ISSN: 2716-9227 Algerian Journal of Engineering and Technology 08 (2023) 001–013 e-ISSN: 2716-9278

Algerian Journal of Engineering and Technology

Journal homepage: https://jetjournal.org/index.php/ajet

Original Article

Drought Analysis of Wheat in Humid (Wales) and Dry (Iraq) Conditions

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ARTICLE INFO

Article history:
Received 30 June 2022
Revised 26 July 2022
Accepted 20 August 2022

Keywords:
Drought Index;
Wheat crop;
Agricultural drought;
Iraq;
Wales.

ABSTRACT

It is necessity to examine the relationships between droughts and plant yields, which are affected by climate change. In this study, by choosing sample countries from the Middle East and Northern Europe, It was aimed to determine the relationship between wheat yields and drought. Considering that Wales represents the wet conditions and Iraq represents the dry conditions in the World, in this study, the drought conditions of these two countries were analyzed with standard precipitation index (SPI), standard runoff index (SRI) and palmer drought severity index (PDSI). In Cardiff, it was determined that the meteorological humidity increased and there is a normal climate in terms of hydrologic. This led to an increase in wheat yields. In terms of meteorologic drought, Iraq cities from arid to humid are Kirkuk, Mosul, Baghdad and Basra, respectively. Agriculturally, they are listed as Basra, Baghdad and Mosul, respectively. It was determined that wheat yield decreases in Iraq were caused by non-climatic factors. Generally, it was determined that drought periods spread homogenously throughout Iraq. Nevertheless, It is determined that drought is much more widespread and severe in Iraq in 2003, 2004 and 1964. In future dry years, production should be supported with irrigation and fertilization in Wales and Iraq.

1. Introduction

Agriculture is the main sector in feeding society and struggle famine. Especially, wheat is the one of important agricultural crops. Climate change may adversely affects agriculture (and wheat yield) as it causes drought and flood [2]. Agricultural product losses due to climate change (drought and flood) should be kept at a minimum level. There are some countries in the world that are sensitive to climate change. Iraq and Wales are some of the countries that will be affected by climate change. Iraq is important in terms of drought because it is one of the dry regions in the Middle East, and Wales is important in terms of flood because it is one of the humid regions in Europe [3, 8, 13, 19]. The mainly way to identify dryness and humidity is to use drought index. In these countries, meteorological, hydrological and agricultural droughts were determined by standard precipitation index (SPI), standard runoff index (SRI) and Palmer Drought Severity Index (PDSI), respectively. For this purpose, some important arid cities (such as Kirkuk, Mosul, Baghdad, Basra) of Iraq were examined. And, representing wetland conditions, the Welsh Taff River basin was examined.

A lot of research was conducted on drought and wheat in Wales. Richter and Semenov [17] evaluated the impact of climate change on drought and yield of winter wheat in Wales (and England). They used Sirius crop model to assess the effect of changing climate on maximum soil moisture deficit (SMDmax), potential yield and wheat yields. Using climate scenarios and Hadley Centre Climate Model (HadCM2), the climate was predicted for the base (1960–1990) and future (between 2020s and 2050s) period. As a result, average wheat yields are expected to increase by 15–23% (between 1.2 and 2 t/ha) by the 2050s.

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Peer review under responsibility of University of El Oued.

 DOI: https://doi.org/10.57056/ajet.v8i1.80

Moreover, in Wales, from 1960 to 2010, the climate went to from arid to humid in terms of meteorological.

Cole and Marsh [8] investigated the drought from 1800 to 2000s in Wales (and England). Over 30 important droughts were identified over the 200 year period. 1798–1805 and 1890–1909 period are examples of the major droughts.

Semenov [19] aimed to analyze changes in the patterns of two parameters for wheat: heat stress for flowering and the severity of drought stress. To compute these parameters, he used a wheat simulation model at 18 points in Wales (and England) combined with climate scenarios and model. Although higher temperature and lower summer precipitation in the UK for the 2050s, the impact of drought on simulated wheat yield is predicted to be smaller than that at present.

Wheat yield of 20 t/ha in the United Kingdom generally is aimed. Potential yield can be predicted from the annual total solar radiation and harvest index. The potential yield of wheat was 12–14 t/ha for annual solar radiation 3300–3800 MJ m^{-2} in United Kingdom [16].

A lot of research was conducted on drought and wheat in Iraq. Yenigun and Ibrahim [23] made drought analysis in the north Iraq by using the SPI. Rainfall data of 15 stations of the northern Iraq from 1979 to 2013 were used to observe the drought. As a result, drought persistence in the 6, 9 and 12 month periods was higher than in the 1 and 3 month periods. Moreover, the driest year was in 2008 and a meteorological drought was experienced in Kirkuk between 1998 and 2010.

During 2007-2012 period in Baghdad and Basra, during 1998-2001 and 2007-2010 periods in Mosul and Kirkuk, severe meteorological droughts were experienced [13].

Ahmad et al. [1] used SPI and Modified Mann-Kendall test to assess meteorological drought at 11 points for 2000-2014 period in Northern Iraq. As a result, correlation coefficient (0.64-0.87), BIAS (1.05-1.81), Nash-Sutcliff efficiency (0.39-0.55) were determined for SPI.

Severe droughts in northern Iraq were experienced between 2006 and 2010. In terms of meteorological drought in Iraq, the driest year between 1970 and 2010 was 2008 (and 2011). In addition, the driest periods in this term, it happened during 1997-2001 and 2007-2010 periods. The period 1950-2010 for all region of Iraq, when evaluated in terms of agricultural drought, drought was seen in 85% of the country in 1998 and 2008 [1]. Jasim and Awchi [13] used the SPI and aimed to analyze meteorological drought in Iraq for 1970–2013 period using rainfall data obtained from 22 points all over Iraq. As a result, according to the SPI, the majority of the droughts were of the mild drought class with percentage of 33.4%. Lastly, the highest drought rates examined the northeastern Iraq.

Northern Iraq is located in extremely arid area. According to SPI result, severe meteorological drought were experienced in the north of Iraq in 1999, 2000, 2008, 2009, and 2012. In Kirkuk, meteorological drought was experienced during 1998-2000 and during 2007-2015 periods [3].

This study is important because it examines the drought conditions in different climates in terms wheat yields. In this study, it is aimed to examine the drought conditions of Iraq, which is close to the dry Mediterranean basin, and Wales, which represents a humid climate. Wheat yield were also examined for the interpretation of drought index results.

2. Materials and Methods

2.1. Material

Climate data of Iraq (Baghdad, Basra, Kirkuk and Mosul) and Wales, and Wheat crop (yields) were used as materials.

Precipitation data between 1961 and 2011 were used in the four Iraq cities to calculate SPI. Discharge data between 1931 and 1997 were used in the four Iraq cities to calculate SRI.

Precipitation and discharge data between 1966 and 1972 were used in the Cardiff (Wales) to calculate SPI and SRI.

Mean potential evapotranspiration (mean temperature) and precipitation data between 1961 and 2011 were used in Iraq to calculate PDSI. Besides, wheat yields data between 1961 and 2011 were used and were produced correlation graph between PDSI and wheat yield.

Features of the research area:

Iraq: 14% of Iraq is arable land. The country's average annual precipitation is 215 mm. In summer, temperatures can reach 46 ºC. 80% of the waters is used in agriculture in Iraq, 6% is used in domestic and 14% is used in industry. The Euphrates and Tigris rivers are the main rivers of Iraq. In the country, cereals, fruits, vegetables and legumes are the main agricultural products. North Iraq has poplar-oak-willow trees, and the South of the country has desert areas [14].

Wales: Wales has the surface area as 8.5% of United Kingdom and has the population as 5% of United Kingdom. Wales has many national parks, metal-coal mining industries. Taff is one of the most important rivers of Wales and Bala is one of the most important lakes. These are important water resourcesin Wales. The country has a maritime climate and has a population of 3 million. 12% of Wales is forested and 80% of Wales is suitable for agriculture. There are places in the country that receive more than 3000 mm (average annual total) precipitation [7].

The cities of Baghdad, Mosul, Kirkuk and Basra in Iraq (Figure 1a) and Cardiff city in Wales (Figure 1b) was investigated in terms of drought. The Precipitation Observation Stations (POS) in the study are the stations in these four city center of Iraq. The Discharge Observation Stations (DOS) in the study are the stations where the Tigris and Euphrates Rivers intersect these cities. In Wales, one POS and one DOS of Taff River in Cardiff city center were used. These POS and DOS points are indicated by blue dots in Figure 1.

Fig 1. The maps of Iraq (a) and Wales (b) (Cardiff)

Cardiff Taff River, whose data are used for Wales, its catchment area is 486.9 km^2 and its average flow is 21.373 m^3/sec. Between 1965 and 1972, the annual precipitation average is 146.31 mm and the annual flow average is 18.18 m^3/sec (Table 1 and Table 2).

Between 1961-2011, annual precipitation averages are 119.8 mm for Baghdad, 127.4 mm for Basra, 344.3 mm for Kirkuk and 361.4 mm for Mosul (Table 3).

Table 1. Precipitation data of Cardiff Taff (mm)

Hydrologic year	October	November	December	January	February	March	April	May	June	July	August	September	Year
1965-66	0.0	0.0	0.0	130.0	261.2	96.0	194.2	154.4	142.6	87.4	164.4	108.1	**111.5**
1966-67	200.1	143.7	321.7	177.7	264.1	99.8	67.5	251.2	42.7	156.1	118.0	231.1	**172.8**
1967-68	462.1	100.0	164.7	201.9	57.0	171.1	104.2	124.9	186.2	130.9	77.7	239.0	**168.3**
1968-69	249.7	142.4	150.7	248.6	89.7	95.5	108.2	174.8	111.1	79.5	144.8	91.4	**140.5**
1969-70	35.3	189.4	175.2	305.4	203.7	107.8	161.2	39.2	92.9	127.4	113.2	148.6	**141.6**
1970-71	195.5	334.5	102.4	312.8	82.1	114.5	67.4	76.4	158.6	67.3	236.4	39.7	**149.0**
1971-72	160.5	141.3	97.3	209.4	191.1	152.7	175.8	193.2	165.4	45.3	83.2	70.5	**140.5**

Table 2. Discharge data of Cardiff Taff (m^3/sec)

Hydrologic year	October	November	December	January	February	March	April	May	June	July	August	September	Year
1965-66	0.0	0.0	0.0	28.8	45.7	15.7	28.3	21.0	12.2	6.4	15.3	11.6	**15.4**
1966-67	19.4	15.9	41.4	29.6	35.2	20.2	10.9	22.8	7.2	7.9	12.5	12.5	**19.6**
1967-68	56.0	23.0	19.0	30.1	13.0	14.7	10.1	14.6	17.1	19.1	4.4	17.3	**19.9**
1968-69	32.1	26.3	28.0	38.5	16.1	13.9	10.9	17.5	10.7	5.4	9.7	5.9	**17.9**
1969-70	4.8	20.7	22.3	39.0	34.7	14.2	21.7	7.9	4.8	6.1	8.3	16.0	**16.7**
1970-71	13.2	53.6	22.1	39.3	20.2	15.8	7.9	5.7	12.9	5.6	21.5	5.8	**18.7**
1971-72	14.3	15.2	18.6	32.9	28.7	24.2	27.2	23.9	23.0	8.3	6.7	5.7	**19.1**

Table 3. Monthly mean precipitation in Iraq between 1961 and 2011 (mm)

	Monthly mean precipitation (mm)			
Months	**Baghdad**	**Basra**	**Kirkuk**	**Mosul**
October	4.03	4.68	12.06	12.97
November	11.22	14.06	38.73	41.44
December	18.89	24.71	57.94	59.12
January	26.64	31.16	67.59	62.38
February	19.21	18.55	61.71	60.11
March	18.04	17.09	53.74	59.79
April	18.75	14.32	45.56	46.26
May	3.97	3.55	16.57	17.79
June	0.05	0.07	0.17	0.94
July	0.00	0.00	0.16	0.13
August	0.00	0.20	0.03	0.03
September	0.19	0.06	0.58	0.46

When the monthly flow data in Iraq between 1930 and 2004 were analyzed, the highest flows were observed in April (Table 4).

Table 4. Monthly mean flows in Iraq between 1930 and 2004 (mm)

Monthly mean flows of Iraq (mm)		
Months	**Baghdad**	**Mosul**
October	1585.057	420.0282
November	1995.392	553.881
December	2545.427	751.2853
January	3246.031	949.4479
February	4381.416	1286.343
March	6136.479	1872.63
April	8031.327	2834.652
May	7937.073	2573.218
June	5028.538	1248.827
July	2748.367	1243.29
August	1901.274	461.3857
September	1565.269	373.5442

When the monthly evapotranspiration data in Iraq between 1961 and 2011 were examined, the highest values were found in Baghdad and Mosul in July, and were found in Basra in June (Table 5).

Table 5. Monthly mean potential evapotranspiration in Iraq between 1961 and 2011 (mm)

Monthly mean potential evapotranspiration of Iraq (mm)			
Months	**Baghdad**	**Mosul**	**Basra**
January	1.69	0.82	1.69
February	2.61	1.35	2.43
March	4.67	2.59	4.00
April	6.71	3.65	4.90
May	9.66	6.14	7.15
June	12.75	8.23	9.08
July	14.04	9.74	8.88
August	12.70	8.42	7.31
September	9.37	6.33	5.94
October	5.92	3.85	4.93
November	3.12	1.81	2.57
December	1.90	0.85	1.81

Wheat Crop

The wheat ear consists of 70% starch, 12% water, 10% protein, 3% oil, 2% sugar and 1% ash. 15% of the agricultural areas in the world are wheat fields [2].

Wheat mainly consists of spike, stem and leaf (Figure 2).

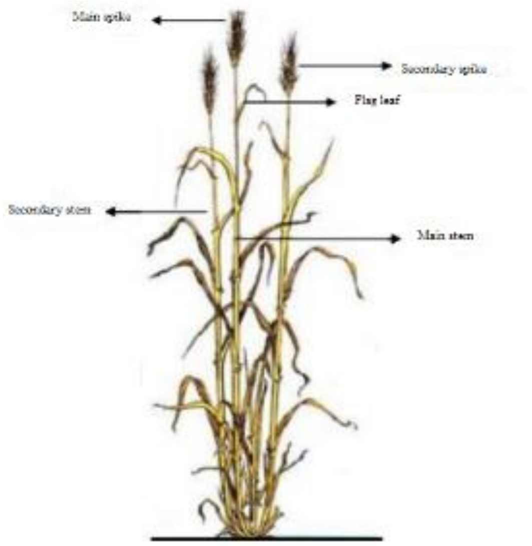

Fig 2. The part of wheat [2]

In general in the world, while the biomass value of wheat is 13 130 kg/ha, the leaf area index is 4.5 and the harvest index is 0.45 [6].

For example, World wheat production yield averages (tons/ha) in 2018 are as follows for some countries [22],

Iraq: 1.74, Turkey: 2.53, USA: 3.2, China: 5.42, Russia: 2.7, European Union: 5.4, World: 3.39 tons/ha.

Wheat production data in Wales

In the UK, the wheat harvest index is about 50% and the leaf area index (LAI) is about 6.3. In Wales, while the wheat leaf area index (LAI) value in 1985 was 3.42, the wheat LAI value in 1986 was 4.45 [9].

In Wales, increases in wheat yields are observed over the years (Figure 3).

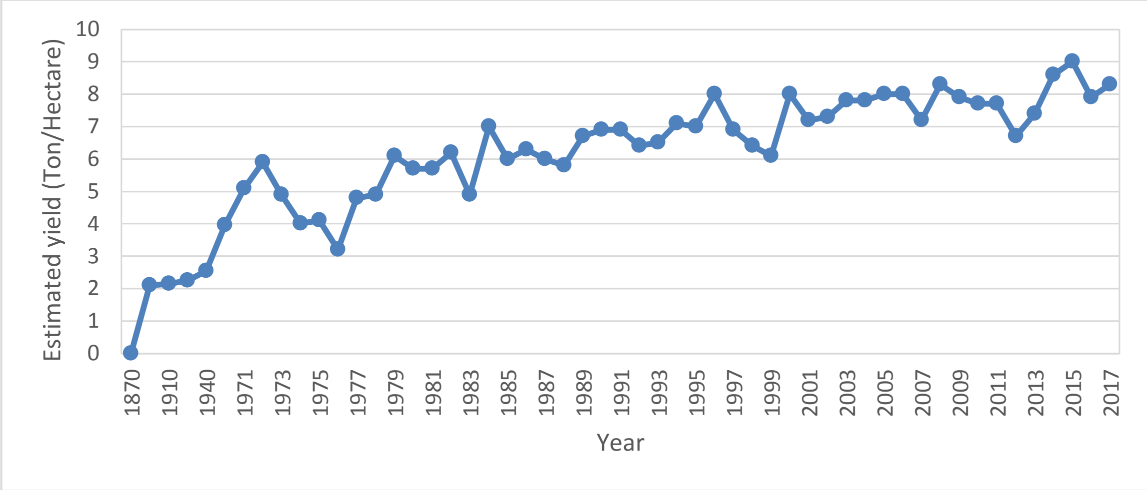

Fig 3. Wheat yields in Wales [4, 5, 10]

Wheat production data in Iraq

Wheat production around Mosul is higher than in other cities of Iraq.

In Iraq, in 2015-2016, the grain yield of bread wheat is 3.48 tons/ha and its biomass is 12.46 tons/ha [21]. The highest wheat yields in the 1981-2003 period in Iraq, it was reached in 1990, 2002 and 2003 (Figure 4).

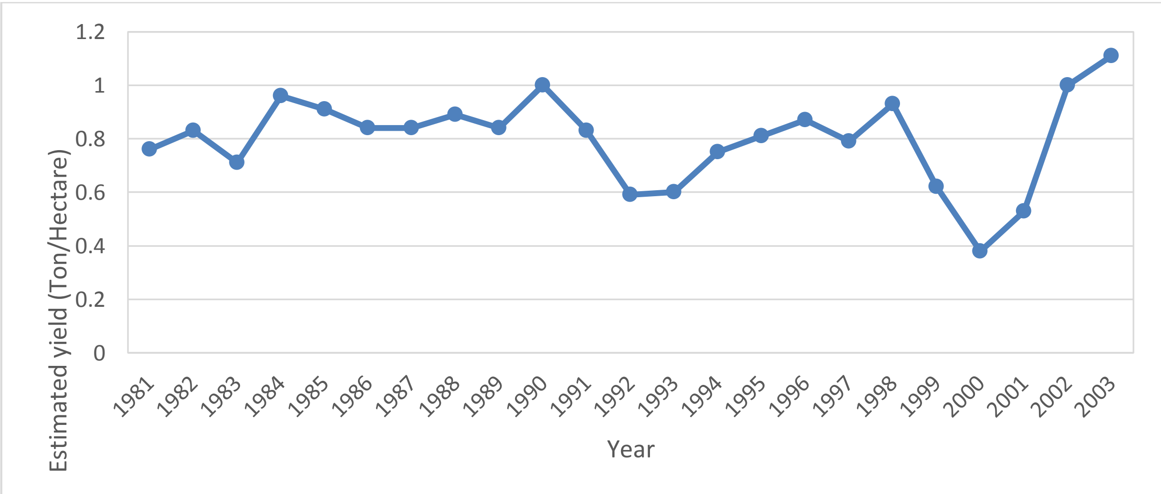

Fig 4. Wheat yields in Iraq [18]

2.2. Methods

Standard Precipitation Index (SPI) is an indices that determines the meteorological drought developed in 1993 by McKee et al. The simple application of the method leads to the preference of its use. Standard Runoff Index (SRI) results can be obtained by using flow data instead of precipitation data in the SPI method.

$$SPI= (X_i - X_i^{ort})/\sigma \quad (1)$$

X_i is rainfall amount, X_i^{ort} is average of the rainfall amount and σ is standard deviation in Equation 1 [12].

As a result of the calculations made with the help of Equation 1, the SPI drought classes in Table 6 and the SRI drought classes in Table 7 can be obtained.

Table 6. Drought Classes of Standard Precipitation Index [11]

Results of SPI	Drought Classes
≥ 2	Extremely wet
1.50 ~ 1.99	Very wet
1.00 ~ 1.49	Moderately wet
0.99 ~ 0	Normal
0 ~ -0.99	Very dry
-1.00 ~ -1.49	Moderately dry
-1.50 ~ -1.99	Extremely dry
≤ - 2	Very extremely dry

Table 7. Drought Classes of Standard Runoff Index [15]

Results of SRI	Drought Classes
0<	Wet
0 ~ -1	Low dry
-1 ~ -1.5	Moderately dry
-1.5 ~ -2.0	Very dry
< -2	Extremely dry

In this study, the palmer drought severity index (PDSI) was used in agricultural drought planning of important cities of Iraq (Baghdad, Kirkuk, Mosul and Basra).

Palmer Drought Severity Index (PDSI) is one of the most widely used agricultural drought indices in the world. It was developed by Palmer in 1965. PDSI determine the drought severity using temperature, precipitation, field capacity, available water capacity (AWC) data with the help of soil-water balance equations. In the method, the soil is thought to be divided into two by 25 mm from its surface. Also, PDSI is based on the assumption that the water does not pass to the lower soil layer without saturated water in the upper soil layer and the surface flow does not occur without the saturation of both soil layers. Evapotranspiration (ET) in the upper soil layer which always occurs as potential ET, is another important assumption of PDSI method [11].

While, Y: Precipitation, TB: Pan Evaporation, ET: Evapotranspiration, K: Loss, B: Supply, A: Flow, EBTN: Largest soil moisture capacity in Equations 2-3-4-5 [20],

If Y<TB now then K=ET-Y (2)

If Y>TB now then B=Y-ET (3)

If B>EBTN now then A=B-EBTN (4)

$$\alpha = \frac{\overline{ET}}{\overline{TB}} \quad \beta = \frac{\overline{B}}{\overline{PB}} \quad \gamma = \frac{\overline{A}}{\overline{PA}} \quad \delta = \frac{\overline{K}}{\overline{PK}} \tag{5}$$

$$F = Y - (\alpha\, ET + \beta\, PB + \gamma\, PA - \delta\, PK) \tag{6}$$

F: Difference between real rainfall and artificial (calculated) rainfall, Y: Precipitation, ET: Evapotranspiration, PB: Potential supply, PA: Potential flow, PK: Potential loss, α- β- γ- δ are coefficients in Equation 6 [20].

As a result of the calculations made with the help of these equations, PDSI drought classes in Table 8 can be obtained.

Table 8. Drought Classes of Palmer Drought Severity Index [11]

Results of PDSI	Drought Classes
4 <	Extremely wet
3-4	Very wet
2-3	Moderately wet
1-2	Light wet
0.5-1.0	Wet
Between 0.5 and -0.5	Normal
Between -0.5 and -1	Dry
Between -1 and -2	Light dry
Between -2 and -3	Moderately dry
Between -3 and -4	Very dry
< -4	Extremely dry

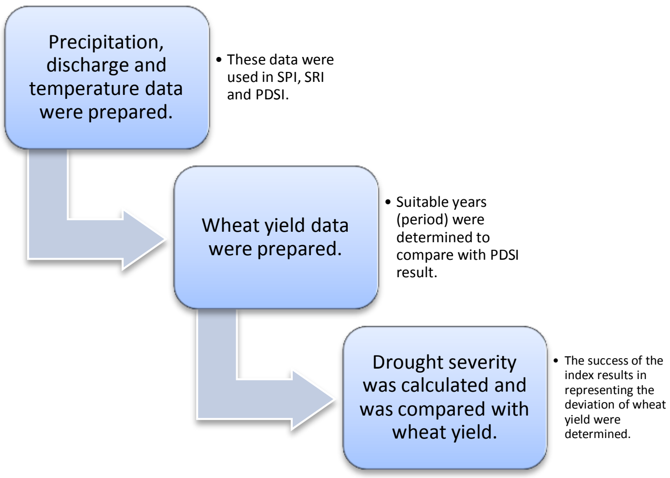

Fig 5. Flow chart of the study

3. Results and Discussion

3.1. Results Related to Standard Precipitation Index (SPI)

With the help of SPI, calculations are made on a monthly basis using stations in some important cities of Iraq and Wales-Cardiff, and the annual results of these calculations are shown in the tables.

3.1.1. SPI Results in Iraq

In Baghdad-Iraq, in terms of meteorological drought in the period between 1961-2011, the wettest year was 1974, the driest years were 1991, 2003 and 2004. The wettest month was March in 1974 that the wettest year, the driest month was February in 1991 among of 1991,2003 and 2004 that the driest years.

In Basra-Iraq, in terms of meteorological drought in the period between 1961-2011, the wettest year was 1986, the driest years were 2003 and 2004. The wettest month was April in 1986 that the wettest year, the driest months were January in 2003 and 2004 that the driest years.

In Kirkuk-Iraq, in terms of meteorological drought in the period 1961-2011, the wettest year was 1973, the driest year was 2011. The wettest month was March in 1973 that the wettest year, the driest month was January in 2011 that the driest year.

In Mosul-Iraq, in terms of meteorological drought in the period 1961-2011, the wettest year was 1993, the driest year was 1999. The wettest month was May in 1993 that the wettest year, the driest months were March and December in 1999 that the driest year.

When Iraq cities are evaluated from arid to humid in terms of meteorological drought, they are listed as Kirkuk, Mosul, Baghdad and Basra, respectively (Figure 6).

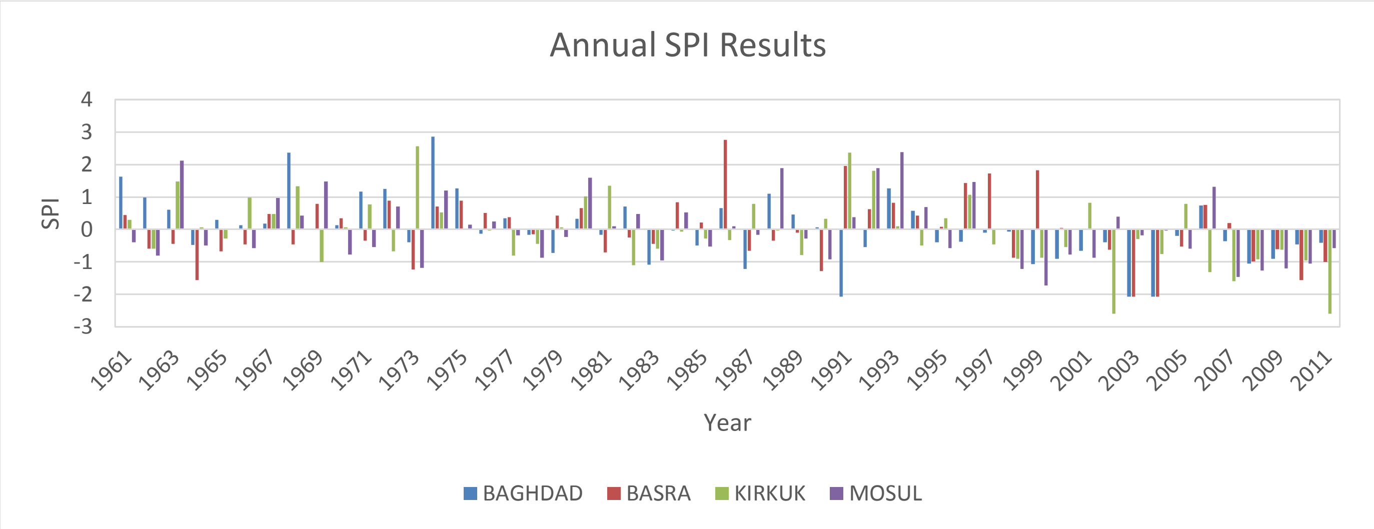

Fig 6. Annual SPI results in some important cities of Iraq

Severe meteorological droughts were experienced in Baghdad and Basra between 2007 and 2012 [13]. As a result of this study, it is thought that the droughts experienced just before the years in the literature are transferred to the following years due to cumulative effect.

In Kirkuk, it was a meteorological drought between 2007 and 2015 [3]. In parallel with the literature, with this study, it was determined that there was a drought in Kirkuk in 2011.

Severe meteorological droughts were experienced in Mosul between 1998 and 2001 [13]. In parallel with the literature, with this study, it was determined that there was a drought in Mosul in 1999.

3.1.2. *SPI Results in Cardiff, Wales*

In terms of meteorological drought in the period 1966-1972, the wettest year was 1967 and the driest year was 1966. The wettest month was October in 1967 that the wettest year, the driest month was January in 1966 that the driest year. As a result, Cardiff has a meteorologically normal climate in the period (Figure 7).

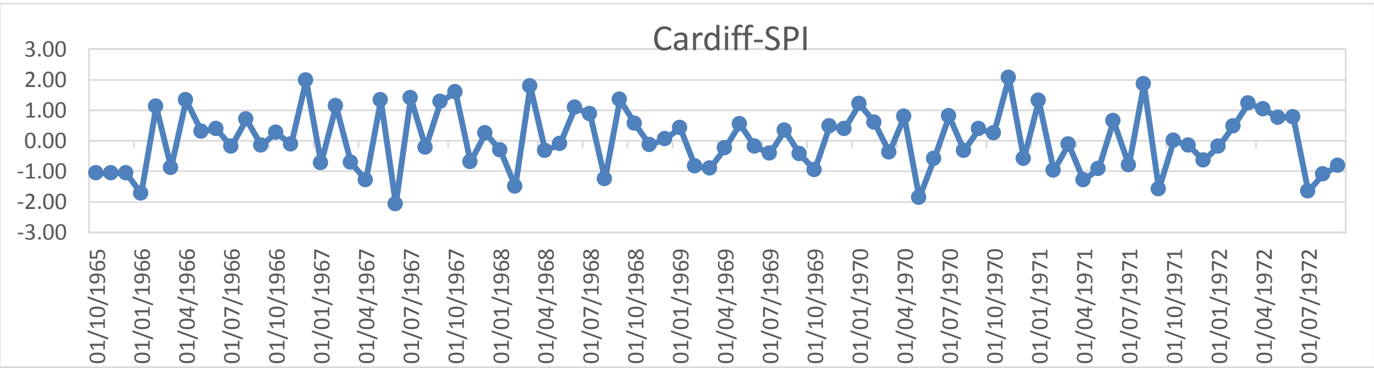

Fig 7. Annual SPI results of Cardiff (Wales)

Richter and Semenov [17] determined that there was a meteorological transition from arid to humid between 1961 and 2011 in Wales. Similar to the literature, with this study, an increase in humidity is observed from 1965 to 1972.

3.2. *Results Related to Standard Runoff Index (SRI)*

With the help of SRI, calculations are made on a monthly basis using stations in some important cities of Iraq and Wales-Cardiff, and the annual results of these calculations are shown in the tables.

3.2.1. *Results of SRI in Iraq*

In Baghdad-Iraq, in terms of hydrological drought in the period between 1931-1997, the wettest year is 1955, the driest years are 1996 and 1997. The wettest month is April in 1955 that the wettest year, the driest month is December in 1996 and 1997 that the driest years.

In Mosul-Iraq, in terms of hydrological drought in the period between 1931-1997, the wettest year is 1969, the driest year is 1986. The wettest month is December in 1969 that the wettest year, the driest month is February in 1986 that the driest year.

When Iraq cities are evaluated in terms of hydrological drought, it is seen that Mosul is drier than Baghdad (Figure 8).

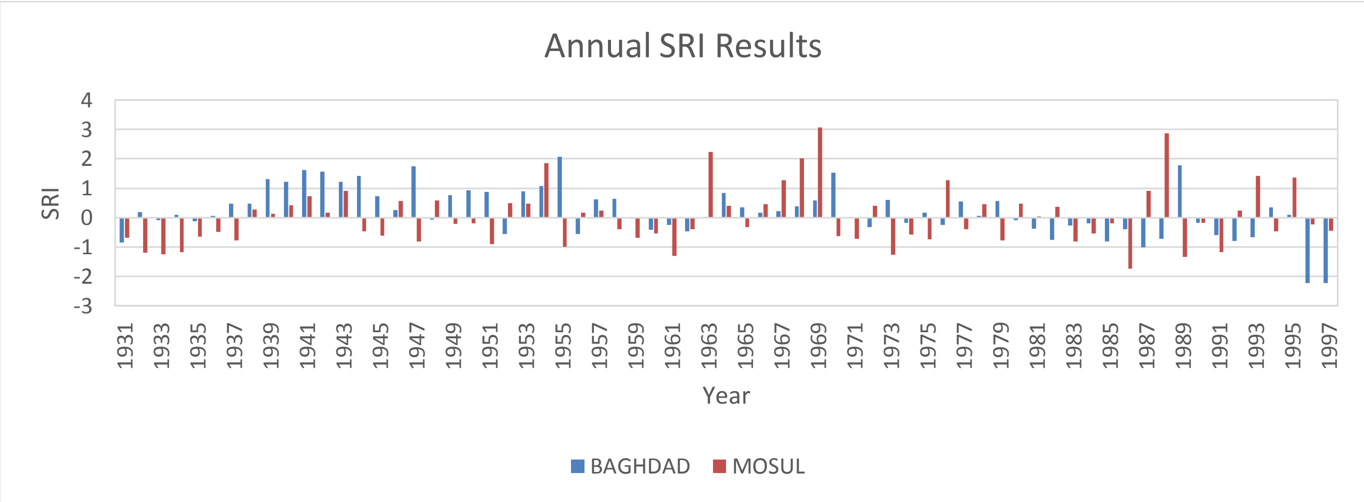

Fig 8. Annual SRI results in some important cities of Iraq

Jasim and Awchi [13] determined that the highest drought rates occur in northern Iraq including Mosul. Similar to the literature, more severe droughts occurred in Mosul than in Baghdad in this study.

3.2.2. *SRI results in Cardiff, Wales*

In terms of hydrological drought in the period between 1966-1972, the wettest year is 1968, the driest year is 1966. The wettest month is July in 1968 that the wettest year, the driest month is January in 1966 that the driest year. As a result, Cardiff has a hydrologically normal climate in the period (Figure 9).

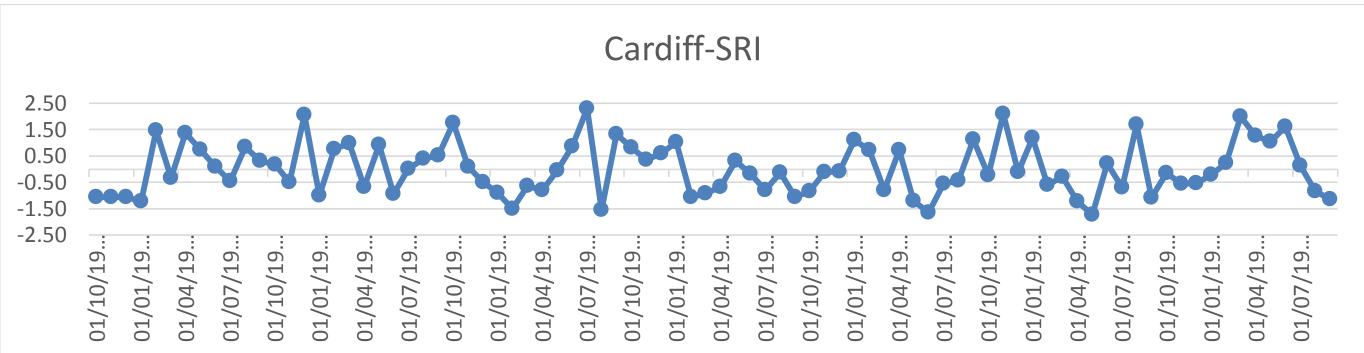

Fig 9. Monthly SRI results in Cardiff (Wales)

In parallel with the literature [8] and the discharge trend results of Cardiff Taff [Table 2], normal climate was seen in Cardiff when the period was evaluated in terms of hydrological drought.

3.3. Results Related to Palmer Drought Severity Index (PDSI)

With the help of PDSI, the stations in some important cities of Iraq are used and monthly calculations are made and the annual results of these calculations are shown in Figure 9.

3.3.1. Results of PDSI in Iraq

In Baghdad-Iraq, in terms of agricultural drought in the period 1961-2011, the wettest year is 1974, the driest year is 1964. The wettest month is March in 1974 that the wettest year, the driest month is April in 1964 that the driest year.

In Basra-Iraq, in terms of agricultural drought in the period 1961-2011, the wettest year is 1976, the driest year is 1964. The wettest month is February in 1976 that the wettest year, the driest month is April in 1964 that the driest year.

In Mosul-Iraq, in terms of agricultural drought in the period 1961-2011, the wettest year is 1988, the driest year is 1966. The wettest month is March in 1988 that the wettest year, the driest month is January in 1966 that the driest year.

When Iraq cities are evaluated from arid to humid in terms of agricultural drought, they are listed as Basra, Baghdad and Mosul, respectively (Figure 10).

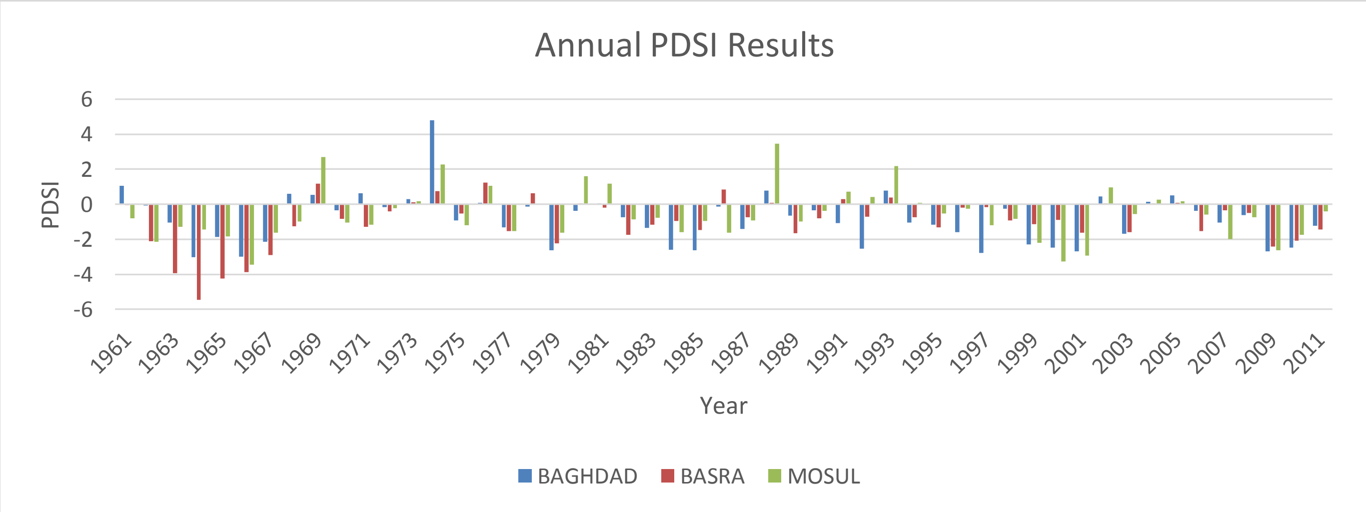

Fig 10. Annual PDSI results in some important cities of Iraq

When the period 1950-2010 throughout Iraq evaluated in terms of agricultural drought, drought was seen in 85% of the country in 1998 and 2008 [1].

In parallel with the literature, In this study, drought was observed in all the examined areas between 1998 and 2008.

With this study, it was determined that from the South to the North of Iraq, the droughts decreased and the humidification increased (Figure 10).

3.4. Results Related to Wheat

There are increases in wheat yields in Wales and decreases in wheat yields in Iraq as time goes. Drought is thought to be the cause of the yield decreases, especially in Iraq in the 2000s. Iraq's PDSI results in this study confirm this information (Figure 11 and Figure 12).

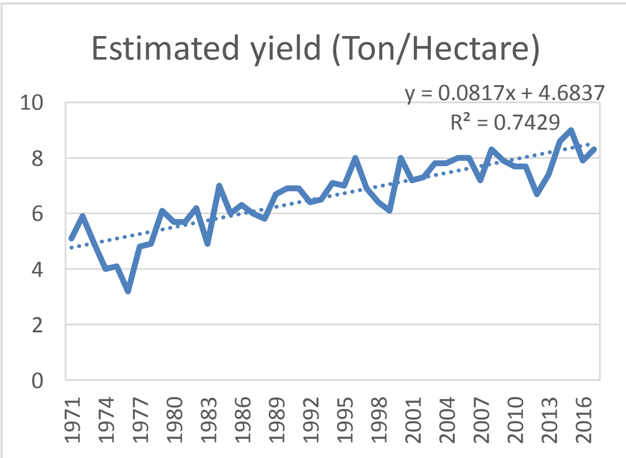

Fig 11. Linear regression trend of wheat yield for Wales

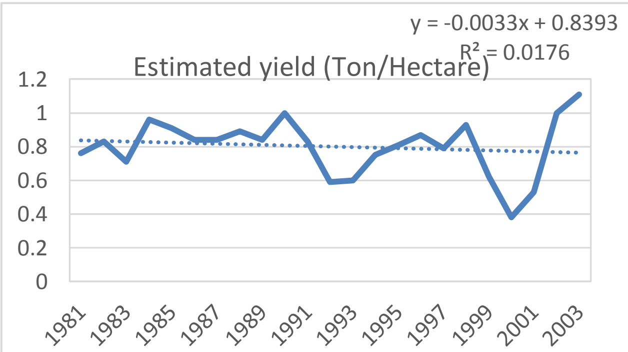

Fig 12. Linear regression trend of wheat yield for Iraq

The period between 1961 and 2011 in Iraq, it was divided into 3 periods of 15 years as the far past, the mid past and the near past. After all, while a normal climate prevails in Mosul, the climate in Baghdad was shifting from normal to arid. In Basra, on the other hand, a shift from arid to moist was detected (Figure 13).

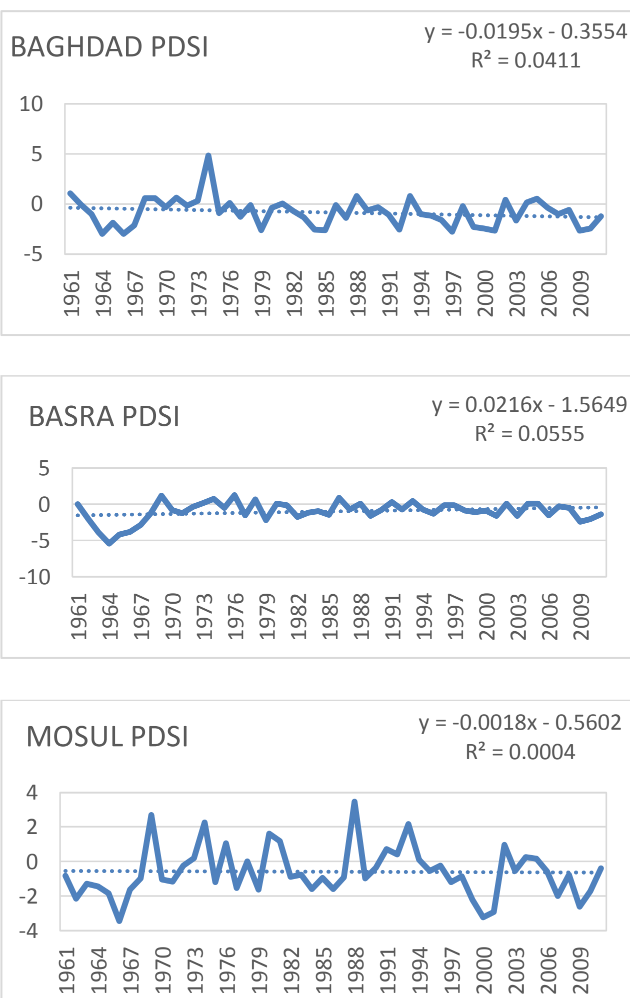

Fig 13. Linear regression trend of PDSI for Iraq

When the correlation of deviations in wheat yields in Iraq and PDSI results were examined, a weak correlation was determined and it was determined that wheat yield decreases were caused by non-climatic factors. Wrong fertilization, plant disease and pest are thought to be these non-climatic factors (Figure 14).

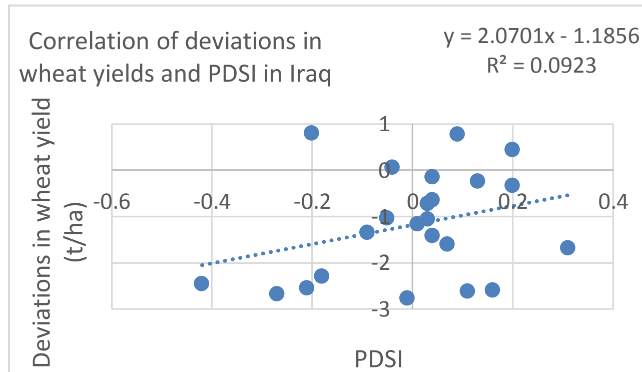

Fig 14. Graph of correlation between PDSI and wheat yield deviation for Iraq between 1981-2003

Wheat yields in Iraq are low and variable. The yields in Wales are higher and more stable (Figure 15).

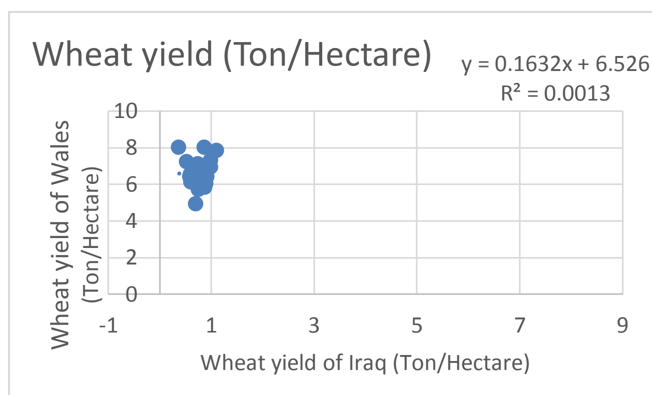

Fig 15. Correlation graph of wheat yields for Iraq and Wales between 1981-2003

In parallel with the literature [4, 10, 18], in this study, wheat yields increased unevenly between 1974-1996 in Wales while cultivation area and yields of the wheat were nearly stable between 1984-2017 in the UK. The wheat yields of Wales-UK vary a lot regionally because the Wales-UK are country that recieve a lot of precipitation. In addition, the wheat yields varied unevenly between 1981 and 2000 in Iraq [18].

4. Conclusion

In this study, considering that Wales represents the wet conditions and Iraq represents the dry conditions in the world, the hydrometeorological and agricultural droughts of these two countries were analyzed. After all, the most severe dry years in Wales (Cardiff) and Iraq were determined as follows.

In Cardiff, it was determined that the humidity increased in terms of meteorologic drought and there was a normal climate in terms of hydrologic drought. This led to an increase in wheat yields.

The meteorological dry year in Iraq-Mosul was 1999, while the hydrological dry year was 1986 and the agricultural dry year was 1966. Meteorological drought years were 2003 and 2004, agricultural drought year was 1964 in Iraq-Basra. The meteorological drought year was 2011 in Iraq-Kirkuk.

The most suitable areas and times for wheat cultivation in Iraq was determined that 1974-March was for Baghdad, 1976-February was for Basra, and 1988-March was for Mosul. In order to reduce the negative effects of drought on wheat agriculture, it is necessary to increase the wheat cultivation areas in these cities of Iraq and to support the production with modern agricultural techniques (irrigation, fertilization and wheat variety selection, etc.).

In terms of meteorologic drought, Iraq cities from arid to humid are Kirkuk, Mosul, Baghdad and Basra, respectively. Agriculturally, they are listed as Basra, Baghdad and Mosul, respectively. In terms of hydrological drought, Mosul seems to be drier than Baghdad.

In terms of agricultural drought, while a normal climate prevails in Mosul, the climate in Baghdad is shifting from normal to arid. In Basra, a shift from arid to humid is detected. Drought is thought to be the cause of the wheat yield decreases, especially in Iraq in the 2000s. When the correlation of deviations in wheat yields in Iraq and PDSI results were examined, a weak correlation was determined and it was determined that wheat yield decreases were caused by non-climatic factors.

Generally, it has been determined that drought periods spread homogenously throughout Iraq. Nevertheless, It was determined that drought is much more widespread and severe in Iraq in 2003, 2004 and 1964. Irrigated farming should be supported to ensure the food security in countries such as Iraq with low wheat yield. It is determined that climate change increases the drought and causes decreasing of the wheat yields in time. However, it is thought that the exacerbation of these decreases can be reduced with the agricultural technologies.

In order to combat climate change, it is recommended that developed countries have to strengthen their agricultural sector by reducing their industrialization.

In this study, some challenges were encountered especially in accessing crop data. Therefore, the analysis was made with fewer crops and in a limited number of countries. In the future, it is expected that crop database will be created under the leadership of the Europe Union and another worldwide associations. Thus, it is expected to help researchers who will investigate the effect of climate on agriculture sector.

Acknowledgements

Author would like to acknowledge Dr. Michaela BRAY for providing sufficient data.

Conflict of Interest

The authors declare that they have no conflict of interest

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Recommended Citation
Alkan Ç. Drought analysis of wheat in humid (Wales) and dry (Iraq) conditions. *Alger. J. Eng. Technol. 2023*, 8(1): 1-13.
DOI: https://doi.org/10.57056/ajet.v8i1.80