agricultural irrigation accounts for nearly 65 percent of the world’s freshwater withdrawals excluding thermoelectric power. Even though water demand in an irrigated area depends on the region’s climate, agricultural water demand is a serious issue particularly at the coastal area of Souk-Alkhamis Al-Khums, Libya. Generally, one of the critical problems that hinder sustainable development in Libya is the lack of renewable water resources [1]. This study on agricultural water demand and crop suitability in Souk-Alkhamis Al-Khums a historical city and one of the oldest agricultural sites intend to examine the region’s water resources and types of crops suitable for cultivation. This is therefore due to over-exploitation of fossil groundwater resources to meet irrigation demands that has already affected the northern aquifers of the country.

Incidentally, in Libya, problems caused by water scarcity and excessive groundwater mining are uneven population distribution and intensive agricultural activities in the coastal plains, seawater intrusion, water quality deterioration, poor crop yields and fragmentation of agricultural land holdings were among others found to be the principal issues in the water sector[1]. In the recent years, the water resources are increasingly becoming a scarce form of natural resources and a judicious and sustainable way of utilization is a priority today. On the basis of that, the present investigation would be carried out to ascertain the quality and quantity of the available agricultural water demand and the crops that should be encouraged for cultivation in the area. This would help agriculturists to improve productivity by cultivating suitable crops that can boost the country’s entire economy.

The groundwater quality study provides an insight for various usage of the water beyond agriculture. By evaluating quality, a conclusion can be drawn on how the water resources can be best utilized for optimum capacity [2]. In view of the fact that water is an important and indispensable commodity for all human beings as well as the plants and animals, history has shown that human civilizations originated around water resources such as rivers, lakes and springs. However, in Libya, due to seasons, the water demand increases from dry to semi-dry environments because it is scarce, limited and...
irregular due to its geographical distribution. Intrinsically, most people devise means of preserving and securing water resources to ensure water availability for contemporary and future demands. All over the world, most countries and the international organizations are concerned with water and have developed laws and programs to enhance and organize water uses in various fields including agricultural activities. [3] States that for five thousand years bed irrigation system was used in Egypt and a dam was built on the Nile River, which was one of the oldest dams built by humans on earth. As time passes by, new methods of water resource investment strategies were developed. Modern machineries are now use in pulling out the ground water to meet the required water demand and supply to the plants due to insufficient rainfall. This continues to increase drawing of ground water prevalence to irrigate agriculture in the large areas of the world including in dry and semi-dry areas including Souk-Al khamis Alkhums. Consequently, the spread of irrigation agriculture and overuse of agricultural water affect the region’s water quality thereby reflecting low crop productivity. In fact, the situation is further compounded by environmental issues such as drought and desertification which comes from the hinterland areas of the country. According to the General Authority for Water (1992), they confirm that ground water contribution in Libya forms 98% of the country’s total water resources. It was estimated that water resources required would amount up-to 1679 million m$^3$ in 2000. This value was also expected to reach 4735 million m$^3$ in 2025. Hence, this research seeks to find out the relationship between agricultural water efficiency and crops cultivation suitability in the study area.

1.1 The location
The area geographically lies between north latitudes 32°25’N and 32°40’N, and between east longitudes 14° 10’E and 14° 25’E with an estimated land mass of about 456.96 km$^2$. In fact, this region is one of the oldest agricultural areas in Libya with the best arable soils for agricultural activities. However, the region has experience remarkable changes in the various living areas very quickly.

![Figure 1. The geographical location of study area.](image)

1.2 Problem statement
Water is essential to all life forms. Uneven population distribution and intensive agricultural activities in the coastal plains of Libya including Souk-Al Khamis is characterized by high population densities, intensive commercial, industrial and agricultural activities that cause the gap between water demands and supply wider [1]. The author added that the imbalance between supply and demand is expected to grow wider in the future, especially for the northern basins. Therefore, the scarcity of agricultural water remains a major issue of concern to most countries particularly countries such as Libya that has a large dry or semi-dry climate. As a result of increased demand for food, the study area is experiencing rapid expansion in cultivated land areas. This requires an urgent need to improve efficiency in the use of water resources due to the area’s growing population. With an annual rainfall of 189.1 mm/annum [4], Souk-AlKhamis Al-khums is strategically located on the coastal strip area. However, the town experience seawater intrusion that affects groundwater quality leading to poor crop yields in the study area. In the last three decades, the study area’s population increased from 28, 647 in 1973 to about 80, 557 in 2005. This population increase requires a balanced increase in demand for food hence leading to an
increased in irrigated agricultural land as well as drilling of wells for water supply to crop production. Hence, the uneven population distribution has brought intensive agricultural activities to a more densely populated area and caused agricultural water scarcity in the coastal plains of Souk-AlKhams Al-khums. Furthermore, the possibility of the emergence of certain contaminants in groundwater as a result of poor sanitation networks, as most of the population uses black wells to drain the water for domestic purposes. The fact is that the proportion of dissolved salts in the groundwater exceeded almost 4,300 mg/L [5].

In Libya, before the discovery of oil in 1959, the agricultural land was actually very small compared to what it is today. However, the state invested a significant part of the oil revenues in the development of agriculture, particularly increasing agricultural lands as well as increasing groundwater sources. In addition, there were increases in drilling of wells for agricultural operations and a change in irrigation methods for agricultural operations. What should be noted here is that irrigation methods in the period before 1959 were limited to the surface irrigation method and farmers continued to use this method until 1980. At present, there are various methods that include sprinkler irrigation and drip irrigation methods.

Finally, it is worthy to note that most population lives in the northern parts of the country, which resulted in the shrinkage of agricultural areas. On the other hand, there is an increase in the demand for ground water to supplement the inadequate rainfall for agricultural activities. Therefore, the deterioration of groundwater in terms of quantity and quality would lead to deterioration in agricultural production as well as degrading agricultural soil. Thus, the increase in the irrigation “ground” water salinity levels over the years in many places in Libya has led to soil salinization and, as a result, irrigation water demand increases and crop yields decreased [1]. This study intends to investigate further and determine the extent of available groundwater suitable for agricultural use so as devise means of its efficient use.

1.3 Research questions
To achieve the above objectives, the following constitutes the research questions to be pursued in this research:

- How does farmers’ demographic and socio-economic characteristic affect water demand and crop production?
- What are the types of agricultural crops grown and is it fit or suitable with the current water condition?
- What are the major sources of agricultural water used and is it compatible for agricultural purposes with crops grown in terms of quantity and quality and how people perceive on the agricultural water quality?
- How to enhance the agricultural water efficiency to help the farmers in improving their agricultural technology and crop productions?

1.4 Aim and objectives of the study
The major aim of this study is to examine the agricultural water demand and its suitability for crop production in Souk-Alkhams Al-Khums town of Libya. However, to overcome the above problem, the study intended to pursue the following specific operational objectives:

- To identify farmers’ demographic and socio-economic status in Souk-Alkhams Al-Khums, Libya;
- To evaluate the various agricultural crops in the area and determine their water and soil requirements;
- To assess the quality and quantity of water resources in Souk-Alkhams Al-Khums Town, Libya so as to determine the most appropriate crops to be grown in the region;
- To suggest best practices for agricultural water use efficiency and recommend suitable crops to be cultivated in the region.
1.5 Research hypotheses
The study intends to attain the following hypotheses null in achieving the above objectives:

- Farmers’ demographic and socio-economic status is not the homogeneous in Souk-Alkhamis Al-Khums, Libya.
- The agricultural crops in the study area may not necessarily have the same water and soil requirements.
- The actual and perception on water quality and water resources quantity do not differ by geographical location in the study area.
- Agricultural water use efficiently may not depend on the types of crops in a given area.

1.6 Conceptual study:
- Groundwater
  Groundwater is the water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water.
- Agriculture
  Agriculture, also called farming or husbandry, is the cultivation of animals, plants, fungi, and other life forms of food, fiber, biofuel, medicinally and other products used to sustain and enhance human life.
- Soil
  Soil is the mixture of minerals, organic matter, gases, liquids and a myriad of organisms that can support plant life. It is a natural body that exists as part of the biosphere and it performs four important functions: it is a medium for plant growth; it is a means of water storage, supply and purification; it is a modifier of the atmosphere; and it is a habitat for organisms that take part in the decomposition and the creation of a habitat for other organisms.

2. Literature review
The literature review provides a general overview of past studies and the current states of knowledge on the agricultural water use, conservation and efficiency on the first part. It is followed by water demand, crop suitability and management as well as models related to agricultural water demand. The agricultural water demand equations and finally, it examines literature on agricultural production and water shortage in Libya among others.

2.1 Agriculture water use conservation and efficiency
The agricultural water is used worldwide to grow fresh produce and sustain livestock for human use. As [1] revealed, this water also makes it possible to grow fruits and vegetables and even raise livestock for our diet. In support of this, the United States Geological Survey (USGS) states that water use for irrigation accounts for nearly 65 percent of the world’s freshwater withdrawals excluding thermoelectric power. The author elaborates further that there is 330 million acres of land used for agricultural purposes in the United States that produces an abundance of food and other products. Hence, water is used effectively and safely, production and crop yield are positively affected for the benefit of mankind. However, a decrease in applied water can cause production and yield to decrease. As such the author added that management strategies are the most important way to improve agricultural water use and maintain optimal production and yield of crops. This can only be achieved if the management strategies improving water use efficiency without decreasing yield are strictly implemented. For instance, improve irrigation scheduling and crop specific irrigation management are some of the strategies that can be followed to achieve maximum harvest in Libya.

Furthermore, the author shows that water efficiency can improve the reliability of existing supplies and reduce vulnerability to drought and other water-supply constraints. In addition, improvements in water efficiency can result in reductions of both consumptive and non-consumptive water use in a given area. [6] Explains that reductions in consumptive use provide additional water supply that can become available for other uses, even though, there are also compelling reasons to seek reductions in non-
consumptive use. Finally, the author assumed that water used efficiently can improve the timing for agricultural productions and maximize the amount of water left in the natural environment, providing benefits to downstream water quality, the environment, recreation and even upstream use [6].

2.2 Water demand, crop suitability and management

Past studies revealed that water is indispensable for farming and farming in turn uses the vast majority of all water withdrawn for human use. Food production needs to be increased in the coming decades to support a growing world population [7]. He further elaborates that the scarcity of freshwater resources proportionally increases the intensity of potential for political conflicts over water within and between countries in the world. [8], views water as public goods which means that it cannot be sold in the market while [8], describes it as the resource that sustains all life on earth and is a key element of sustainable development. The author further stressed that in Pakistan, studies revealed that the available water resources are becoming fully committed and the irrigation expansion option will be increasingly difficult to pursue because many river basins have already been developed to their maximum capacity. Moreover, groundwater resources play a significant role in the hydrologic cycle and a region’s water balance since they act as a buffer, providing significant amounts of water during years of low precipitation or storing a significant part of runoff on the occasion of high precipitation. This water stored in the ground forms major source for irrigation activities in many countries including Libya. However, in view of meagre recharge in areas of low rainfall, aquifers are destined for ultimate depletion unless prudent and very conservative development is carried out. He further argued that the exploitation of aquifers in regions of low natural recharge and scarce surface water is to a large extent controlled by the low rainfall and the relatively small amounts of runoff, which is often associated with high erosion when the vegetative cover is poor and flash floods are the rule. Hence, the amount of erosion depends considerably on the type and state of the land surface [10].

![Figure 2. The arid and semi-arid regions of the world.](image)

2.3 Factors affecting water demand

A report from the Food and Agricultural organisation reveals that factors affecting water demand are all anthropogenic by nature. These factors include; population, where its growth rate and changes in consumption patterns directly affect demand for goods and services, and the water associated with their production, processing and delivery. Secondly, it was observed that human pressure on water resources increases as their income grow which applies not just for household water demand for domestic but also to municipal demand and most importantly the growth in demand for industrial and agricultural products [7]. Moreover, the author added that increasing incomes lead to a rise in the per capita demand for food in which people diversify their diets (meat and dairy products) which also requires more water than a diet based on staple crop products (cereals or root crops). And lastly, urbanisation is also another factor that affects water demand. The authors explains that urbanization affects food consumption for instance in cities where supermarkets, restaurants and convenience foods that demand more water usage become more important.
2.4 Models related to agricultural water demand
The Agriculture Water Demand Model (AWDM) was developed in the Okanagan Watershed. The model was developed in response to rapid population growth, drought conditions from climate change, and the overall increased demand for water which indeed, reflects the current situation of Libya. Therefore, the author asserts that AWDM helps to understand current agricultural water use and helps to fulfill the commitment under the “Living Water Smart - BC Water Plan” to reserve water for agricultural lands. The Model calculates water use on a property-by-property basis, and sums each property to obtain a total water demand for the entire basin or each sub-basin which provide current and future agricultural water demand. Hence according to him, the type of crop, type of irrigation system, soil texture and climate data are used to calculate the water demand. However, the model is based on a Geographic Information System (GIS) database that contains information on cropping, irrigation system type, soil texture and climate [11].

2.4 Agricultural production and water shortage
According to [12], in Libya agricultural production is dominated by crop production where most of the activities are limited to a long narrow strip along the Mediterranean coast, low mountains and scattered oases in the desert. They elaborate that agricultural production account for 5 percent of the Gross Domestic Product (GDP) and occupy about 13 percent of the total labour force of the country. Libya’s vast dry areas of land constraint the entire region’s agricultural activities. However, the total arable land is approximately 2,170,000 ha which is 355,000 ha are permanent crops while the permanent pasture and rangeland occupy about 13,300,000 ha and the forest and woodland about 320,000 ha. In view of this therefore, majority of lands are been cultivated despite the need for crop production as stressed by the Food and Agricultural Organisation.

2.5 Research design
The findings of this research rely upon the combination of quantitative and qualitative frameworks (See Fig. 3 Framework for the research approach) to understand the socio cultural behaviors and the natural factors influencing levels of agricultural water demand, quality and crop suitability within the study area.

![Figure 3. Conceptual framework.](image-url)

3. Research methodology
This research will be consisting of four basic stages:
3.1 Data collection stage
In this stage, we will rely on books, journals, thesis and scientific researches to collect all the information and data related to the topic of study.

3.2 Sample of study
Due to the favorable climate, soil for agricultural activity and the availability of groundwater, the study area is of the same nature of the agricultural areas in Libya. It could be argued that it will be collecting groundwater samples from agricultural wells, including 5% of the agricultural wells, estimated at about between (800-1000) wells.

3.3 Field study
There is much information and data needed to go to field work to collect them, via following steps:
- Conducting personal interviews with peasants and specialists in the field of agriculture and groundwater.
- Using (GPS) the Global Positioning System to determine sites the agricultural wells in the study area.
- Design a questionnaire which contains series questions that related to the subject of study.

3.4 Data analysis stage
This stage will involve the following steps:
- Analyse the samples of water in special laboratories.
- All the samples will be submitted for analysis in special laboratories, to detect pollutants which pollute the wells
- Use (SPSS) to analyze the data.
- Use (GIS) Geographic Information System to produce maps which will contribute to determine groundwater current status.

3.5 Data collection and analysis

| Objective                                      | Data collection               | Data analysis       |
|-----------------------------------------------|-------------------------------|---------------------|
| Inventory and mapping of groundwater demand   | Field measurement, GPS        | GIS approach        |
| identify the best agricultural crops for cultivation |                               |                     |
| Factors leading to the deterioration of groundwater. | Questionnaire Water samples | SPSS Laboratory analysis |
| Recommendation                                | Literature review, questionnaire | SPSS                |

Table 1. data collection and analysis.

4. Expected results
The expected results evolve from the current study are based on the data in the region. Firstly, deterioration in the quality of groundwater might cause a decline in agricultural production in the area of study. In fact, this kind of decline is located at the lower levels of deterioration as it heads south and moves away from the sea. Secondly, the agricultural areas more likely show a notable increase in the
region in comparison with the previous conditions. In point of fact, such increase contributes widely to the demand for water. Thirdly, there is a possibility that some cultivated crops are not in line with the quality of water used for irrigation.

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