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Specification of Actual Evapotranspiration in Iraq by GIS

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Abstract

Evapotranspiration (ET) is produced from vegetation transpiration and soil evaporation. The ET measurements must be considered to study water management systems and irrigation (planning, designing and operating). This study is based on USGS (United States Geological Survey) data by the SSEBop (Simplified Surface Energy Balance) model to estimate the total annual amount of ET using ArcGIS software. The ET values were determined for seventeen years from 2003 to 2019. Also, these values for year 2020 were estimated based on the value of the monthly ET for seven months, i.e. until August by summation. The field data of gauge stations spread throughout Iraq for the year 2012 were used to verify the ET values for the same year. There was distinct compatibility between them. For the four years 2017, 2018, 2019 and 2020, the area of zero ET was a little more than half the area of Iraq (56%). While the years from 2003 to 2016, the average percentage of the area was about 24% of Iraq’s area. For classification for ET values 0 - 50 mm, the area percentage was 29% of total area for years from 2003 to 2016, while from 2017 to 2020 the percentage was 10%. The ET values of 50-100 mm have an area ratio of 12% of total area for years 2003 to 2016, while the percentage was 4% for the remaining years. For all years of study, the area percentage was approximately the same for ET values greater than 100 mm. The study recommends increasing the water quotas and speeding up the construction of strategic projects in Iraq to compensate the shortage of vegetation cover, especially in last the four years, more than half of the area had ET values equal to zero.

Keywords: Evapotranspiration, SSEBop model, GIS

تخصيص تبخر النتح الفعلي في العراق بواسطة نظم المعلومات الجغرافية

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الخلاصه

ينتج التبخر (ET) من نتح الغطاء النباتي وتبخر التربة. يجب مراعاة قياسات ET لدراسة أنظمة إدارة المياه والري (التخطيط والتصميم والتشغيل). استندت الدراسة الحالية إلى بيانات USGS (هيئة المسح الجيولوجي الأمريكية) بواسطة نموذج SSEBop (توازن الطاقة السطحي المبسط) لتقدير المبلغ الإجمالي السنوي لـ ET باستخدام برنامج ArcGIS. تم تحديد قيم ET لمدة سبعة عشر عامًا من 2003 إلى 2019. أيضا، تم تقدير هذه القيم لعام 2020 بناءً على قيمة ET الشهرية لمدة سبعة أشهر، أي حتى أغسطس عن طريق الجمع. تم استخدام البيانات الميدانية لمحطات القياس المنتشرة في جميع أنحاء العراق لعام 2012 للتحقق من قيم ET لنفس العام. كان هناك توافق واضح بينهما. بالنسبة للسنوات الأربع 2017 و2018

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و2019 و2020، كانت مساحة صفر ET أكثر بقليل من نصف مساحة العراق (56٪). بينما في السنوات من 2003 إلى 2016، كان متوسط النسبة المئوية للمنطقة حوالي 24٪ من مساحة العراق. بالنسبة لتصنيف قيم ET 50 – 0 ملم، كانت النسبة المئوية للمنطقة 29٪ من المساحة الإجمالية للأعوام من 2003 إلى 2016، بينما بالنسبة للسنوات من 2017 إلى 2020 كانت النسبة 10٪. تبلغ قيم ET 100– 50 ملم نسبة مساحة 12٪ من إجمالي المساحة للأعوام 2003 إلى 2016، بينما كانت النسبة 4٪ للسنوات المتبقية. بالنسبة لجميع سنوات الدراسة، كانت النسبة المئوية للمساحة متماثلة تقريبًا لقيم ET أكبر من 100 مم. وتوصي الدراسة بزيادة حصص المياه والإسراع في إقامة المشاريع الاستراتيجية في العراق لتعويض النقص في الغطاء النباتي وخاصة خلال السنوات الأربع الماضية حيث أن أكثر من نصف المساحة كانت قيمها ET تساوي الصفر.

1. Introduction

Many regions in the world suffer from a scarcity of water, especially freshwater, which is consumed by farmers for irrigations. Usually, the amount of water that was used for irrigation more than the plant's absorption (i.e. the plants need) [1, 2]. The excess water on the ground (included the water bodies and water content in soil) will evaporate along with the transpiration which results from the plants, this phenomenon is called evapotranspiration (ET). Evapotranspiration is a fundamental and important factor in the hydrological cycle. Evapotranspiration leads to the loss of most of the amounts of rainfall as varying percentages in the world [3]. ET is important for energy and mass exchange between soil, water, plants, and the atmosphere, so it is a key parameter in the hydrogeological budget [4]. Therefore, the reliability of the ET calculation is important and the estimation of its quantities is close to a field that provides solutions to problems in hydrology, forests, agriculture, land management, and climate studies [5]. The most prominent climatic conditions affecting the ET values are radiation, wind, relative humidity, and temperature [6]. The type of vegetation cover and the degree of soil moisture are also factors that significantly affect the amount of ET [6].

There are many methods of estimating the amount of ET, including simple and complex methods and remote sensing methods. Simple methods include the following, the Pan Method, Temperature-Based Methods, Radiation-Based Methods, Solar Radiation–Maximum Temperature Method and Mass Transfer Method. While complex methods are two classes, the first being Energy Balance Methods and the second by Penman Method. The calculation of ET by remote sensing depends mainly on the amount of spatial surface energy fluxes, which include the energy budget (net radiation, heat, soil heat flux, latent heat, and sensible heat) and parameters of land cover. The remote sensing techniques are based on the radiative and reflective data of the satellite images with thermal ranges, including sensors of Landsat TM (Thematic Mapper) and ETM+ (Enhanced Thematic Mapper Plus), MODIS (MODerate Resolution Imaging Spectroradiometer), and ASTER (Advanced Spaceborne Thermal Emission and Reflection). Six evaporation models to estimate the ET values include the following: Surface Energy Balance Algorithm for Land (SEBAL), Surface Energy Balance System (SEBS), Two-Source Energy Balance (TSEB), Simplified Surface Energy Balance Index (S-SEBI), Mapping Evapotranspiration at High Resolution using Internalized Calibration (METRIC) and finally Simplified Surface Energy Balance (SSEB) [3]. The SSEB formulation depends on the hot and cold pixel of METRIC and SEBAL models [4]. The SSEBop is the modified form of the original model SSEB with parameterized operational applications. Twelve years (from 2000 to 2011) were used in the SSEBop model depending on Global Data Assimilation System (GDAS) data streams and MODIS. The monthly eddy changes of ET data of the contiguous United States (CONUS) were compared with the SSEBop ET results. It is possible to use the SSEBop model not only in the CONUS but also in other parts of the world [7]. Jaber et al. [8] evaluated the SEBAL model of actual evapotranspiration estimation to Babil city of Iraq country based on field data for one year and two different months March and September evapotranspiration only. The study concluded that the model was efficient to estimate the actual evapotranspiration value by relying on remote sensing. In northern Iraq, a SEBAL model was used based on the thematic Landsat (TM5) satellite imagery for the years 2006 and 2007 along the Al-Khazir River to estimate the water budget for the basin. Actual evapotranspiration was estimated to be lost within this basin based on the remote sensing of this model [9]. Jawad and Mohamed [10] measured actual daily evapotranspiration by FAO Penman-Monteith method every ten years for the past 31 years, for the following years only: 1987, 1997, 2007 and 2017. Then the actual annual evapotranspiration values were calculated for these four years only. Spatial analysis was used to compare the evapotranspiration values.

This study was the first of its kind in terms of the broad ranges of years from 2003 to the eighth month(August) of 2020. The world maps drawn with the model SSEBop, which are available within the USGS (United States Geological Survey) data to estimate the ET values of Iraq for different years, will be adopted as the first study for this region.

2. Materials and methods

2.1. Study area

The study area is the country of Iraq and it is located on the side of the longitude and latitude in Figure 1. The total area of the country is about 437,072 square kilometers. In addition, two main rivers, Tigris and Euphrates flow through the territory and reach southern part of Iraq until they merge with the Arabian Gulf.

The reason for studying the evapotranspiration is the fact that this region is under high solar radiation, especially in the Summer, and it will lead to the loss of water from these two rivers and other water bodies.

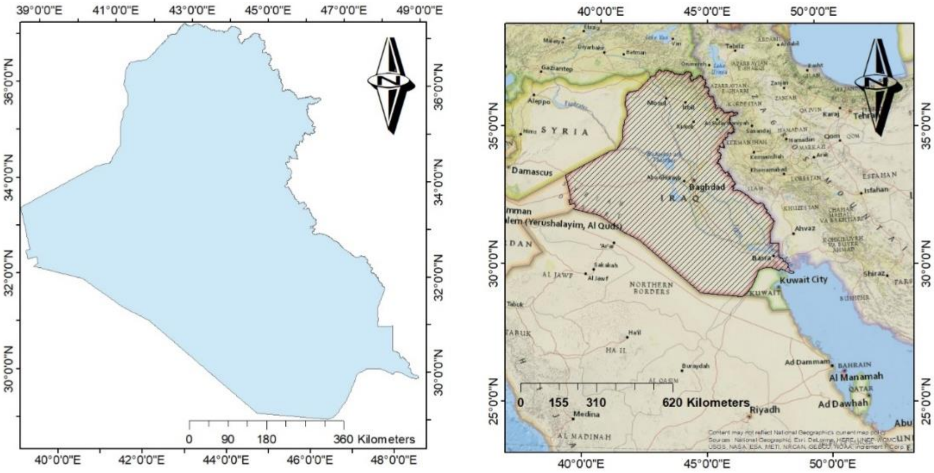

Figure 1-The polygon map and geographic location of Iraq

2.2 Data collection

The data used to estimate the annual actual evapotranspiration (ET) depends on the global data available on the website of USGS for years from 2003 to 2019, as well as the value of the monthly ET from the beginning of the year 2020 to the seventh month. These global data are derived based on the SSEBop model and using the ArcGIS software, Iraqi data can be extracted from the world maps for the aforementioned dates. One of simplified and regionally available techniques for ET mapping is the Simplified Surface Energy Balance model (SSEB). To guess the value of ET, we need two main steps, values of reference ET and a satellite imagery. The SSEB model was based on imagery from Landsat 5 TM. Statistically, this model can be used for daily predictions of ET values, quickly and accurately. Model performance was excellent for daily predictions of ET values in irrigated and arid lands [11]. The extracted data of actual annual evapotranspiration values were reclassified for easy comparison between maps and that it covers all the colors shown on the map of ET values. To make verification of the resulting maps of the evapotranspiration values, field data of the year 2012 measured by ground measurement stations were used as in Table 1. In previous studies, the SSEB model was statistically examined for dry and irrigated lands to estimate ET values. We adopted one year because data were not available for actual ET values except for this year, and they were included. The number of stations used was about seventeen stations, and the monthly evapotranspiration values for this year were summed to obtain the annual actual evapotranspiration.

Table 1- Field evapotranspiration locations and values of measuring stations (2012) [12]

No.	Name	longitude	latitude	ET (mm)
1	BAGHDAD	44.24	33.2	3053.6
2	AL_HAI	46.03	32.1	3969.2
3	NAJAF	44.32	32.03	2685.8
4	SAMAWA	45.16	31.18	3533.5
5	HILLA	44.26	32.29	2159.4
6	KUT	45.45	32.3	3743.8
7	AZIZYIA	45.06	32.91	3227.8
8	AIN_ALTAMUR	43.48	32.48	2853.1
9	KARBALA	44.01	32.37	2671.5
10	HADITHA	42.22	34.04	2326.5
11	AMARA	47.1	31.51	2981.9
12	BADRA	45.98	33.09	3231.2
13	AL_KHALIS	44.53	33.84	2692.91
14	RAMADI	43.2	33.45	2656.9
15	TAL_AFAR	42.38	36.36	3604.7
16	AL_QA'IM	41.14	34.38	3020.7
17	TIKRIT	43.63	34.64	2666.2

3. Results and discussion

Figures 2, 3, and 4 include the annual values of evapotranspiration from the year 2003 to 2019, as they contain nine classifications of the values. To check the validity of the maps extracted based on the SSEBop model, the data of Table 1 was utilized of the annual values of evapotranspiration for seventeen stations spread over Iraq of the year 2012 and then projected on the evapotranspiration map in the same year (Figure 5). Noted that all the measuring stations are located in or close to the dark blue color, meaning that they have ET values greater than 1400 mm, and this was identical to the field measurement values (Table 1).

Depending on the size of the cell used, which is 30 * 30 for the images, the area of each part of these classifications can be extracted by multiplying the area of one cell by the number of cells for each classification, and then the percentage of the area value was estimated as in Figure 6 for study years.

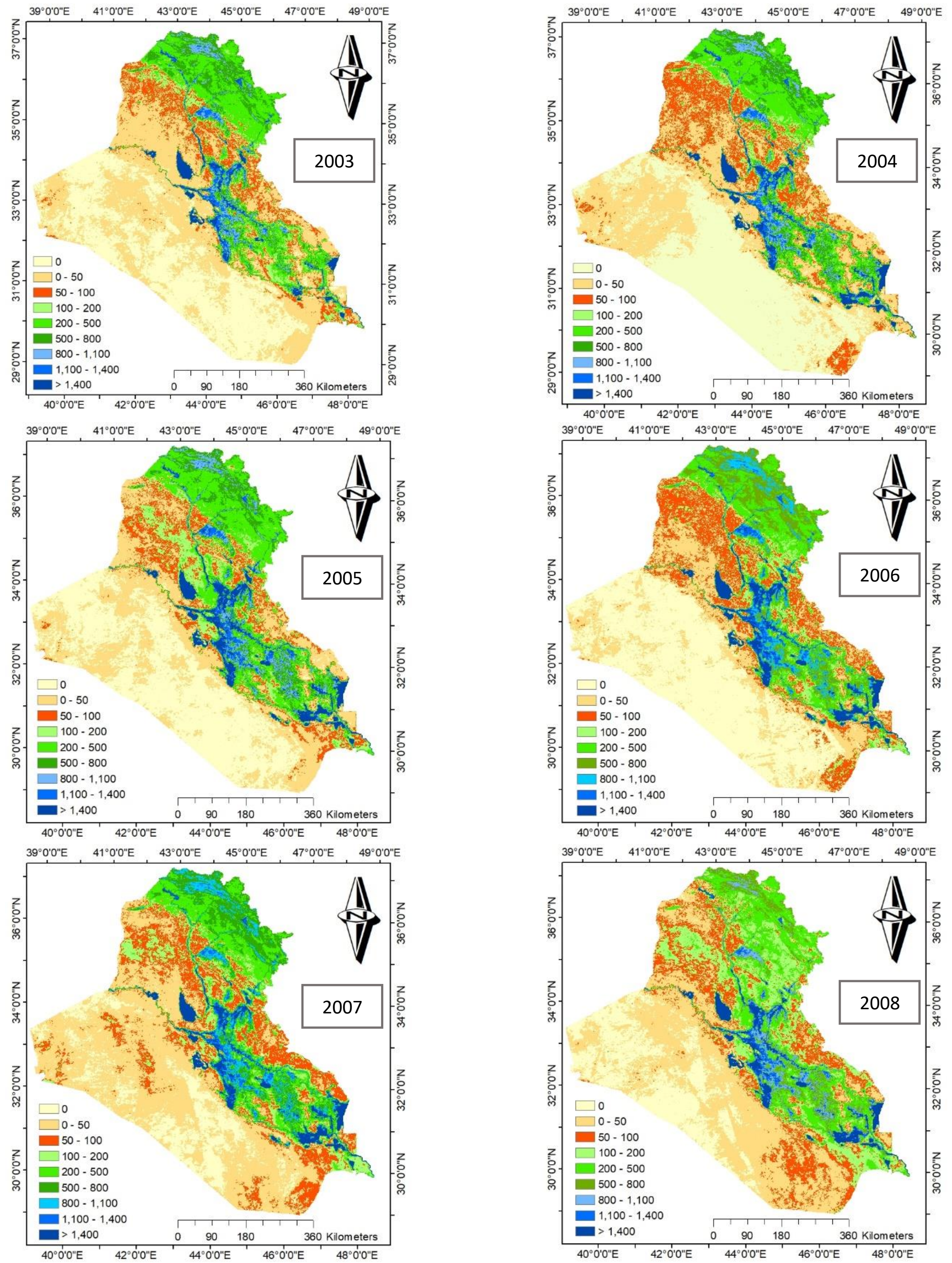

Figure 2- Annual actual evapotranspiration values from 2003 to 2008

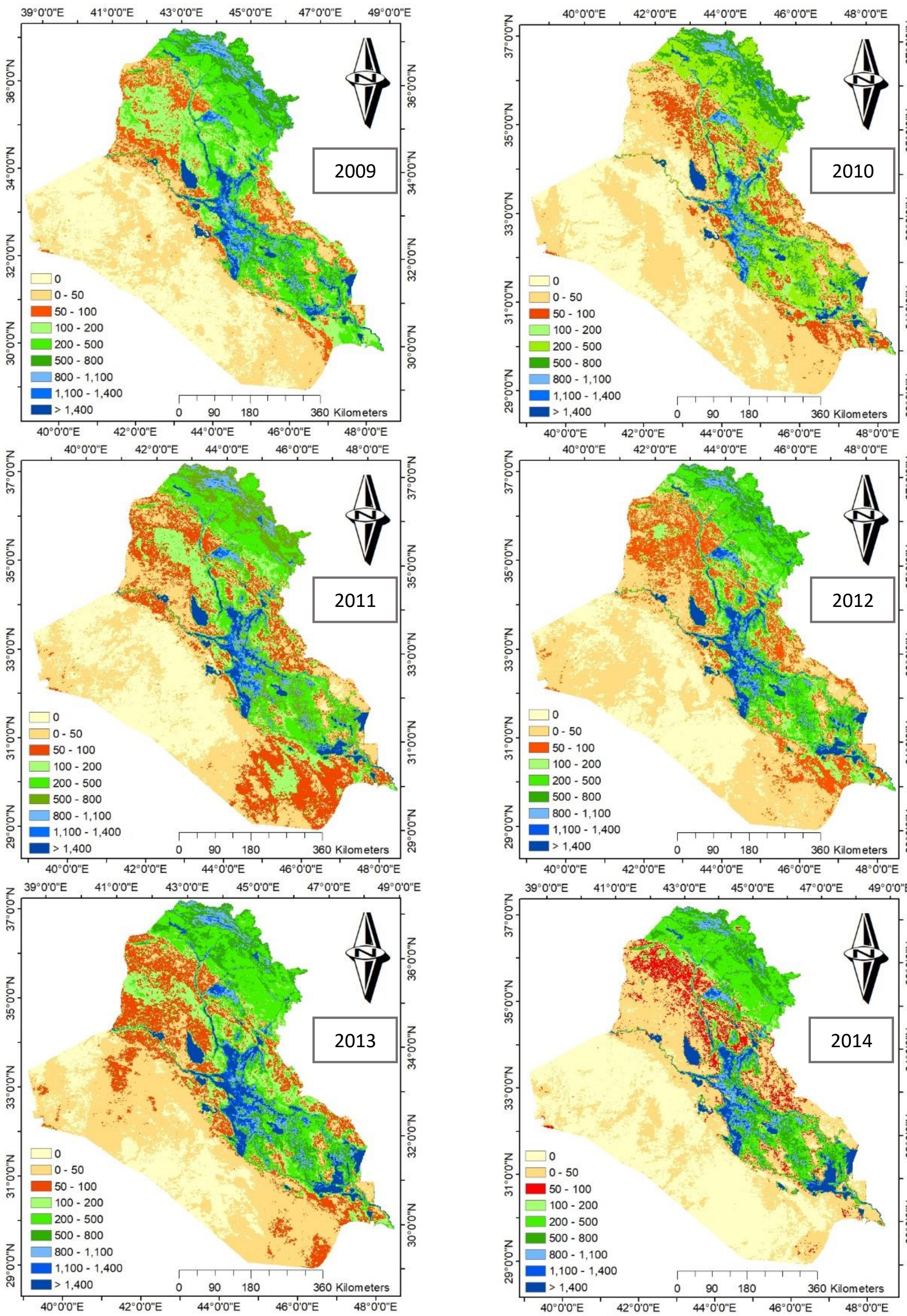

Figure 3-Annual actual evapotranspiration values from 2009 to 2014

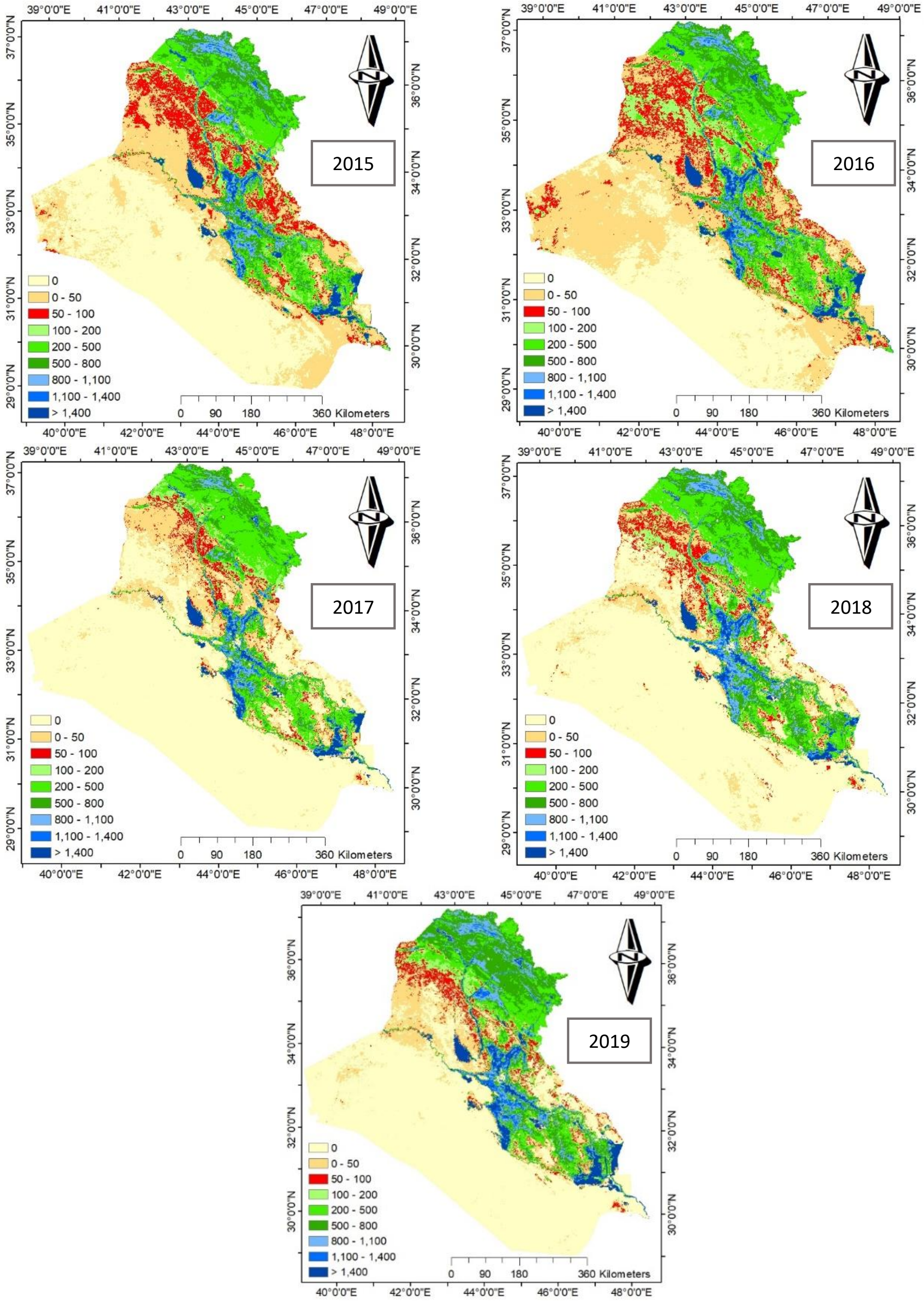

Figure 4- Annual actual evapotranspiration values from 2015 to 2019

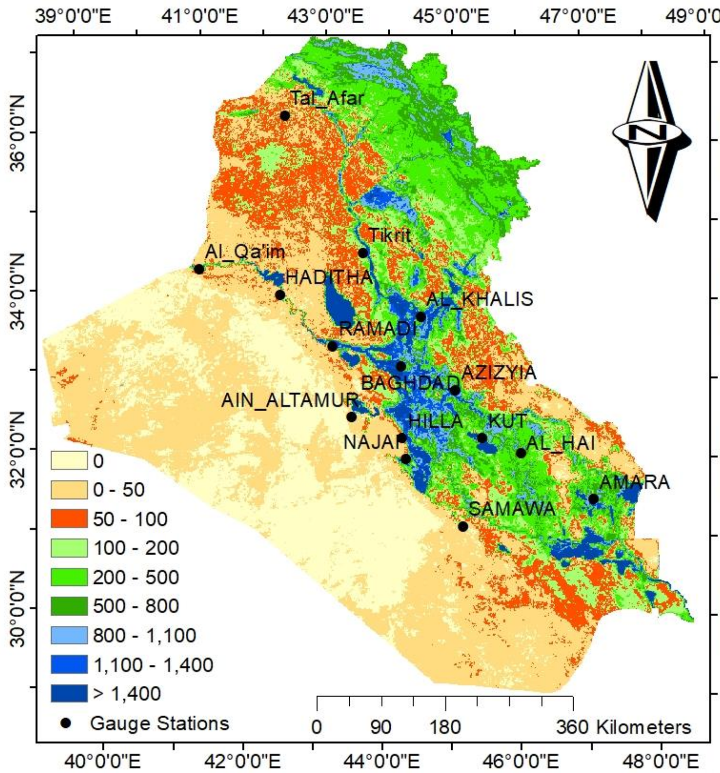

Figure 5-The location of the measuring stations distributed over Iraq for the ET map in 2012

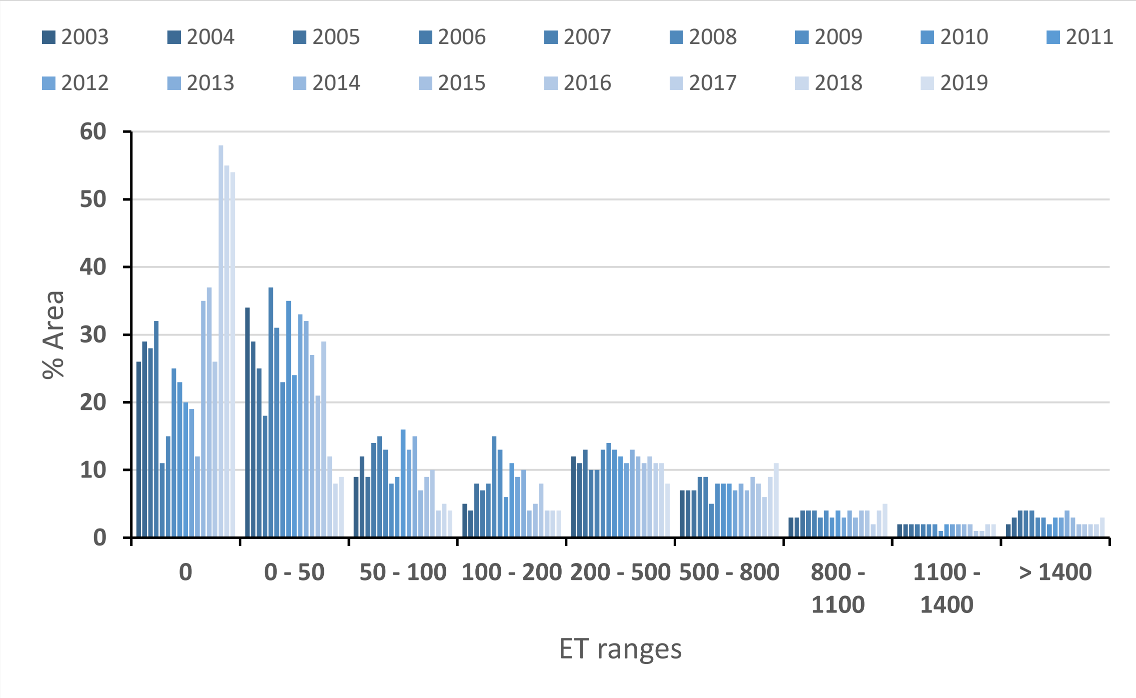

Figure 6-The ratio of area of each classification of evapotranspiration values to total area of Iraq for years 2003 to 2019

The above Figures (2 to 6) showed that the year 2017 contained more yellow color areas than other years. From Figure 6, the percentage of this color is 58% of total area, which matches with actual annual of ET equal to zero. As for years 2018 and 2019, they follow year 2017 with an area of 55% and 54%, respectively, of the whole area. For half of the study area, the value of ET was almost equal to zero for these three years (2017, 2018, and 2019) due to the reduction of Iraq's water quotas of Tigris and Euphrates rivers. In addition, the rainfall was low, which led to a lack of vegetation cover and an increase in desertification especially in a hot season like summer. Therefore, surface water plays an essential role in increasing ET values, as it is necessary to increase vegetation cover in summer. The clear impact of water quotas releases from neighboring countries and the lack of strategic projects to store water inside Iraq are two main reasons for the lack of abundance of water in the summer. The increase in the actual ET values is by increasing the vegetation cover and surface water in the hot season like summer, i.e., by increasing the temperature. For ET values from 0 to 50 mm, years from 2003 to 2016 had an area percentage of about 29% of the area of Iraq, while in the rest of the years (2017, 2018 and 2019) the area ratio was about 10%. While the value of ET from 50 to 100 mm had an area ratio of 11% of the total area for years from 2003 to 2016 and a rate of 4% for the last years (2017, 2018 and 2019). Finally, the other classifications that had ET values greater than 200 mm were the same area percentage for all years, i.e. from 2003 to 2019. The reason for this is that most of these values were located within water bodies, which are almost not different for these years.

The evapotranspiration value for 2020 can be partially calculated, especially the year is not complete and the data is not available, based on the available data for the first seven months of this year. By utilizing the tool of raster calculator in ArcGIS software, the total ET for the months up to August were estimated. The procedure to obtain this is by subtracting the map of ET for the month of January from the map of the world, and so on for the residue of the six months, and then determining the total ET as illustrated in Figure 7 by summation. With the same technique explained above to estimate the area of each classification, the area computed and then found its percentage from the entire area, as presented in Table 2. It is noticeable that the value of ET, which is equal to zero, occupy an area of 58% of the study area, these values which ranged from 0 to 50 mm, occupies about 10%, and the classification of ET, which ranges from 50 to 100 mm, reached by 4%. Therefore, these were close to the same area ratio for the three years 2017, 2018 and 2019. Accordingly, we noticed that the values of ET had declined in Iraq during the last four years, as the reason was previously explained.

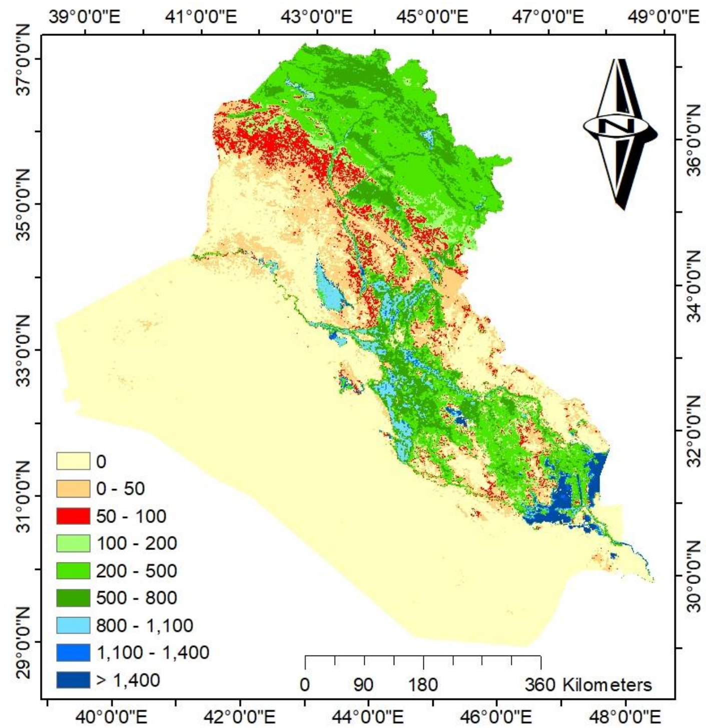

Figure 7-Total monthly evapotranspiration until August 2020

Table 2-Area percentage of the ET categories

Range (mm)	% area
0	58
0 - 50	10
50 - 100	4
100 - 200	3
200 - 500	14
500 - 800	7
800 - 1100	2
1100 - 1400	1
> 1400	1

4. Conclusion

The prediction of evapotranspiration (ET) is important for water regulation and management, as it presents a fundamental role in the hydrological cycle. Estimating the amount of annual evapotranspiration in Iraq helps specialists, and engineers of water resources to know the current and future state of lost water due to this phenomenon. The model data was verified with field data for 2012 and there was a coincidence between them. Conclusions for the ET values can be summarized in the following points:

- For years from 2003 to 2016, there was a lack of ET (ET = 0), the average percentage of its area was about 24% of the area of Iraq, while for years from 2017 to 2020, the average area percentage was more than half of the study area, or about 56%.
- For years from 2003 to 2016, the value of ET ranged from 0 to 50 mm, it occupied an area of 29% of the entire area of Iraq and 10% for years from 2017 to 2020.
- The ET value, which ranges from 50 to 100 mm, involved an average area of about 12% of the whole area for years from 2003 to 2016 and 4% for years from 2017 to 2020.
- ET values greater than 100 mm, the area ratio was close for all years, as these values were in water bodies such as rivers and lakes.

From the above-mentioned, we noted that last four years (2017 to 2020) the values of ET equal to zero had an area that occupied a little more than half of the area of Iraq. This indicates the lack of vegetation cover in these years due to the lack of water quotas of Tigris and Euphrates and the lack of precipitation, especially in the high-temperature season (i.e. summer).

5. Recommendation

Recommending an increase for discharges from neighboring countries, especially Turkey, Syria, and Iran, as they are the source of entry of Tigris and Euphrates water into Iraqi lands. As for Iraq, the act of accelerating the construction of water reservoirs, such as the construction of dams, barrages, and regulators increases the vegetation cover and eliminates water scarcity.

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