Journal of Water Resources and Geosciences

Vol.5, No.1, 2026

Evaluation of Agricultural land Productivity and Irrigation Performance Indicators by Using Remote Sensing Techniques via Wapor3 Platform and ARCGIS Software (Salah Al-Din Governorate lands as a Case Study)

Ghaith Mohammed.Ali Majeed[1,*], Hatem H.Hussien[2], Shatha Salem Majeed[3], Galwah Talal Sami[4], Mohammed Tawfiq[5]

[1,5] National center for water resources management- Ministry of Water Resource- Baghdad

[2,3,4] Ministry of Water Resource- Baghdad

Corresponding author's email ghaith81alsaffar@gmail.com

Abstract

Improving water management, based on irrigation performance analysis and water productivity assessment tools, leads to better water resource management, ensuring optimal use and minimizing losses. Therefore, this study aimed to highlight a crucial issue: investing in technology, such as remote sensing techniques, to enhance monitoring and surveillance of agricultural fields. In this paper, remote sensing models were developed using open-source software such as ArcGIS to calculate land productivity coefficients and irrigation parameters for the lands of Salah al-Din Governorate. Wapor 3 platform products were used, and the remote sensing models showed that the highest productivity rates for wheat and barley crops in Salah al-Din Governorate, both within and outside irrigation boundaries, ranged from(0.61 - 1.1) tons/dunum. Additionally, the water productivity of plants corresponds to areas with insufficient irrigation, along with other detailed findings presented in this paper.

Keywords: Irrigation performance indicators, water productivity, remote sensing, Wapor, yield productivity.

Journal of Water Resources and Geosciences

Vol.5, No.1, 2026

تقييم انتاجية الاراضي الزراعية و مؤشرات أداء الري باستخدام تقنيات التحسس النائي عبر منصة Wapor3 وبرنامج ARCGIS (اراضي محافظة صلاح الدين كحالة دراسية)

غيث محمد علي مجيد[1,*] ، حاتم حميد حسين[2] ، شذى سالم مجيد[3] ،غلوى طلال سامي[4]، محمد توفيق[5]

[1,5] وزارة الموارد المائية- المركز الوطني لادارة الموارد المائية

[2,3,4] وزارة الموارد المائية -دائرة التخطيط والمتابعة

* البريد الالكتروني للمؤلف المراسل: ghaith81alsaffar@gmail.com

الخلاصة

يؤدي تحسين إدارة المياه، بالاعتماد على تحليل أداء الري وأدوات تقييم إنتاجية المياه، إلى إدارة أفضل للموارد المائية مما يضمن الاستخدام الأمثل وتقليل الفاقد. ولذلك، هدفت هذه الدراسة إلى تسليط الضوء على قضية بالغة الأهمية وهي الاستثمار في التكنولوجيا مثل استخدام تقنيات الاستشعار عن بُعد لتعزيز رصد ومراقبة الحقول الزراعية. في هذه الورقة، طُوّرت نماذج الاستشعار عن بُعد باستخدام برامج مفتوحة المصدر مثل ArcGIS لحساب معاملات إنتاجية الأراضي ومعايير الري لأراضي محافظة صلاح الدين حيث استُخدمت منتجات منصةWapor 3 ، وأظهرت نماذج الاستشعار عن بُعد بان أعلى معدلات إنتاجية لمحاصيل القمح والشعير في محافظة صلاح الدين، داخل حدود الري وخارجها، حيث تراوحت بين (0.61 -1.1) طن/دونم، بالإضافة انتاجية المياه للنباتات تتوافق مع المناطق ذات الري الغير كافي بالاضافة إلى نتائج أخرى مُفصّلة في هذه الورقة.

الكلمات المفتاحية: مؤشرات اداء الري , الانتاجية المائية ,الاستشعار عن بعد ,Wapor, انتاجية المحصول.

1.Introduction

Remote sensing, which includes sensors on aircraft or satellites, is a valuable tool for assessing crop productivity. It allows spectral data to be analyzed to identify crop types and monitor changes in crop health over time. This technology can also identify areas of failure, which can aid in interventions such as improving irrigation and fertilization performance to boost productivity. Various platforms, including the satellite-based Wapor platform such as Sentinel 2, provide high-resolution images for detailed crop mapping. However, there are challenges with clouds (FAO,2022). The origin of the word Wapor is an acronym for the first letters of the words shown (Water Productivity Open-access of Remotely) or in other words, as a comprehensive definition of its name as a platform:

(the portal to monitor Water Productivity through Open-access of Remotely sensed derived data)

ArcGIS is a free and open-source program that anyone can use at no cost. It is also multi-platform and run on Windows, Mac, and Linux operating systems, It is easy to use and feature a user-friendly graphical interface, it is powerful and offer a wide range of tools for analyzing geographic data. it is customizable and can be expanded using add-ons and their uses in creating maps, it can also be used to create interactive maps that display geographic data and analyze data, it can be used to analyze geographic data, discover patterns and relationships, and solve problems, it can also be used to solve problems related to geographic location. It are also used for planning projects and determining locations, among other advantages of both programs. The project of monitoring land and water productivity through remote sensing is considered one of the important projects that came through a contract between the Iraqi Ministry of Water Resources and the Food and Agriculture Organization (FAO), where the latter developed the project with the support of the Dutch government, an open database close to real time using satellite data that allows monitoring agricultural water productivity, as the Wabor platform currently covers Africa and the Near East, where the Food and Agriculture Organization established a partnership with the IHE Delft Institute for Water Education and the International Water Management

Institute (IWMI) (Food and Agriculture Organization of the United Nations). As for Iraq, the Wabor platform has developed two major projects with a spatial accuracy of (20*20) meters, which are a project in Erbil and a project west of Al-Gharraf between (Ministry of Water Resources, 2022).

Remote sensing and platforms have several uses in relation to water resources and crop monitoring. (ALsaffar, Ghaith, et al, 2025). used remote sensing models as a tool in water resources management, including river and drain basin management, as was the case with the Nasr Depression. Researchers (Al-Ahealy, Mustafa W., et al, 2024) also used platforms to monitor agricultural lands, including GEE.

(Fakhar and Kaviani, 2024). Researchers used the WaPOR platform, based on the FAO-56 methodology, to calculate several platform products in 16 provinces in Iran. They also derived the relationship between actual evaporation and transpiration and biomass, in addition to assessing water consumption in four climatic zones in Iran. The researchers considered the model's results to be a valuable guide for water resource planning in Iran.

(Dhonthi et al. 2024). The research paper included an explanation of the WaPOR platform, its main objectives, and its advantages in facilitating access for all researchers and specialists in water management and agriculture. It also highlighted its importance in evaluating performance indicators that assess the efficiency of irrigation systems. Given the platform's significance, the researchers developed the WaPLUGIN plugin for QGIS software. This plugin enables users to retrieve WaPOR data within QGIS. (Seijger, Chris, et al.,2023) The researchers assessed the variability in biomass and evapotranspiration data through agronomic linear regression analyses, for two large irrigated sugarcane farms in Ethiopia (Wonji) and Mozambique (Xinafani). The aim of this research was to assess whether the spatial variability in biomass and evapotranspiration as revealed by WaPOR could be attributed to anthropogenic factors, local climate differences, or methodological inaccuracies inherent in the WaPOR data. The paper reported cases in which 82-94% of the variability in biomass and evapotranspiration could be attributed to crop photosynthetic efficiency (very large effect), local climate (large effect) and irrigation technology (small effect) in addition to other findings included in the research. (Blatchford, Megan L., et al,2020). The present study examined long-term water availability and water balance by investigating continental spatial and temporal trends of major climates in Africa. The paper involved using the WaPOR platform with direct validation of ETIa-WaPOR against in situ data for 14 stations. Their results indicated that ETIa-WPOR performs well, but with some significant overestimation. ETIa-WPOR shows expected spatial and temporal consistency across climate categories. The quality assessment of ETIa-WPOR product is enhanced by combining multiple evaluation methods. Based on the results, the ETIa-WPOR dataset is of sufficient quality to contribute to understanding and monitoring local and continental hydrological processes and water management. Improving water management based on the analysis of irrigation performance evaluation tools and water productivity leads to improving water resource management to ensure optimal use and reduce water loss. Therefore, this study came to clarify an important issue, which is investing in technology such as using remote sensing techniques to improve monitoring and monitoring of agricultural fields. The current research paper includes calculating all the required parameters for this, starting with calculating several determinants specific to calculating land productivity determinants and determinants of irrigation management efficiency for agricultural lands in Salah al-Din Governorate for agricultural lands within and outside the irrigation boundaries, including the total agricultural yield with forests (AGBP), net agricultural yield (Yield).

Benefit factor (BF) in addition to other factors that we will discuss in the research paper. Figure No. (1) Wapor 2.3 platform interface. (FAO,n.d).

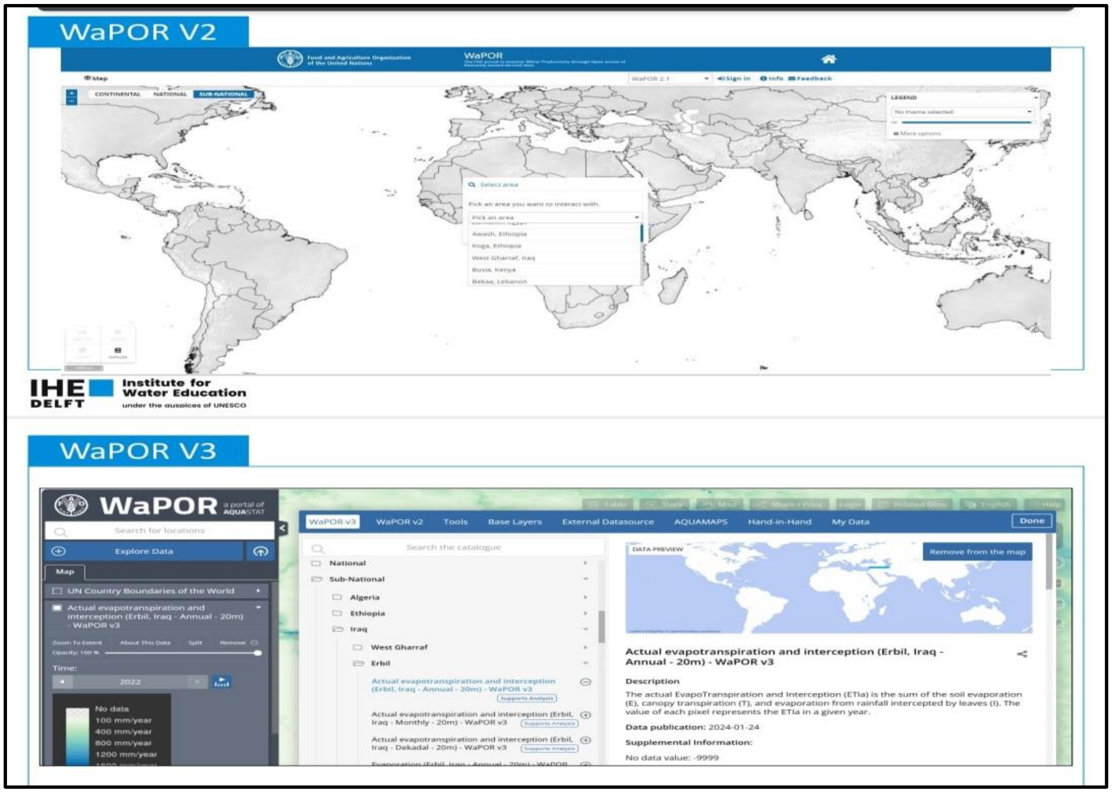


Figure (1): Wapor 2.3 platform interface, (National Center for Water Resources Management, 2024)

2.Study area

The study area extends between horizontal coordinates (Easting) 3,600,020 to 3,950,020 m and vertical coordinates (Northing) 260,030 to 500,030 m,) UTM coordinate system.). It encompasses cultivated agricultural lands of Salah Al-Din Governorate, which rely on surface water and wells (rainfed agriculture). 2023-2024 agricultural season was chosen as a case study for this research paper, during which the total cultivated area, both within and outside irrigated areas, reached 1,417.9 million dunams (National Center for Water Resources Management, 2023). Salah al-Din Governorate is one of the governorates that depends on surface water for irrigation, in addition to rainwater and wells. Figure (2).

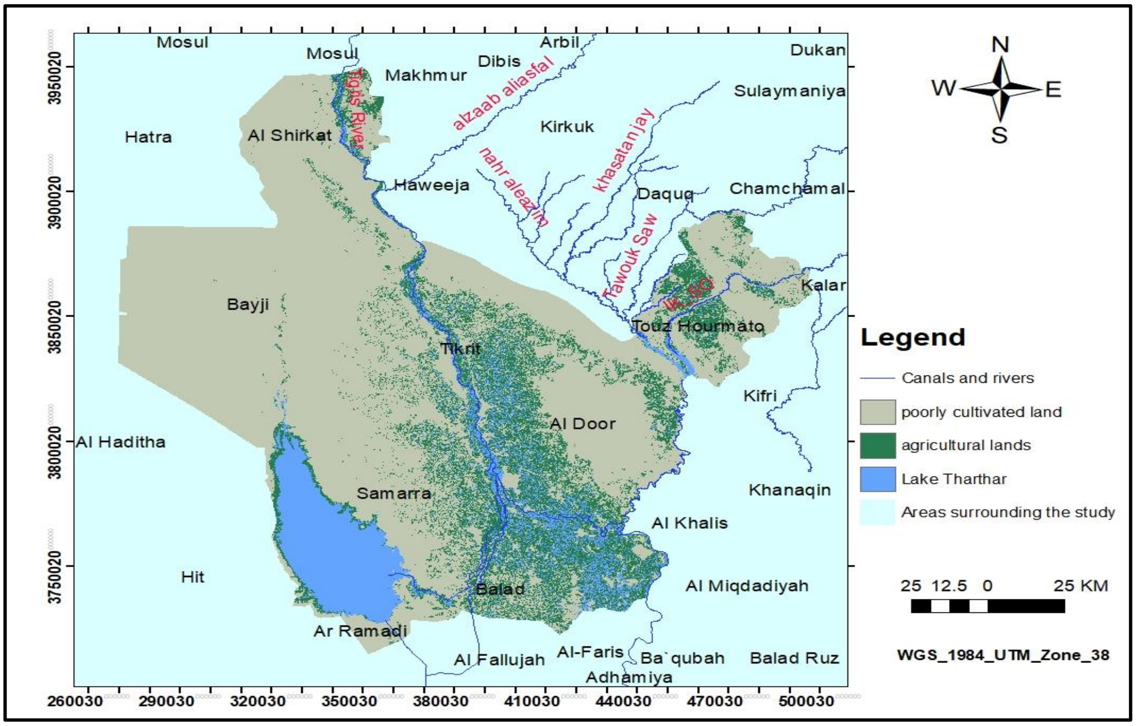
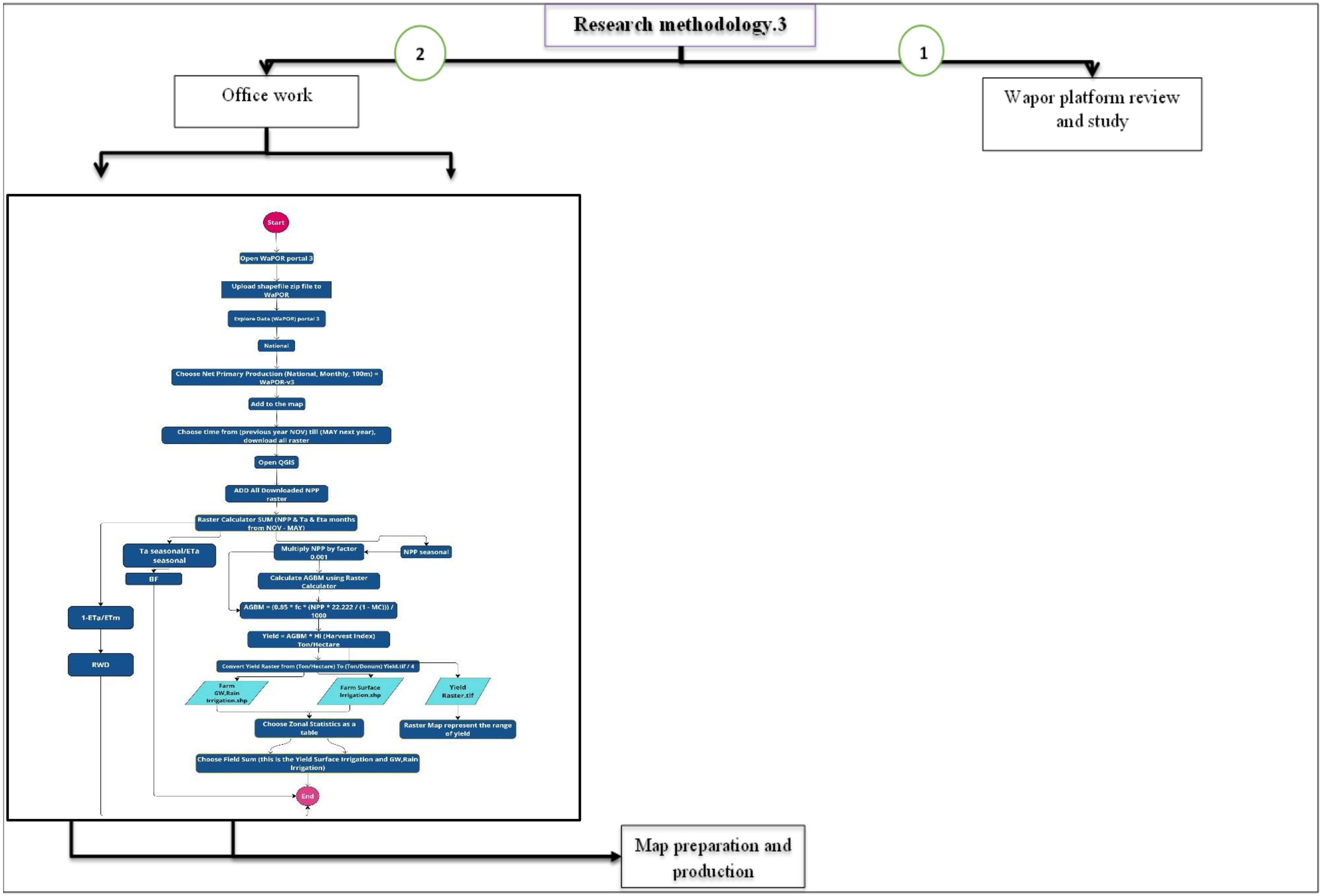


Figure (2): A grid map of the study area in Salah al-Din Governorate with a statement of agricultural lands.

3.Research Methodology

The study methodology includes the methods and techniques that were used to complete the research paper, which included all stages of work from collecting information, downloading data and products, and implementing remote sensing models, as shown in Figure 3.


Research methodology.3
2
1
Office work
Wapor platform review and study
Start
Open WaPOR portal 3
Upload shapefile zip file to WaPOR
Explore Data (WaPOR) portal 3
National
Choose Net Primary Production (National, Monthly, 100m) = WaPOR-v3
Add to the map
Choose time from (previous year NOV) till (MAY next year), download all raster
Open QGIS
ADD All Downloaded NPP raster
Raster Calculator SUM (NPP & Ta & Eta months from NOV - MAY)
Ta seasonal/ETa seasonal
BF
Multiply NPP by factor 0.001
NPP seasonal
Calculate AGBM using Raster Calculator
AGBM = (0.85 * fc * (NPP * 22.222 / (1 - MC)) / 1000
1-ETa/ETm
RWD
Yield = AGBM * Hi (Harvest Index) Ton/Hectare
Convert Yield Raster from (Ton/Hectare) To (Ton/Donum) Yield.tif / 4
Farm GW,Rain Irrigation.shp
Farm Surface Irrigation.shp
Yield Raster.tif
Choose Zonal Statistics as a table
Raster Map represent the range of yield
Choose Field Sum (this is the Yield Surface Irrigation and GW,Rain Irrigation)
End
Map preparation and production

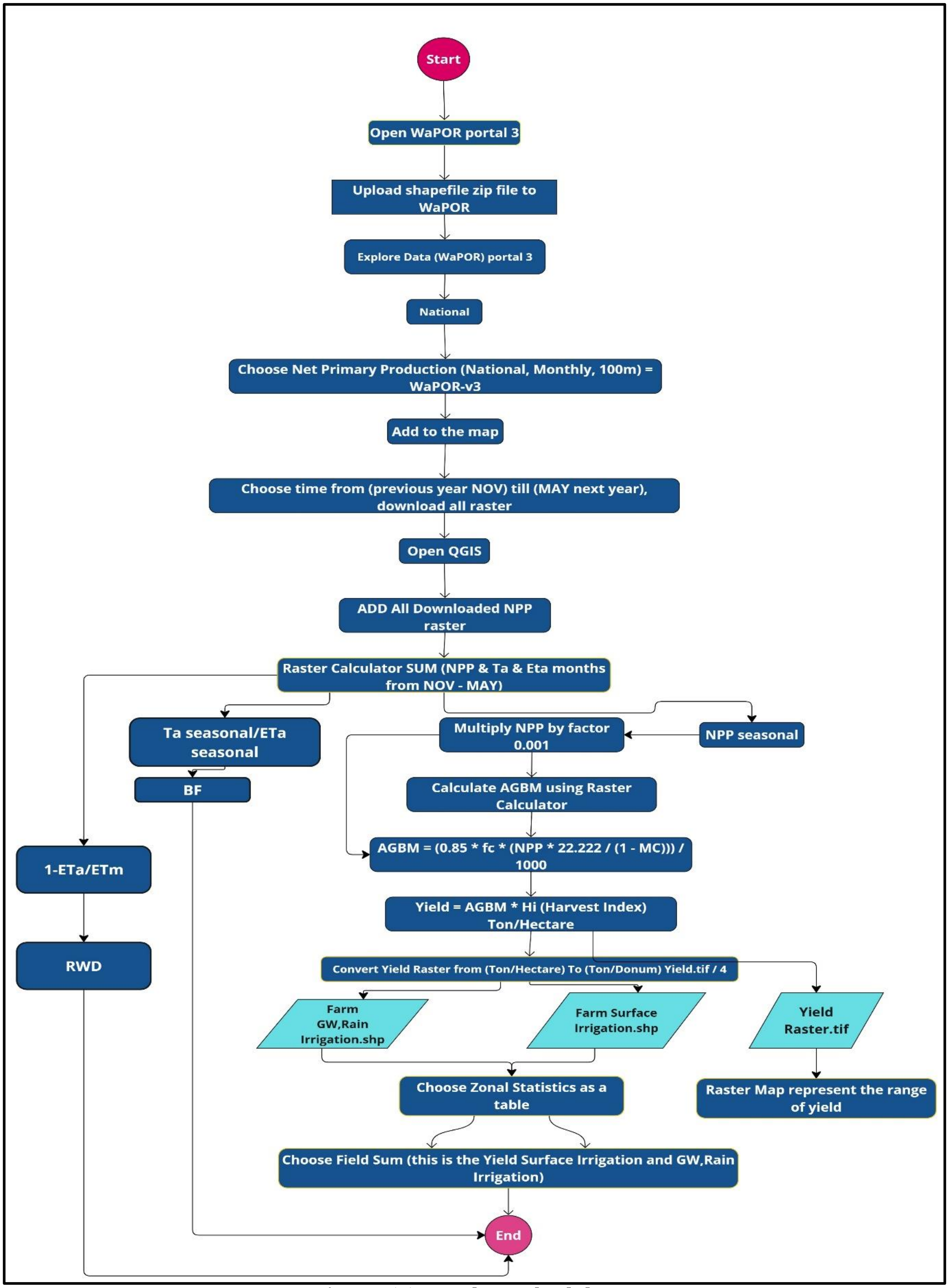


Figure (3): Study methodology

3.1 Wapor platform study

The Wapor platform is an indispensable tool in the field of agriculture and water resources management, especially in arid and semi-arid areas. The platform can also be used in many other areas, such as assessing the impact of changes in land use on water resources and studying the relationship between climate change and health. (Ministry of Water Resources, 2023). The platform provides a wide range of information covering various aspects of this vital sector. Below we list the most prominent data provided by the platform.

Remote sensing data including satellite images, where the Wapor platform provides images from different satellites covering large areas of the world and allows monitoring changes in vegetation cover, land use, water resources, etc. The remote sensing data also provides the Wapor platform with different vegetation indicators such as NDVI (Normalized Difference Vegetation Index) which reflects the condition and activity of vegetation cover, which helps in assessing plant productivity.

The platform provides comprehensive climate data, including temperature and rainfall, presenting rainfall amounts, intensity, and distribution throughout the year. It also offers ample climate data that can be used in hydrological programs.

The platform provides a variety of analytical tools that enable users to extract valuable information from raw data, and perform complex operations such as analyzing time trends and comparing data between different regions. WaPOR data is updated periodically, ensuring that users have access to this data, which includes the latest information on the water and agricultural situation for farmers and decision-makers in better agricultural planning, identifying crops suitable for climatic conditions and available soil, and helping to assess water availability, identify areas suffering from water shortages, and plan irrigation projects.

There are practical applications for the WaPOR platform, including the development of smart irrigation systems that rely on data. The WaPOR platform is a revolution in the field of monitoring and managing agricultural water productivity by providing open-source data and advanced analysis tools. WaPOR contributes to building a more sustainable future for future generations (Ministry of Water Resources, 2023).

3.2 Office work

The office work included all the work that was taken to complete the remote sensing model using Arcgis program, in addition to the work related to using the Wapor 3 platform, which included choosing the study area to download the required products from the platform and according to the targeted dates in the research, as the winter season 2023-2024 (from November 2023 to May 2024) was chosen for the agricultural lands of Salah al-Din Governorate, northern Iraq, under the National (100*100 m) tab in the Wapor platform, as the platform allows open access to remotely sensed derived data (WaPOR) evaporation and transpiration data on a 10-day basis throughout Africa and the Middle East from 2009 onwards at three spatial resolutions. The continental level (250 meters) covers Africa and the Middle East (L1). The national level (100 meters) covers 21 countries and 4 river basins (L2). The third level (30 meters) covers eight irrigation areas (L3) (Blatchford, Megan L., et al,2020)

3.2.1 Downloading products from Wapor3 platform

This chapter summarizes the use of the Wapor platform. Before that, you must register on the platform to access the platform and benefit from its products. Also, you must prepare a complete shape file with all its attachments compressed for the study area with the Zip extension. We go to the load local/web data tab on the platform interface to download the compressed file above to see the file (shape file) appear on the main panel of the Wapor platform. After that, we go to Explore Data, where the classifications and levels of the Wapor 3 platform appear, which are three classifications: Global - Sub National - National. The current study area was selected using the National classification with an accuracy of 100*100 meters, as this classification currently gives more accurate products for the selected study area. There is no classification that gives more accuracy at the present time, as the products are downloaded Npp (Net primary production) Eta (Actual evapotranspiration) Ta (Transpiration).

3.2.2 Setting up the remote sensing model using ArcGIS

To prepare the project model, we start by calling all Raster for all products (Eta, Ta, NPP) downloaded from the Wapor platform in ArcGIS, where we start by finding the total for each product using the Raster Calculator tool and exporting them as three equivalent Raster for each group, and we work on them zonal statistics. After that, we must perform a Clip raster to isolate the targeted agricultural fields. In this research, we use wheat and barley and barley fields for the winter agricultural season (2023-2024) for which we want to calculate the efficiency of irrigation management from the rest of the areas in the resulting image, and this is done using the Clip raster by mask tool. We apply the equations for finding the determinants for calculating agricultural productivity and irrigation tool efficiency, the first of which is calculating AGBP. (Above Ground Biomass Production)

By applying the equation

AGBP = AOT *fc*(NPP*22.222/(1-MC)) ……..……………………...……………………. (1)

AOT (above ground over total biomass is equal 0.8)

fc (crop light use efficiency correction factor is equal 1)
MC (moisture content is equal 0.15)

-The crop yield was calculated using the equation

Yield=AGBP*HI (Harvest index is equal 0.38) …………………………………….…… (2)

After that calculate zonal statistics

-BF is calculated using the Raster Calculator tool, where we write the equation:

BF=Ta/Eta …………………..…………………………………………..………………. (3)

(The amount of water that evaporates from the plant (Ta The amount of water that evaporates from the plant and soil Eta) and calculate zonal statistics too

-RWD (Reference Water Deficit) where the equation for that is applied

RWD=1-Eta / Etm………………………………..……………………………………. (4)

(Etm is the highest value of evaporation in the Raster of Eta) and the equivalent Eta Raster for which the mask layer is applied. Then we calculate the Zonal Statistics for it in the same previous ways.

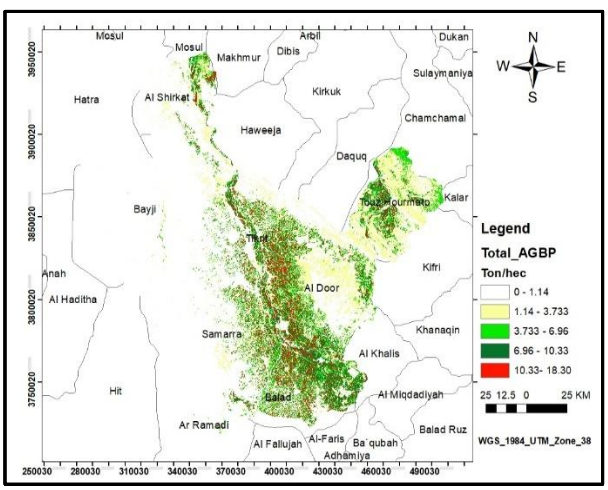
- WP (Water productivity for plants) where the equation for that is applied

WP = yield/Eta…………………………………………………………………………..(5)

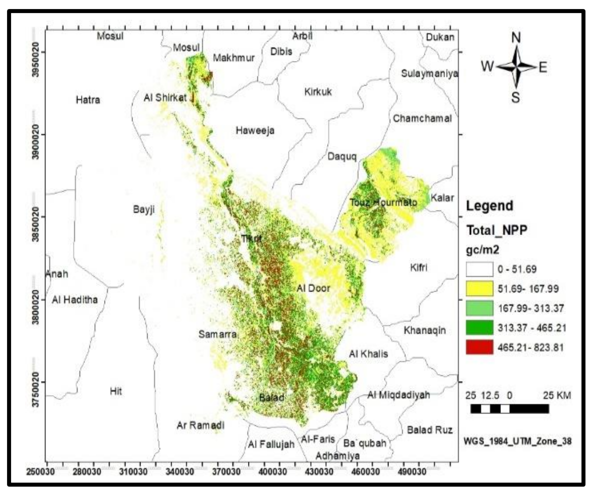
4.Results

4.1 Remote sensing model results

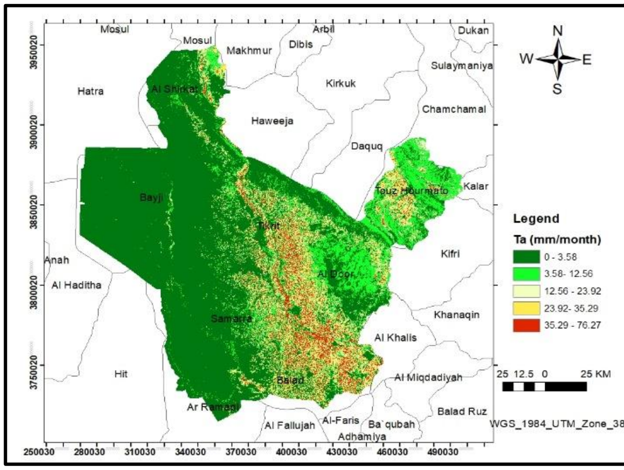
The results of the remote sensing models included finding the irrigation evaluation tool coefficients in addition to the agricultural yield quantities wheat and barley using the equations specified in the previous paragraph and using the variables in the equations for the wheat and barley plant according to what was recommended by the Food and Agriculture Organization of the United Nations **(FAO,2022)** which were stated above.



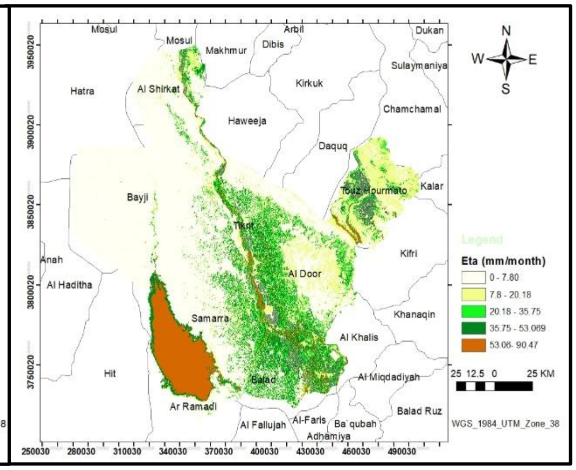
B- Map showing AGBP rates for the total area of salah al-Din governorate for the winter season 2023-2024



A-Map showing NPP rates for the total area of salah al-Din governorate for the winter season 2023-2024



D-Map showing the rangers of transpiration rates for the total area of salah Al-Din governorate for the winter season 2023-2024



C- Map showing the rangers of Evapotranspiration rate (Eta) for the total area of Salah Al-Din governorate for the winter season 2023-2024

Figure (4): shows satellite images of the products that were downloaded from the Wapor 3 platform for the winter season 2023-2024 for the lands of Salah Al-Din Governorate.

Table (1): shows a model of the calculations of the transpiration rates values obtained from the remote sensing model for the wheat and barley crops grown using surface water for the winter season 2023-2024.

Count_Pixel	Min_Ta Mm/month season	Max_Ta Mm/month season	Mean_Ta Mm/month season	Standard deviation STD	SUM _Ta Farm
1.0	62.0	62.0	62.0	0.0	62.0
1.0	61.6	61.6	61.6	0.0	61.6
1.0	60.4	60.4	60.4	0.0	60.4
1.0	60.3	60.3	60.3	0.0	60.3
2.0	59.3	59.3	59.3	0.0	118.6
1.0	59.0	59.0	59.0	0.0	59.0
1.0	59.0	59.0	59.0	0.0	59.0
1.0	58.9	58.9	58.9	0.0	58.9
1.0	58.4	58.4	58.4	0.0	58.4
1.0	58.4	58.4	58.4	0.0	58.4
1.0	57.8	57.8	57.8	0.0	57.8
1.0	57.6	57.6	57.6	0.0	57.6
1.0	57.6	57.6	57.6	0.0	57.6
1.0	57.5	57.5	57.5	0.0	57.5
1.0	57.4	57.4	57.4	0.0	57.4
2.0	57.2	57.2	57.2	0.0	114.4
1.0	57.0	57.0	57.0	0.0	57.0
1.0	57.0	57.0	57.0	0.0	57.0
1.0	56.8	56.8	56.8	0.0	56.8

The values in the table above represent a sample of the data resulting from the calculations carried out in the remote sensing model. Given that data resulting from the model are large in size and cannot be included in the research paper, a sample was taken from it, which shows the calculations of the rates of transpiration values for agricultural lands planted with wheat and barley that depend on surface water for the winter season 2023-2024 within Salah al-Din Governorate, where the calculations are activated using zonal statistics tool, which included in the table above the smallest and highest values of pixels and the rates of transpiration values in pixels and the sum of pixel values in a single field. As we mentioned earlier, the pixel accuracy used to download products from the Wapor 3 platform is (100*100) meters. It must be noted that it is possible to activate other calculations according to the user's desire through the tool above. From our observation of the table above, the highest values of transpiration for agricultural lands planted with wheat and barley plants that depend on surface water (within the irrigation boundaries) reached 76 mm/month/season. As for lands that depend on well water and rain (rain), we include below a table of a sample of the results using the same model.

Table (2): shows a model of the calculations of the transpiration rates values obtained from the remote sensing model for the wheat and barley crops grown using well water and rain for the winter season 2023-2024.

Count_Pixel	Min_Ta Mm/month season	Max_Ta Mm/month season	Mean_Ta Mm/month/ season	Standard deviation STD	SUM _Ta Farm
1	76.3	76.3	76.3	0.0	76.3
2	52.5	70.3	61.4	8.9	122.8
69	9.0	67.4	35.7	10.1	2462.1
13	18.7	67.0	54.4	12.7	706.9
10	29.3	66.2	46.1	13.2	461.3
17	25.1	64.2	36.3	11.7	616.3
6	18.7	64.1	41.2	14.5	247.4
47	0.0	64.1	27.9	10.2	1312.5
10	0.0	63.9	27.2	21.2	272.3
3	57.8	63.8	60.6	2.5	181.8
427	0.0	61.6	30.1	9.8	12841.0
2	57.4	61.6	59.5	2.1	118.9
5	32.9	60.3	42.6	10.5	213.2
79	11.2	60.1	39.9	8.5	3150.3
9	36.8	60.1	45.4	7.7	408.6
6	26.4	59.6	44.8	10.0	268.8
17	20.2	58.8	44.0	9.6	747.9
67	9.4	58.1	35.8	11.1	2396.5
2	7.3	57.9	32.6	25.3	65.2

The highest value of transpiration in agricultural lands planted with wheat and barley and dependent on well water and rain is 76.3 mm/month/season and lowest value within range (0-0.35) mm/month/season as figure 4-D

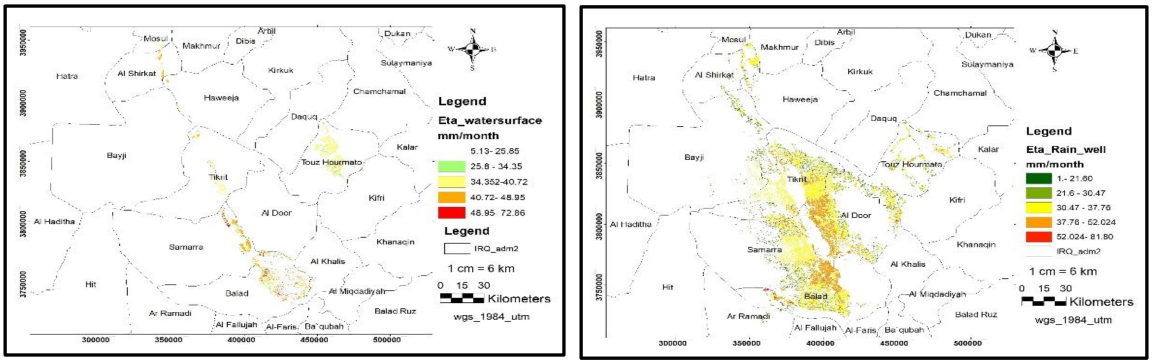


Figure (5): Map showing evapotranspiration rate of the wheat and barley crops for the winter season 2023-2024 for the lands of of Salah Al-Din Governorate, which depend on surface water, well water and rain.

Table (3): shows a model of calculations of the values of evapotranspiration rate obtained from the remote sensing model for wheat and barley crops grown using surface water for the winter season 2023-2024.

Count_Pixel	Min_Eta Mm/month season	Max_Eta Mm/month season	Mean_Eta Mm/month/ season	Standard deviation STD	SUM _Eta Farm
1	72.86	72.86	72.86	0.00	145.72
1	71.79	71.79	71.79	0.00	71.79
3	71.52	71.52	71.52	0.00	71.52
1	70.93	70.93	70.93	0.00	70.93
3	70.77	70.77	70.77	0.00	70.77
1	70.56	70.56	70.56	0.00	70.56
1	70.55	70.55	70.55	0.00	70.55
2	70.38	70.38	70.38	0.00	70.38
2	69.54	69.54	69.54	0.00	69.54
3	69.45	69.45	69.45	0.00	69.45
4	69.08	69.08	69.08	0.00	138.16
1	68.74	68.74	68.74	0.00	68.74
2	68.71	68.71	68.71	0.00	68.71
1	67.37	69.41	68.56	0.97	342.79
1	68.18	68.77	68.48	0.30	136.95
6	62.93	70.75	68.37	2.32	615.31
1	68.36	68.36	68.36	0.00	68.36
3	68.11	68.11	68.11	0.00	68.11

The highest values of evapotranspiration rate for agricultural lands planted with wheat and barley and dependent on surface water (within the irrigation boundaries) reached 72.28 mm/month/season and the lowest value reached 5.13

Table (4): shows a model of calculations of the values evapotranspiration rate obtained from the remote sensing model for wheat and barley crops grown using well water and rain for the winter season 2023-2024.

COUNT	MIN	MAX	MEAN	STD	SUM
1	81.81	81.81	81.81	0.00	81.81
1	79.60	79.60	79.60	0.00	79.60
1	76.74	76.74	76.74	0.00	76.74
2	76.10	77.10	76.60	0.50	153.20
1	76.05	76.05	76.05	0.00	76.05
3	73.96	77.00	75.52	1.24	226.57
1	74.10	74.10	74.10	0.00	74.10
2	72.12	75.78	73.95	1.83	147.90
1	73.11	73.11	73.11	0.00	73.11
167	59.71	78.18	72.94	3.38	12180.36
3	71.98	74.10	72.69	1.00	218.07
5	71.64	74.59	72.69	1.01	363.43
23	66.89	74.39	72.65	1.76	1671.03
59	50.93	80.35	72.43	4.15	4273.55
4	69.46	73.85	71.73	1.58	286.91
1	71.67	71.67	71.67	0.00	71.67
2	63.20	80.11	71.66	8.45	143.31
1	71.62	71.62	71.62	0.00	71.62
20	57.17	79.89	71.60	4.79	1431.91

The highest values of evapotranspiration rate for agricultural lands planted with wheat and barley and dependent on well water and rain (outside the irrigation limits) where 81.81 mm/month/season on the lowest value was 1.0

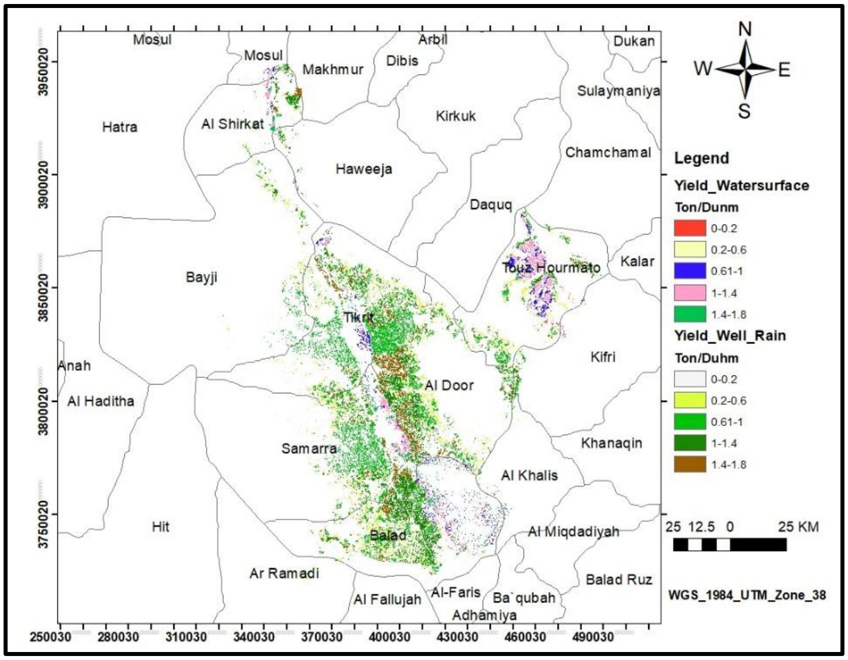
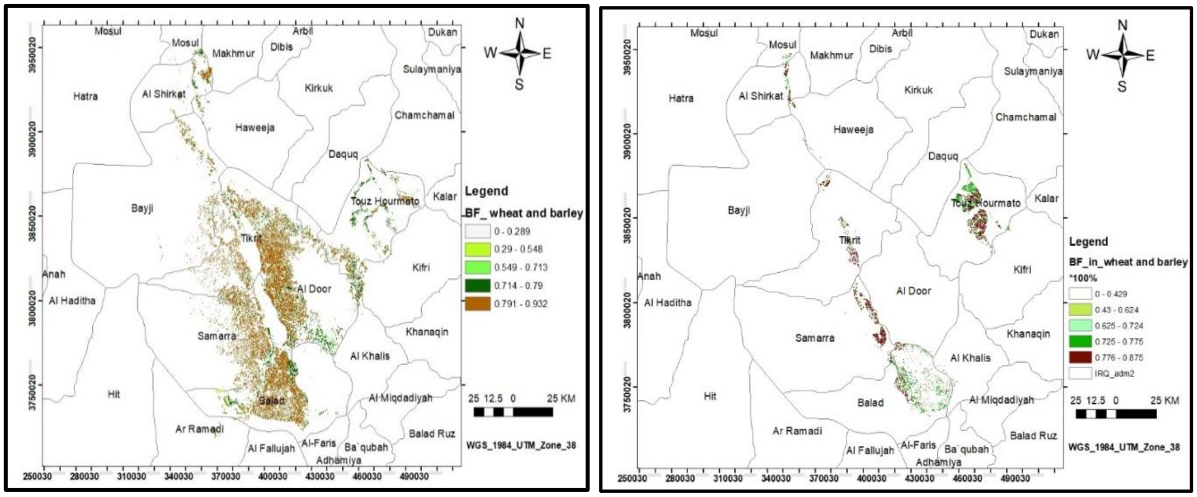


Figure (6): Map showing the productivity ranges of the wheat and barley crops for the winter season 2023-2024 for the lands of Salah Al-Din Governorate that depend on surface water, well water and rain.

From the figure above, we notice that wheat and barley cultivation during the winter season 2023-2024 is concentrated within the districts of Tikrit, Al-Dour, Balad, Samarra and Sharqat. Most of the fields have wheat and barley production rates for the above winter season, as shown in the figure above, within the range (0.61 -1.1) tons / dunum. Through the Wapor platform, we were able to find crop production rates and how to distribute them within the borders of one governorate, and this is one of the goals of the current research paper.

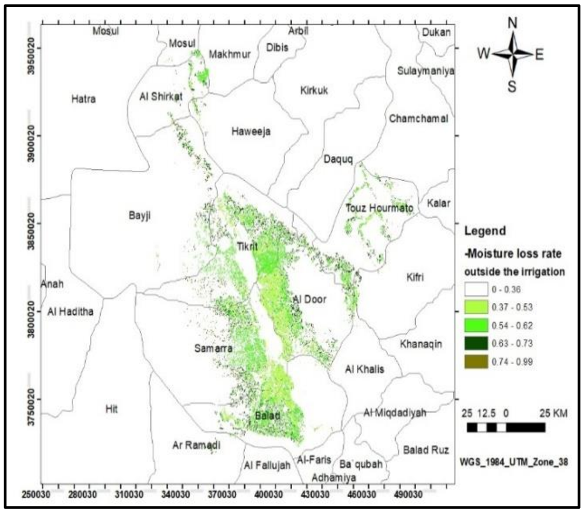


B-Water utilization efficiency for lands outside the irrigation boundaries.

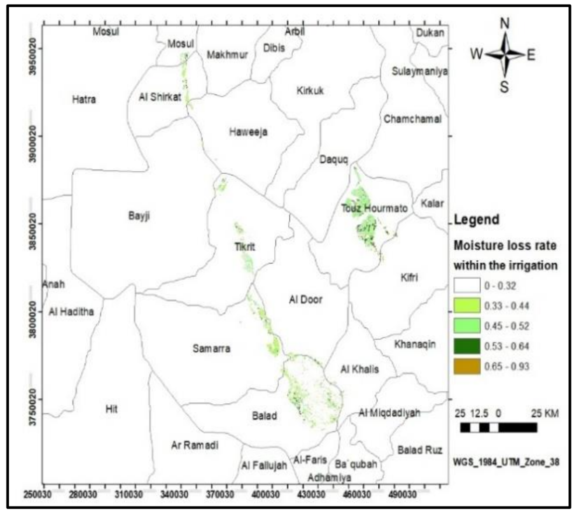
A-Water utilization efficiency for land within the irrigation boundaries.

Figure (7): Map showing the utilization factor (BF) rates for the wheat and barley crops for the winter season 2023-2024 for the lands of Salah Al-Din Governorate that depend on surface water, well water, and rain.

From the figure above, we notice the beneficial factor, which is one of the efficiency factors of irrigation systems, which represents the benefit ratios from the irrigation process. We notice that agricultural lands located outside the boundaries of surface water (outside the boundaries of irrigation) have a better benefit ratio than lands located within the boundaries of irrigation (surface water). This is due to the fact that lands outside the boundaries of irrigation are lands that mostly depend on sprinkler irrigation systems based on wells in addition to rainwater.



B-Moisture loss rate of soils outside the irrigation boundaries.



A-Moisture loss rate of soils within the irrigation boundaries

Figure (8): Map showing the rates of moisture deficiency coefficient (RWD) for the wheat and barley crops for the winter season 2023-2024 for the lands of Salah Al-Din Governorate, which depend on surface water, well water and rain.

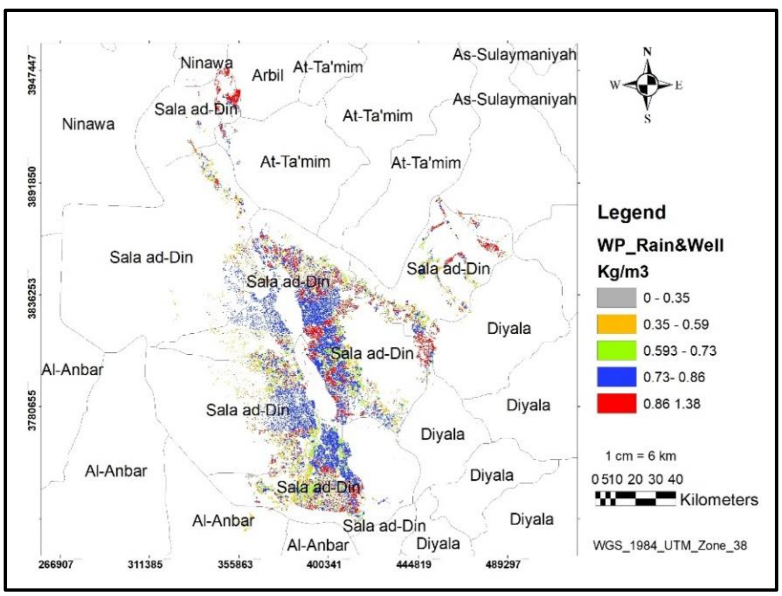


Figure (9): Map showing the rates of water productivity for the wheat and barley crops for the winter season 2023-2024 for the lands of Salah Al-Din Governorate, which depend on well water and rain.

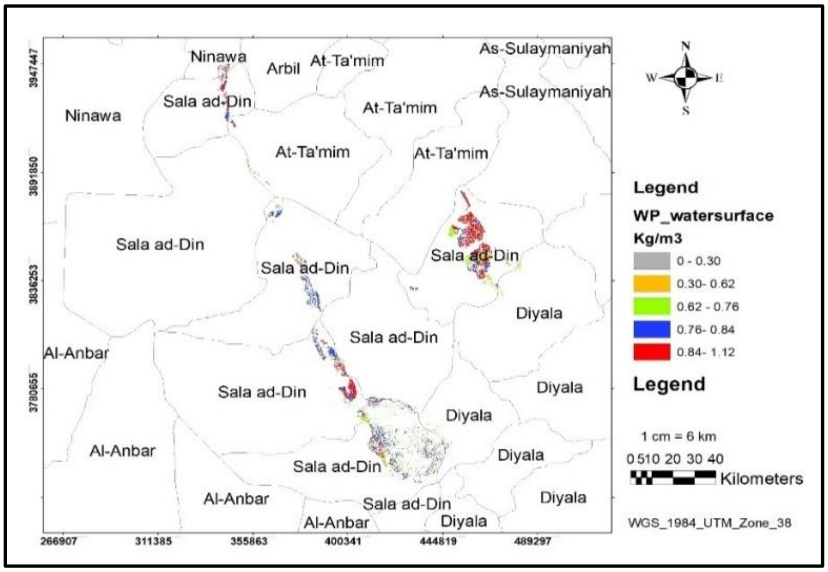


Figure (10): Map showing the rates of water productivity for the wheat and barley crops for the winter season 2023-2024 for the lands of Salah Al-Din Governorate, which depend on water surface

Based on figures and after using zonal statistic function, we observe that the average water productivity for lands within the irrigation boundaries was 0.73 kg/m³.

Meanwhile, it was 0.68 kg/m³ for lands outside the irrigation boundaries, or an average of 0.7 kg/m³. This aligns with areas of lower productivity in insufficiently irrigated regions, as confirmed by recent studies, including (P. Singh et al. 2025), which found that water productivity for wheat ranges between 0.61 and 0.93 kg/m³.

5 . Model Calibration and Verification

Model calibration and verification of results are among the most important aspects of scientific research., the shapefile used in model (wheat Season 2023-2024 for Saladin Area) from (National Center for Water Resources Management, 2024), it was calibrated and verified by using ERDAS IMAGINE 2022. As shown below: -

150 ground truth data points were collected for wheat crops at the governorate level. These points represent locations where the land cover type (in this case, wheat or any other land cover) was directly or reliably identified. Additionally, a classifier was trained using 100 ground truth data points to train the classifier in a supervised classification process using

the licensed ERDAS IMAGINE 2022 software. In supervised classification, these known data points (training samples) are used to teach the algorithm how to recognize the spectral signature of wheat crops and distinguish them from other land cover types in satellite imagery. Accuracy Assessment. The remaining 50 ground truth data points were used to assess accuracy. These data points are independent of the training data points and were not used in building the classification model. The classification results at these 50 locations are compared with the known ground truth values at those locations. This allows for the calculation of various accuracy metrics, such as overall accuracy, product accuracy, user accuracy, kappa coefficient, and confusion matrix.

Method for assessing accuracy using 50 ground verification points and ERDAS IMAGINE 2022 software

Table (5): shows assessing wheat crop classification accuracy using ERDAS IMAGINE 2022

Explanation	(%) Value	Accuracy scale
Confusion Matrix (Example)		
No wheat (reference)	Wheat (reference)	
3	43	Wheat (classified)
Out of a total of 50 checkpoints, 43 wheat points were correctly classified and 2 wheat points were incorrectly classified. (43 + 2) / 50 = 0.90	%90	(Overall Accuracy)
(Producer's Accuracy)		
Of the 45 wheat points in the reference data, 43 points were correctly classified. (43/45) * 100	%95.6	Wheat
(User's Accuracy)		
Of the 46 points classified as wheat, 43 points were actually wheat in the reference data. (43 / 46) * 100	%93.5	Wheat
Indicates good agreement between the classification and the reference data, taking into account the probability of random agreement. (The actual value depends on the distribution in the confusion matrix.)	0.75~	(Kappa Coefficient)
(Omission Errors)		
Two areas of true wheat were incorrectly classified ."as "no wheat	out of 45 wheat 2 (%4.4) reference points	Wheat
(Commission Errors)		
Three points from the "no wheat" areas were ."incorrectly classified as "wheat	out of 46 points 3 (%6.5) classified as wheat	Wheat

Confusion Matrix: This table shows the actual distribution of the classified points compared to the reference data. For example, 43 points were classified as wheat but were actually wheat, while 3 points were classified as wheat but were actually "not wheat”

Overall Accuracy (90%): This number indicates that 90% of the total checkpoints were correctly classified

Product Accuracy

Wheat (95.6%): This means the classifier was good at identifying true wheat areas

User Accuracy، wheat (93.5%): This means that most of the areas classified as wheat are actually wheat on the ground.

Kappa coefficient (~0.75): This value indicates a good level of agreement between the classified map and the reference data, which is higher than chance.

Errors of omission: Shows the number of points that were ignored or misclassified as another category.

Assignment errors: Shows the number of points that were incorrectly included in a given category.

6.Conclusions and recommendations

- Conclusions

Medium and high values for average water and crop productivity are concentrated in agricultural areas near the Tigris River, such as Tikrit, Samarra, and Balad, thanks to the abundance of surface water and reliance on irrigated agriculture. However, these values decrease in areas far from water sources, necessitating a review of water and field management methods in water-scarce regions. Similarly, regarding water productivity, the results showed that areas relying on surface water have slightly higher productivity than lands dependent on rainwater and wells.

- Recommendations

Collaborating with research institutions to conduct advanced studies that contribute to regulating water use under water scarcity conditions, based on WaPOR system data, where the platform provides indicators of crop and water productivity, which gives indicators for reconsidering the policies used in field management and irrigation methods used.

References

ALsaffar, G., Hommadi, A. H., Hussien, H. H., Razzaq, I. A., & Hussien, A. A. A. (2025). Evaluation of Operation Al-Nasr Lake Basin in Dhi Qar Governorate Using Remote Sensing Technology. *Journal of Water Resources and Geosciences*, *4*(1), 143-159.

Al-Ahealy, M. W., Al-Saedi, Z. J., Hussein, Q. F., & Hussien, H. H. (2024). Monitoring the growth of agricultural crops phenology using Google Earth Engine in Wasit Governorate/Central Iraq. Journal of Water Resources and Geosciences, 3(1), 116-132

Blatchford, M. L., Mannaerts, C. M., Njuki, S. M., Nouri, H., Zeng, Y., Pelgrum, H., & Karimi, P. (2020). Evaluation of WaPOR V2 evapotranspiration products across Africa. *Hydrological Processes, 34*(15), 3200–3221.

Fakhar, M. S., & Kaviani, A. (2024). Estimation of water consumption volume and water efficiency in irrigated and rainfed agriculture based on the WaPOR database in Iran. *Journal of Water and Climate Change*, *15*(6), 2731-2752.

Food and Agriculture Organization of the United Nations (FAO). *WaPOR database and portal*. FAO. https://wapor.apps.fao.org

Food and Agriculture Organization of the United Nations (FAO) (2022).

Ministry of Water Resources, National Center for Water Resources Management. (2023). *Water resources report*. Baghdad, Iraq.

Ministry of Water Resources, National Center for Water Resources Management. (2024). *Water resources report*. Baghdad, Iraq.

Ministry of Water Resources, Planning and Follow-up Department. *Planning and follow-up report (2022)*. Baghdad, Iraq.

National Center for Water Resources Management. (2024). *Water resources report*. Baghdad, Iraq.

Seijger, C., Chukalla, A., Bremer, K., Borghuis, G., Christoforidou, M., Mul, M., & van Halsema, G. (2023). Agronomic analysis of WaPOR applications: Confirming conservative biomass water productivity in inherent and climatological variance of WaPOR data outputs. *Agricultural Systems, 211*, 103712

Singh, P., & Kothari, K. (2025). Assessing wheat crop water productivity for sustainable agricultural water management in diverse agro-climatic regions of Uttarakhand, India. *Environmental and Sustainability Indicators*, *27*, 100738.