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Estimation of Spatial Groundwater Recharge Using WetSpass Model for East Wasit Province, Iraq

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Abstract

Groundwater is an important water source, especially in arid and semi-arid areas. Recharge is critical to managing and analyzing groundwater resources despite estimation difficulty due to temporal and spatial change. The study aim is to estimate annual groundwater recharge for the eastern Wasit Province part, Iraq. Where suffers from a surface water shortage due to the region's high elevation above Tigris River water elevation by about 60 m, it is necessary to search for alternative water sources, such as groundwater use. The spatially distributed WetSpass model was used to estimate the annual recharge. The inputs for the model were prepared using the ARC-GIS program, which includes the topography and slope grid, soil texture grid, land use, groundwater level grid, and meteorological data grids for the study area for the period (2014-2019). The result shows that the annual recharge calculated using the WetSpass model (2014-2019) varied of 0 to 65.176 mm/year at an average of 27.117 mm/year, about 10.8%, while the rate of the surface runoff was 5.2% and Evapotranspiration formed 83.33% of the annual rainfall rate of 251.192 mm. The simulation results reveal that the WetSpass model simulates the components of the hydrological water budget correctly. For managing and planning available water resources, a best grasp of the simulation of long-range average geographical distribution around the

Keywords: Groundwater recharge, WetSpass model, east Wasit province, spatial distribution

الخلاصة: تعتبر المياه الجوفية مصدرًا مهمًا للمياه ، خاصة في المناطق القاحلة وشبه القاحلة. التغذية أمر بالغ الأهمية لإدارة وتحليل موارد المياه الجوفية على الرغم من صعوبة التقدير بسبب التغيير الزماني والمكاني. تهدف الدراسة إلى تقدير التغذية السنوية للمياه الجوفية للجزء الشرقي من محافظة واسط ، العراق. حيث تعاني من نقص المياه السطحية بسبب ارتفاع المنطقة عن ارتفاع مياه نهر دجلة بحوالي 60 م ، من الضروري البحث عن مصادر مياه بديلة ، مثل استخدام المياه الجوفية. تم استخدام نموذج WetSpass الموزع مكانيًا لتقدير التغذية السنوية. تم إعداد مدخلات النموذج باستخدام برنامج ARC-GIS ، والذي يشمل التضاريس وشبكة المنحدرات ، وشبكة نسيج التربة ، واستخدام الأراضي ، وشبكة مستوى المياه الجوفية ، وشبكات بيانات الأرصاد الجوية لمنطقة الدراسة للفترة (2014-2019). تظهر النتيجة أن التغذية السنوية المحسوبة باستخدام نموذج WetSpass (2014-2019) تراوحت من 0 إلى 65.176 ملم / سنة بمتوسط 27.117 ملم / سنة ، حوالي 10.8٪ ، بينما كان معدل الجريان السطحي 5.2٪ وشكل التبخر النتح 83.33٪ من معدل هطول الأمطار السنوي 251.192 ملم. تكشف نتائج المحاكاة أن نموذج WetSpass يحاكي مكونات الميزانية المائية الهيدرولوجية بشكل صحيح. لإدارة الموارد المائية المتاحة وتخطيطها ، من المفيد الحصول على فهم أفضل لمحاكاة متوسط التوزيع الجغرافي على المدى الطويل حول مكونات توازن المياه.

1. INTRODUCTION

The world's largest freshwater resource is groundwater, which is essential for irrigated agriculture and, as a result, for global food security. Despite this, large groundwater systems have been depleted in both semi-arid and humid regions of the globe. The primary source of depletion is excessive irrigation extraction in areas where groundwater is slowly recharged, and climate change can exacerbate the situation in particular areas. Therefore, groundwater levels must be stabilised in such areas for long-term food production to be sustainable. To do this, we must change the way we value, manage, and classify groundwater resources [1]. Groundwater is the subsurface water that exists under the water table in soils and geologic formations completely saturated [2]. One of the most significant natural resources on the planet is groundwater. Many major cities and small towns worldwide rely on groundwater for their water supplies, owing to its quantity, consistent quality, and low cost of extraction [3].

To determine the amount of recharge from rainfall, it is necessary to understand the relationships between rainwater and surface runoff. The first step is determining the portion of precipitation available to recharge groundwater after subtracting the lost land flow (surface runoff) and evapotranspiration ET. Groundwater recharge is an important parameter that controls groundwater's state and fluctuations and needs a complete evaluation. The groundwater recharge is affected temporally and spatially by many factors such as meteorology, soil characteristics, geology, surface cover, slope, and depth of the groundwater table [4].

WetSpass is an acronym for transferring water and energy between soil, plants, and the atmosphere in a quasi-static state. WetSpass is a spatial distributed hydrological model. This model was created at the Vrije Universiteit Brussels Department of Hydrology and Hydraulic Engineering and is thoroughly explained in various publications [5]. It is a physical model used to estimate long-term mean spatial patterns of runoff, actual evapotranspiration, and groundwater recharge employing physical and empirical relationships. It is a model embedded within GIS (ARC View), coded in Avenue, built into ARC View. Several studies have used the WetSpass model in different regions of the world and different circumstances. It gave good results and recommended using the WetSpass model in calculating the water balance components as it provides accurate results [6, 5, 7.8, 9, 10, 11,12,13,14,15,16,17,18,19,20, and 21]. It is constructed using WetSpa, a time-dependent spatially distributed water balance model. Grids of land use, groundwater level, precipitation, potential evapotranspiration, wind-speed, temperature, soil, slope, and topography are used inputs in this model, with factors like soil texture, land use and runoff linked to the model in the form of attribute tables [5].

Seasonal and annual runoff and evapotranspiration are deducted from seasonal and annual precipitation, the WetSpass model calculates the quantity of the long-range seasonal and annual geographical distribution of groundwater recharge [12]. The model allows researchers to understand better and estimate interactions between the atmosphere and surface water and groundwater and produces a spatially distributed recharge needed for further groundwater modelling and simulation. It also estimates other seasonal hydrological components that are spatially distributed, such as evapotranspiration, transpiration, surface runoff, interception, and evaporation from the soil [7]. Many studies were conducted on the study area, where the surface runoff was calculated [22], and the SWAT model was used to calculate the surface runoff [23, 24]. The morphometric analysis was conducted for the study area [25], but the groundwater recharge was not calculated for the study area in the previous studies. The study aims to estimate the recharge of groundwater distributed spatially in the eastern part of Wasit Governorate, Iraq.

2. METHODOLOGY

2.1. Study area

The location of the study area is in the eastern part of Wasit Governorate, Iraq. The area covers an area of roughly 5043 km² and includes the areas of Badra District (Jassan Zorbatiyah) and Sheikh Saad District, where the site is located between (32°30'-33°30'N) north latitude and (45°30'- 46°45'E) east longitude. Figure 1shows the study area location.

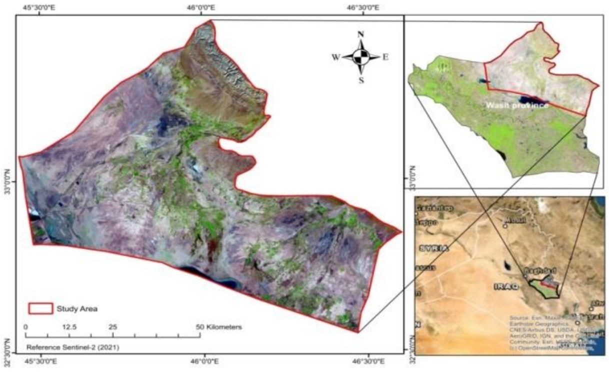


Figure 1 The Study Area Location

2.2. WetSpass model

Hydrological models are frequently employed as a standard tool for investigating hydrological courses, using various applications, from tiny watersheds to global models [19]. Each model has its own set of applications, traits, and flaws. The water balance of a grid cell is calculated using the WetSpass (Water and Energy Transfer between Soil, Plants, and Atmosphere under Steady-State Conditions) model in this work (considering the fractions of bare soil, vegetation, impervious area, and open water) . This model has a lot of advantages when it comes to analysing long-range average spatial styles of groundwater recharge [5]. The WetSpass model can accurately estimate groundwater recharge [26, 8, 19, and 27]. The spatial groundwater recharge yearly is estimated using the WetSpass model in this article. The following equations are used to compute the total water balance constituents of the vegetated, bare soil, open water, and impervious fraction per raster cell [6]:

$$ET_{raster} = avETv + asEs + aoEo + aiEi \quad (1)$$

$$S_{raster} = avSv + asSs + aoSo + aiSi \quad (2)$$

$$R_{raster} = avRv + asRs + aoRo + aiRi \quad (3)$$

ET_raster, S_raster, R_raster the total evapotranspiration, surface runoff, and groundwater recharge of a raster cell have a vegetated, bare-soil, open-water, and impervious area component, denoted by av, as, ao, and ai, respectively. The water balance was discussed in each component and is as follows. The water balance for all of the components mentioned above of a raster cell is computed starting with precipitation. Then, the rest of the processes (interception, runoff, evapotranspiration, and recharge) follow logically. This order becomes a requirement for the processes to be quantified on a seasonal time scale.

2.2.1. Vegetated Area

The water balance in the cultivated area depends on the average seasonal rainfall (P), interception fraction (I), Surface runoff (Sv), actual transpiration (Tv), and groundwater recharge (Rv), all in units of length to units time.

$$P = I + Sv + Tv + Rv \quad (4)$$

2.2.2. Interception

The interception portion is a predetermined percentage of the yearly precipitation value, depending on vegetation cover. Thus, the fraction value drops as the rain increases because the vegetation cover remains constant during the simulation period.

2.2.3. Surface runoff

The amount of precipitation, precipitation intensity, interception, and infiltration capacity are used to determine surface runoff, with the potential of surface runoff (Sv-pot) being calculated first:

$$Sv - pot = Csv\,(P - I) \quad (5)$$

Sv: is the surface runoff coefficient of vegetative infiltration areas being a function of vegetation cover, soil type, and slope. Surface runoff occurs in groundwater drainage areas, which leads to a very high surface runoff coefficient. The reason is the dependence on the soil, the type of vegetation cover, and the area's periphery from the river. Typically assume the coefficient is to be constant. Then, in the second step, the actual $Sv - pot$ runoff is calculated by looking at the rainfall intensity differences concerning soil infiltration capabilities [6].

$$Sv = C_{Hor} - S_{v-pot} \quad (6)$$

C_{Hor}: It is a parameter for parameterising part of the seasonal precipitation that contributes to the Hortonian overland flow. Because all precipitation intensities contribute to surface runoff, for groundwater discharge zones C_{Hor} equals 1.0. Surface runoff can only be generated by high-intensity storms in infiltration zones [5].

2.2.4. Evapotranspiration

To calculate seasonal evapotranspiration, a reference value of transpiration from open water evaporation and a vegetation coefficient are obtained [6].

$$T_{rv} = c\,Eo \quad (7)$$

T_{rv} = The plant surface's reference transpiration $[LT^{-1}]$
Eo = Evaporation from open water $[LT^{-1}]$
c = vegetation coefficient [–]
In light of the Penman-Monteith equation for the probability of open water evaporation, as shown in the Penman equation, the vegetation coefficient can be derived as a reference ratio of vegetation transpiration.

$$c = \frac{1+\gamma/\Delta}{1+\gamma/\Delta(1+\frac{r_c}{r_a})} \tag{8}$$

γ = constant psychrometric $[LT^{-1}T^{-2}C^{-1}]$;
Δ = the slope of the saturation vapour pressure curve's first derivative (the tendency for saturation vapour pressure at the predominant air temperature) $[LT^{-1}T^{-2}C^{-1}]$;
r_c = resistance to the canopy $[LT^{-1}]$ and
r_a = resistance to aerodynamic $[LT^{-1}]$ provided through

$$r_a = \frac{1}{k^2 u_a} \left(\ln\left(\frac{z_{a-d}}{z_o}\right)\right)^2 \tag{9}$$

k is the constant of Von Karman (0.4) [–];
u_a is the wind speed $[LT^{-1}]$ at the measurement level z_a = 2m;
d is the length of the zero-plane displacement [L] and
zo is the vegetation's or soil's roughness length [L].
The Penman coefficient (/) is temperature dependent and can be found in the table below:

Table 1 Variation in Penman coefficient/values as a function of temperature

T (°C)	-20	-10	0	5	10	15	20	25	30	35	40
λ/Δ	5.86	2.83	1.46	1.07	0.76	0.59	0.45	0.35	0.27	0.25	0.17

The values of actual transpiration Tv are equal to the values of reference transpiration. Therefore, there is no limit to the availability of soil or water for plant groundwater drainage areas.

$$T_v = T_{rv} \quad \text{if } (G_d - h_t) \leq Rd \tag{10}$$

G_d is the depth of the groundwater [L];
h_t is the height of saturated tension [L], and
Rd is the depth of the rooting [L].
The groundwater level is lower in cultivated areas than the zone of the root, as the actual transpiration is obtained from the equation.

$$T_v = f(\theta)\, T_{rv} \quad \text{if } (G_d - h_t) > Rd \tag{11}$$

It is a function for water content, and it is defined as in a time-variant condition.

$$f(\theta) = 1 - {a_1}^{w/T_v} \tag{12}$$

provided,

$$w = (p + \theta_{FC} - \theta_{pwp})R_d \tag{13}$$

a_1 is a calibrated measure related to a soil type's sand content [-];
w is the amount of water available for transpiration $[LT^{-1}]$ and
$\theta_{FC} - \theta_{pwp}$ is the plant's accessible water content. the variation in water content at field capacity per time step $[T^{-1}]$ and the permanent wilting point is stated.
It is the water content available to plants $[T^{-1}]$ for each time step, it is referred to as the difference in water content at the field capacity and the permanent withering point.

2.2.5.Recharge

Recharge is the inflow of water into a saturated groundwater area at the surface of the water level. It is estimated as a residual range for the water balance system in the model because the model determines the long-range geographically distributed average recharge as a spatial variable, which is affected by soil texture, land use, slope, and meteorological variables [28]. Recharging is when water is in motion down from surface water to a groundwater region (Vaduz) below plant roots. The WetSpass model calculates groundwater recharge as a residual term for the water balance.

$$R_v = p - S_{FC} - ET_V - I \quad (14)$$

ET_V is the real evapotranspiration $[LT^{-1}]$ It is calculated as the total of transpiration T_V and evaporation E_s (evaporation from bare soil between vegetation).

After applying the above equations and relationships, spatially distributed recharge estimates can be made from vegetation type, soil type, slope, groundwater depth, precipitation, potential evapotranspiration, temperature, and wind speed. Furthermore, a little unsaturated zone is present even in discharge locations and will be some recharging associated with discharge areas. However, substantial potential transpiration due to vegetation occurs during the summer. As a result, recharge values in discharge areas are negative. A high winter recharge can occasionally compensate for low recharge numbers**.**

2.2.6. The “water balance” of “bare soil, open water,” and impermeable surfaces

Recharge is estimated from the water balance of bare soil,

$$P = Ss + Es + Rs \quad (15)$$

(P) refers to precipitation, Ss is surface runoff, Es is actual evaporation, Rs is groundwater recharge measured in units of (L/T). Equation 4.4 is the same as this one, except there is no objection and the term transpiration. The ET_V, in this case, becomes Es. The runoff is simulated in a similar way to the vegetation fraction in two stages. In the first stage, the potential surface runoff is calculated (Sv - pot), and in the second stage, the actual surface runoff is calculated using equation 16. The water balance is defined for the open water portion of a pixel is defined as:

$$P = So + Eo + Ro \quad (16)$$

P is precipitation, Eo is evaporation from the water surface and part of precipitation that travels across the water’s surface, and Ro is groundwater recharge from open water, and both contain L / T unit.

Finally, water balance is also provided for impermeable surfaces is also provided by:

$$P = S_i + E_i + R_i \quad (17)$$

Seasonal and annual runoff and evapotranspiration are subtracted from seasonal and annual precipitation. The WetSpass model predicts the quantities of the long-term seasonal and annual geographical distribution of groundwater recharge. Figure (2**)** shows a schematic representation of water balance.

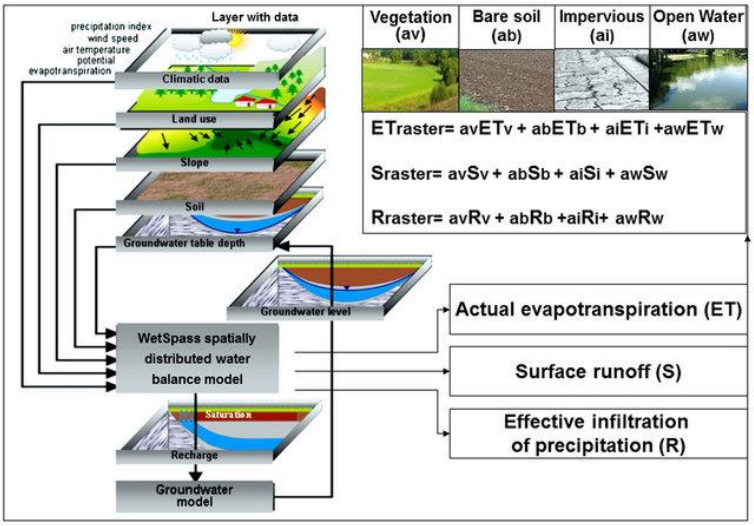


Figure 2 water balance diagram [6, 29].

2.3. Input Data

WetSpass model inputs maps and tables were prepared for the period (2014-2019). They are the climatic data, the land use/land cover map for 2018, the soil map for the study area, and the topography, slope data and groundwater level. In addition, the tables for the land cover parameters for winter and summer and soil and runoff were used. Thiessen polygons were chosen above other approaches because it produces more logical results [10].

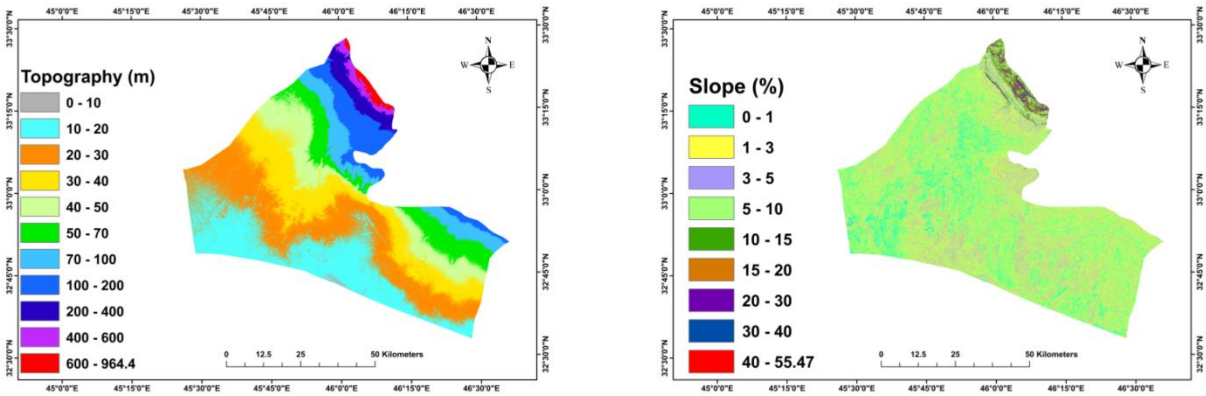
According to the Thiessen polygon method, the climate stations shown in Table 2 was used to produce the climate maps. The input maps were prepared to the WetSpass model using GIS software, and the cell size was 30 m * 30 m.

Table 2 The coordinates and elevations of the stations of the study area (Iraqi Meteorological organisation and seismology).

Station	latitude	Longitude	Elevation(m)
Badra	33°.1000	45°.9500	64
Ali Al-Garbi	32°.5200	46°.8500	15
Kut	32°.5000	45°.8167	19
Aziziyah	32°.9167	45°.0667	25

2.3.1.Topography and slope

The US Geological Survey website (https://earthexplorer.usgs.gov/) provided the Digital Elevation Model (DEM) (SRTM) at a resolution of 30 meters for the year 2014. The topography values of the area of study range from 0 to 964.4 m at a rate of about 58.9 m above sea level with a standard deviation of 94.4. Figure (3a) shows the topography map of the study area. Slope values range from 0 to 55.46%, with a mean of 2.05% and a standard deviation of 2.86. Figure (3b) shows the slope map of the study area. The basis of the WetSpass spatially distributed hydrological model is the area's topography in question since topography determines most of the hydrological processes.

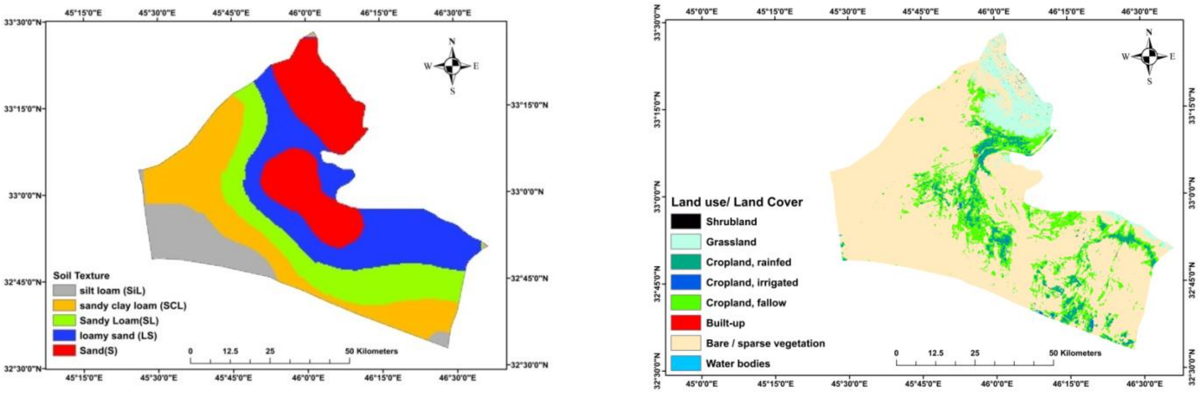


(a) (b)

Figure 3 (a) Topography map, (b) slope map

2.3.2.Soil texture and Land use

The soil texture map used as an input to the WetSpass model was produced by collecting 25 soil samples from the study site, conducting the sieve analysis, examining the hydrometer and making the soil texture map shown in Figure (4a). There are seven uses recognised by the World Food and Agriculture Organization for 2018: Shrubland, Grassland, Cropland rainfed, Cropland fallow, Built-up, Bare land/sparse vegetation, and water. Bare land/sparse vegetation constitutes a large part of the study area. Figure (4b) shows land use for the study area. Permeability and soil texture are essential in calculating recharge because coarse-grained soils generally have higher recharge rates than fine-grained soils [31, 32]. Land use is essential for boundary conditions, directly or indirectly affects hydrological processes. The most apparent effect of land use on the water balance is the evapotranspiration process. Different land-use types have different evapotranspiration rates due to the difference in vegetation cover, leaf area, and root depth [6].



(a) (b)

Figure 4 (a) Soil Texture for the study, (b) Land use (https://wapor.apps.fao.org/, 2018)

2.3.3.Groundwater level

The location of the groundwater table must be considered when estimating recharge since evapotranspiration from shallow groundwater can be considerable, especially in groundwater-dependent wetlands [5]. The groundwater table map is one of the inputs that the WetSpass model needs to run the model. Therefore, Wells data was obtained from (Ministry of Water Resources, General Commission for groundwater, Wasit Branch). Figure 5 shows the groundwater level for the study area.

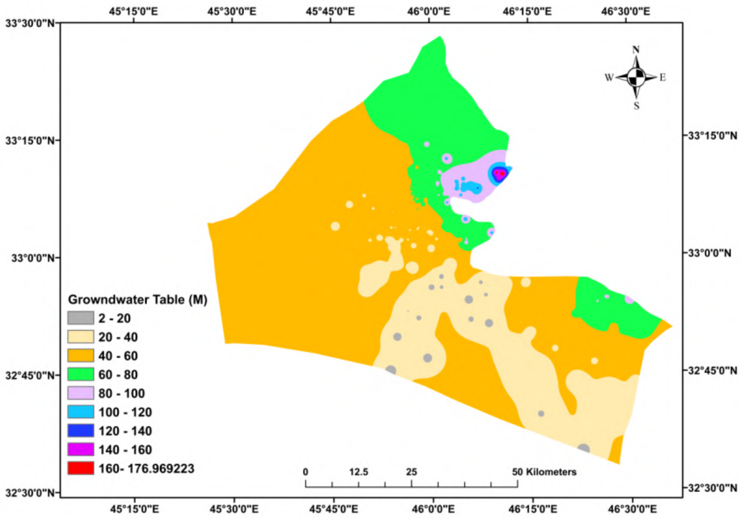
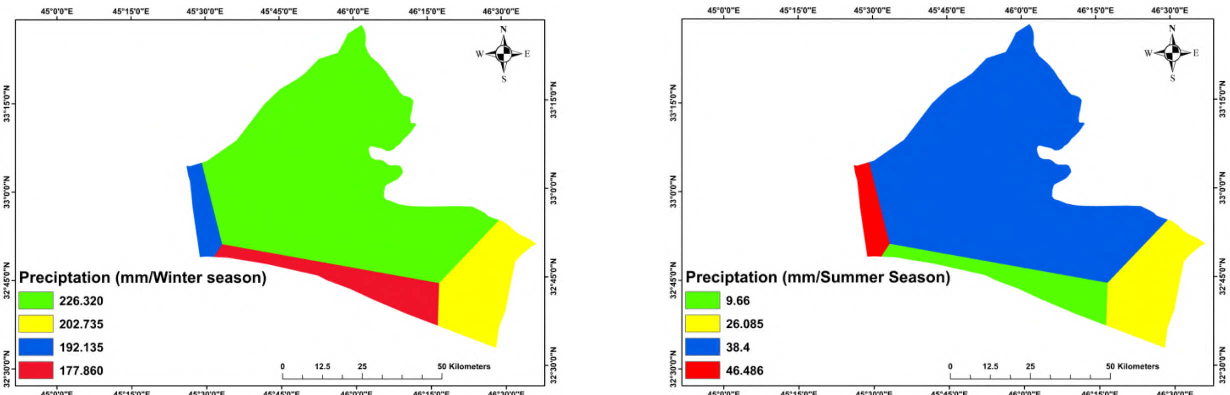


Figure 5 groundwater level for the study area

2.3.4.Precipitation

Figure 6 (a,b) shows the two maps of precipitation for the winter and summer seasons over the study area from 2014 to 2019, where the average rainfall ranges from 177.860 mm to 226.320 mm at an average of 217.508 mm. and a standard deviation of 16.004 mm for the winter season and average rainfall ranges from 9 mm to 46.486 mm for the summer season. The essential aspect of the hydrological process is precipitation. It is the driving force in the hydrological cycle and the availability of water, which will eventually recharge the groundwater system. Precipitation is an important source of groundwater recharge, especially in dry and semi-arid environments [30].

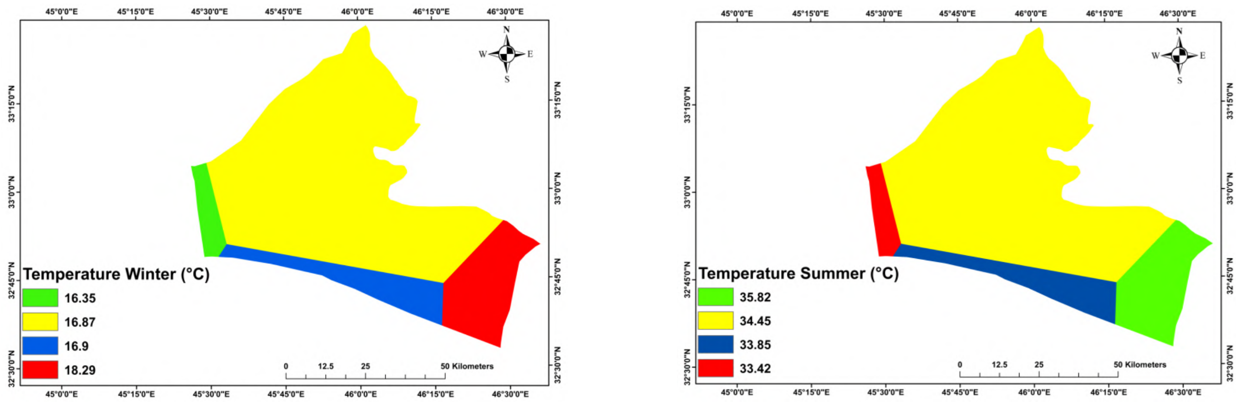


(a) (b)

Figure 6 (a) Precipitation winter season, (b) Precipitation summer season

2.3.5. Temperature

Figure 7 (a) shows the two temperature maps during the winter and summer seasons. The average temperature during the winter season ranged from 16.35 C° to 18.29 C° at a rate of 17.034 C°, while Figure 7 (b) shows the average temperature during the summer season ranged from 33.42 C° to 35.82 C° with a rate of 34.533 C° for the region of study during the period 2014-2019. Temperature affects groundwater recharge, as the relationship between temperature and recharge is inverse.

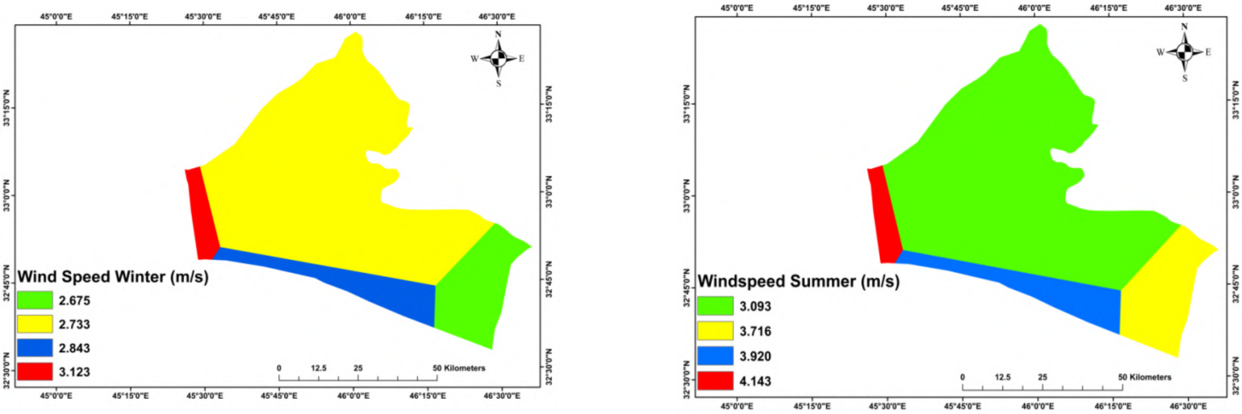


(a) (b)

Figure 7 (a) Temperature for the winter, (b) Temperature for the summer

2.3.6. Wind speed

Figure 8 (a) shows the two maps of the average wind speed for the study area for the winter and summer seasons during the period 2014-2019. The average wind speed for the winter season ranged from 2.675 m/sec to 3.123 m/sec at an average rate of 2.749, while the rate wind speed during the summer season ranged from 3.093 m/sec to 4.143 m/sec at a rate of 34.533 m/s. While Figure 8 (b) shows the rate wind speed during the summer season ranged from 3.093 m/sec to 4.143 m/sec at a rate of 34.533 m/s.

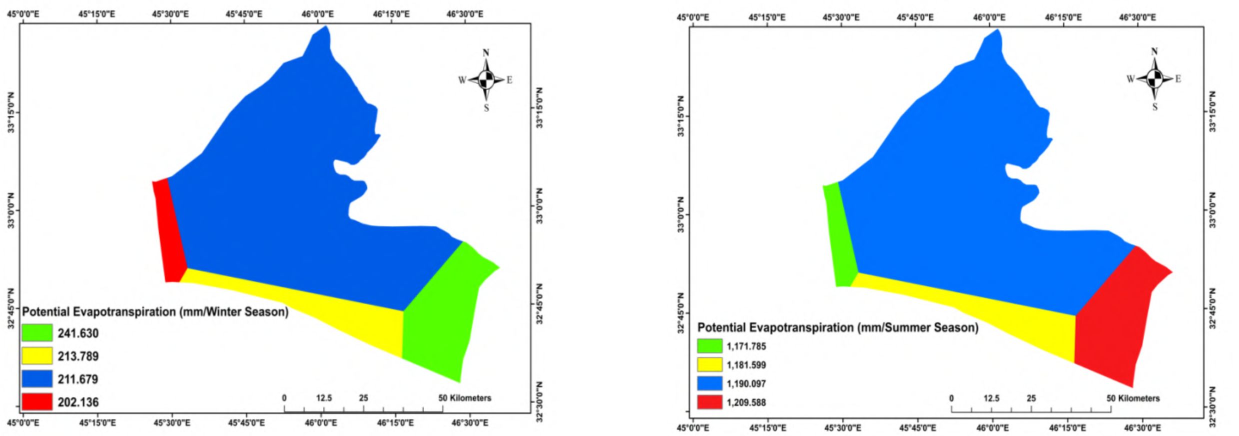


(a) (b)

Figure 8 (a) the wind speed for the winter, (b) the wind speed for the summer

2.3.7.Potential evapotranspiration

The method (Thornthwaite 1984) was used to make accurate calculations of potential transpiration evaporation. This method is more suitable for the study area than other methods because it depends on the average monthly temperatures and the information available for modifying the radiation hours during the day. Figure 9 (a,b) shows the potential evapotranspiration maps during the winter and summer seasons. The potential evapotranspiration rate ranges from 202.136 mm to 241.630 mm during the winter season rate of 215.346 mm. At the same time, the evapotranspiration rate in the summer ranges from 1171.785 mm to 1209.588 mm, at an average of 1191.122 mm. Thus, the rate of potential evapotranspiration during the summer season is high due to high temperatures.



(a) (b)

Figure 9 (a) Potential evapotranspiration for the winter season, (b) Potential evapotranspiration for the summer season

3. RESULTS AND DISCUSSION

Figure 10 shows the spatially distributed annual recharge values ranging from 0 to 65.176 mm/year at a 27.117 mm/year rate distributed over the study area of 5043 km2. The volume of water from the annual recharge obtained by groundwater is 136.751 million cubic meters of groundwater.

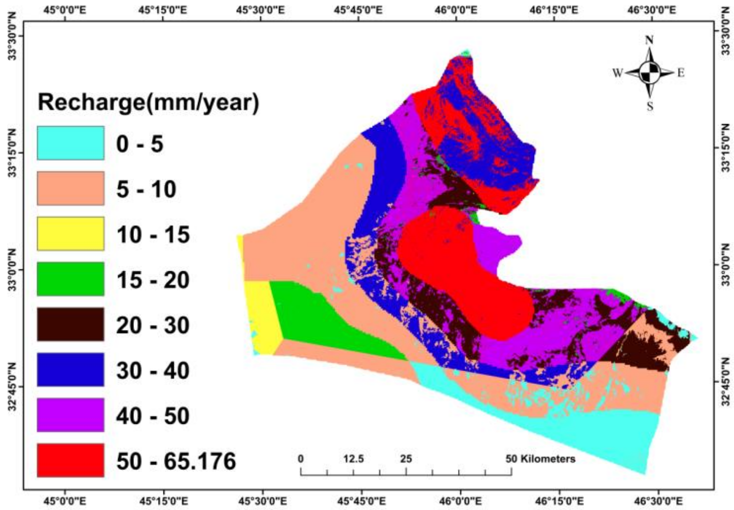


Figure 10 groundwater recharge map for the period (2014-2019)

Table 3 shows the distribution of annual recharge in the study area. The value of the recharge spatially distributed (0-5) mm. This value represents 9.615% from the area of study. This part is located in southwestern part of the study area. The soil texture in this part is sandy clay loam. The land cover is agricultural land and bare land section. The topography of this part ranges from (10-30) m above sea level, and the groundwater level in this part is (20-60) m. The value of the spatially distributed recharge is (10-5) mm. This value represents 28.224% of the area of the study area, and this section of the research area is in the northwest corner. The soil texture in this part is sandy clay loam. The vegetation cover is barren land. The topography of this part ranges from (30-20) m from sea level, and the groundwater level in this part is (40-60) m. The value of recharge (10-15) mm constitutes about 2.388% from the area of study and is located in the north western part. The soil texture in this part is silt loam, type of vegetation cover, bare land, groundwater level (40-60) m terrain (10 -20) m above sea level. Distributed recharge (15-20) mm. This part constitutes 66.5 percent of the area of the study area. This part is located northwest of the study area. Soil type silt loam, land cover, bare land. Groundwater level (40-60) m and topography (10 -30) m. Distributed feeding (20-30) mm. This part constitutes 94.95% of the area. This part is located in the middle of the study area, soil texture Sand Loamy. The vegetation cover in this part is barren land and agricultural lands. The topography of this part is (30-70) m level. The groundwater level in this part (20-60m). Distributed recharge (30-40) mm. This part constitutes 4.114% of the area. This part is located in the middle and north of the study area. Soil type is Sandy Loam, land cover, and part of agricultural cropland. Distributed recharge (40-50) mm This part constitutes 13.03% of the area. This part is located in the middle of the study area. Soil type loamy sand land cover Agricultural croplands and barren lands groundwater level (20-60) m topography (40-70) m. The spatially distributed nutrition (50-65.176) mm. This part is located in the middle of the study area and constitutes 17.021% of the area of the study area. Soil type: Sandy soil, land cover, agricultural croplands and bare lands. Figure 11 shows the study area’s spatially distributed annual surface runoff map (2014-2019). The annual runoff ranges of (0 to 113.752) mm, with an average of 13.07 mm and a standard deviation of 17.989.

Table 3 Annual recharge spatial distribution for the period (2014-2019)

No.	Recharge(mm/year)	Area (Km^2)	Percent from study area%
1	0-5	484.899	9.615
2	5-10	1423.361	28.224
3	10-15	120.449	2.388
4	15-20	285.543	5.662
5	20-30	501.528	9.945
6	30-40	711.752	14.114
7	40-50	657.095	13.030
8	50-65.176	858.373	17.021

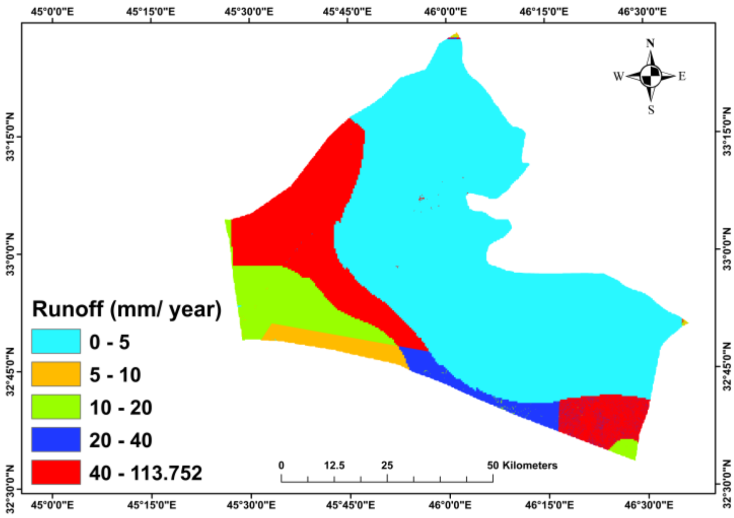


Figure 11 Runoff for the period (2014-2019)

Table 4 shows the annual runoff values distributed spatially over the area of the study area for the period (2014-2019). The value (0-5) mm occupies the largest area of the study area, representing 66.543%. Figure 12 shows the map of the actual annual evapotranspiration in the study area (2014-2019), values ranging from 131.725 mm to 1373.921 mm at a rate of 209.316 mm.

Table 3 Annual Runoff spatial distribution for the period (2014-2019)

No.	Annual runoff (mm/year)	Area (Km^2)	Percent from study area%
1	0-5	3355.747	66.543
2	5-10	131.229	2.602
3	10-20	404.839	8.028
4	20-40	162.260	3.218
5	40-113.752	988.924	19.610

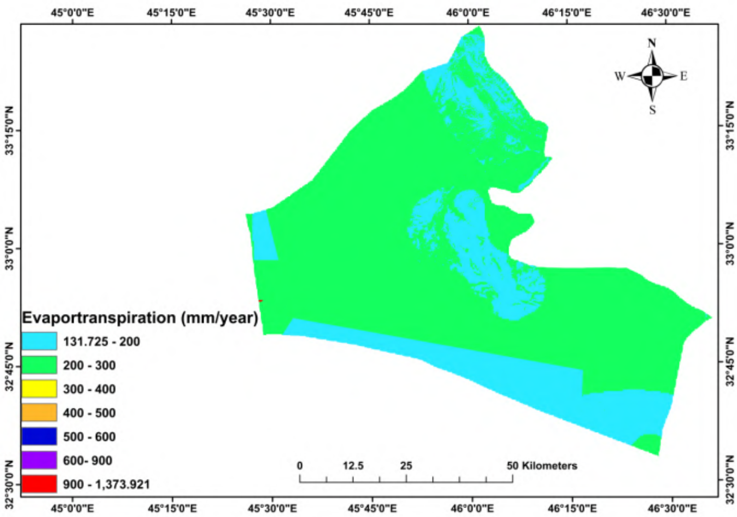


Figure 12 Evapotranspiration for the period (2014-2019)

Table 5 shows the annual evapotranspiration values distributed spatially over the area of the study area for the period (2014-019). The value (200-300) covers the most significant proportion of the area of the study area, which constitutes 74.288 %.

Table 5 Annual Evapotranspiration spatial distribution for the period (2014-2019)

No.	Evapotranspiration (mm/year)	Area (Km^2)	Percent from study area%
1	131.725-200	1296.306	25.70505
2	200-300	3746.361	74.28834
3	300-400	0.333604	0.006615

4. CONCLUSIONS

In this study, the WetSpass model was applied to calculate the spatially distributed annual recharge for the eastern part of Wasit province, Iraq. The WetSpass model displayed that the average annual recharge in the study area was 27.117 mm/year, about 10.8% of the annual rainfall rate (136.75 million meter cubics). High recharge occurred in Agricultural lands and the sandy texture soil class. As a result of sandy soils' high permeability and the absence of surface runoff on agricultural regions with relatively mild slopes, low recharge was observed in areas with barren lands that contain clay soils and wet drainage areas. Evaporation formed about 83.33% of the yearly average precipitation in the study area. The results indicated that evapotranspiration is the main process of water loss in the study area due to high temperatures, solar radiation, and the persistence of strong dry winds. Assess groundwater recharge in east Wasit province, critical for integrated groundwater modelling and effective long-term planning and management of the region's available water resources. The geographic variability of groundwater recharge is influenced by climate data, groundwater depth, distributed land cover, soil texture, terrain, and slope. Soil textures and land cover. The spatially distributed Wetspass model was used to calculate the long-range annual and seasonal recharge of groundwater and the water balance components for the eastern region of Wasit Province.

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