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Evaluation of Water Demand of Rise Cultivation in Thi-Qar Province, Iraq

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Abstract: *In areas such as Thi-Qar, Iraq, the need of blue and green water resources in sustaining agriculture makes effective water management critical to crop production. Understanding the water demand patterns of crops is essential to allocate resources efficiently and promote sustainability. In Thi-Qar, Iraq, using of blue and green water for growing crops is studied. By analyzing various meteorological factors and soil conditions, the CROPWAT8.0 model is using for calculate the using of total water for each crop. Evapotranspiration is determined using the Penman-Monteith method. The outcomes show that the green water footprint varies from 47 m³/ton to 1,235 m³/ton over 10 years, while the blue water consumption for crops ranges from 761 m³/ton to 2,275 m³/ton over the same period. This comprehensive research not only sheds light on the specific water needs of rice cultivation in Thi-Qar, but also provides valuable insights into sustainable water management practices in the province.*

Keywords: *Water Footprint, Blue Water Resources, Water Scarcity, Green Water Resources, Water Consumption, Crop Production, Sustainability.*

1. Introduction

Water scarcity and efficient water management are critical issues in agriculture, where agricultural practices heavily rely on irrigation. Rice cultivation, in particular, is a water-intensive crop that plays a significant role in the local economy and food security. The sustainable management of water resources for rice cultivation is essential to ensure agricultural productivity while preserving water quality and quantity for future generations. Freshwater is a critical resource for human life and agriculture, but global regulations on freshwater resources are lacking and often ineffective **[1].** Unlike other commodities, there is no substitute for water **[2].** Increasing water scarcity due to growing demand and climate change is a major challenge for many countries. Achieving sustainable water management requires cooperation and action across multiple sectors **[3].**

Problems of water shortage will only grow in the future due to population growth, worsening water quality, uneven distribution of resources, and climate change. This has resulted to climate variability, water pollution, extensive water demand as well as over utilization as the main causes of water scarcity. The stated economic water scarcity is as a result of inefficient utilization of available water resources **[4].** Freshwater is a critical resource for human life and agriculture, but global regulations on freshwater resources are lacking and often ineffective **[5].**

It is also evident that the Python Agricultural sector uses the highest proportion of water with more than 70% of water requirement for this region **[6].** Water scarcity means that serious efforts must be made toward the sector of agriculture. The Arab region also suffers from water scarcity severely and Iraq is amongst one of those countries severely affected **[7].** Monitoring the sustainability of agricultural water use requires the application of a water foot printing approach that includes both direct and indirect water intake rates **[12].** Attributable water use refers to the amount of water that is utilized and/or contaminated expressed as volume per time. In this way, the water footprint performs a geographically differentiated measurement not only of water used and polluted but also where **[9].** This metric is used to define the territory in which the availability of water is crucial to delivering goods and services **[10].**

This paper aims to evaluate the water demand for rice cultivation in Thi-Qar Province, Iraq, through a comprehensive analysis of water usage, irrigation practices, and crop water requirements. By understanding the current water demand patterns and exploring potential water-saving practices. The aim of this paper is to provide valuable insights for policy makers, agricultural stakeholders and farmers to improve water efficiency in rice cultivation and promote sustainable water management practices in the region.

Through a detailed study of water requirements for rice production, this research will contribute to the development of strategies and recommendations for optimizing water use, increasing agricultural productivity, and addressing water scarcity challenges in Thi-Qar Province. This study aims to support evidence-based decision making and promote water sustainability in agricultural practices in the region by assessing the dynamics of water demand and factors influencing water use in rice production.

The water demand for rice cultivation in Thi-Qar Province, Iraq, poses a significant challenge due to water scarcity and the need for sustainable water management practices. The inefficient use of water resources in rice farming leads to environmental degradation, water wastage, and potential conflicts over water allocation. Understanding the water demand dynamics of rice cultivation in this region is crucial for promoting water efficiency, agricultural sustainability, and water security.

The contributions of this paper are:

❖ Assessment of Water Demand Patterns: The current water demand patterns for rice cultivation in Thi-Qar Province are assessed, providing insightful data on water usage, irrigation methods, and crop water requirements.

❖ Identification of Water-Saving Practices: Potential water-saving practices and techniques that can be implemented to reduce water consumption in rice cultivation without compromising crop yield are identified and evaluated.

❖ Policy Recommendations for Water Management: By analyzing the water demand for rice cultivation, this paper contributes towards the development of policy recommendations and strategies for efficient water management in agriculture, aiming to enhance water sustainability in Thi-Qar Province.

❖ Promotion of Sustainable Agriculture: The findings of this study contribute to promoting sustainable agricultural practices in the region by highlighting the importance of water conservation, improving water use efficiency, and fostering long-term sustainability in rice farming.

❖ Decision-making support: The research results supports valued understandings for policy makers, agricultural stakeholders and farmers to make informed decisions on water allocation, irrigation practices and agricultural water management in Thi-Qar province, Iraq.

The rest of this paper is arranged as follows: Section 2 introduces the research methodology. Section 3 discusses the results. Section 4 introduces limitations and recommendations for future research. Finally, Section 5 concludes the paper.

2. METHODOLOGY OF THE RESEARCH

2.1. Area of the Study

Thi-Qar province is situated in the south of Iraq and northen of Basra governorate, sharing its borders with Missan, Muthanna, Qadissiya and Wassit provinces. The total area of Thi-Qar is about 13,552 km² with population of 1,450,200, it is located approximately 370 kilometers southeast of Baghdad at 31° 14' N and 46° 19' E. The provincial capital, Nasiriyah, is known for its long warm summers, short winters and low annual rainfall.

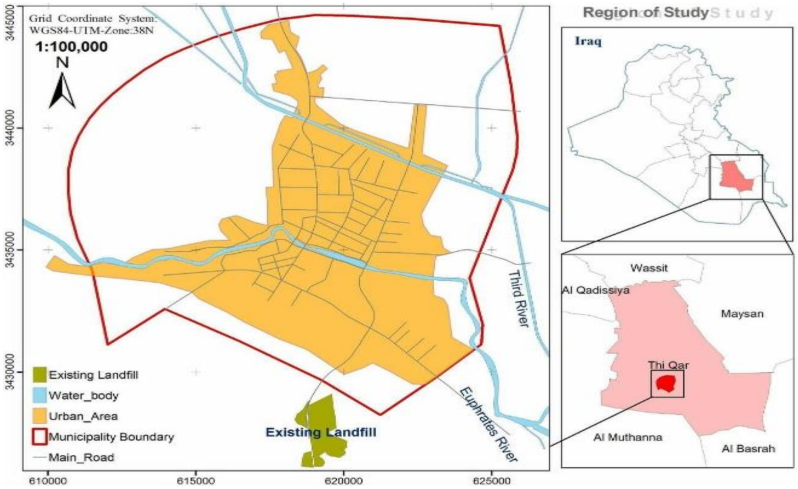

Figure1. *The spatial location of the area*

2.2. Conceptual Framework

The paper applies the nomenclature and the computation model described in the Water Footprint Assessment Manual of the globally established Water Footprint Network. Water consumption by the consumers or producers the direct as well as the indirect water consumption is estimated in the water footprint **[11].** This is the water consumption in the processes of production of the supply chain of a product. The individual consumption of water in all steps of the manufacturing process is totaled to find out the water volume per good or service, which is referred to as a water footprint. Such a water use is measured in water quantity consumed, specifically, in terms of the volume of water. In the case of crop production, the recent study looks at the blue and green footprints. The blue water footprint refers to the amount of water that is withdrawn from the global blue water resources – rivers, lakes, wetlands, aquifers and other open sources – to meet the needs of production processes. On the other hand, the green water footprint is the amount of water evaporated from green water sources in the world which is rain water stored in the soil.

2.3. Data Inventory

Information for this study is collected from various sources, including the meteorological, agricultural and irrigation departments, reports, books and other sources. Freshwater use during the growing season is tracked in a comprehensive database. As important tool helping with irrigation planning and management, one can use CROPWAT 8.0 designed by FAO's Land and Water Development Division. This application computes crop water requirements, reference evapotranspiration, and irrigation needs to manage the irrigation systems.

Table (1) data inventory of the study area.

Data	Input	Output
Climate	• Monthly mean of max and min temperature. • Sunshine. • Wind speed. • Relative humidity. • Monthly rainfall.	• Reference evapotranspiration.
Crop	• Crop coefficient. • Monthly rooting depth. • Area planted. • Initial and moisture depletion.	• Irrigation scheduling. • Actual crop evapotranspiration. • Soil moisture deficit.
Soil	• Total amount of available soil moisture. • Infiltration of maximum rainfall.	• Estimation of yield loss due to crop stress.
Irrigation	• Irrigation scheduling criteria.	• Crop water requirement and irrigation requirement.

Guidance is provided on how to improve irrigation practices, how to develop irrigation schedules tailored to specific water supply scenarios, and how to evaluate yield results in rainfed or inadequately irrigated environments (FAO 1992). CROPWAT 8.0 uses the water balance technique to formulate irrigation schedules. The input and output modules shown in Table (1) are included in the configuration of CROPWAT 8.0.

The meteorological characteristics that define the CROPWAT 8.0 structure are altitude, coordinates, precipitation, wind speed, minimum and maximum temperature, relative humidity, and sunshine duration. These datasets are collected from different meteorological stations in Thi-Qar and are managed by the Iraqi Meteorological Institute. For instance, the month means of the maximum and minimum air temperature in FROM degree Celsius (°C) are required.

The ratio of water in the air to its capacity at the same temperature, known as relative humidity, is a key input. Relative humidity fluctuates with changing temperatures throughout the day. Daily wind speed at 2 meters above ground is also a key factor, as wind speeds vary at different heights. Precipitation data are collected from climate stations in Thi-Qar province, along with sunshine duration to indicate cloud cover in the CROPWAT 8.0 model.

Details identified Include Crop attributes such as growth cycle, major components, root zones, and other features, in order to assess irrigation requirements of Thi-Qar province. Within the irrigation framework, a field survey will be conducted to compare crops grown under rainfed and irrigated conditions. An assessment of the existing crop configuration will be conducted through first-hand field assessments, interviews with farmers, and supplemental details obtained from agencies such as the Department of Revenue. Crop data collected in the field will include

- Crop types and varieties.
- Initial and final sowing dates.
- Initial and final harvesting dates.
- Projected yield capacity.

Accumulated data on irrigation practices, crop characteristics and soil parameters from agricultural research stations provide more accurate information for irrigation scheduling. This includes factors such as growth stages, crop components, evapotranspiration, rooting depth, depletion levels, and yield response. The plant coefficient is determined by the ratio of actual plant evapotranspiration to reference plant evapotranspiration.

To calculate ETo, the Penman-Monteith method (FAO 1998) is used. Effective precipitation is the portion of rainfall used by the crop after adjusting for losses due to runoff and infiltration. This effective precipitation is used to estimate the irrigation needs of the crop. Rainfall efficiency decreases as rainfall amounts increase. For rainfall amounts below 100 mm/month, the efficiency hovers around 80%.

The assessment of the feasibility of irrigation in Thi-Qar province includes the investigation of soil and water reservoirs and the determination of the irrigation water requirement (IWR). The net irrigation water requirement (NIWR) is the amount of water required for the development of the crop in m3/ha per year. Irrigation efficiency data is collected to calculate Gross Irrigation Water Requirement (GIWR), which includes water waste. By multiplying the GIWR by the corresponding irrigated area, the total water demand for the province of Thi-Qar can be determined.

2.4. Assessment of water footprint

The Water Footprint Assessment Manual of Hoekstra et al. is used, published in 2009. The total water footprint of an agricultural crop $WF_{(crop,total)}$ is calculated as the combination of the blue $WF_{(crop,blue)}$ and the green $WF_{(crop,green)}$ water footprints, measured in m³/ton [12]. Blue water footprint encompasses the use of surface and groundwater. It covers blue water evaporation, recharge back into the system and the return flow that is not fully captured. The green water footprint can be represented by the water needed to complete crop evaporation and the water consumed during crop development. Cloud water is rain water which infiltrates through the soil surface without running off or recharging the groundwater. The life cycle of sustainability consists in calculating the blue and green footprints from planting to harvest, which is completed within a specific temporal frame known as the growing season. The calculations are made on (1), (2);

$$\boldsymbol{WF_{(crop,blue)} = CWU_{(blue/Y)}\ (m^3/ton)} \qquad \textbf{(1)}$$

$$\boldsymbol{WF_{(crop,green)} = CWU_{(green/Y)}\ (m^3/ton)} \qquad \textbf{(2)}$$

where:

CWU = crop water use (m^3/ha)

Y = crop yield (ton/ha)

The blue and green water footprints are added together to calculate the total water footprint as (3) shows.

$$WF_{(crop,total)} = WF_{(crop,green)} + WF_{(crop,blue)}(m^3/ha) \quad (3)$$

3. RESULTS AND DISCUSSION

3.1. Climate

The climate in Iraq is known for its hot to very hot summers from July to September. The rainy season usually lasts from October to May. Most of Iraq has a subtropical climate with heavier rainfall in October and January. During the summer months, Iraq experiences a dry and warm season with temperatures peaking in July and August. The southern region of the country, near the Persian Gulf, has the highest humidity compared to other areas. In the study area, winter temperatures average around 15°C during the day and drop to 3°C at night, sometimes remaining above freezing. In summer, temperatures can rise to a maximum of 47°C in July and April.

Sunshine in Thi-Qar Province lasts for approximately 5.3 hours per day during the winter and can reach up to 87.3 mm of rainfall, with occasional floods. Wind speeds range from 2.1 m/s to 5.1 m/s in the summer. Humidity levels drop to around 15% in the dry and hot summer months, compared to 80% in the winter. Temperature plays an important role in weather and has a significant impact on the environment and living organisms. Changes in temperature can have a major impact on the agricultural sector by increasing evaporation rates and potentially harming plants that cannot tolerate high temperatures. Higher temperatures can also increase photosynthesis and respiration rates, resulting in increased water requirements for crops. This may have a negative impact on basic crop productivity [13].

Temperature record as the dependent variable is gathered through time series method over a period of ten years: 2005-2015. The record high of temperature is 46.41°C in summer period more specifically in July and April while that of the record low temperature is 6.7°C in winter specifically in January. The temperature starts to rise from April to the highest in June, then starts falling and hits the low levels in January. Iraq winter starts from the month of January every year and the minimum temperature recorded goes as low as 33.15°F. Summer is long and is between May and September with the highest temperature for the month reaching forty-six centigrade in June. Figure 2 shows the average maximum and minimum temperatures of Thi-Qar city during the ten years from the year 2005 to 2015. According to the analysis it was found that the region experiences the highest mean average temperature in the months of June July and August whereas the region experiences the lowest mean average temperature in January and December.

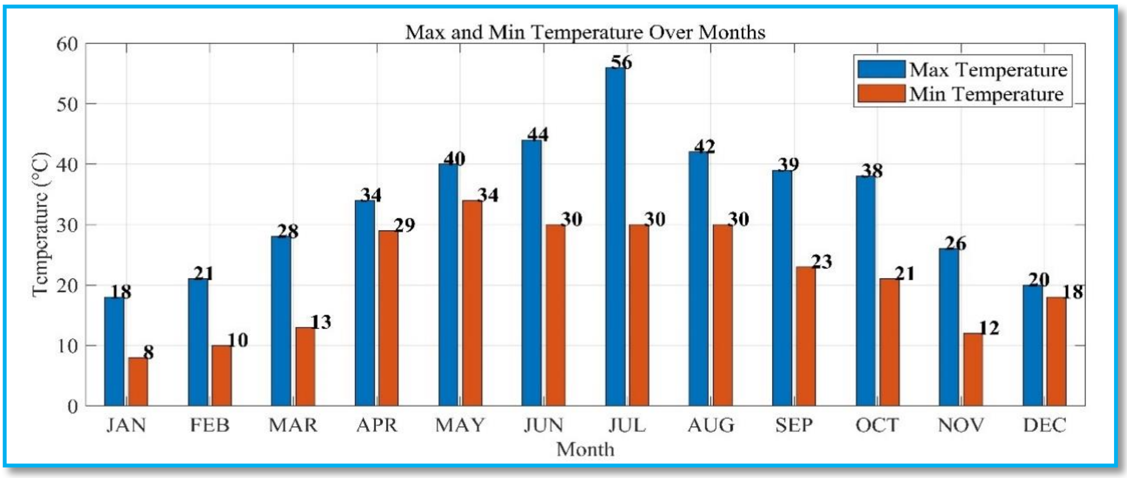

Figure2. *Average of annual maximum and minimum temperature in Thi-Qar Province.*

Humidity refers to the amount of water vapor in the atmosphere, or the ability of the vapor in the air to hold moisture [14]. Evaporation rates are higher in the summer and during the day than in the winter and at night. Thi-Qar Province experiences low levels of humidity even in the winter months, with the highest documented level in January at 62.2% and the lowest levels in June and July at about 18.9%, coinciding with peak temperatures. The minimum average level of 18.9% is observed in June, while the maximum average level is recorded in February during the winter season at 53.5%.

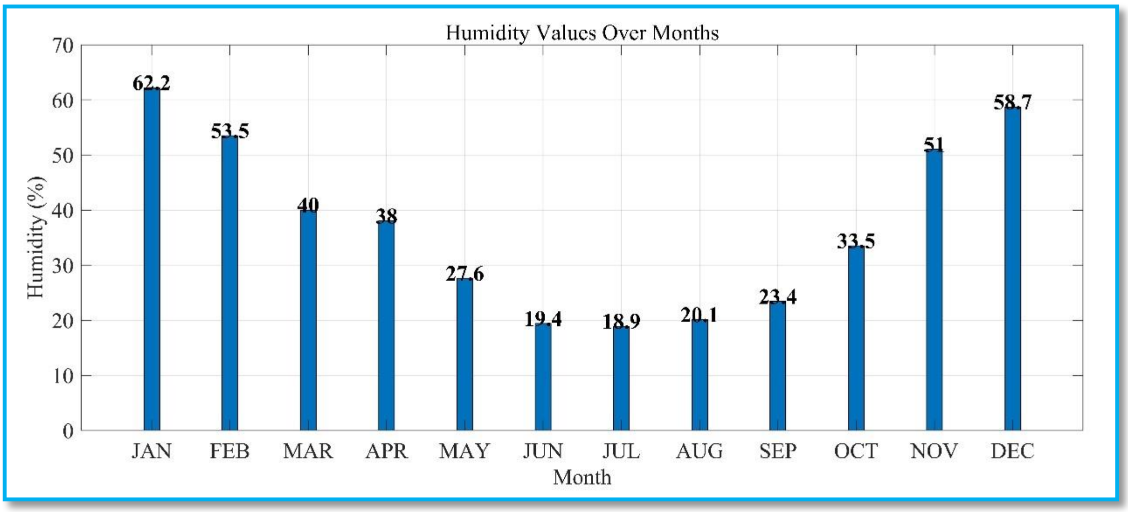

Figure3. *Average of annual humidity in Thi-Qar Province.*

As shown in Figure (4), the precipitation starts in October at just 9.84 mm, gradually increasing to 22.4 mm by November. Due to decreased air depression activity, rainfall in Thi-Qar province continued into May, reaching 7.24 mm. There is no recorded rainfall is observed from June to September.

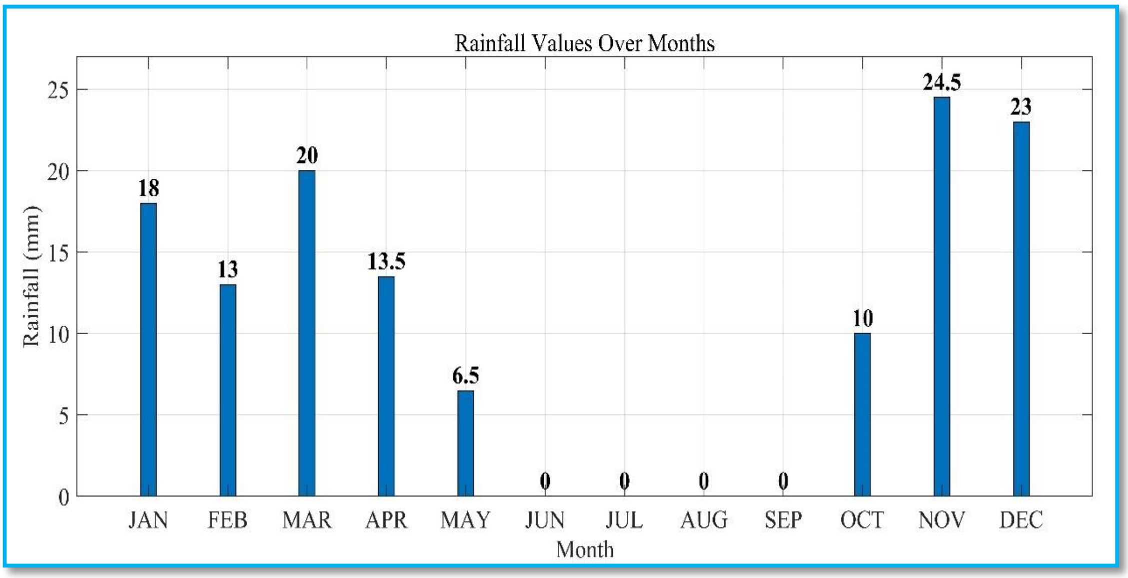

Figure4. *Average annual of rainfall in Thi-Qar Province.*

The sunlight which is a source of energy in earth is emitted from the sun itself. The average of the amount of sunlight experienced in Thi-Qar Province for a decade is illustrated in figure (5). Thi-Qar Province, in the subtropical zone, enjoys a strong sunlight and therefore a high level of Solar Direct Radiation. The minimum values of sunlight are observed in January-February and equal to 5.6 and 5.4 hrs per day in average, correspondingly. June (334) and July (11.2 hours/day) have the lightest. Partial and is directly opposite to the temperature trends where it rises from January and up to July but declines in August. It also falls From November to January, which receives the least amount of sunlight among all the months." Kent combined with the Northern parts of Maine has comparatively shorter amount of sunlight in winter season attributed to high degrees of cloudiness and humidity than in the summer months.

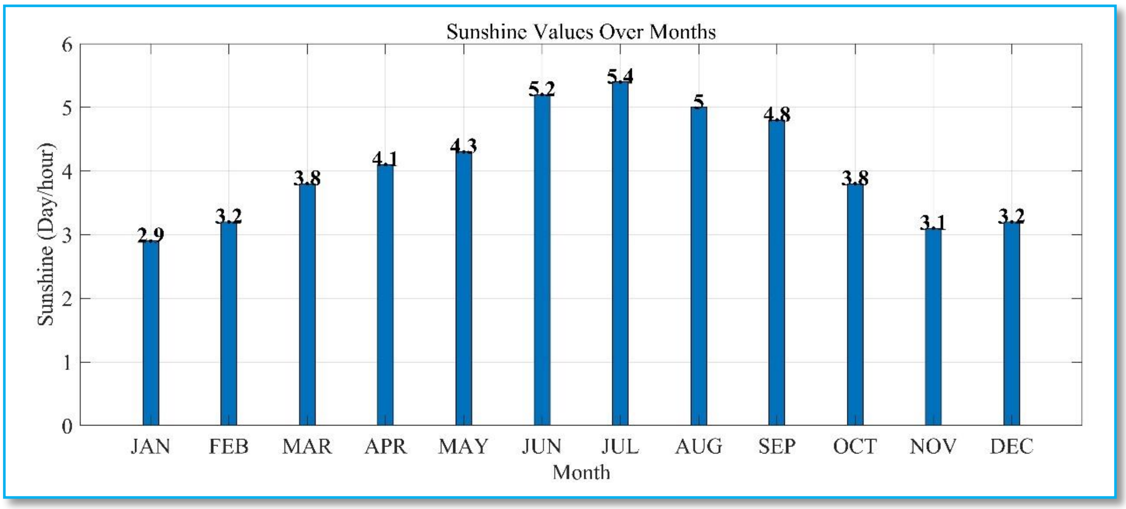

Figure5. *Average annual of sun shine in Thi-Qar Province.*

Measured average annual wind speeds over the past ten years are depicted on Figure (6). Weather wind on the other hand is referred to as the systematic flow of air on the earth's surface. That is because it occurs due to temperature changes which in turn affects pressure enabling air to be transported from high pressure zone to low pressure zone. The two predominant forces that influence the movement of wind is the pressure gradient force and coriolis force related to the rotation of the earth. Three locations of Thi-Qar province have wind speeds ranging from 2.0 m/s to 5.0 m/s in the youth's seasons. From records, the highest ever recorded winds speeds are 5.2 while the lowest recorded winds speeds are 1.9.

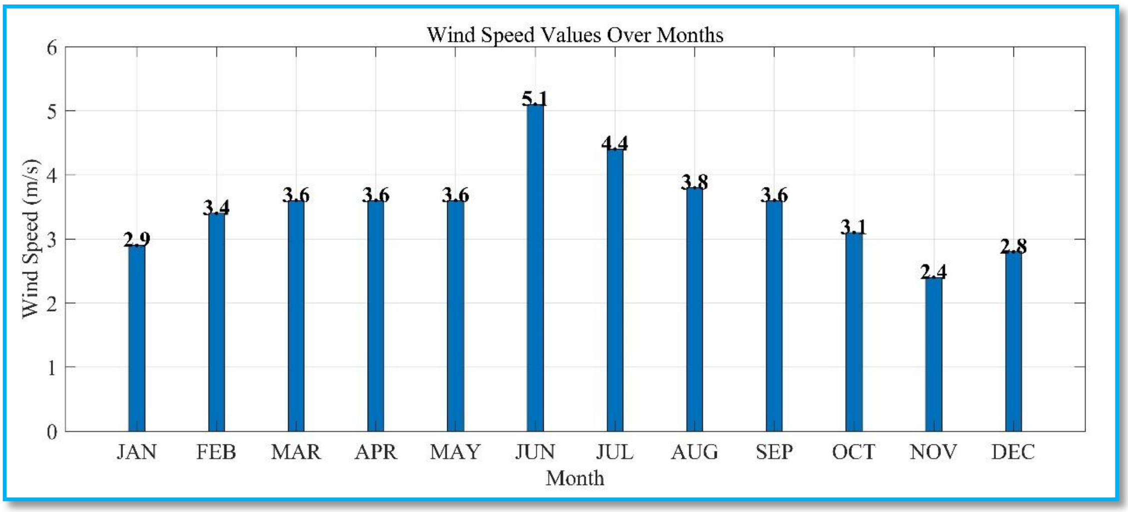

Figure6. *Average annual of wind speed in Thi-Qar Province.*

3.2. Water Footprint Assessment in Thi-Qar Province

To assess freshwater use for rice cultivation, the study in Thi-Qar Province uses the Water Footprint methodology. Both blue and green water footprints are calculated to determine water demand. The blue water footprint represents the amount of surface and groundwater used to grow crops, while the green water footprint represents the amount of rainwater used. Thi-Qar Province now faces a number of challenges related to the lack of freshwater resources after years of climate change and drought.

In 2016, the minimum production was documented at 166 tons per year, due to insufficient rainfall and the prolonged decline in the water level of the Euphrates River over consecutive years. In Iraq, blue water is of great importance, especially for agricultural practices during the dry season. Iraq falls under the subtropical classification with an extended dry season, resulting in a continuously high blue water footprint to meet the significant water demand for crop irrigation in the region. Blue water footprints associated with barley cultivation observed over a decade ranged from 761m³/ton to 2,275m³/ton.

As a measure of water supply, the Water Footprint reflects consequences of poor availability of water. In Thi-Qar province the type of agriculture is rice growing in the winter season and vegetables and summer grains in the summer season. It is well understood that rice prefers saline solonetz soils, which are high in soil salinity. Barley mostly goes to animals and unlike other types of grains, is usually harvested before it has reached this stage. Iraq has a bimodal growing season and barley is mostly grown between October and November and about 0.4 million – 0.8 million hectares of the grain are irrigated every year. In as much as it requires moderate water supply, Barley is not good for waterlogged soils. Taking into consideration the fact that the year 2022 experienced more rainfall than the previous years, the highest level of barley production will be observed for Thi-Qar province.

Studied carried out to ascertain the water requirements of various crops needed in the Kurdistan province, which is in the northern part of Iraq. Unlike previous research, the study establishes that green water footprint is higher as compared to blue water footprint. This is due to, Thi-Qar Province receives less rainfall compared to Kurdistan Province according to the rainfall rate per province. This is because the extent of rain water utilized in production process forms part of green water foot print. They take up water in the soil particularly from water that percolates through the soil [18]. Cropping systems in the central region depends on this water for irrigation since the region receives low amounts of rainfall and water is scarce. Due to occurrence of rain growing crops in Thi-Qar province is promoted particularly during the summer period. Irrigation by surface water is vital to this region since it is tropical [19].

This high-water footprint suggests that inefficient agricultural practices are occurring in this area. To manage and distribute water for irrigation during both summer and winter seasons, the construction of dams is considered a critical need. The implementation of advanced rainwater harvesting techniques and the establishment of an irrigation network system to ensure adequate water supply can improve water productivity in agriculture. In addition, farmers need to improve their skills and resources to use these technologies, secure additional funding to replace aging water infrastructure with modern systems, and improve the quality of agricultural products. This research has the potential to motivate food and beverage companies to optimize their supply chains and reduce water use in their operations.

3.3. The impact of climate change on water scarcity

The challenge of water scarcity due to climate change poses a significant obstacle to agriculture and water sustainability, especially in regions like Thi-Qar. By studying the changing patterns of rainfall and temperature in the region, we can better understand the impact on water resources. In Thi-Qar, changes in rainfall patterns and rising temperatures may worsen the water situation, as higher temperatures can lead to increased evaporation from soil and crops, resulting in greater water demand and ultimately contributing to water scarcity.

Variations in the rainy season due to fluctuating rainfall patterns may affect the availability of water for crop irrigation. Agriculture, particularly in areas dependent on natural water sources, could be significantly affected by reduced rainfall. This could affect the ability of farmers to meet their water needs for rice cultivation. Failure to address these challenges could lead to reduced water efficiency in agriculture and affect the sustainability of agricultural practices in Thi-Qar. Thus, it is crucial to understand these changes and develop tactics for improved and sustainable water management in order to protect water resources and ensure the continued practice of rice farming in the Thi Qar region. The impact of climate change on water scarcity in the Thi-Qar region is shown in Figure (7).

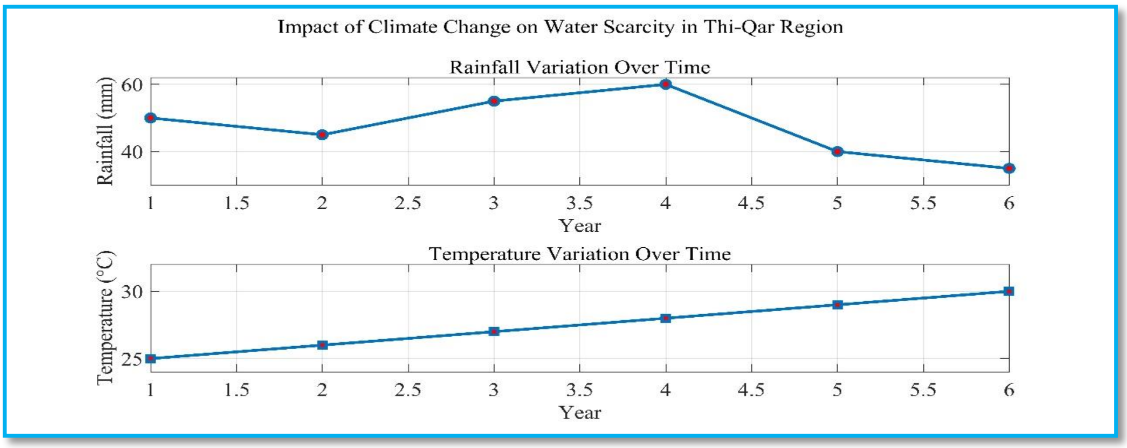

Figure7. *The impact of climate change on water scarcity in Thi-Qar region.*

3.4. Thi-Qar's Environmental Impact of Water Scarcity

Water scarcity poses a significant environmental challenge with various negative impacts on the ecosystem, such as soil degradation, stunted plant growth, and disrupted wildlife habitats in the Thi-Qar region of Iraq. Numerous factors contribute to the environmental impact of water scarcity, the most important of which are:

❖ Lack of water causes the soil to dry out and degrade, reducing its ability to sustain plant growth and provide vital nutrients. Lack of water can increase soil oxidation and decrease the activity of beneficial microorganisms, disrupting the biological and ecological balance of the soil.

❖ Inadequate water can lead to stunted plant growth, reduced health, and increased susceptibility to pests and diseases. Water shortages can alter soil quality and nutrient levels, affecting biodiversity and the overall plant environment.

❖ Wildlife: Water scarcity puts wildlife at risk of starvation and displacement due to lack of water for drinking and irrigation. Water scarcity affects the balance of wildlife ecosystems, increases competition for natural resources, and impacts the food chain.

These adverse effects of water scarcity on soil, plants and wildlife threaten the ecological balance in the Thi-Qar region of Iraq and call for urgent action to effectively manage water resources, promote sustainable water use practices, and raise awareness of the importance of environmental conservation to ensure the sustainability of the ecosystem and the preservation of biodiversity in the region. The environmental impact of water scarcity in Thi-Qar, Iraq is shown in Figure (8).

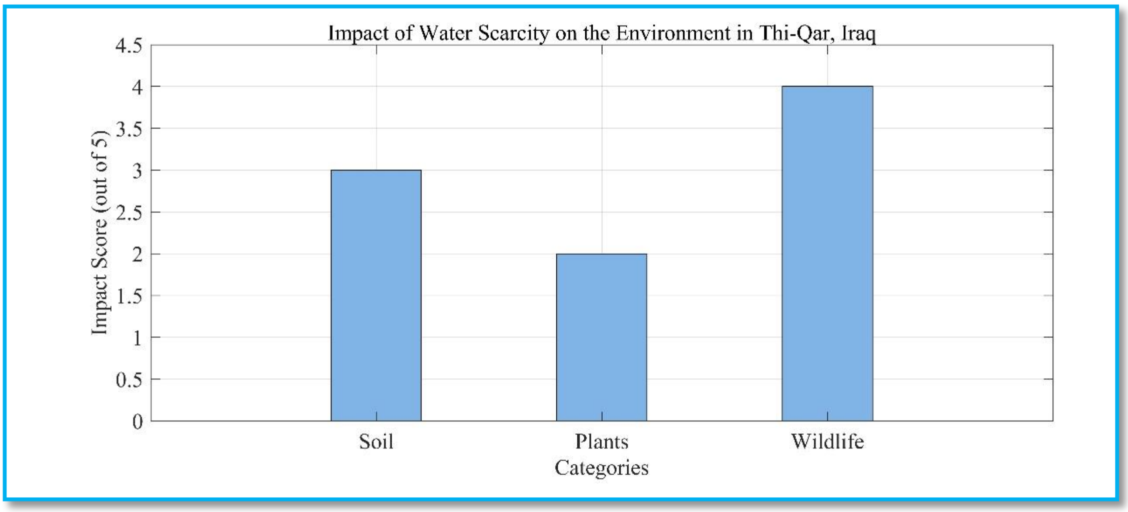

Figure8. *The impact of water scarcity on the environment in Thi-Qar Iraq.*

3.5. Analysis of water use efficiency in Thi-Qar

The contrast between blue and green water use highlights the potential for increased water use efficiency in rice production and opportunities for improvement. Assessing water efficiency in Thi-Qar, Iraq, plays a critical role in promoting sustainable water management practices for rice production. Examining the distinction between blue and green water use introduces a novel approach in the fields of ecology and agriculture. It emphasizes the importance of optimizing water resources. Blue water refers to surface and groundwater used for irrigation in agriculture, while green water refers to rainfall and atmospheric moisture that can contribute to crop water requirements.

Analyzing water use efficiency involves multiple steps:

❖ Evaluate current water consumption: This includes examining the water usage (blue and green) for rice cultivation in Thi-Qar, Iraq.

❖ Efficiency assessment: Calculate the water consumption per unit of rice produced and compare to determine efficiency.

❖ Identify influencing factors: Recognize factors that impact water use efficiency, like irrigation methods, soil composition, and groundwater levels.

❖ Recommend enhancements: Based on the analysis results, suggest improvements to enhance water use efficiency, such as adopting modern irrigation techniques like sprinkler or drip irrigation, enhancing drainage systems, and utilizing advanced irrigation control technologies.

This paper proposes a study on water use efficiency in rice production in Thi-Qar, Iraq to enhance the utilization of water resources and also obtain higher rice yields in a sustainable environment friendly method. It is important to evaluate water usage in the attempt to promote new agriculture in the Iraq due to climate change and environmental problems. Water use analysis of rice cultivation in Thi-Qar is depicted in figure (9).

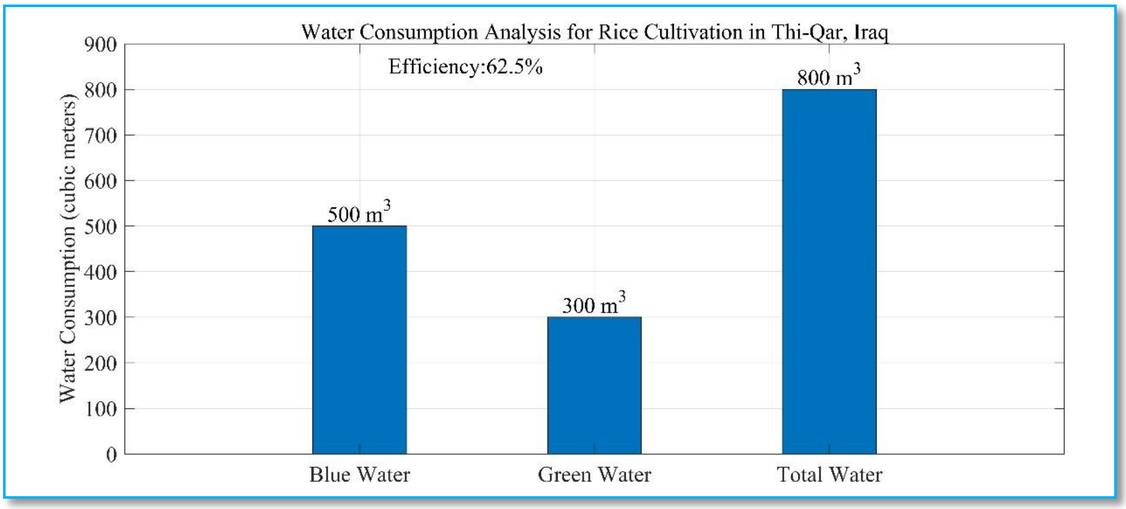

Figure9. *The water consumption analysis foe rice cultivation in Thi-Qar.*

4. LIMITATION AND RECOMMENDATION FOR FUTURE STUDY

Several limitations and constraints exist in the calculation of the gray water footprint of rice in this study. The researcher concludes that the main factor that poses a challenge to the assessment and quantification of water footprint of rice production in Thi-Qar province is data constraints. Recommendations for future research are also provided:

- The allocation and pricing of water for ecological uses shall be established from objective evaluation using the best available information which includes the space and time required.
- The water resource used is water and the water allocation system separates and distinguishes water use permits from land tenure.
- Management of water resources in Thi-Qar Province requires that stakeholders play their part in the sustainability of water resources.
- Applying the footprint concept to decide on efficient water use in irrigation systems and to increase crop production in Thi-Qar Province, water use for basic crops is assessed. This brings out the issue of water accessibility, whereby you will find that the region experiences either equal availability or scarcity.

To improve the sustainability of water management in Thi-Qar, Iraq, and to promote efficient water use, several sustainable solutions can be proposed. These solutions focus on optimizing water resources, improving agricultural techniques, and ensuring long-term water availability. Proposed sustainable solutions include the promotion of modern irrigation methods, such as drip and sprinkler irrigation, to minimize water waste and ensure uniform water distribution. Implementing water-efficient agricultural practices such as crop rotation and mulching can improve soil health, reduce water use and retain soil moisture. Additionally, implementing precision agriculture through advanced technologies like sensors and drones can optimize water use by providing real-time soil moisture and crop data. Improving water infrastructure by promoting rainwater harvesting and maintaining canals can minimize water loss and increase the efficiency of water delivery to farms.

Improving water desalination systems, including solar-powered desalination and reuse of treated wastewater, can provide clean water for irrigation while reducing reliance on freshwater sources. In addition, capacity-building initiatives aim to educate and raise awareness about sustainable water management practices and the importance of water conservation, such as farmer training programs and public awareness campaigns.

By implementing these sustainable solutions and taking proactive measures to improve water management practices in Thi-Qar, Iraq, stakeholders can work toward ensuring long-term water security, agricultural sustainability, and environmental protection in the region. Figure (10) Proposed sustainable solutions for water management in Thi-Qar, Iraq.

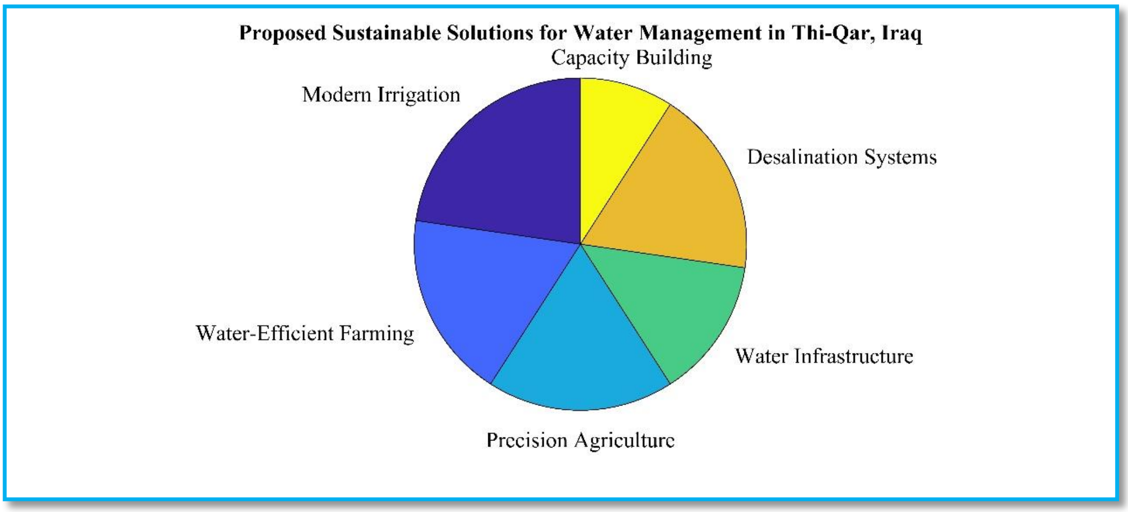

Figure10. *proposed sustainable solutions for water management in Thi-Qar Iraq.*

5. CONCLUSION

This view means that the water balance approach applied in this study is recognized as a versatile environmental approach to striking the problem of freshwater resources and determine what changes are required to make water use more sustainable, efficient, and equitable. This meant that the-demands for water in Thi-Qar Province are likely to rise- in line with population increase and the expansion of urban areas –dominated by the agricultural sector. These findings show that the blue water footprint is greater than the green water footprint in Thi-Qar Province. Second, the green water footprint is a function of annual precipitation, and Thi-Qar Province lacks adequate precipitation. Blue water is for irrigation water, Euphrates as source of fresh water is taken as a source.

Thi-Qar Province is known for its arid climate, in contrast to the northern provinces, which receive more rainfall. A recent study finds that the water footprint of Thi-Qar Province is heavily dependent on surface water, particularly for irrigation. Furthermore, significant differences in water footprints and crop water requirements exist between different provinces in Iraq due to varying weather and geographic factors. In northern Iraq, the growth of major crops is highly dependent on rainfall as the main source of nutrients for their development. The amount of rainfall in this region is significantly higher than in provinces such as Thi-Qar in the south, which are more dependent on irrigation systems. Thi-Qar Province receives less than 100 mm of rainfall per year.

Differences in the climate patterns in arid and semi-arid regions give a high number of annual evaporation rates which are affected mostly by temperature combined with other climatic factors including; wind speed and solar radiation. These rates are higher than the total annual evaporation rates in Thi-Qar Province. The findings of the present study should shed factual light on the ability of the Iraqi authorities to address the management of water resources for optimal irrigation throughout Iraq and, more specifically, Thi-Qar Province. Moreover, the outcomes obtained also can contribute to the practical management of crop in this region as well.

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