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Investigate the Optimum Agricultural Crops Production Seasons in Salah Al-Din Governorate Utilizing Climate Remote Sensing Data and Agro-Climatic Zoning

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Abstract

Agriculture is one of the major sources of livelihood for the Iraqi people as one-third of Iraq population resides in rural areas and depends upon agriculture for their livelihoods. This study aims to estimate the impact of temperature variability on crops productivity across the agro-climatic zones in Salah Al-Din governorate using climate satellite-based data for the period 2000 to 2018. The average annual air temperature based on satellite data was downloaded from the GLDAS Model NOAH025_M v2.1, and interpolates using Kriging interpolation/spherical model. Thirteen strategic crops were selected which is Courgette, garlic, Onion, Sweet Pepper, Watermelon, Melon, Cucumber, Tomato, Potato, Eggplant, Wheat, Barley, and Maize. Temperature requirements for each crop during the growing period were compared with actual temperature from GLDAS data. The study highlighted the impacts of temperature changes on agricultural productivity. The results show that there are some crops that are not achieving optimum productivity, such as Courgette first seasons (December-March), Garlic, Onion, and Cucumber. Whereas, there are other crops that achieve good productivity, such as Courgette second season (March-June), Sweet Pepper, Watermelon, Melon, Tomato, Potato, Eggplant, Maize, Wheat, and Barley. The study recommends proper mitigate and adaptive strategies to enhance the positive and lessen the adverse impacts of temperature changes on crops productivity across agro-climatic zones in Iraq.

Keyword: Agro-Climatic, temperature change, remote sensing, GIS; Iraq.

تحديد مواسم الإنتاج الأمثل للمحاصيل الزراعية في محافظة صلاح الدين باستخدام بيانات التحسس النائي المناخية والاقاليم المناخية الزراعية

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الخلاصة

تعتبر الزراعة واحدة من المصادر الرئيسية لكسب الرزق للشعب العراقي، حيث يعيش ثلث سكان العراق في المناطق الريفية ويعتمدون على الزراعة في كسب عيشهم. تهدف هذه الدراسة الى تحديد تأثير تغييرات درجات

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الحرارة على إنتاجية المحاصيل في المناطق المناخية الزراعية لمحافظة صلاح الدين باستخدام البيانات المناخية المستمدة من الأقمار الصناعية للفترة من عام 2000 إلى عام 2018. تم تنزيل متوسط درجة حرارة الهواء السنوية من بيانات الأقمار الصناعية (GLDAS NOAH025_M (v2.1. تم اختيار ثلاثة عشر محصولاً استراتيجياً وهي الكوسا، الثوم، البصل، الفلفل الحلو، البطيخ، الرقي، الخيار، الطماطم، البطاطا، الباذنجان، القمح، الشعير والذرة. تمت مقارنة متطلبات درجة الحرارة لكل محصول خلال فترة النمو مع درجة الحرارة الفعلية من بيانات GLDAS. سلطت الدراسة الضوء على آثار التغيرات في درجات الحرارة على الإنتاجية الزراعية. اظهرت النتائج أن هناك بعض المحاصيل التي لا تحقق انتاجية مقبولة، مثل محصول الكوسا الموسم الأول (من ديسمبر إلى مارس) والثوم والبصل والخيار. إضافة الى ذلك توجد محاصيل أخرى تحقق إنتاجية جيدة، مثل الكوسا الموسم الثاني (من مارس إلى يونيو)، الفلفل الحلو، البطيخ، البطيخ، الطماطم، البطاطا، الباذنجان، الذرة، القمح والشعير. توصي الدراسة بإيجاد استراتيجيات مناسبة للتخفيف من اثار التغيرات في درجات الحرارة على إنتاجية المحاصيل للمناطق المناخية الزراعية في العراق.

1. Introduction

Agriculture is one of the major sources of livelihood for the Iraqi people as one-third of Iraq population resides in rural areas and depends upon agriculture for their livelihoods. Additionally, is the main source of employment in rural areas, with crop production being the major source of income for 75% percent of Iraqi farmers. The sector of agriculture provides 20 % of employment and it is the second contributor to Gross Domestic Product (GDP) after the oil sector in Iraq. The World Food Programme (WFP)/Government of Iraq food security analysis conducted in 2007/2008 revealed that about 930,000 Iraqis are food–insecure, and about six and a half million are on the threshold of food insecurity[1]. Food security is defined as the condition when "all people, at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". Improved food security that relies on firm sustainable food systems that make advantages from information technologies is essential to meet the United Nations Sustainable Development Goals (SDGs) [2].

Understanding the association between crops productivity and climatic variables such as temperature and precipitation become a high priority [3]. To address this, spatiotemporal tools that can integrate climate data with other information of interest are required. Remote sensing plays an important role in various studies as it provides up-to-date information on spatial and temporal scales. Climate remote sensing data provides the opportunity to monitor vegetation dynamics in a systematic manner [4]. In another hand, GIS is the basic platform through which data can be easily stored, its packages of applications were used by specialists in the various field especially in the environmental studies [5-8]. The satellite has emerged as an effective tool for monitoring and assessing areas [9]. Among the available global gridded reanalysis datasets, Global Land Data Assimilation System (GLDAS) offers several advantages; Firstly, GLDAS provides a consistent quality-controlled long global gridded time-series of the required variables at a high spatial resolution, and secondly, it runs in near real time, offering the potential to regularly update the database [10]. Comparing the land data assimilation system with other simulation models, the advantage of GLDAS's data is that it is closer to the actual situation and the results are more in line with the actual standards [11].

Agro-Climatic Zones (ACZs) are recognized areas with different potential products according to their environmental conditions. All plants are sensitive to weather conditions in a way or another. They have a minimum, as well as, maximum requirements regarding weather conditions to satisfy their physiological needs; beyond certain limits, they are negatively affected. Evidently, as climate changes, the ACZs change and adjustments need to be made to identify most suited crops for the new conditions. Literature shows attempts to manage the challenge of increasing productivity through matching agricultural products with favorable climatic conditions. For example, Kamali [12] studied the importance of relating cultivating different agricultural crops to bio-climatic potentials in each region. Whereas Venkateshwarlu et al. [13] highlighted the relationships between climatic variables and crops in a region. Robertson [14] considered the relationship between climatic variables and wheat growth in Canada. Baban [15] discussed the agricultural productivity in Kurdistan/Iraq; he proposed a way forward through identifying the major physical and climatic parameters influencing agricultural productivity.

This study aims to estimate the impact of temperature variability on crops productivity across the ACZs in Salah Al-Din governorate using climate satellite-based data for the period 2000 to 2018. Thirteen strategic crops were selected which is Courgette, garlic, Onion, Sweet Pepper, Watermelon, Melon, Cucumber, Tomato, Potato, Eggplant, Wheat, Barley, and Maize.

2. Materials and methods

2.1. Study Area

The study area lies in Salah-Al-Din Governorate north of Baghdad capital, between longitudes 42° 00' – 45° 05' E, and latitudes 33° 00'–36° 00' N (Figure-1). It is an important economic area, where the primary source of livelihood is agriculture, especially crops of grain production, such as wheat, barley and corn. Farmers depend on rainwater and groundwater to plant some summer and winter vegetables [16]. The areas of the two banks of the Tigris and the Al-Idhaim_rivers depend on the water of these rivers for agriculture.

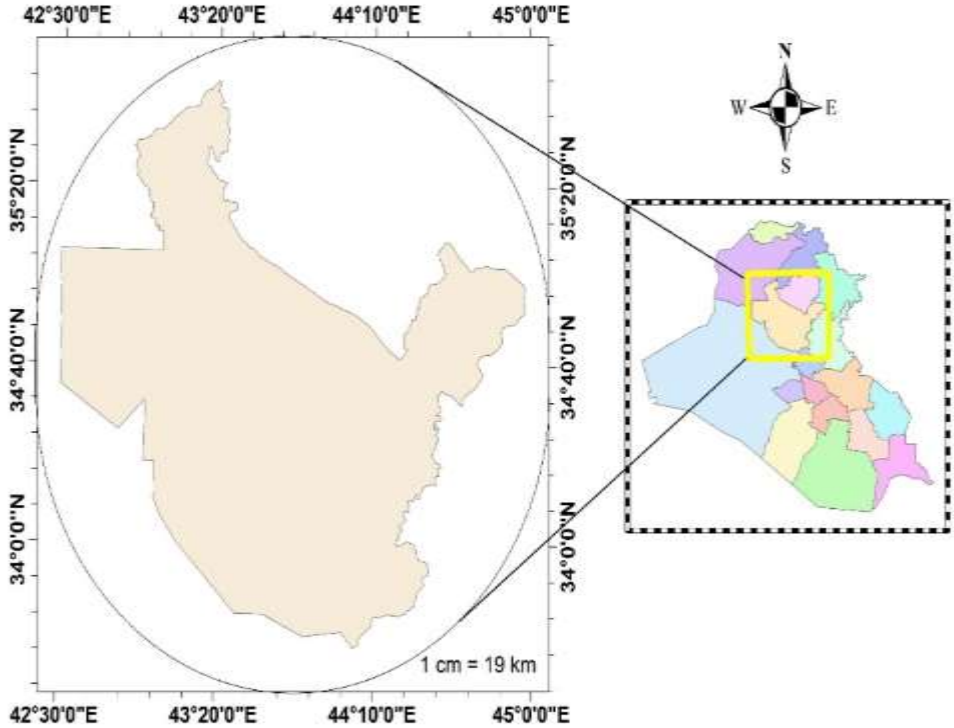

Figure-1 Location of the study area.

2.2Climate remote sensing data

The GLDAS aims to integrate the satellite-based data and ground observational data, by advanced land surface modeling and data assimilation techniques, to generate optimal fields of land surface states [16]. There are four GLDAS models coalesce data from both of the land surface and satellites, which is, Mosaic, Noah, the Community Land Model (CLM), and the Variable Infiltration Capacity (VIC). All four GLDAS models are widely used in climate research [17]. In this study, the average annual air temperature based on satellite data during the period January 2000 to January 2018 was downloaded from the GLDAS Model NOAH025_M v2.1 with a spatial resolution of 0.25 x 0.25 degree. The temperature data were in the Kelvin unit (Kº), and was converted to Celsius (Cº) using the equation:

$$T(°\mathrm{C}) = T(\mathrm{K}) - 273.15 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Monthly and annual temperature have spatial structure and their spatial variation conforms to the spherical and exponential models [18,19]. In this study, the Kriging interpolation/spherical model was used to interpolate the temperature data using Arc GIS 10.5 software. The mean temperature during the warmest month, which is July, varied from 35.8 ºC to 37.9 ºC. The mean temperature during the coldest month, which is January, ranged between 8.4 ºC to 10.5 ºC. Figure-2 shows the mean temperature for each month during the period 2000-2018 based on GLDAS data.

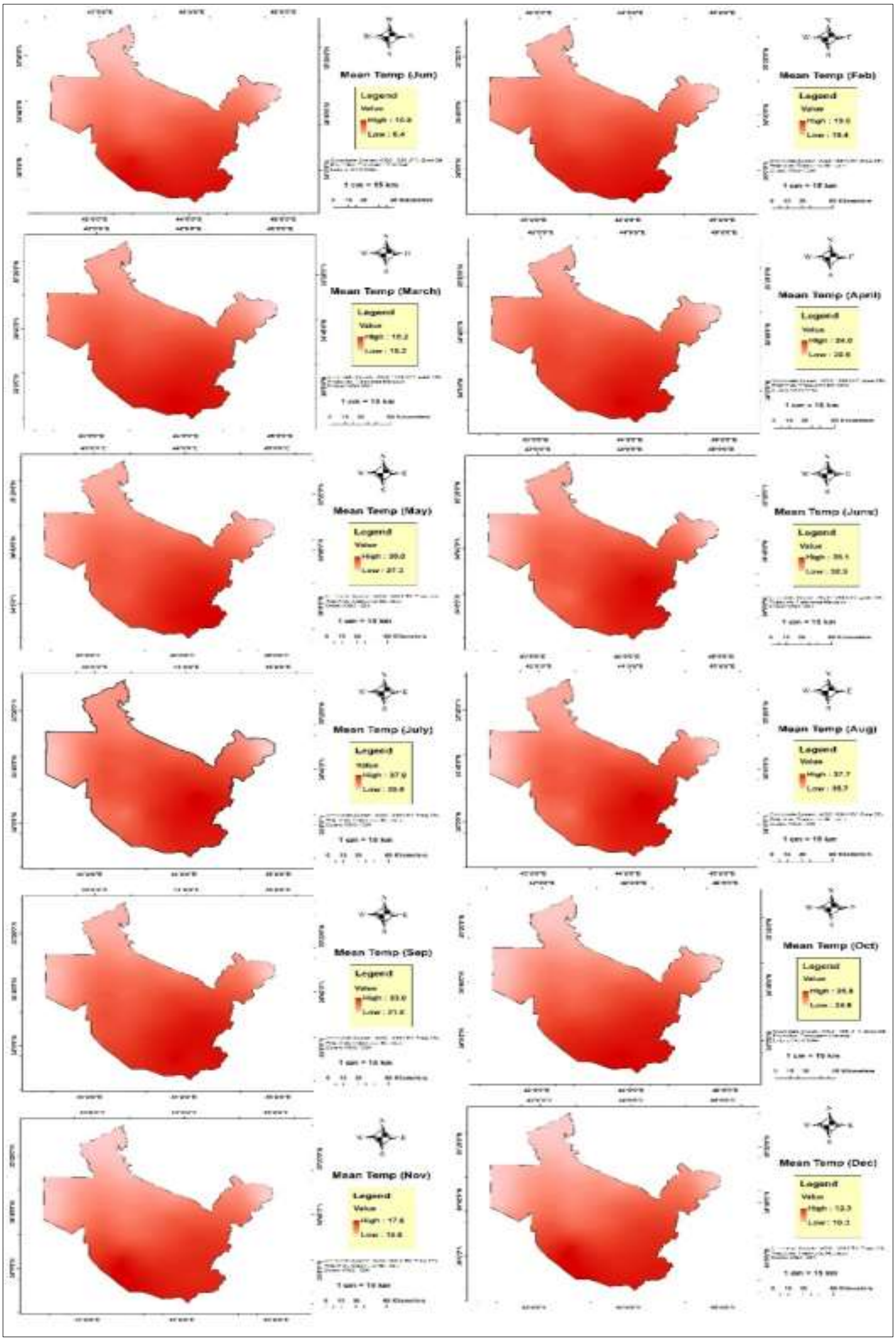

Figure-2 the mean temperature for each month during the period 2000-2018 based on GLDAS data.

2.3 Agro-Climatic Classification

Agro-climatology is highly valuable in the identification of agro-climates with the optimal conditions to introduce new agricultural crops. The requirements, limits and bio-meteorological tolerance and conditions of crops must be evaluated with reference to the native areas climatological characteristics for successful cultivation around the world [20]. The agro-climatic zones can be defined as integrating and homogeneous portions of land in which the particular combinations of potentially available water resources and climate conditions create unique environments more or less suitable for crops cultivation. The agro-climatic classification is defining the major climate condition and its suitability for the cultivation of certain crops. The ACZs of an area helps to define the ecological potential of that area. In order to define the ACZs, a classification system is used which is based on three criteria; winter type, summer type and moisture regime [21].

2.4Crops thermal requirements

This study aims to estimate the impact of temperature variability on the productivity of the crops across the ACZs in Salah Al-Din governorate. Thirteen strategic crops were selected which is Courgette, garlic, Onion, Sweet Pepper, Watermelon, Melon, Cucumber, Tomato, Potato, Eggplant, Wheat, Barley, and Maize. Temperature requirements for each crops during the growing period were compared with actual temperature from GLDAS data (Figure-2). Table-1 shows the temperature requirements for the selected crops; this data was collected from the Ministry of Agriculture/Iraq.

Table- 1 Temperature Boundary for the selected crops.

No.	Crops	Planting	Harvest	Temperatures (Centigrade)		
				Min	Optimal	Max.
1	Courgette	Dec	March	15	25-30	45
		March	Jun			
2	garlic	Sep	May	15-18	31-37	40-44
3	Onion	Sep	May	15	25-30	45
4	Sweet Pepper	April	Jun	15-18	31-37	40-44
		May	Aug			
5	Watermelon	April	Jun	15-18	31-37	40-44
		Jun	Sep			
6	Melon	April	Jun	15-18	31-37	40-44
		Jun	Sep			
7	Cucumber	March	Jun	25	25-30	30
8	Tomato	April	Jun	12	15-20	28-34
9	Potato	Nov	April	12	15-20	28-34
		April	Jun			
10	Eggplant	Feb	Jun	16	25-30	45
11	Wheat	Nov	May	5	20-25	38
12	Barley	Nov	Jun	5	20-25	38
13	Maize	Jun	Oct	20	22-25	32-34
		April	Aug			

3 Results and discussion

3.1 Agro-Climatic Zones

The study area is within three ACZs as shown in Figure-3, which are arid, cool winter, very warm summer (ACZ 1); arid, mild winter, very warm summer (ACZ 2); and semi-arid, cool winter, very warm summer (ACZ 3) [22].

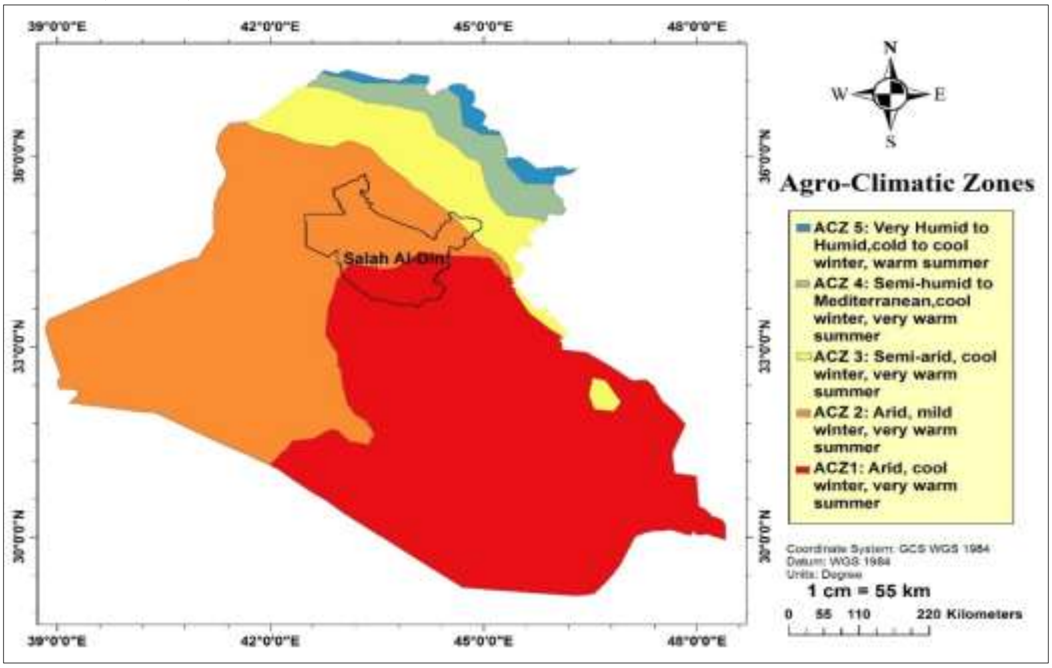

Figure 3-the study area ACZs (modified [22]).

3.2 Estimation of the Crops Productivity

3.2.1 Courgette

Courgette is cultivated in two seasons, in the first season; it is planted in December and harvested in March. By monitoring the mean temperature during the period December-March, it is shown that the mean temperature is less than the minimum required. According to this, it may not be helpful for acceptable productivity. In the second season, it is planted in March and harvested in June. By monitoring the mean temperature during the period of March- June, it is shown that the temperature is optimum. Accordingly, it is recommended to cultivate Courgette in the second season.

3.2.2 Garlic

Garlic is planted in September and harvested in May. By monitoring the mean temperature during the period September-May, it is shown that the mean temperature is less than the minimum required in three months (December, January, and February). Accordingly, it may not be helpful for acceptable productivity.

3.2.3 Onion

Onion is planted in September and harvested in May. By monitoring the mean temperature during the period September-May, it is shown that the mean temperature is less than the minimum required in three months (December, January, and February). Accordingly, it may not be helpful for acceptable productivity.

3.2.4 Sweet Pepper

Sweet Pepper is cultivated in two seasons. In the first season, it is planted in April and harvested in June. By monitoring the mean temperature during this period, it found that the temperature is suitable. In the second season, it is planted in May and harvested in August, by monitoring the mean temperature during this period it is shown that the temperature is optimum. Accordingly, the two seasons are suitable, but the second one may achieve better productivity.

3.2.5 Watermelon and Melon

Watermelon and Melon are cultivated in two seasons. In the first season, it is planted in April and harvested in June. By monitoring the mean temperature during this period, it is shown that the temperature is suitable. In the second season, it is planted in June and harvested in September. By monitoring the mean temperature during this period, it is shown that the temperature is optimum. Accordingly, the two seasons are suitable, but the second one may achieve better productivity.

3.2.6 Cucumber

Cucumber is planted in March and harvested in June. By monitoring the mean temperature during this period, it is found that the temperature is less than the minimum required in two months (March, and April), as well as, it higher than the maximum required in June. Accordingly, it may not be helpful for acceptable productivity.

3.2.7 Tomato

Tomato it is planted in April and harvested in June. By monitoring the mean temperature during this period, it is shown that the temperature is suitable. According to this, it is expected to achieve acceptable productivity.

3.2.8 Potato

Potato is cultivated in two seasons. In the first season, it is planted in November and harvested in April. By monitoring the mean temperature during this period; it is shown that the temperature is slightly less than the minimum required in January. In the second season, it is planted in April and harvested in June. By monitoring the mean temperature during this period, it is shown that the temperature is slightly higher than the maximum required in June. According to this, the two seasons are suitable and expected to achieve acceptable productivity.

3.2.9 Eggplant

Eggplant is planted in February and harvested in June. By monitoring the mean temperature during this period, it is shown that the temperature is slightly less than the minimum required in February. Accordingly, it may achieve acceptable productivity.

3.2.10 Wheat

Wheat is planted in November and harvested in May. By monitoring the mean temperature during this period, it is shown that the temperature is suitable and may achieve good productivity.

3.2.11 Barley

Barley is planted in November and harvested in June. By monitoring the mean temperature during this period, it is shown that the temperature is suitable and it may achieve good productivity.

3.2.12 Maize

Maize is cultivated in two seasons. In the first season, it is planted in June and harvested in October. In the second season, it is planted in April and harvested in August. By monitoring the mean temperature during these periods, it found that the temperature is slightly higher than the maximum required. Accordingly, the two seasons may be of acceptable productivity.

4. Conclusions

This study aims to estimate the effect of temperature on thirteen selected strategic crops yields cultivated across three ACZs in Salah Al-Din Governorate. Satellite-based data for the period 2000 to 2018 were used. Temperature is an important determinant affecting crops productivity. The result shows that there are crops that are not achieving acceptable productivity, such as Courgette first seasons (December-March), Garlic, Onion, and Cucumber. Whereas, there are other crops that are achieving acceptable productivity, such as Courgette second season (March- June), Sweet Pepper, Watermelon, Melon, Tomato, Potato, Eggplant, Wheat, Maize, and Barley. Finally, the study recommends proper mitigate and adaptive strategies to enhance the positive and lessen the adverse impact of temperature change on crops productivity across ACZs in Iraq. Additional researches are recommended to investigate the impact of other climate variables on crop yields productivity across the ACZs in Iraq.

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