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Community-Based Approach for Agricultural Water Management of Summer Crops

Abordagem comunitária para gestão de águas voltada para culturas agrícolas de verão

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ABSTRACT

Globalization, population change, and rural-to-urban movement are the main causes of the enormous issues faced by rural communities. Every growing nation, including the Kurdistan Region of Iraq (KRI), has a sizable proportion of rural farmers among its populace. This study was done in the Sulaimani Governorate, which was divided into six main districts namely; Garmian, Penjwin, Halabja, Chamchamal, Sharazur, and Raniya, and aimed to compare the groundwater level with summer crop water demand. The weighted Sum Method (WSM) and a Normalized Difference Vegetation Index map (NDVI) were used to analyze and illustrate the current water demand status for summer crops. The study employed a participatory research design, utilizing a purposive sampling method to select 60 representative farmers, 25 key decision-makers, representatives from Non-Governmental Organizations (NGOs), and experts in the field of water management. Data was collected through the use of focus group discussions (FGDs) and Key Informant Interviews (KIIs) to gather information from the selected participants. This study is innovative in its attempt to establish a correlation between the yield of summer crops and the availability of groundwater. As a conclusion for this study, the results suggest that the level of groundwater plays a significant role in determining the production of summer crops. Additionally, the sustainable development of various regions within the Sulaimani Governorate is influenced by a complex interplay of environmental, economic, and social factors. Future work will be focus on doing a detail research regarding time series for ground water level (GWL) vs. crop production vs. NDVI.

KEYWORDS: rural community; sustainable development; Sulaimani governorate; ndvi; summer crops; climate change.

RESUMO

A globalização, a transição demográfica e o êxodo rural são as principais problemas enfrentados pelas comunidades rurais. Cada nação em crescimento, incluindo a região do Curdistão do Sul no Iraque, ainda mantém uma proporção considerável de agricultores em propriedades rurais. Este estudo foi feito na província de Sulaimani, que foi dividida em seis distritos principais, a saber; Garmian, Penjwin, Halabja, Chamchamal, Sharazur e Raniya, e teve como objetivo comparar o nível das águas subterrâneas com a demanda de água das culturas de verão existentes. O Método da Soma Ponderada e o índice de vegetação de diferença normalizada (IVDN) foram usados para analisar e ilustrar o estado atual da demanda de água para as culturas de verão da região. O estudo empregou um projeto de pesquisa participativa, utilizando um método de amostragem intencional para selecionar 60 agricultores representativos, 25 tomadores de decisão, representantes de organizações não governamentais e especialistas na área de gestão de recursos hídricos. Os dados foram coletados por meio do uso de discussões de grupos focais e entrevistas com pessoas-chave para coletar informações dos participantes selecionados. Este estudo é inovador em sua tentativa de estabelecer uma correlação entre o rendimento das culturas de verão e a disponibilidade de água subterrânea. Como conclusão para este estudo, os resultados sugerem que o nível das águas subterrâneas desempenha um papel significativo na determinação da produção de culturas de verão. Além disso, o desenvolvimento sustentável de várias regiões da província de Sulaimani é influenciado por uma complexa interação de fatores ambientais, econômicos e sociais. O trabalho futuro será focado em fazer uma pesquisa detalhada sobre séries temporais para nível de água subterrânea vs. produção agrícola vs. IVDN.

PALAVRAS-CHAVE: comunidade rural; desenvolvimento sustentável; governo de Sulaimani; ivdn; culturas de verão; mudanças climáticas.

INTRODUCTION

The rural community in the Sulaimani Governorate is highly vulnerable to the challenges posed by water scarcity, particularly in the agricultural sector. This vulnerability is exacerbated by a lack of an agricultural water policy, outdated irrigation technology, limited government support for farmers, and the absence of participatory approaches in the water management system. The purpose of this paper is to analyze the current status of various regions within the Sulaimani Governorate and explore potential strategies for sustainable agricultural water management in light of the challenges faced by these areas.

Farmers in KRI are experiencing the effects of water scarcity, particularly in regions such as Garmian and Chamchamal, as a result of climate change. This has led to the migration of the rural population to urban areas in search of better living conditions, thus exacerbating the decline of the agricultural industry in the Sulaimani Governorate.

A prolonged dry season has already affected the productivity of summer crops in the Sulaimani Governorate, highlighting the need for a comprehensive agricultural water policy to address water management challenges. The lack of such a policy has hindered the ability of the rural community to maintain sustainable agricultural practices. Furthermore, the rural communities in KRI, particularly farmers, have been excluded from decision-making processes related to agricultural water management for several decades. This lack of participation has contributed to the unsustainable nature of the rural community and the agricultural sector in the Sulaimani Governorate. It is imperative to consider the interplay of environmental, social, and economic factors in order to create a sustainable rural community in KRI. This research aims to fill the existing gap in the studies conducted in this country regarding the correlation between summer crop coverage and groundwater level in the Sulaimani Governorate and to identify ways in which each area can receive appropriate support for a sustainable agricultural water management system.

Addressing sustainable water management in the Mediterranean region requires more than just technological solutions. It involves taking into account various factors, such as the social behavior of rural communities, economic constraints, and the legal and institutional framework that may support or hinder the implementation of certain measures. Thus, sustainable water management in the Mediterranean is a complex issue that requires a comprehensive approach to effectively address the challenges it poses (CHARTZOULAKIS & BERTAKI 2015).

The challenges of sustainable development, particularly in the area of water management, are grave. While the world's population continues to grow, so does the amount of water used by various sectors. A sustainable strategy may be one that can cope with climatic variability (in the near future) and is flexible enough to respond to any sort of change brought on by climate change, socioeconomic progress, or changing viewpoints (HAASNOOT et al. 2011). Innovative irrigation, fertilizer technology, and agronomic expertise are driving significant changes in agriculture (GARCÍA-TEJERO et al. 2011). According to (TOMISLAV 2018), the concept of development and its association with economic advancement had been discussed by numerous classical theorists before the introduction of sustainable development by Brundtland in 1987.

Also, the UN and international organizations support sustainable development program, which aims to improve food and social security (alleviate hunger and eradicate poverty). This strategy has the effect of allocating more water for agriculture in water resource systems. As a result, the current global water problem is primarily a food catastrophe (GREEN 2003).

Achieving sustainable water usage is not possible without implementing effective agricultural water policies. Based on water policy in MENA countries (2020), Iraq is one of the countries which withdraw around 79% of freshwater for agricultural activities in 2014. Conflicts harmed the ecology by affecting water supply management (UKPAI 2022). Using freshwater for irrigation is still common in Iraq and is currently leading to a decline in surface and groundwater levels throughout the country. Only in extraordinary drought situations and when drought conditions go beyond what might be considered typical risk management will policy offer financial aid to farmers (YAZDANDOOST 2020). Also, a significant reduction in the climatic water availability (CWA) during the growing season for summer crops in a majority of regions within Iraq, with the exception of the KRI (SALMAN et al. 2020).

In Iraq, irrigated agriculture consumes more than 80% of the Tigris and Euphrates Rivers and their tributaries' total water supplies. Large sections of agricultural land are affected by salt and waterlogging, notably in central and southern Iraq, where salinity is the most serious problem confronting Iraq's irrigated agriculture (BARZINJI 2017, FAO 2018). An argument suggests that the integration of soil-based, plant-based, and weather-based monitoring techniques within a modeling framework utilizing model predictive control can lead to a substantial enhancement in water use efficiency (BWAMBALE et al. 2022).

The Kurdistan Region of Iraq has a "Mediterranean" climate, with hot, dry summers and temperatures between 43 and 48oC (HARUN et al. 2015). The KRI is separated into three zones based on average rainfall according to the FAO conservation guide (SALEM 1989): (a) Secure-zone (more than 500 mm year-1), (b) Semi-arid zone (350-500 mm year-1), and (c) Arid zone (100-300 mm year-1).

The main water resources in the Sulaimani Governorate are surface water including lakes and rivers, natural springs, karez, and groundwater. In Sulaimani Governorate, internal sources of water are far more abundant than external sources, which primarily originate from Iran. As a result, we can state that effective water management in the governorate can ensure the sustainability of the water for the following decades without fear of facing water shortage (HARUN et al. 2015).

Based on the report from the Food and Agriculture Organization (FAO) on crops and water resources in 2019, the number of permitted water wells in the Sulaimani Governorate from 2016 till the end of 2018 was 28532, and only 8888 of them were agricultural well-used for irrigation purposes (FAO 2019). In some parts of Sulaimani Governorate, the level of water has declined by some meters (Table 1).

Table 1. The changes in groundwater level in the Sulaimani Governorate between 2018 and 2021 (MOAWR 2022b).

Name of the area	Name of the monitoring well	The decline of the level of groundwater/m	Years of comparison
Bazyan	Bastanai Bazyan	6.14	2018-2021
Bngrd/Surdash	Sarsyan	13.2	2009-2021
Khurmal/Halabja	Haji Namiq village	8.4	2009-2021
Kalar	Shorsh area	2.41	2001-2021
Kifri	hunarmandan area	5.82	2001-2022
kifri	Rizgrai area	3.73	2002-2022

The precipitation ratio in the Sulaimani Governorate from 2012 to 2022 had a great fluctuation with the least precipitation ratio in 2021 to the highest in 2018 (Figure 1). The average of precipitation in the Sulaimani Governorate is around 722mm/year, which is placed in a secured zone (more than 500 mm y^{-1}). But, it has to be mentioned that the precipitation in the Sulaimani Governorate still varies from one area to another. For instance, in 2022, the precipitation ratio in the Sulaimani Governorate was 427.4 mm y^{-1} with the highest ratio recorded at 873.1 mm y^{-1} in Penjwin to the lowest in Kalar which was 110 mm y^{-1}.

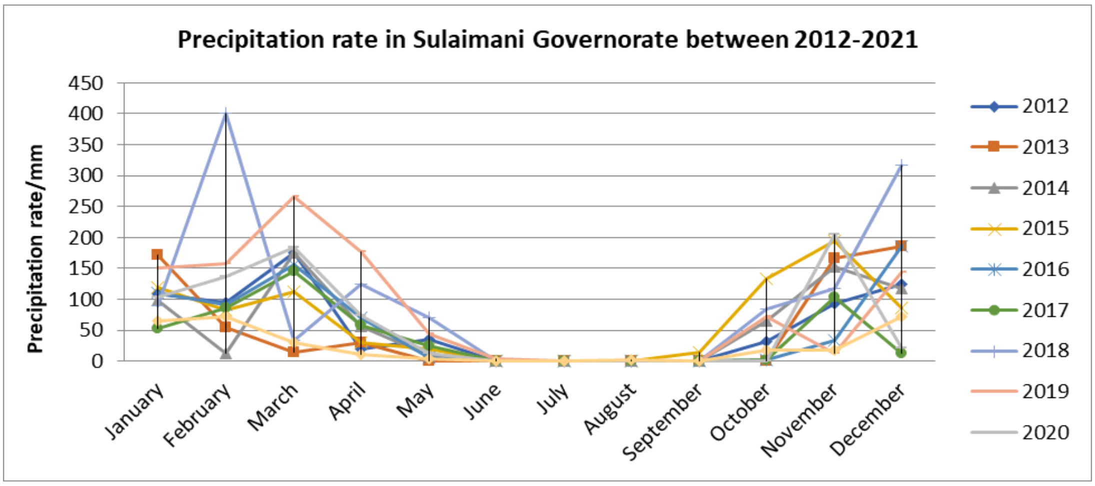


Figure 1. Precipitation ratio in the Sulaimani Governorate between the years 2012-2021. Adopted from (KRSO 2021).

However, in Halabja province, the highest precipitation for the last ten years was in 2020 (909.4 mm y^{-1}) and the lowest was in 2021 (290.4 mm y^{-1}) (Figure 2). The average of precipitation ratio in Halabja province for the last ten years is 540.3 mm y^{-1}, which is placed in the guaranteed rainfall “secure zone with more than 500 mm y^{-1}.

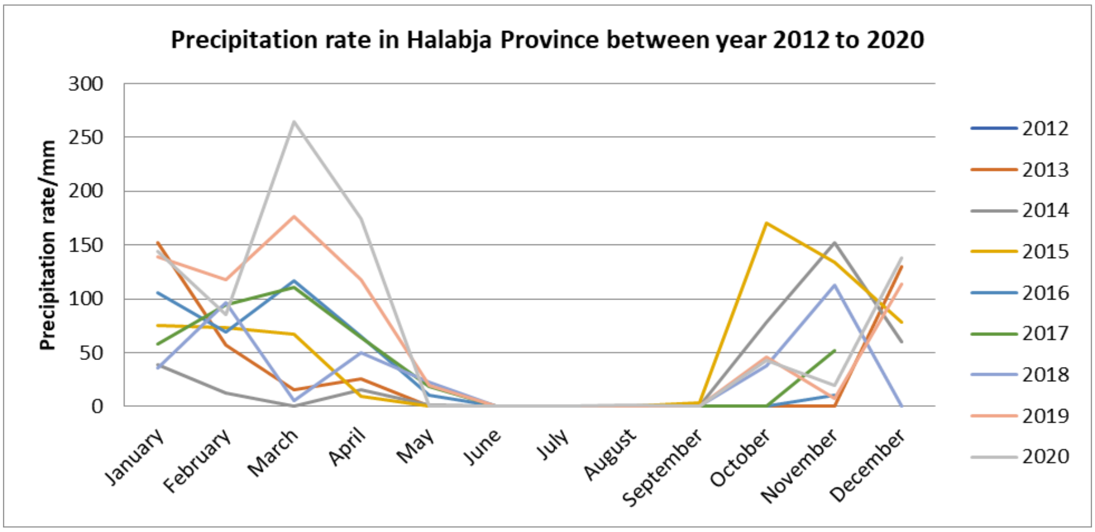


Figure 2. Precipitation ratio in Halabja province between 2012-2020. Adopted from (KRSO 2021).

The total areas were cultivated with summer crops in the Sulaimani Governorate in 2021 and 2022 were around 127167 and 111940 dunums, respectively.

The demand for groundwater is increasing continually, especially for irrigating summer crops. Because the primary source of water is groundwater in many areas in the Sulaimani Governorate where surface water is inaccessible due to the absence of irrigation canals or dams or applying new technology for transferring the water to the cultivated land. The number of wells is rising daily in the KRI. For instance, Sulaimani Governorate had 37724 total wells in 2017, according to data from the General Directorate of Water Resources in KRI, and 95000 wells were legally drilled there in 2018. The inability to manage illegal wells and the unrestricted water extraction by licensed wells, which is rapidly depleting the aquifers, are the fundamental problems across the whole KRI (KRSO 2021).

MATERIAL AND METHODS

The Kurdistan region in Iraq is located between latitude 34.3o- 37o and longitude 42.3o-46.33o The KRI encompasses the most fertile plain area of Iraq as well as highlands and hills. Kifri has its lowest point at a height of 140 meters above sea level, and Halgurd Mountain is Kurdistan's highest peak at 3607 meters above sea level (MOAWR 2022a). The Sulaimani Governorate is located near the Iranian border in the eastern part of Iraq's Kurdistan Region. The Garmian Administration, which includes the districts of Kalar and Kifri as well as a portion of Khanaqeen that was once a part of the Diyala Governorate, makes up the governorate's southernmost region (Figure 3).

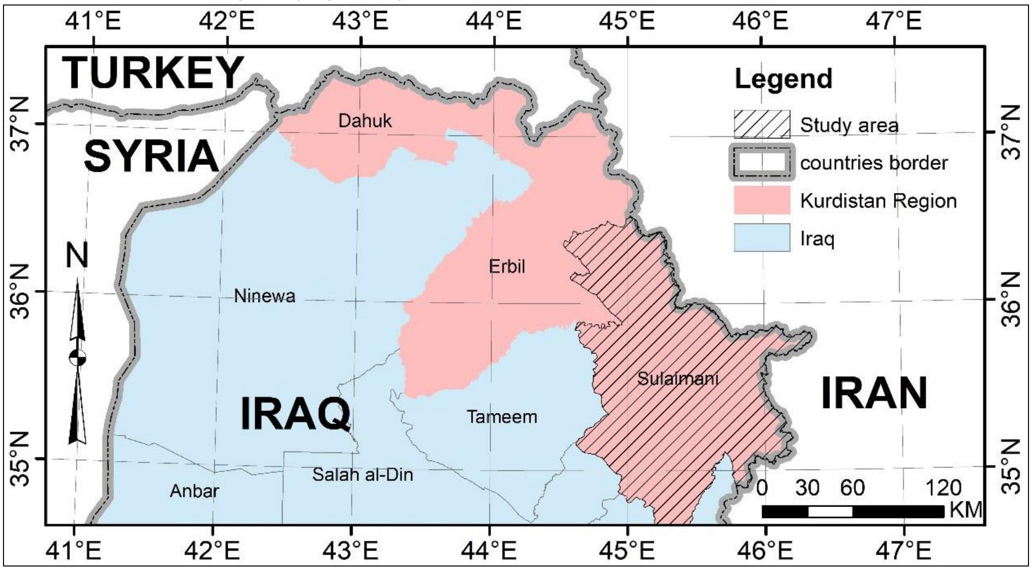


Figure 3. The study area map in the Kurdistan Region of Iraq.

Study Area

The present study aimed to gather accurate and reliable data on the management of agricultural water for summer crops in the Sulaimani Governorate. This was achieved through the use of qualitative research methodologies, including focus group discussions (FGDs) and key informant interviews (KIIs). The data was collected from a diverse range of stakeholders, including government decision-makers, farmers, scholars, and non-governmental organizations (NGOs). Participatory approaches for water management was suggested by Dublin statement in 1992 as one of the best approach for community-based water management (MOSTERT 2006). The study was focused on summer crop production and included several locations in the Sulaimani Governorate and Halabja Province, given the interdependence of water sources in these regions. Urban areas of the Sulaimani Governorate were excluded from the study due to the low ratio of summer crop cultivation and agricultural practices in these areas like the city Centre since it is more expanded by the residential and industrial areas (Figure 4). The stakeholders were coded according to their job titles and locations (Table 2).

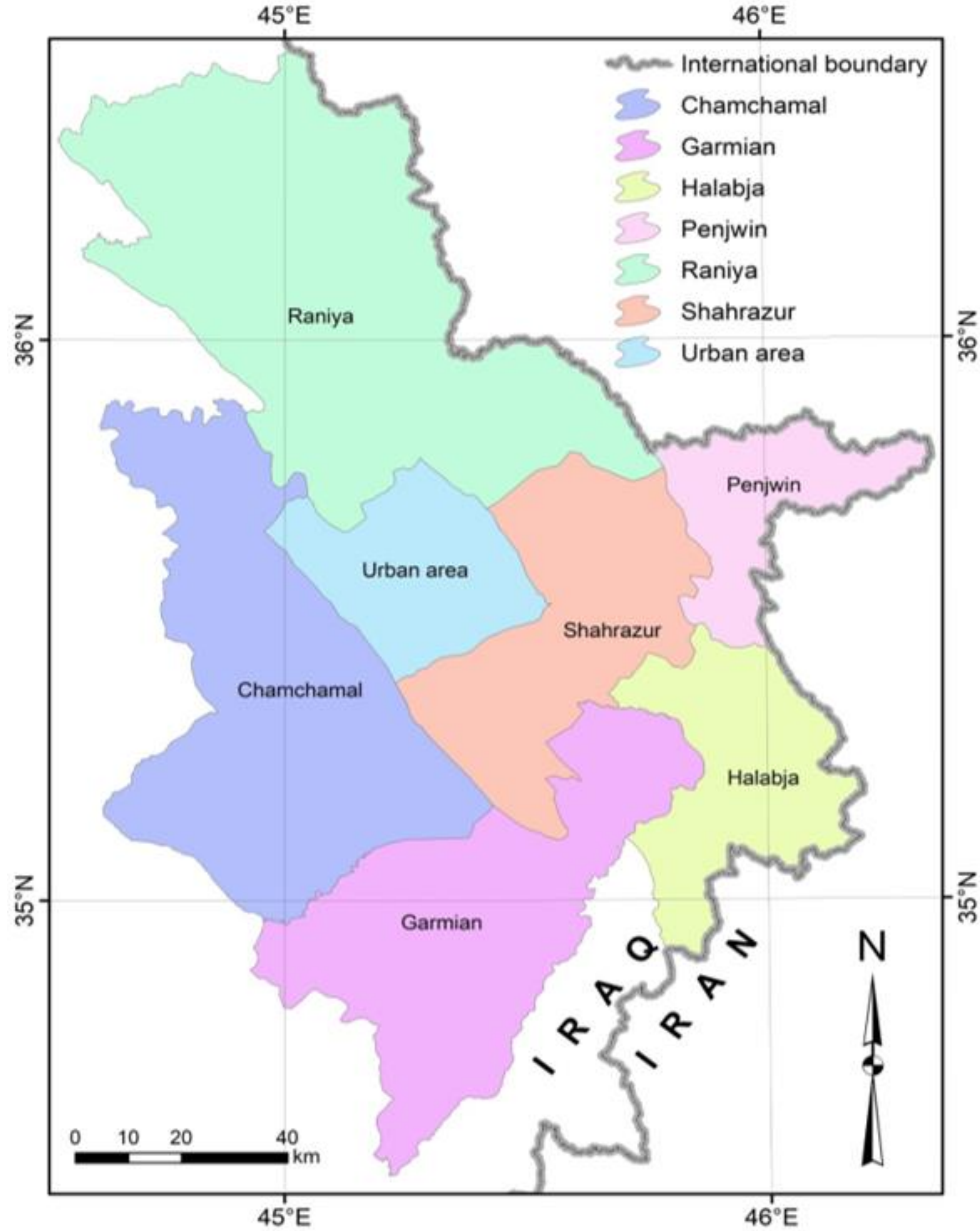


Figure 4. The population sampling map in the Sulaimani Governorate.

The Jenks approach is used to divide the data into groups that maximize the variation between groups while minimizing the variance within groupings. To make reading maps easier for everyone, the data cut points have been modified to be rounded (OTHMAN et al. 2018). Furthermore, the Weighted Sum Method (WSM) was employed to integrate multiple inputs and generate a comprehensive analysis (Kumar et al., 2020). The WSM was recommended by (OTHMAN et al. 2018) as one of the best straightforward and applicable approaches for multi-criteria decision analysis (MCDA). The method used to assign weights to each factor based on their relative importance, and then multiplying each factor by its corresponding weight and summing the results to obtain the overall score because this allows decision-makers to take into account multiple factors when making decisions, even when those factors may be difficult to compare directly.

Table 2. The Coding of participants and their locations.

Title	Code
Exemplary Farmer- Raniya	S-RA-EF#
Exemplary Farmer- Shahrazur	S-SH-EF#
Exemplary Farmer- Halabja	S-HA-EF#
Exemplary Farmer- Chamchamal	S-CH-EF#
Exemplary Farmer- Garmian	S-GA-EF#
Exemplary Farmer- Penjwin	S-P-EF#
Decision Maker-Ministry	DM-MI
Decision Maker-Parliament	DM-PM#
Decision Maker- Directory of Dams	DM_DD
Decision Maker-Directory of Agriculture	DM-AG#
Scientific Scholar	US-S#
Non-Governmental Organization	NG-EF#

The collected data was quantitatively processed and normalized for utilization in ArcGIS to depict the alterations in summer crop vegetation and groundwater demand. To determine the weights of the factors, experts recommended the summing of all factors in the next phase (OTHMAN et al. 2020). The formula for the WSM is expressed as:

$$\text{WSM} = \sum_{i=1}^{n} wjaij \tag{1}$$

In addition, a Normalized Difference Vegetation Index (NDVI) map was obtained from the NOAA Center for Satellite Applications and Research (STAR) to provide a visual comparison of vegetation coverage during the month of August, with the coverage of summer crops being portrayed via NDVI. NDVI is a commonly used Vegetation Index by satellites and is calculated by dividing the difference between near-infrared radiation (NIR) and visible radiation (VIS) by the sum of NIR and VIS, which serves as an indication of plant growth density on Earth. The mathematical expression for NDVI is as follows:

$$\text{NDVI} = (\text{NIR} - \text{VIS}) / (\text{NIR} + \text{VIS}) \tag{2}$$

The outcome of an NDVI calculation for a particular pixel is always a number between minus one (-1) and plus one (+1); nevertheless, the absence of green leaves yields a value that is very near to zero. A value of zero denotes the absence of vegetation, whereas a value of +1 (0.8–0.9) denotes the highest potential density of green leaves (NASA 2000).

RESULTS

Groundwater in the Sulaimani Governorate has already decreased as a result of overuse for drinking and irrigation in many locations since the source of surface water is no longer sufficiently adequate to supply water in such places. In addition, the Sulaimani Governorate may experience a water deficit sooner than expected due to the increased demand for groundwater brought on by population growth, climate change, and rising temperatures as well as a lack of enforcing environmental law for protecting water resources (DM-AG#4).

According to the result found in this study, the mean annual NDVI value of Penjwin, Halabja, part of Shahrazur, and Raniya were in the range of 0.5–0.6 in 2022, and the highest value was found in Penjwin District (+0.55) and the lowest value (-0.2 and -0.17) in Chamchamal District. Also, Garmian areas like Kifri and Khanaqin were suffering from a lack of vegetation during summer (Figure 5). This was most probably because of the declining level of groundwater, humidity, and raising the temperature, especially in some areas like Garmian reached 48 ^{o}C. The greatest value was discovered in Penjwin District and the lowest value was found in Chamchamal and Raniya Districts. The crop diversity that is mostly expressed by the metric of percent crop cover has a strong positive relationship with higher groundwater levels.

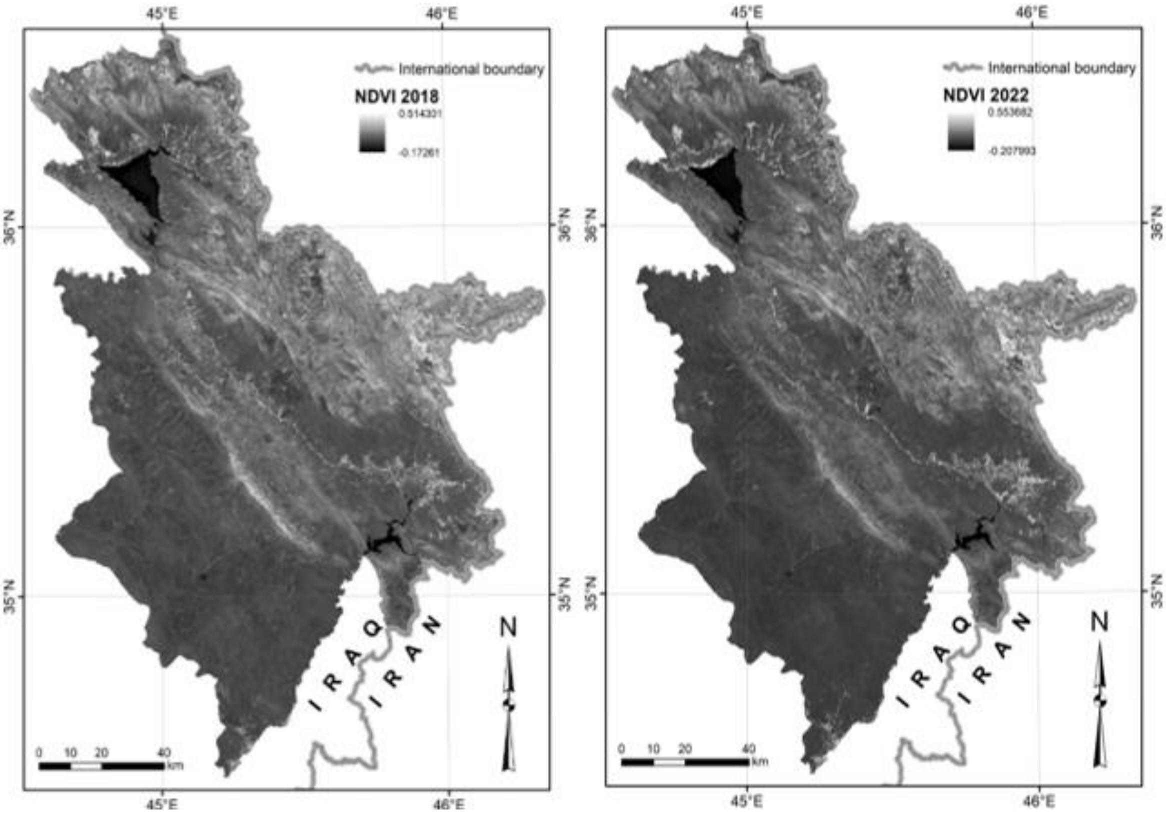


Figure 5. The NDVI maps for comparing the summer crop coverage in the Sulaimani Governorate for the years 2018 and 2022.

Sustainable Water Management for Summer Crops

Water demand (million m^3) for summer crops in the Sulaimani Governorate mainly relies on groundwater for many areas. This caused drastically declining groundwater levels in many areas as no proper management for agricultural water is practiced (Figure 6A). The observed rise in water demand for the cultivation of summer crops in Chamchamal and Garmian areas suggested a significant increase in the planting of these crops, with farmers opting for a diverse range of summer crops that are dependent on the utilization of groundwater resources.

Furthermore, the result shows a decrease in the water demand for summer crops in the Raniya region in 2021 compared to 2017. This reduction could potentially be attributed to shifts in land use practices within certain areas in Raniya, where some landowners have converted their upstream agricultural lands for the purpose of constructing fish ponds, instead of maintaining their original use for crop cultivation. Consequently, the water requirement for summer crop irrigation has already decreased in this region. A comprehensive approach to agritourism development, in line with the strategy for the development of tourism in the Raniya area, holds great potential for boosting tourism and improving income in the rural communities as was already studied in other countries (EVGRAFOVA et al. 2020).

The data indicates that in Shahrazur, there has been a decrease in water demand starting in 2021 compared to previous years. This reduction in demand is likely the result of a decrease in the cultivation of certain summer crops in that year. In Penjwin, the demand for water for summer crops has increased over time, reaching 190 million m3 in 2021. This is a marked increase from the 67 million m3 reported in 2017. This shift in water demand can be attributed to an increase in the cultivation of certain summer crops in the region (Figure 6B).

After conducting a comparison between the water demand for summer crops in different regions and the levels of groundwater, it was discovered that in the Penjwin area, the water demand for summer crops is increasing while the groundwater levels are declining, as shown in Figure 7. In other areas such as Chamchamal and Garmian areas, the decline in groundwater levels is significant and cannot be solely attributed to the water demand for summer crops. Other factors, such as climate change and the use of groundwater for oil refining purposes, also play a significant role in these areas. In Rania, the decline in groundwater levels is also high, but not all of it is related to summer crop cultivation. The main factor in this area might be the fish pond. However, in Shahrazur, the levels of groundwater are still stable, as the rate of summer crop cultivation is not as high as in other areas.

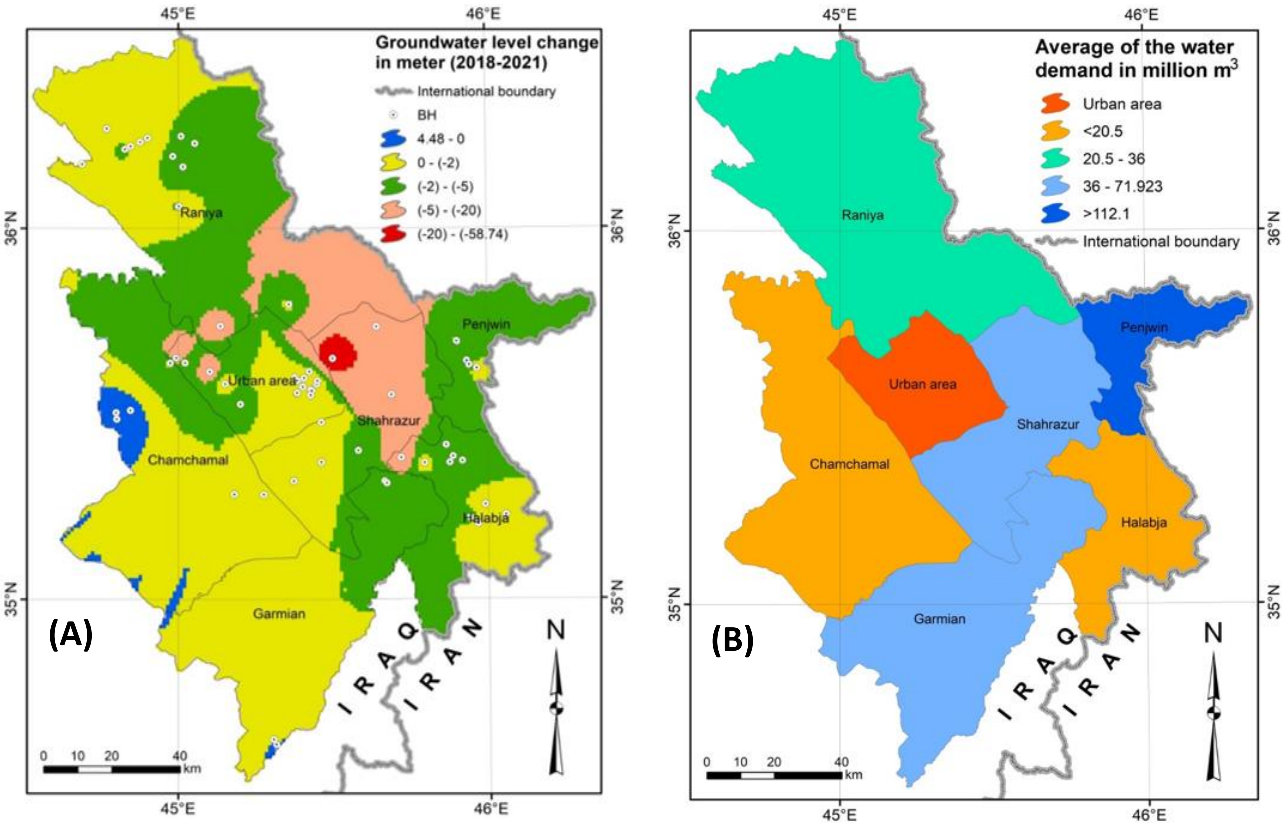


Figure 6. Groundwater changes in the Sulaimani Governorate for the years 2018 to 2021 (A) and Average of the water demand (million m^3) per each area (B).

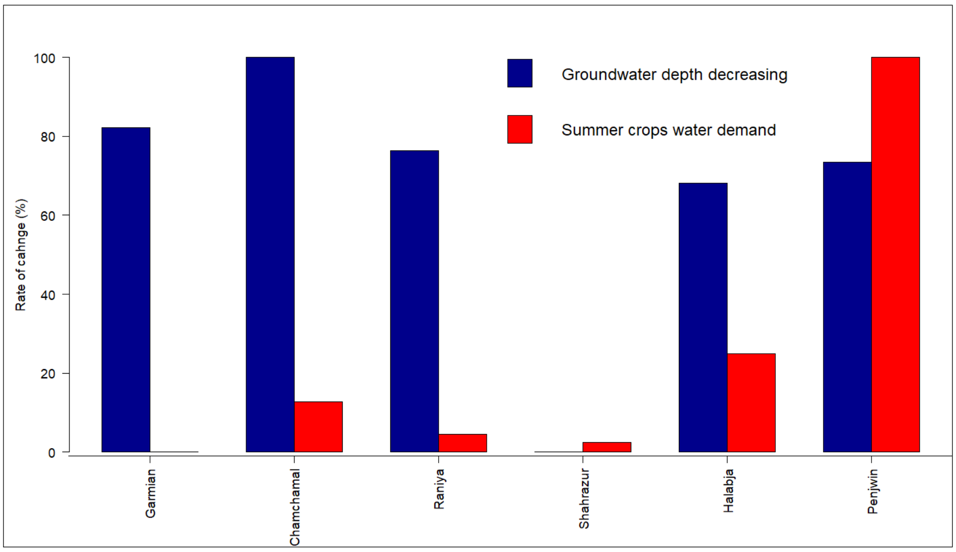


Figure 7. The comparison between summer crop water demands versus groundwater depth declining.

The yield of various summer crops was analyzed across various districts in the Sulaimani Governorate from 2017 to 2021. When comparing the summer crop production data of 2021 to that of 2017, it can be observed that Penjwin and Chamchamal have experienced significant growth in their crop yield. Meanwhile, Shahrazur, Halabja, and Garmian have shown relatively modest changes over the past five years, and Raniya has recorded a noticeable decrease in crop yield. In terms of the area (km2) cultivated with summer crops, Penjwin leads the districts with a total of 29.6 km^2, followed by Shahrazur (19.8 km^2) and Garmian (17.05 km^2). On the other hand, Raniya and Chamchamal have the smallest summer crop cultivated area at 7.7 km^2 and 6.9 km^2, respectively (Figure 8A).

The density of summer crops in relation to the total area of each district in the Sulaimani Governorate has shown fluctuations over the period of 2017-2021. Results indicate that the highest increase in summer crop density was observed in Penjwin, with a growth of 2.9% over the five-year period. Shahrazur demonstrated stability in the proportion of land utilized for summer crops, with values ranging from 0.58 to 0.94%. In contrast, Halabja and Garmian showed slower growth in the cultivation of summer crops, with densities ranging from 0.3 to 0.58 (Figure 8B).

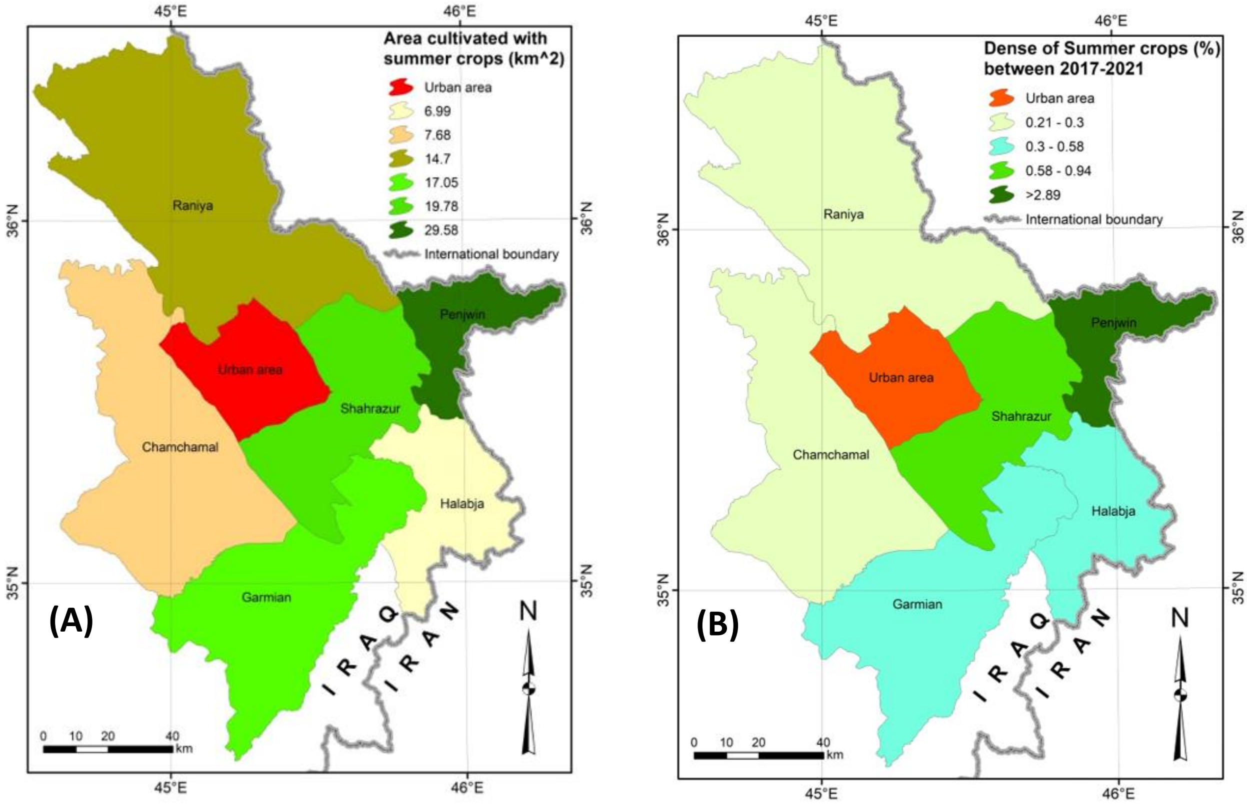


Figure 8. Area cultivated with summer crops in Sulaimani Governorate (A) and Dense of summer crops in the Sulaimani Governorate for years 2017-2021 (B).

Raniya and Chamchamal were found to have the lowest increase in the density of summer crops, with values ranging from 0.21 to 0.3%. This can be attributed to several factors, including the impact of climate change, the conversion of agricultural land into fish ponds in Raniya, and oil refinery operations in Chamchamal. Additionally, the lack of modern equipment and facilities for planting, irrigation, and harvesting has also discouraged farmers from pursuing agriculture in these regions.

Also, the results showed that the per-district productivity of some summer crops was different from one area to another (Figure 9A). The productivity of crops, such as rice, tomatoes, cucumbers, zucchini, and ladyfingers, which have high water requirements (m3/dunum), was greatly influenced by the water availability during the summer season. Thus, the water supply during the summer season became a crucial factor in determining the success rate of these crops in a particular region. As a result, farmers made informed decisions regarding the cultivation of summer crops by considering both the crop's success rate in their respective regions and the local market price of the product.

When the sustainable development pillars were studied, the regions of Garmian and Chamchamal exhibit a stronger impact from environmental factors compared to other locations. This phenomenon is likely attributed to the exacerbation of climate change effects and a general lack of environmental consciousness in these areas (S-GA-EF#5; DM-AG#3) (Figure 9B). The regions of Raniya, Shahrazur, and Halabja also exhibit significant environmental impact, though to a lesser extent. Conversely, the data suggests that the region of Penjwin in the Sulaimani Governorate has experienced the least impact from climate change when compared to other areas within the governorate. The environmental factors including population growth, environmental awareness, climate change impacts and effective water management.

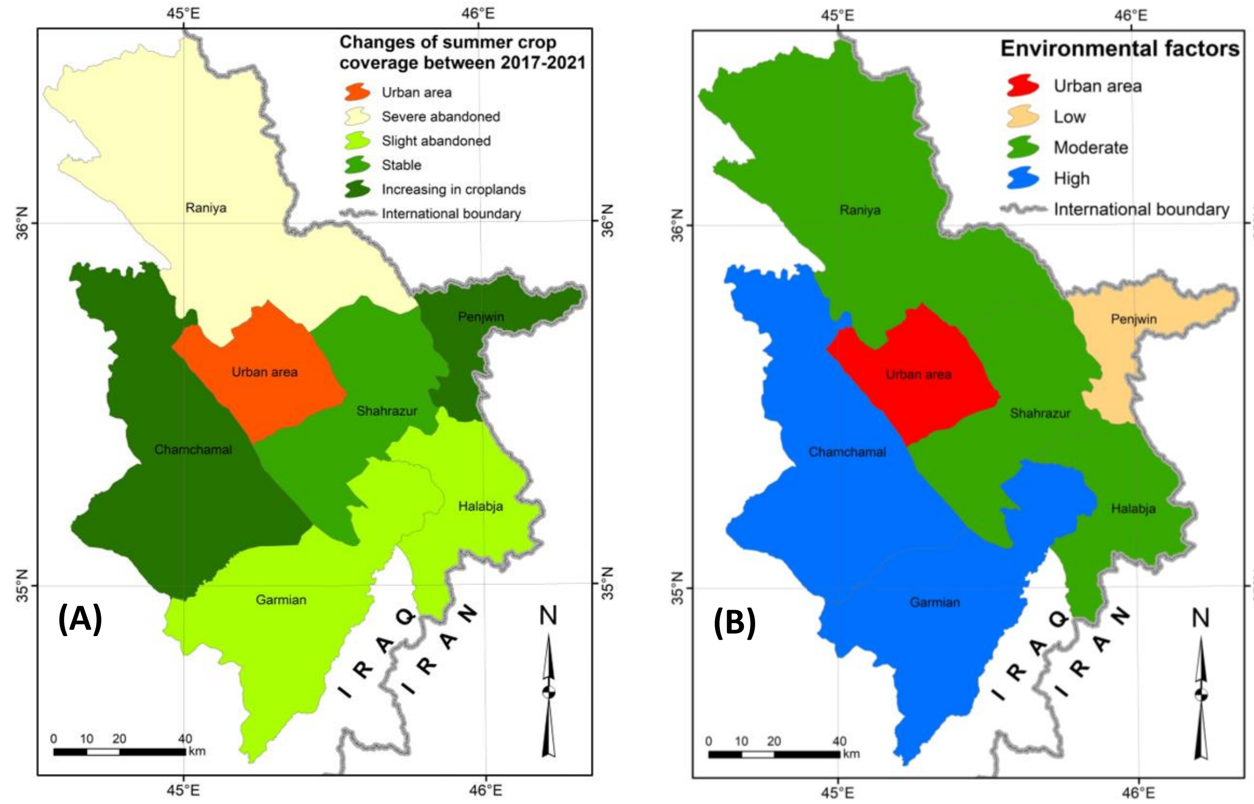
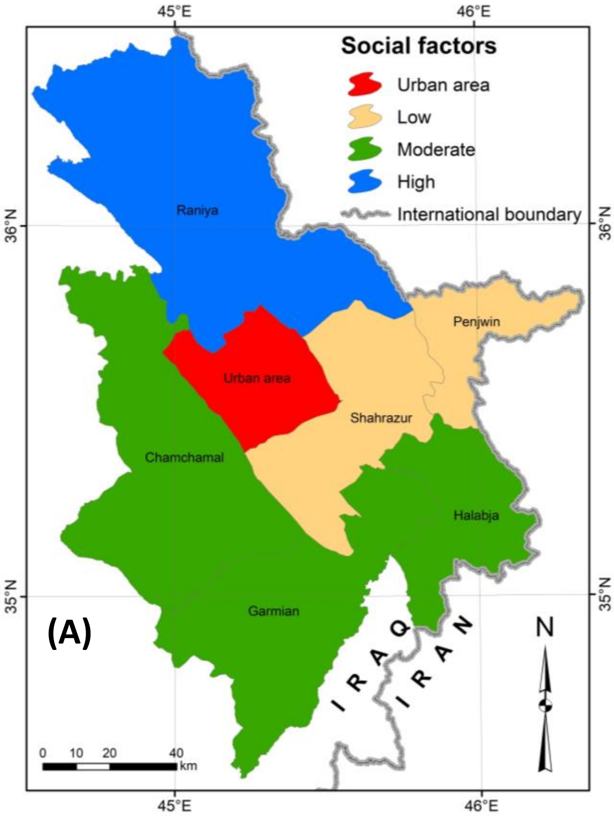


Figure 9. Changes of summer crop coverage in the Sulaimani Governorate between 2017 to 2021 (A). The environmental factors affecting the sustainable development in Sulaimani Governorate using WSM (B).

While for the social factors, Raniya is more pronounced compared to other areas in the governorate. This is likely due to the unresolved issues of land ownership and the prevalence of water and land disputes (S-RA-EF#3; DM-PM#1) (Figure 10A). Social factors including conflict over water, agricultural extension, unrest policy, social service and education.

The analysis shows that economic variables have a significant impact on the sustainability of agricultural water supply in the Sulaimani Governorate. In particular, the study highlights that Penjwin and Halabja are more susceptible to economic challenges compared to other regions. This can be attributed to the growing importance of summer crop farming as a source of income for the rural community in both areas and the direct impact that changes in agricultural product prices have on the farmers' livelihoods (US-S#6; DM-AG#1; S-HA-FM#1) (Figure 10B). The economic factors were willingness to pay for water irrigation, income of the farmers, lack of charging per rate of water consumption and lack of investments in water management.



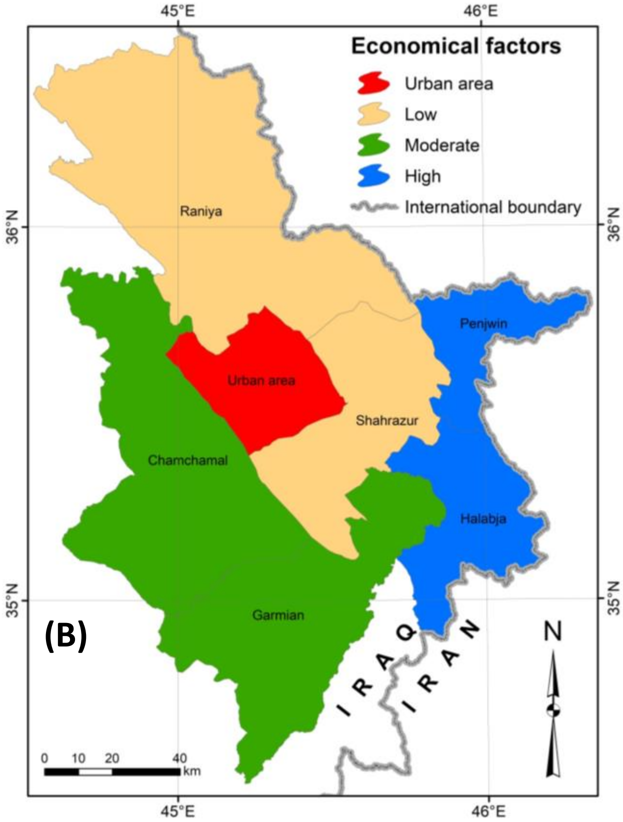


Figure 10. Social factors affecting sustainable development in the Sulaimani Governorate using WSM (A). Economic factors affecting sustainable development in the Sulaimani Governorate using WSM (B).

DISCUSSION

The findings of the research demonstrate a significant correlation between the demands for water in the cultivation of summer crops and the reduction of groundwater levels. The main strategies to counteract the decrease in groundwater levels are the adoption of alternative cropping systems and the implementation of water-efficient irrigation schedules (DM-AG#6; DM-PM#3; S-P-EF#5) as was already proved by (SUN et al. 2019). Moreover, the effects of climate change have already become evident in numerous regions, making it imperative for farmers to adopt contemporary agricultural techniques and modernize their irrigation systems in order to remain sustainable as was also approved by (TRIPATHI et al. 2016). The extensive utilization of water sources for agricultural purposes has led to a significant decrease in the amount and deterioration in the quality of water in many areas in the Sulaimani Governorate even as was the case in many other places (FOROUZANI & KARAMI 2011).

The demand for water used in crop irrigation varies greatly between different seasons and geographical locations as was previously studied (BIEMANS et al. 2016). It's important to note that the increased demand for water may put a strain on the region's water resources (DM-MI; US-S#1; S-CH-EF#3). The future demand for irrigation water is uncertain, as it is expected to be significantly impacted by the predicted changes in climate as was considered before (WADA et al. 2013). Also, the farmers have to implement efficient irrigation methods, and for the local government has to plan and manage the water resources effectively to ensure that the growing crops receive enough water while also preserving the region's water supply for future use. Also, the study suggested that incorporating a variety of crops into rotation patterns could significantly contribute to preventing the excessive depletion of groundwater while preserving food security and increasing farmers' earnings as was also studied by (YANG et al. 2015, MORIONDO & BINDI 2007).

Furthermore, the findings also indicate that variations exist among the regions regarding their status with respect to the components of sustainable development. To ensure a sustainable approach to agricultural water management, it is necessary to tailor the strategies to the specific conditions and needs of each region in order to achieve a balance between environmental, economic, and social sustainability.

In order to address the challenges posed by climate change and ensure sustainable agricultural water management in the Sulaimani Governorate, a combination of environmental, economic, and social factors needs to be considered. Specifically, the warmer temperatures in the regions of Kalar, Kifri, and

Chamchamal compared to other parts of the governorate necessitate the implementation of additional measures to mitigate the effects of drought and desertification.

From an environmental perspective, enforcing existing environmental laws and regulating illegal water wells can help to conserve water resources. Additionally, the implementation of small ponds, dams, and underground irrigation systems may be more effective in these regions compared to other areas.

From an economic standpoint, the concept of water trading and virtual water can play a crucial role in ensuring sustainable water management. Transboundary water cooperation with neighboring countries, such as Iran, may also be necessary to address the impact of dams on water flow in the Garmian area.

From a social perspective, planning the growth and progress of rural regions, it's essential to recognize the significance of villages and to highlight their strengths and unique features in order to drive sustainable development. By doing so, we can maximize the potential of rural areas and create a brighter future for everyone as was also agreed with CIZLER (2013). Therefore, for sustainable water management in agriculture, the following recommendations are proposed:

- Redistribution of summer crops based on the current climate conditions, water availability, and soil characteristics.
- Continuous monitoring of groundwater levels through boreholes, and prevention of illegal well drilling.
- Establishing agricultural water policy per region.
- Establishment of participatory local water management councils.
- Implementation of community-based agricultural water management as a priority in water resource management planning.
- Provision of tailored support by local authorities for areas with varying levels of environmental, economic, and social vulnerability.
- Adoption of advanced irrigation techniques such as drip, sprinkler, and subsurface irrigation systems.
- Expansion of agricultural extension programs to provide updated information and best practices to rural communities.

CONCLUSION

The sustainable water supply was assessed while taking into account the summer crop coverage in each location during the years (2017-2021) and the water demand for all six districts in the Sulaimani Government. The outcome demonstrated that, if new irrigation techniques, such as drip irrigation, sprinkler systems, and building ponds for harvesting rainwater and floods during the rainy season and using it for agriculture during the summer, are applied, each area can sustainably have enough water supplies for summer crops.

Furthermore, the overall analysis of all the pillars of agricultural water management's sustainability revealed that Penjwin, Halabja, and Rania were more impacted by economic and social factors respectively, while Garmian and Chamchamal's rural communities were more impacted by environmental factors. Due to the area's extremely rich soil and the fact that farmers were already aware of the effects of these variables and the need for adaptation in the event of water scarcity in the near future, Shahrazur saw only a minimal to moderate influence from all of the causes.

Future research in the field of water management could focus on exploring specific strategies for enhancing resilience in different regions. Each rural community has its own unique needs and challenges, and therefore, it's important to identify tailored mechanisms that can support their survival and sustainable agriculture practices.

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