Assessment of the climate changes impact on agricultural lands productivity of Al-Muwafaqiyah

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Abstract

Although agriculture is characterized by relative stability; But it has undergone change according to the surrounding conditions. Agriculture in Iraq has recently witnessed a rapid change in its characteristics, the cultivated areas, and the productivity of these areas, albeit to varying degrees, for several reasons, including: wars, water scarcity, and climatic changes in the region that led to its deterioration. This climate change has negatively affected agricultural crops and vegetative cover. This study revolves around the basics and details of the cultivation and production of strategic crops (wheat and barley) in the Al-Muwfiqiyah district, as a sample, in Wassit Governorate / Iraq, to detect the impact of climatic changes on productivity and vegetation cover during the past two decades. The change in productivity and area of agricultural crops (using NDVI) was monitored according to changes in climate elements (temperature, humidity and rain), as they are the most influential climate elements on agriculture, This study showed that the relationship between the productivity of hectares and the climate change parameters adopted in this study is random and this result was logically reflected on the vegetation cover index. The aim of this study is to prepare a guide and develop a tool for planners and decision makers in preparing appropriate development plans and programs necessary to advance the reality of cultivation and production of those crops, and finding appropriate ways to develop and upgrade them in the future.

Keywords: climate change, productivity, NDVI, cultivation

تقييم تأثير التغيرات المناخية على إنتاجية الأراضي الزراعية بالموفقية

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الملخص

على الرغم من أن الزراعة تتميز بالاستقرار النسبي ؛ لكنها تغيرت حسب الظروف المحيطة. شهدت الزراعة في العراق مؤخراً تغيراً سريعاً في خصائصها ، والمساحات المزروعة ، وتدهور إنتاجية هذه المناطق ، وإن كان بدرجات متفاوتة ، لعدة أسباب ، منها: الحروب ، وندرة المياه ، والتغيرات المناخية في المنطقة التي أدت إلى انتشارها. أثر هذا التغير المناخي سلبًا على المحاصيل الزراعية والغطاء النباتي. تدور هذه الدراسة حول اساسيات وتفاصيل زراعة وانتاج المحاصيل الاستراتيجية (القمح والشعير) في منطقة الموفقية كعينة في محافظة واسط / العراق ، للكشف عن اثر التغيرات المناخية على الانتاجية والغطاء النباتي خلال العقدين الماضيين. تم رصد التغير في إنتاجية ومساحة المحاصيل الزراعية باستخدام (NDVI) حسب التغيرات في عناصر المناخ (درجة الحرارة والرطوبة والمطر) ، حيث أنها أكثر العناصر المناخية تأثيراً على الزراعة ، وأظهرت هذه الدراسة أن العلاقة بين إنتاجية الهكتار من المحاصيل الزراعية ومعايير تغير المناخ المعتمدة في هذه الدراسة عشوائية وقد انعكست هذه النتيجة منطقيًا على مؤشر الغطاء النباتي. تهدف هذه الدراسة إلى إعداد دليل وتطوير أداة للمخططين ومتخذي القرار في إعداد الخطط والبرامج التنموية المناسبة والضرورية للنهوض بواقع زراعة وإنتاج تلك المحاصيل ، وإيجاد السبل المناسبة لتطويرها في المستقبل والارتقاء بها .

الكلمات المفتاحية: التغيرات المناخية ، الإنتاجية ، NDVI ، الزراعة

Introduction

Globally, climate change (CC) is the most serious environmental threat that adversely affects agricultural productivity (Anselm and Taofeeq, 2010).Climate change affects ecosystems, human societies, economies, agriculture and thus food security in a variety of ways. Despite the technological progress represented by industrial crops, genetically modified organisms and the use of advanced irrigation systems, climate is still the main effected factor in agricultural yields, in addition to the characteristics of the soil and natural communities. Usually, agricultural production is linked to changes in local climate patterns rather than global climate patterns. Climate-Smart Agriculture (CSA) is a recognized suite of well-informed approaches to land and water management, soil conservation and agronomic practice that sequester carbon and reduce GHG emissions. CSA practices help to retain soil structure, organic matter and moisture under drier conditions, and include agronomic techniques (including irrigation and drainage) to adjust or extend cropping calendars to adapt to seasonal and inter annual climate shifts (UNESCO, 2020). There is much evidence that climate is rapidly changing at a global scale, especially regarding mean annual temperatures, precipitations and evaporation (Stefano, et al., 2010). There is a scientific consensus on the role of human activities in direct or indirect carbon emissions, which subsequently lead to climate change. Figure (1) presents the interrelationship between human activities and the surrounding environmental conditions (Jain, et al. 2019; Jenna, et al. 2020).

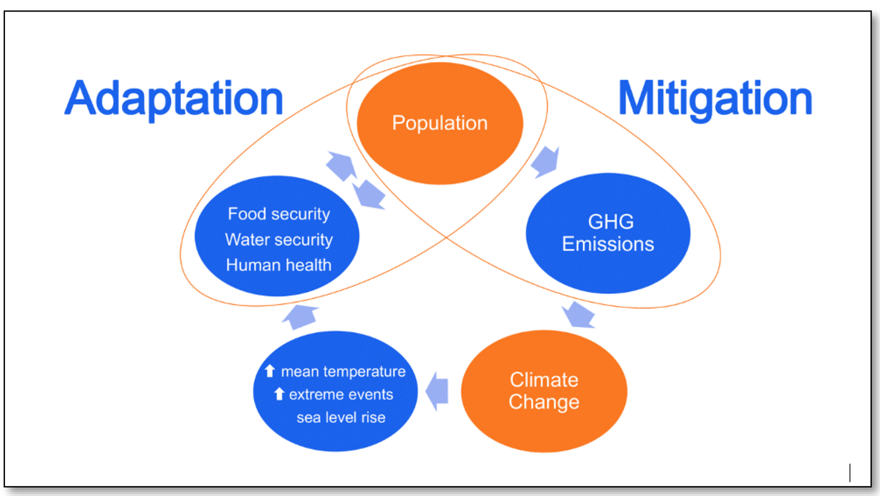

Figure 1: Major socio-economic sectors Vs. climate variability and change (Jenna, et al. 2020).

Climate change is defined according to the (United Nations Framework Convention, 1992) on Climate Change as "the change resulting directly or indirectly from human activities that lead to a change in the composition of the global atmosphere, which is observed at similar time intervals". The International plan of climate change (IPCC) defines climate change as "all forms of changes that can be expressed in a statistical description which can persist for decades, resulting from human activity or resulting from the internal interactions of the components of the climate system." Climate change is the result of both human activity and natural factors, and is characterized by continuity, as although its causes are immediate, its negative effects will continue for the future generations (Wassem, 2020;Conrad, et al. 2019).In summary, climate change is a change in the climatic characteristics of the Earth as a result of the current increases in the concentration of gases generated by combustion processes in the atmosphere, due to human activities and natural factors that raise the temperature of the atmosphere, and these gases include: carbon dioxide methane, nitrogen oxides, and chlorofluorocarbons (Sarhan, 2015).

The Arab region will be the region most vulnerable to the potential effects of climate change, because it includes the driest regions in the world, and about 75% of the cultivated areas depend on rain-fed agriculture. The amount of rain in it, especially in the Arab East, will decrease by 10-30% during the next fifty years, with variation in its distribution and intensity. The frequency and intensity of drought cycles will increase, temperatures will increase, and the rate of water loss by evaporation-transpiration will increase, the productivity of crops grown in rainy areas in the Arab world will decrease by about 50% by 2050 (Hussain, 2007).Therefore, the sensitivity of agriculture to climate change has become an important area of research in the current era, where 20% of the damage caused by climate change is expected to occur in the agricultural sector at the global level (Younes and Nidhaleddine, 2014). Tawfiq, showed a relationship between the achieved production and the cultivated areas of the various crops grown in the study area, with significant differences between the linear relationships (Tawfiq, 2015) .

The Normalized Difference Vegetation Index (NDVI) is one of the most widely used indicators of photosynthetic activity in urban ecology (UNESCO, 2020). The NDVI (Normalized Difference Vegetation Index) is computed as the difference between near infrared (NIR) and red (RED) reflectance divided by their sum, a basic indicator of photosynthetic activity frequently employed in landscape and urban ecology (Stefano, et al., 2010; UNESCO, 2020).

$$\mathcal{NDVI} = \frac{\mathcal{NIR}-\mathcal{RED}}{\mathcal{NIR}+\mathcal{RED}}$$ (1) (Rouse, et al, 1974)

However, the high-resolution determination of NDVI requires an expensive multi-spectral digital camera. Low NDVI values indicate moisture-stressed vegetation and higher values indicate a higher density of green vegetation. It is also used for drought monitoring and famine early warning NDVI is the difference between near infrared (NIR) and red (RED) radiations emitted by vegetation divided by its sum (Hussain, 2007). Remote sensing technology has been used to get information ,when in situ data could not be obtained from the operational institutions of the study area. Remote sensing is as an art and science of obtaining information about an object or feature without physically coming in contact with that object or feature. And it is the process of inferring surface parameters from measurements of the ELECTROMAGNETIC RADIATION (EMR) from the Earth’s surface. This (EMR) can either be reflected or emitted from the Earth’s surface. (Anselm and Taofeeq, 2010)

Study area

Al-Muwaffaqiyah sub-district Figure (2), is one of the sub-districts of the district of (Al-Hayy) in Wassit Governorate in Iraq, on the western side of the Al-Gharraf River and to the north of (Al-Hayy) at a distance of 20 km and south of Al-Kut by about 25 km and bounded to the west by the Al-Bdeir district in Al-Diwaniyah governorate. And it is located in (32.26°N , 45.92°E) with (52234(population(According to the statistics of the Iraqi Electoral Commission / 2018) .about (34374 capita) live in rural area and it's divided into 17029 females and 17345 males with a population growth rate of about 3% / year., most of them working in agriculture and animal farming. The most of community in the city is Arab origin. The area is the ancient regions and it was considered one of the important places in Wassit Governorate Known for producing wheat and barley. The people are also famous for working in agriculture and animal farming, the living standard for the population ranging from poor to middle. From the southwest, it is adjacent to Al-Fajr sub-district of Dhi Qar governorate. The area of this district is about (1108) km2 (based on the calculation of remote sensing) .It is also one of the important places in Wassit Governorate due to its agricultural capacity.

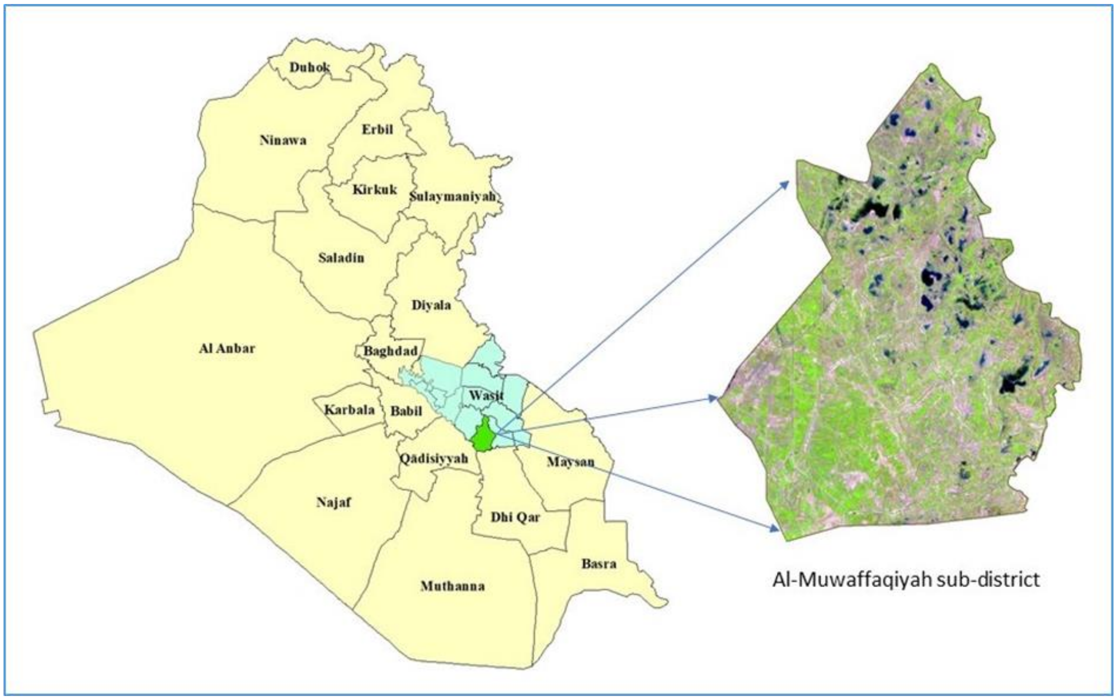

Figure 2: Study area: Al-Muwaffaqiyah sub-district

Methodology and Tools

The methodologies of this study shown in Figure (3) using a new approach to assess the agricultural productivity under the effective climatic factors changes (temperature, precipitation and humidity) and from other hand assessing of the vegetative cover and the same climatic elements for the same two-decade study period., than clarify , the similarity of the two process results., using;

a) A) Agricultural productivity data: Agricultural productivity data for the previous two decades were obtained from the Wasit Agriculture Directorate and from the Grain Marketing Center in Wasit.
b) Climate parameters value; obtaining data for climate elements used in research and for the past two decades from the NASA website and weather station.
c) Calculate NDVI; Vegetation Cover: Digital satellite images were obtained for the purpose of calculating the vegetation cover index.
d) Computers programing; Using of GIS v10.7 to indicate the vegetation cover index and assess the distribution of vegetative cover for the previous two decades with the correction

and processing of missing data by satellites, and using of Microsoft Office / Excel for numerical calculations for the results of productivity analysis and the results of the vegetation index.

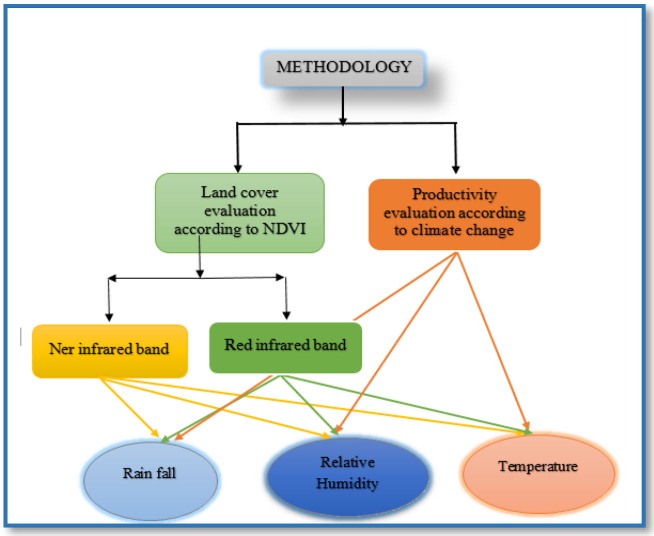

Figure 3: The study Methodology.

Results

A. Productivity evaluation according to climate change

The productivity of agricultural dunums (kg/acres) for the strategic winter crops (Wheat& Barley) were tracked according to the change in the important climatic factors (Temperature, Relative Humidity, Rainfall) over the past two decades (2000-2020). The study was divided according to these factors which was obtained from SWAT website and World Bank, Figure (4), vs. Agricultural production data according to the records of Wassit Agriculture Directorate and Wassit Trading Directorate, Table (1). Maximum and minimum temperatures were tracked and the average was adopted for evaluation purposes. The average of the studied climatic factors that were adopted for the most famous winter agricultural season in Iraq for the cultivation of wheat and barley crops from October to April.

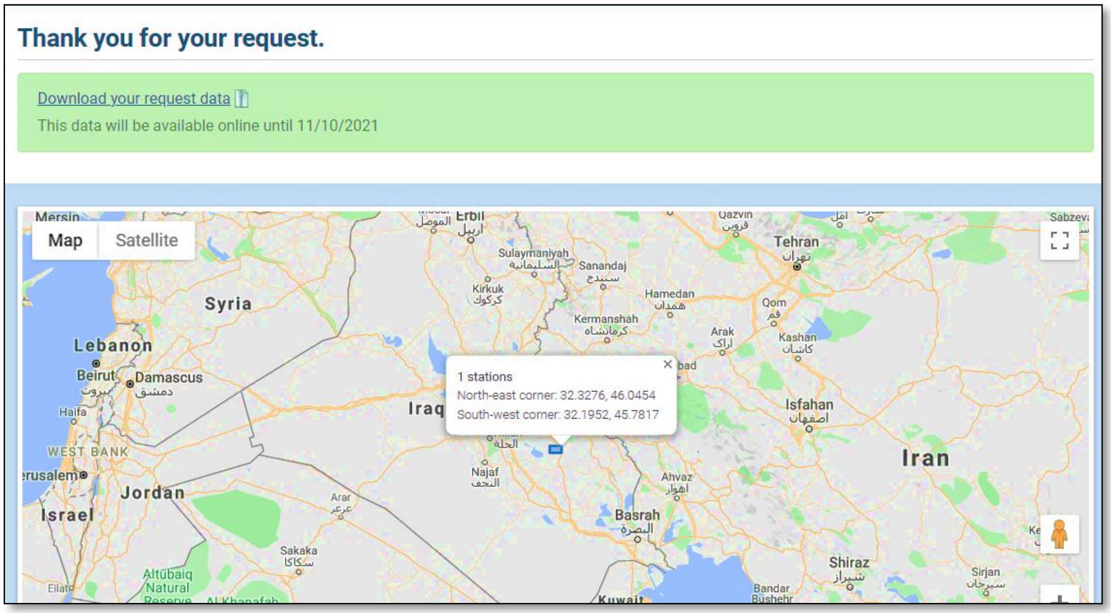

Figure 4: SWAT website historical climate data.

Table 1: Climate parameters Vs crop productivity

Year	Temperature. °c			rain (mm)	RH %	Crop productivity (kg/acres)	
	Max.	Min	Avr.			Wheat	Barley
2000	25	11	18	17	22	329	132
2001	27	12	19	15	21	388	259
2002	28	13	21	16	22	190	209
2003	28	13	21	16	21	230	12
2004	26	12	19	20	21	255	121
2005	26	11	19	16	21	363	141
2006	25	12	18	23	21	421	167
2007	25	11	18	15	21	245	173
2008	26	11	18	11	21	497	57
2009	26	12	19	13	16	473	299
2010	28	13	20	11	11	551	213
2011	25	11	18	13	17	655	321
2012	25	12	18	15	14	585	254
2013	26	11	18	16	17	643	126
2014	25	12	18	13	14	750	486

2015	26	12	19	12	23	689	552
2016	26	12	19	19	8	714	757
2017	25	11	18	12	15	865	723
2018	26	13	20	22	15	718	445
2019	24	10	17	26	25	517	500
2020	24	11	17	26	12	729	500

1. Temperature (T):

Mean annual temperatures have risen across Iraq since the 1950's at a rate of 0.7 (°C / century) as shown in Figure (5).

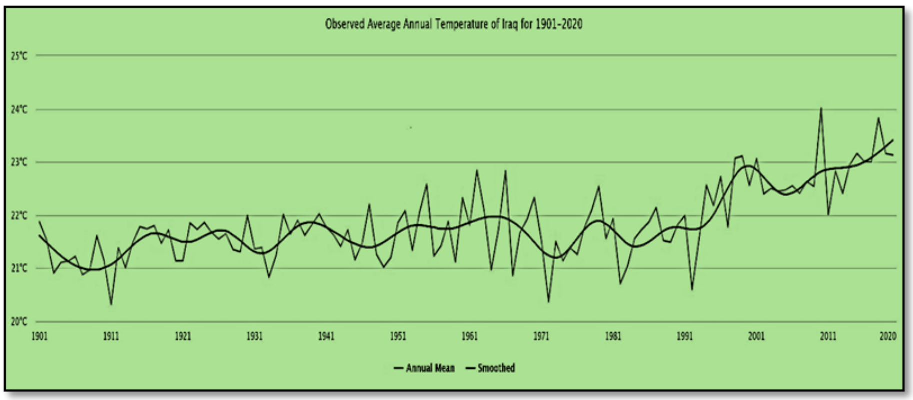

Figure 5: Mean annual temperatures

For the wheat crop, Figure (6) showed how the fluctuation of wheat crop productivity (kg/acres)/year with the change in temperature (c°) during agriculture annual winter session.

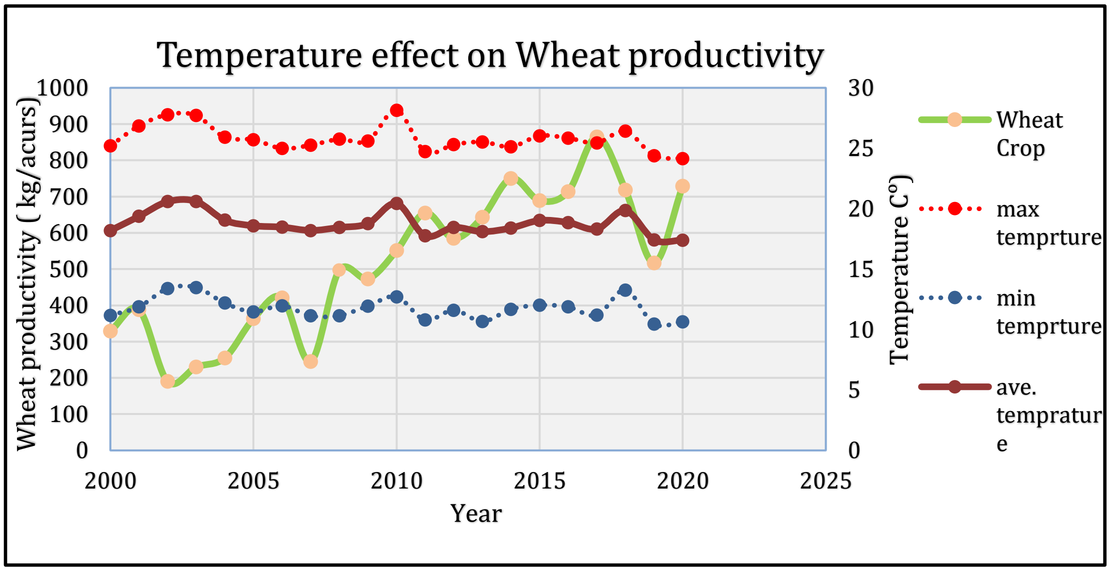

Figure 6: annual temperatures Vs. wheat crop productivity (kg/acres)/year.

For the Barley crop Figure (7) showed how the fluctuation of Barley crop productivity (kg/acres)/year with the annual change in temperature (c°) during agriculture annual winter session.

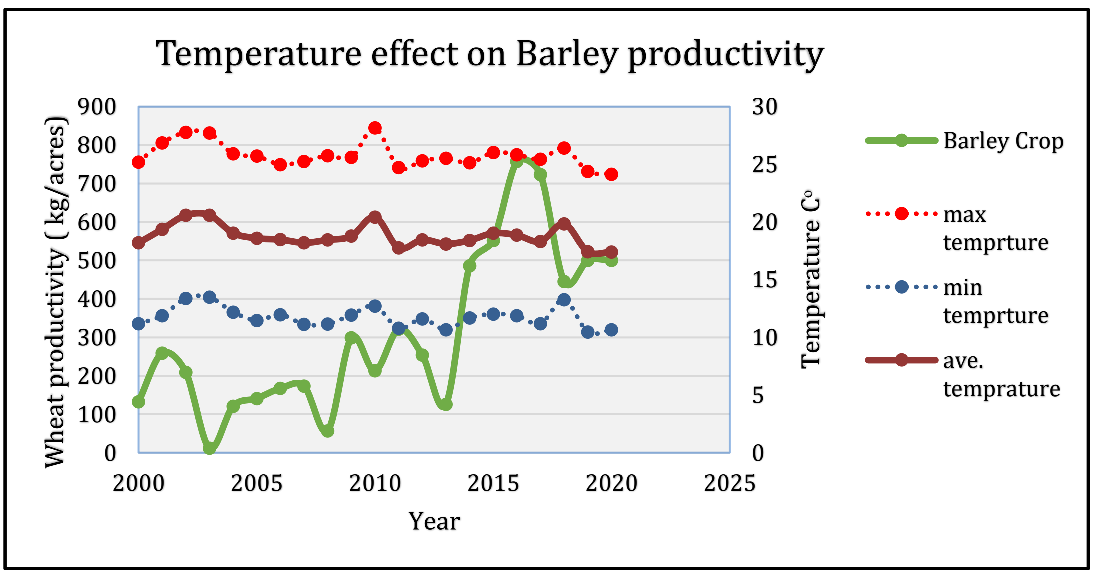

Figure 7: annual temperatures Vs. Barley crop productivity (kg/acres)/year.

2. Rainfall (R)

For the period 1951 to 2000, the nearest station precipitation records for the northeast of Iraq show an increase of 2.4 mm/month per century, while the nearest station records for the southeast indicate a decline of only 0.88 mm/month per century. The nearest station record to the west indicates a decline of 5.93 mm/month per century as shown in Figure (8).

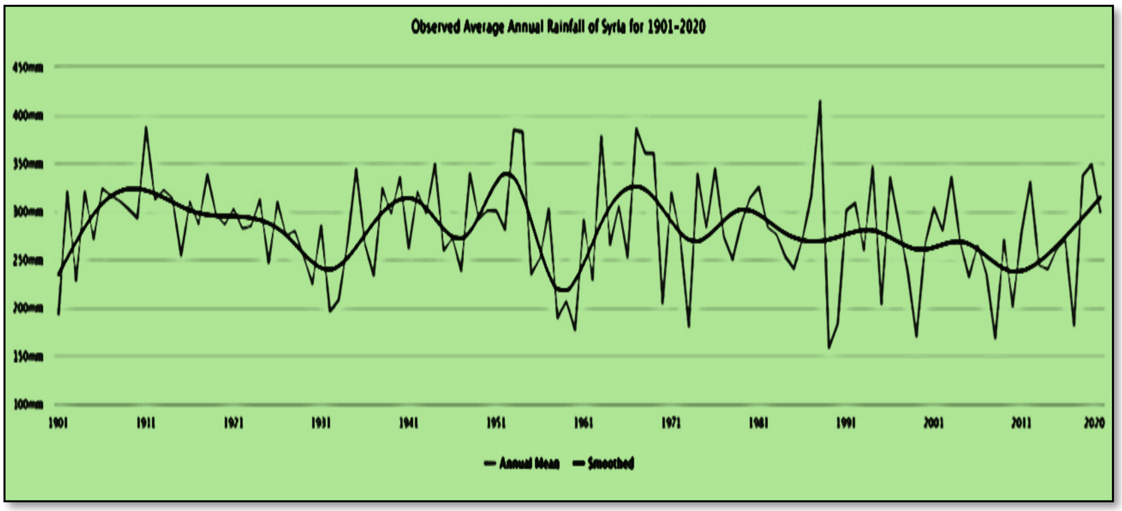

Figure 8: Mean annual precipitation

For the wheat crop, Figure (9), showed how the fluctuation of Wheat crop productivity (kg/acres)/year with the change in precipitation rate (mm) during agriculture annual winter session.

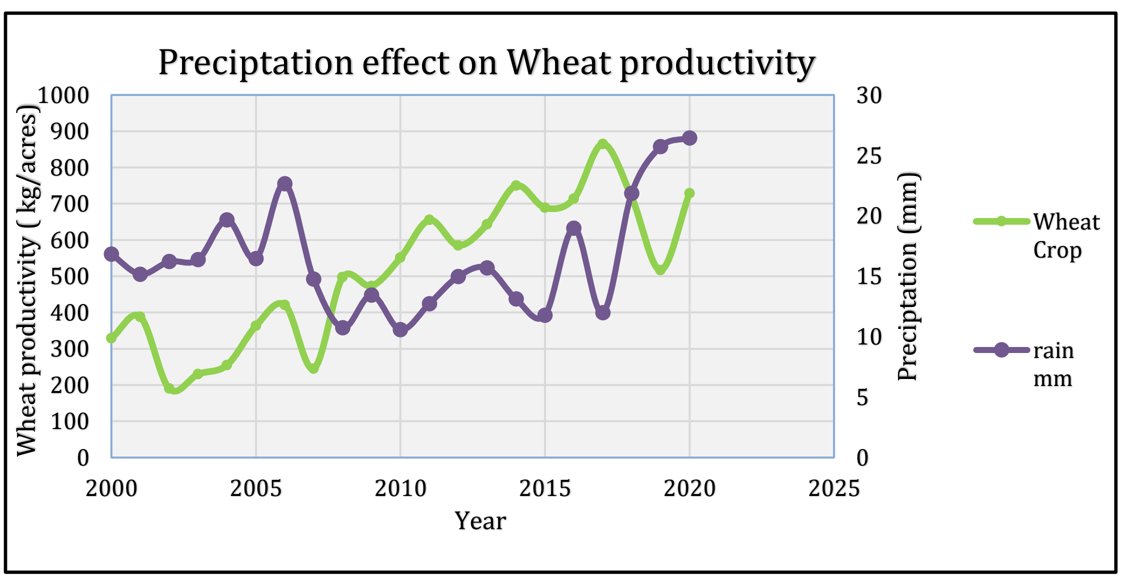

Figure 9: Mean annual precipitation Vs. Wheat productivity (kg/acres)/year.

For the Barley crop, Figure (10) showed how the fluctuation of Barley crop productivity (kg/acres)/year with the change in precipitation rate (mm) during agriculture annual winter session.

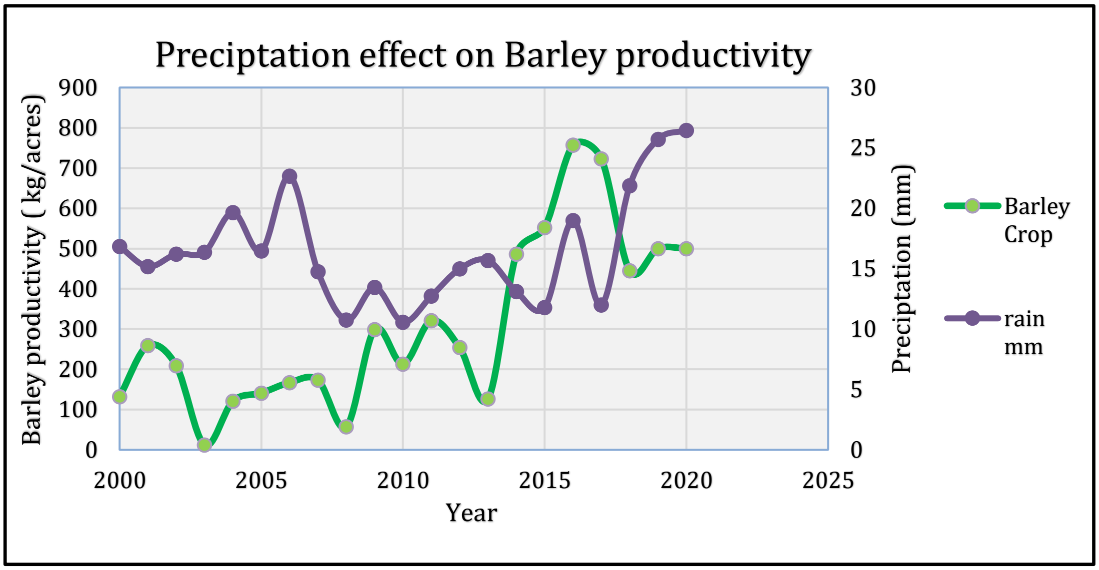

Figure 10: Mean annual precipitation Vs. Barley crop productivity (kg/acres)/year.

3. Relative Humidity (RH);

Figures (11, 12) represent the fluctuation of the Wheat and Barley productivity (kg/acres)/year achieved for the winter season according to the relative humidity changes for the study period.

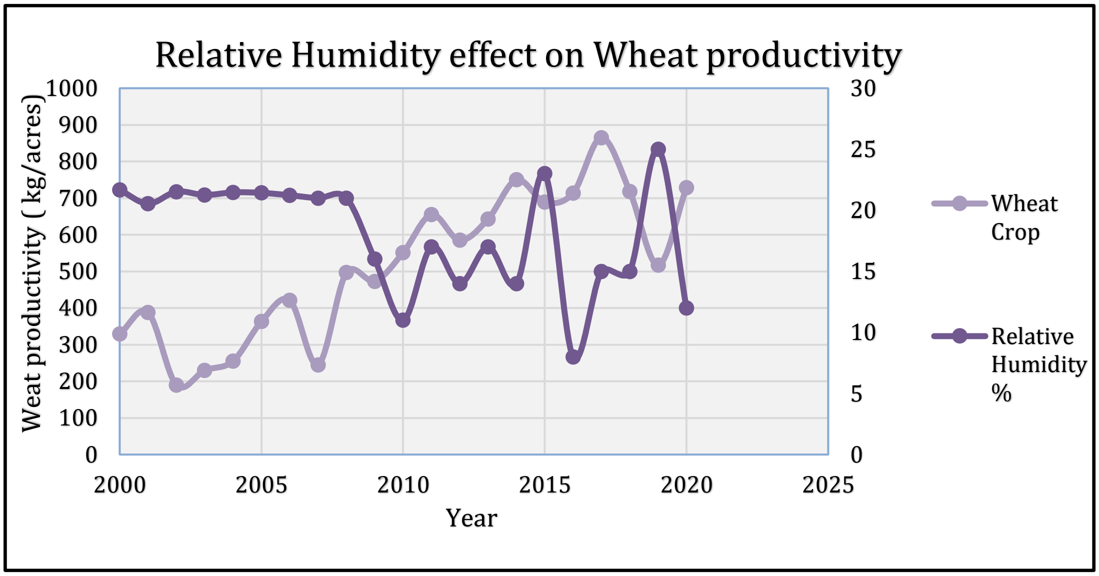

Figure 11: Mean annual Relative Humidity (mm) Vs. Wheat crop productivity (kg/acres)/year.

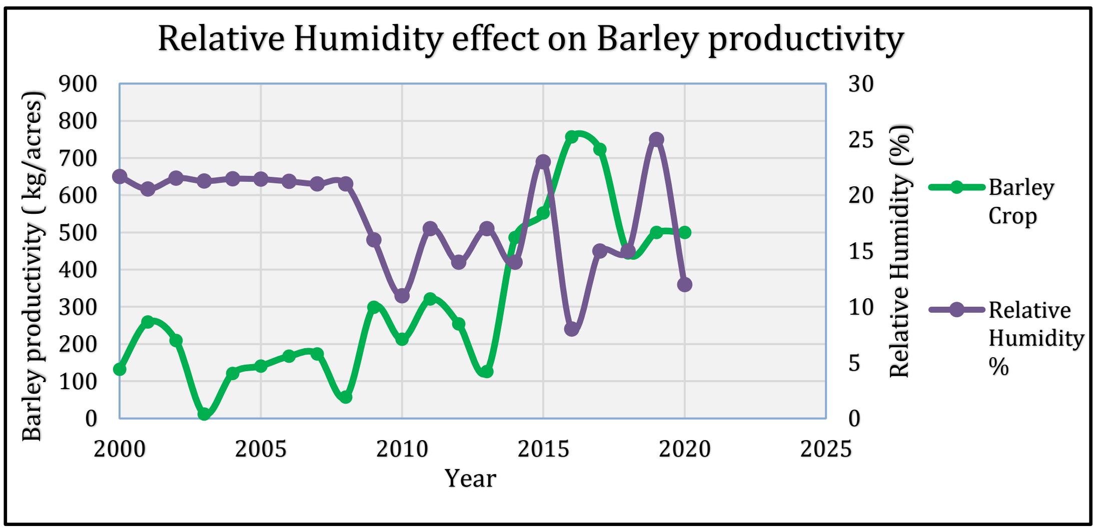

Figure 12: mean annual Relative Humidity (mm) Vs. Barley crop productivity (kg/acres)/year.

B. Land cover evaluation according to NDVI

The values of the vegetation cover index recede between (+1 for green areas to -1 for desert areas). In this study, (analysis multi temporal NDVI) was applied by using satellite images for the years (2000, 2010, 2020) respectively by applying an equation on the raster calculator within Arc Toolbox for calculating the change in vegetation cover. The formula includes calculating NDVI based on the bands of the red and near red regions, which give a clear distinction to the vegetation cover. The reflection of red and near red rays is much greater than other beams due to the structure of plant cells, so it is included in the NDVI calculation equation. Infrared (0.96-0.63) is one of the most important ranges, as it can distinguish between types of vegetation cover and also well to show the boundaries of soil types and pictures of geological formations. Nerinfrared (0.90-0.76) shows the reflection of the quantities and density of plants, distinguishes them from soils, and it shows the boundaries of water areas. NDVI was calculated after acquiring the landsat-7 ʾs satellite images of the ETM+ sensor and using the GIS V.10.7 program to perform some digital processing operations necessary for this study:

1- Deduction of satellite images

2- Merge satellite packages

3- Correcting distorted images

4- Re-categorize photos

5- Calculation of the area of vegetation cover NDVI

Figures (13, 14 and 15) present NDVI for Al-Muwaffaqiyah sub-district (winter session (before harvest /2000)), winter session (before harvest /2010) and winter session (before harvest /2020)) respectively.

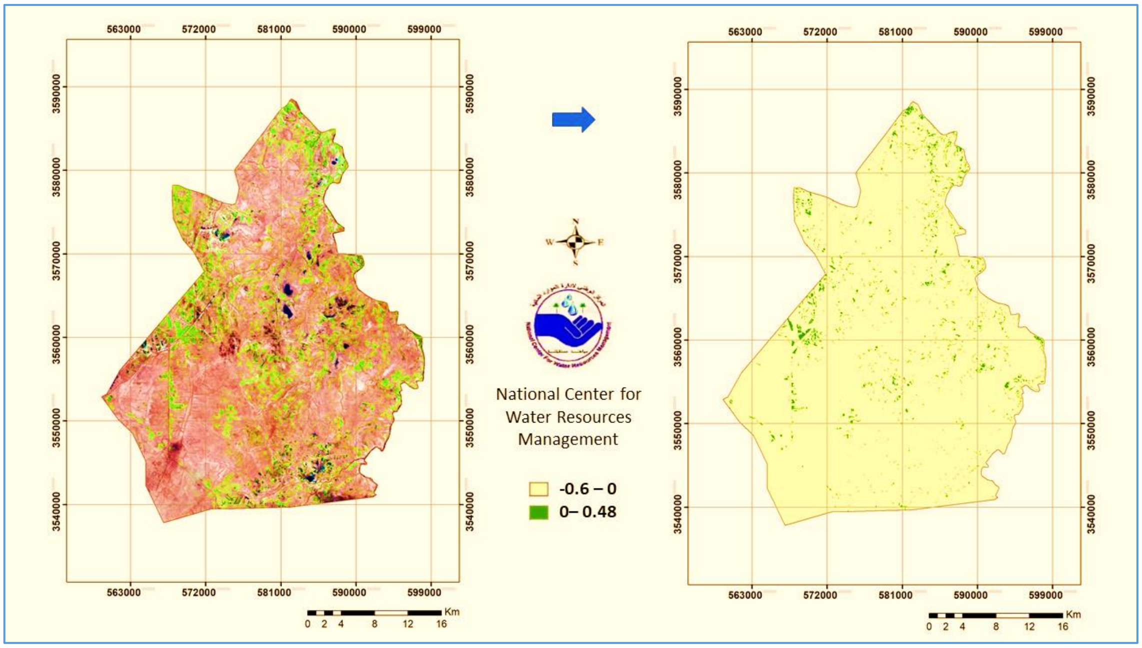

Figure 13: NDVI for Al-Muwaffaqiyah sub-district (winter session (before harvest /2000))

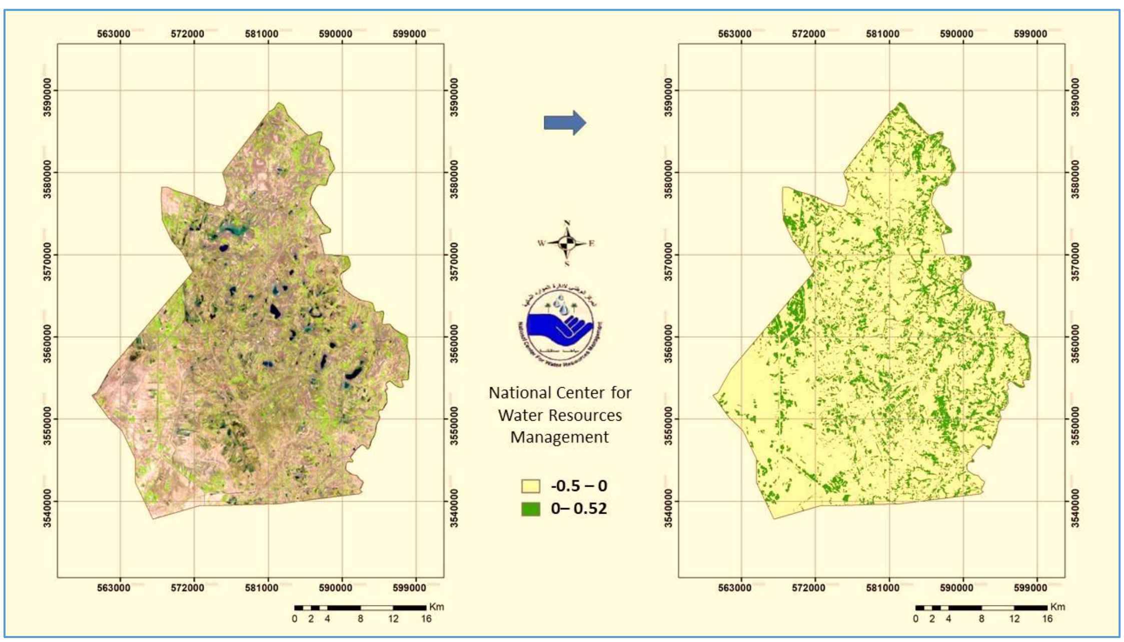

Figure 14: NDVI for Al-Muwaffaqiyah sub-district (winter session (before harvest /2010))

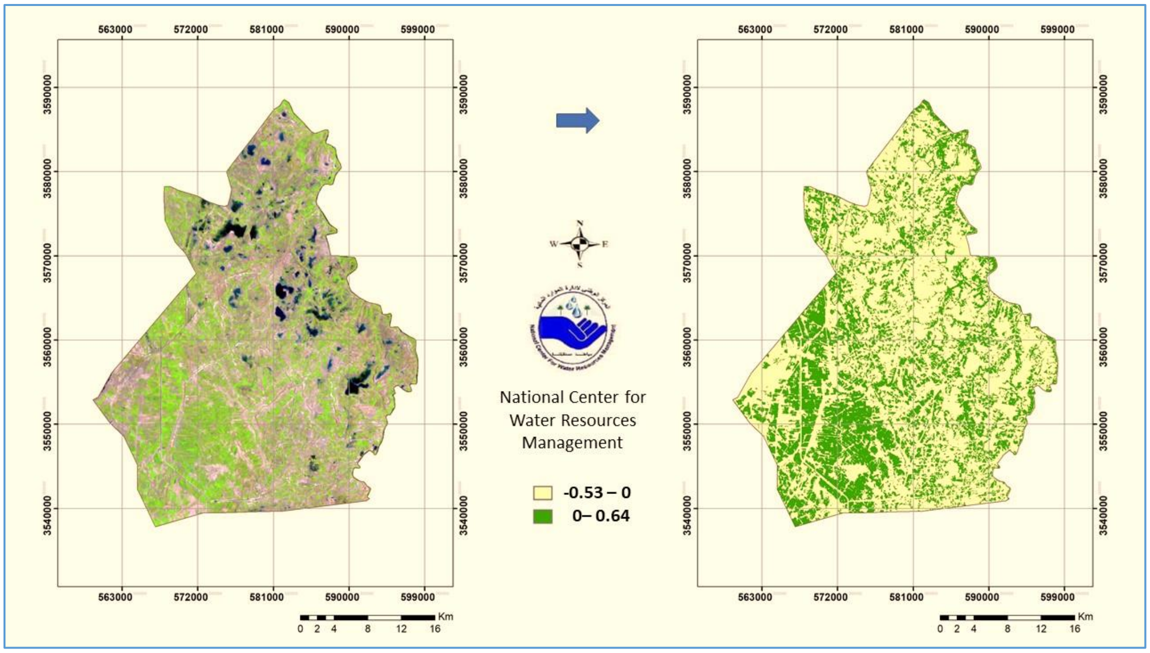

Figure 15: NDVI for Al-Muwaffaqiyah sub-district (winter session (before harvest /2020))

Table (2) listed the mean of study climatic parameter obtained and the green coverage area from satellite images for the shown years.

Table 2: The NDVI and Green cover area V_S the decade average (temperature, precipitation and relative humidity)

Decade	2000	2010	2020
NDVI	(-0.6) – (0.48)	(-0.5) – (0.52)	(-0.53) – (0.64)
Area (km2)	123	216	389
Temperature (c°)	29	33	29
Precipitation (mm)	17	11	26
Relative humidity (%)	22	11	12

Temperature Vs Green coverage area

The expected release from temperature limitation under future warming highlights the importance of non-temperature limitations in mediating ecosystem responses to future climate change (Trevor and Riley,2018). Figure (16) indicates analyses relationship between change in temperature since last two decades Vs green coverage area for the study area.

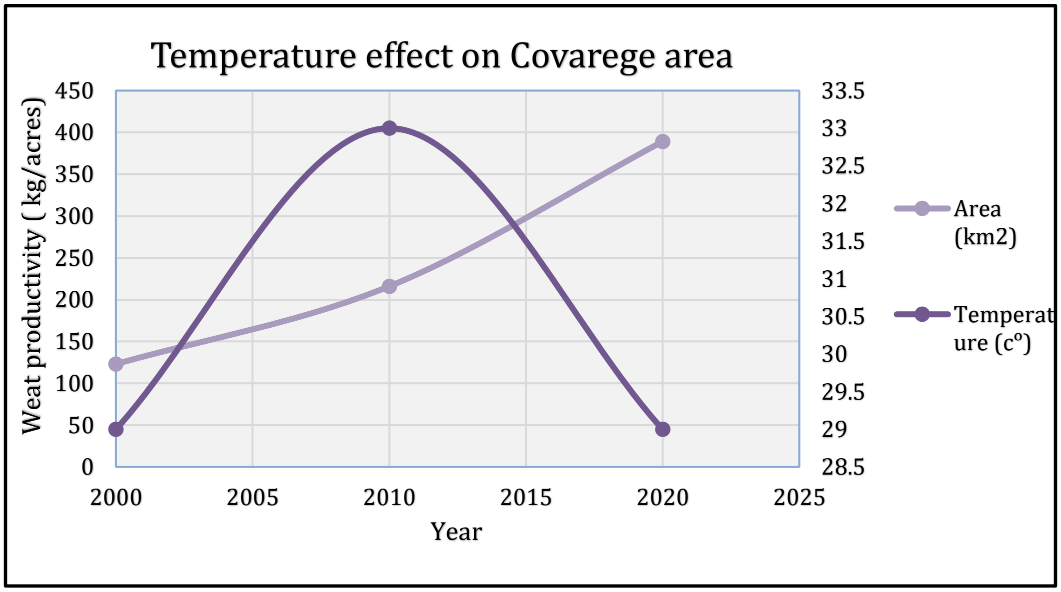

Figure 16: Temperature Vs Green coverage area

Precipitation Vs Green coverage area

The links between forests and precipitation gained prominence in the scientific community during the second half of the nineteenth century and again during the past three decades. The popularity of links between forests and rain has coincided with societal and scientific interest in anthropogenic climate change and deforestation. Theories linking forests to precipitation reached a peak in the 1850s and 1880s, a period in which scholars expressed concern that deforestation caused a regional decline in rainfall (Brett and Gregory, 2013). Figure (17) indicates analyses relationship between changes in temperature since last two decades Vs green coverage area for the study area. Which is intersect with the above study due to external corruption issues) Corruption in marketing and transgression of the agricultural plan).

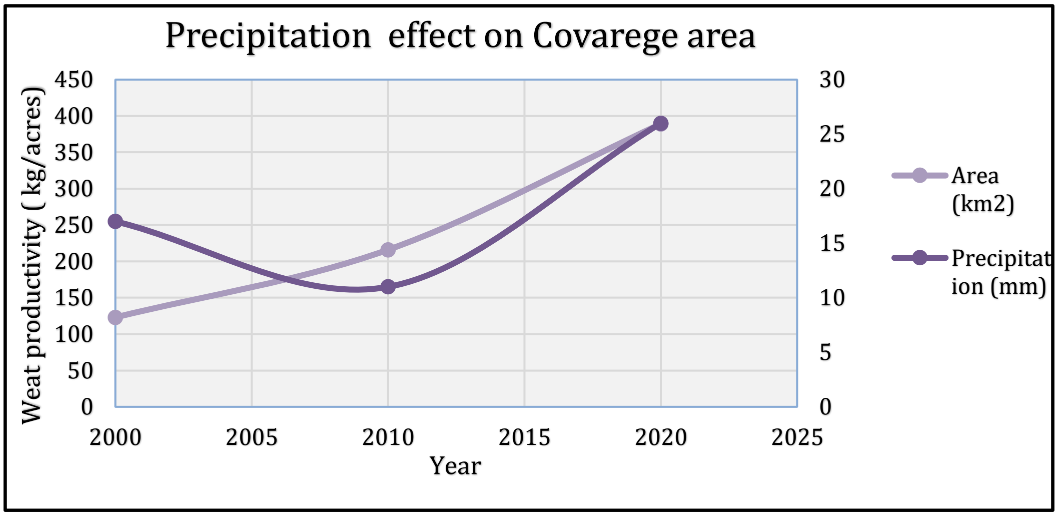

Figure:17 Precipitation Vs Green coverage area

Relative humidity Vs Green coverage area

Relative humidity is the amount of water vapor saturation of the air, as it is the ratio between the vapor that is actually in the air and the vapor necessary for its presence until the air reaches the point of saturation at a certain temperature, which is measured in percentage. Relative humidity affects other climatic factors (the amount and quality of precipitation, wind dryness, and temperatures), and therefore it affects the spatial distribution of plants and vegetation cover (Inam, 2021). Figure (18) indicates analyses relationship between changes in Relative humidity and its reflection on green coverage area for the study area.

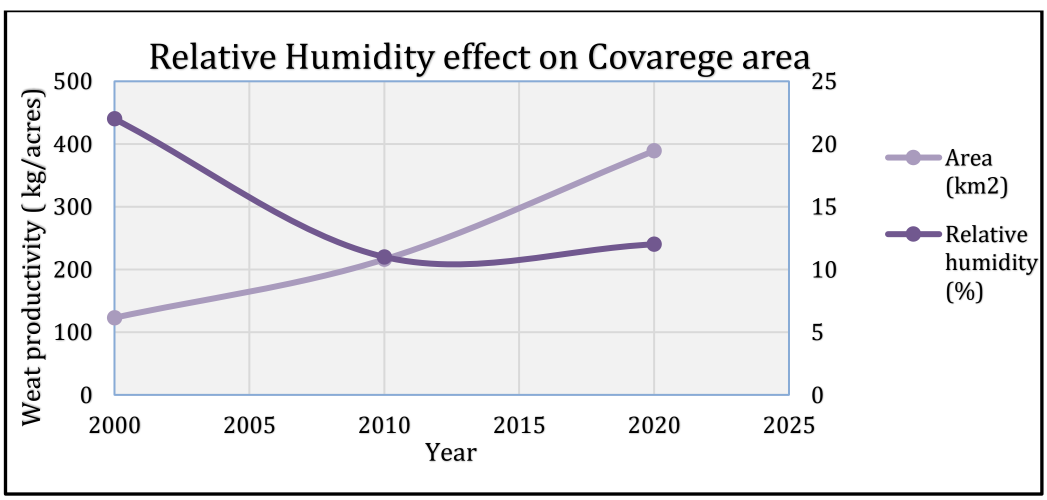

Figure 18: Relative humidity Vs Green coverage area

Results and Discussion

Globally, climate change (CC) is the most serious environmental threat that adversely affects agricultural productivity (TNAU,2021).There are many references that showed the relationship between temperature and agricultural production, At lower latitudes, especially in seasonally dry and tropical regions, crop productivity decrease for even small local temperature increases (1-2°C) (Jian et al., 2019 ; OCED, 2015) Crop yields show a strong correlation with temperature change and with the duration of heat or cold waves, and differ based on plant maturity stages during extreme weather events (Tamiru and Fekadu,2019), but as shown in Table 1, this study doesn't recognize a certain relationship between them Which may be due to dramatic external reasons such as :-

- Availability of surface water in the study area.
- Exceeding the cultivation of crops in areas outside the agricultural plan to ensure higher yields and therefore a greater financial return. Taking into account that planting areas outside the plan means consuming more water than the prescribed share, and thus maximizing the effects of climate changes.

Mensah shows that the direct impact of monthly rainfall on agriculture for instance. In the absence of that, average yearly major and minor rainfall amount will also provide enough basis for assessing the effect of the variability on crop production in each CAD (Climate Assessment Decade) (Conrad et al., 2019).This study found a relationship between the change in precipitation and crop is consistent with what was stated in most scientific sources, where the spatial distribution of the density and quality of agricultural crops is related to the intensity of rainfall until the year 2015, when the randomness of the relationship began to appear and for the same second reason mentioned in the temperature discussion paragraph above.

Relative humidity (RH) directly influences the water relations of plant and indirectly affects leaf growth, photosynthesis, pollination, occurrence of diseases and finally economic yield. Very high or very low RH is not conducive for high grain yield. Under high humidity. The yield reduction was 144 kg/ha with an increase in one percent of mean monthly RH. Wheat grain yield is reduced in high RH. It can be attributed to adverse effect of RH on pollination and high incidence of pests. On the contrary, increase in RH during panicle initiation to maturity increased grain yield of sorghum under low humidity conditions due to favorable influence of RH on water relations of plants and photosynthesis. With similar amount of solar radiation, crops that are grown with irrigation gives less yield compared to those grown with equal amount of 'water as rainfall. This is because the dry atmosphere, which is little affected by irrigation, independently suppresses the growth of crops (Conrad et al., 2019). The dryness of the atmosphere as represented by saturation deficit (100%RH) and reduces dry matter production through stomatal control and leaf water potential. The analysis of the results of this study showed a direct inverse relationship with relative humidity, as the relative humidity is affected by the amount of transpiration of plants, and the increase in transpiration is a reflection of the increase in plants.

After calculating the (NDVI) values, which range between (-1) for the deserted area and (+1) for the full green cover area, and using the Landsat7 satellite imagery (ETM +) for the years 2000, 2010 and 2020, respectively, and using the program (GIS v10.7.) By applying the raster data calculation equation within the Arc Tool Box, it was found that the results obtained from the assessment of monitoring change in climate elements with productivity are very similar.

Conclusions

- Al-Muwaffaqiyah lands are located within the irrigation limits of the Gharraf River, and since there is a future reclamation project for these lands, it became necessary to establish a hydrological and environmental monitoring and control station covering this important agricultural area.
- Preparing a site study in conjunction with the beginning of an agricultural season, taking into account all variables (type of grain, type of fertilizer, water incomes, climatic conditions, marketing integrity, etc.) to indicate productivity and compare it with the productivity of extreme and normal climatic years for previous seasons or according to a period proposed by specialists .
- Governments' programs should being closer to reality and made participatory in structure for effectiveness in agricultural adaptation to climate change.
- There should be an explicit national agricultural research policy framework to provide a conducive environment for continuity and effectiveness in agricultural programmers/projects
- Preparing the same study on another agricultural area and comparing the results to show the effect of soil type simultaneous with climatic changes on vegetation cover.

- Preparing a hydrological model that simulates the impact of climatic changes on the area of vegetation through multiple scenarios of operation according to the variables that can be controlled, in order to be one of the tools for the integrated operation of the water source in the region
- Since the grains are shallow-rooted, greedy for nutrients and water from the surface layer, therefore, specific conditions for seasonal cultivation must be followed and not to continue cultivation every season because this reduces productivity.
- Establishing mechanisms for intersectional coordination and raising awareness on climate change adaptation production and food security issues.
- Develop and implement climate adaptation strategies that improve productivity, profitability efficiency and the principle of justice in agricultural production and marketing systems.
- Using remote sensing and GIS to monitor climate deterioration and follow up on its changes and its impact on the quantity and quality of agricultural crops, and the adoption of images provided by satellites with an accuracy of less than (30m) to provide a more accurate control of the influence of anaerobic factors at different wavelengths.
- Encouraging the cultivation of crops that are resistant to climate change.

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