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ANALYSIS AND DETECTION OF INUNDATION IN AL-HAMMAR AND CENTRAL MARSHES/ SOUTHERN IRAQ USING GOOGLE EARTH ENGINE

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ABSTRACT

Marches have a significant impact on the ecosystem of Iraq and provide habitat for several types of organisms. The study area, Al-Hammar Marsh, is situated entirely south of the Euphrates, extending from near Al-Nasiriyah city in the west to the outskirts of Al-Basrah city along the Shatt Al-Arab in the east, while the Central Marshes formed between the Tigris and Euphrates rivers. The goal of the study is to detect changes in Al-Hammar and Central marshes by using Modified Normalized Difference Water Index (MNDWI) via Google Earth Engine (GEE) cloud; considering GEE adds great value to users of remote sensing data, especially, no experts who may not be aware of the intricacies involved with data organization and large-scale computing. Sensors Landsat 5, 7, and 8 were used and 10802 scenes were analyzed and filtered to get MNDWI by special code under the GEE environment. Flood data were used to validate the results, which represent flood years and scarce years. Among flood years are 1946, 1954, 1963, 1968, 1969, 1988, 1993, 1995 and 2019. Whereas the years of scarcity were 1934, 1935, 1961, 1999, 2000, 2001, 2008, and 2009, while the year 2018 was the scariest year for Iraq.

Many factors affect the study area’s inundation, such as related to the amount of rain and snow that falls in the main river basins (Tigris and its tributaries), the operation policy of the dams and reservoirs, which are built at the top of the shared rivers in Turkey, Syria, Iraq, and Iran. In addition to the position of Iraq as a downstream country, the geological setting of marshes because they are depression areas as well as the long path for the Euphrates and Tigris rivers, and the existence of tens of regulators and agricultural lands. By applying the Pearson equation between hydrological years data and inundation years in the study area, the value for Tigris was $R^2 = 0.5$, which is an acceptable relationship, whereas for the Euphrates was $R^2 = 0.4$, which is a poor relationship.

التحليل والكشف لمناطق الاغمار في هور الحمار والاهوار الوسطى/ جنوب العراق بأستخدام المنصة السحابية Google Earth Engine (GEE)

يوسف سامر المعملجي و زياد جميل الساعدي

المستخلص

الاهوار لها تأثير كبير على النظام البيئي في العراق وتوفر موطنًا لأنواع عديدة من المخلوقات الحية. تقع منطقة الدراسة والتي تشمل هور الحمار بالكامل جنوب نهر الفرات وتمتد قرب الناصرية غربا الى اطراف البصرة على شط

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العرب شرقا بينما تشكلت الاهوار الوسطى بين نهري دجلة والفرات. الهدف من الدراسة هو الكشف عن التغيرات التي تطرأ على هور الحمار والأهوار الوسطى باستخدام مؤشر الماء الفرق القياسي المعدل (MNDWI) عبر المنصة السحابية (GEE) مع الأخذ في الاعتبار ما يقدمه GEE من اضافة قيمة كبيرة لمستخدمي بيانات الاستشعار عن بعد، وخاصة غير الخبراء الذين قد لايكونون على دراية بالتعقيدات التي ينطوي عليها الأمرمع تنظيم البيانات والحوسبة على نطاق واسع. تم استخدام بيانات القمر لاندسات 5 و 7 و 8 وتم تحليل 10802 مشهد (صورة فضائية) وترشيح (فلترة) للبيانات للحصول على مؤشر الماء المعدل MNDWI بواسطة كود خاص تحت بيئة GEE.

أثرت العديد من العوامل على غمر منطقة الدراسة، مثل كمية الأمطار والثلوج التي تتساقط في أحواض الأنهار الرئيسية (دجلة وروافده والفرات)، وسياسة تشغيل السدود والخزانات المقامة على قمة الأنهار المشتركة. في تركيا وسوريا وإيران. بالاضافة الى موقع العراق كدولة مصب، والوضع الجيولوجي لأنها منطقة منخفضة وكذلك المسار الطويل لنهري دجلة والفرات ووجود عشرات لنواظم للمياه وكذلك الأراضي الزراعية، وبتطبيق معادلة بيرسون بين بيانات الهيدرولوجية وسنوات الفيضان. في منطقة الدراسة كانت القيمة التي حصلنا عليها لدجلة $R^2 = 0.5$ وهي علاقة مقبولة وبالنسبة للفرات $R^2 = 0.4$ وهي علاقة ضعيفة.

INTRODUCTION

There are many individual marshes (the local name is “Hor”) and lakes developed in different parts of the Mesopotamia Plain in Iraq, particularly, in its southern and central sectors. The marshes may be developed in any shallow depression if favorable conditions (stagnant water) are available for the growth of dense marsh vegetation. Consequently, such marshes are considered a special case of shallow depressions (Hamza and Yacoub, 1982; and Domas, 1983). The marshes and lakes system of the southeastern part of the Mesopotamia Plain are rather complicated and might be developed and survived not only due to tectonically active subsiding land. However, it is also due to very low sedimentation rates that prevailed in the marshes region after total regression of the sea influence (i.e., since about 2500 years) (Aqrawi, 1993). Many authors, such as Purser (1973); Larsen and Evans (1978), and Yacoub *et al*. (1981) have confirmed that the marshes region has been more influenced by eustatic sea level changes and deltaic progradation, rather than tectonic events. Moreover, they have distinct geomorphic features and possess an important sedimentary environment being predominant in the southeast of the Mesopotamia Plain. During the last three decades, the marshes and lakes system underwent big changes in the geomorphic and environmental situation (Yacoub, 2010).

These marshes were distributed in three main areas, named: Hor Al-Huwaizah (east of the Tigris River), Hor Al-Hammar (south of the Euphrates River), and Central marshes (west of the Tigris River). They were filled with fresh water and inhabitants of swamp plants. The water depth was varying from a few decimeters to 2 m, exceptionally reaching (3 – 4) m, in Al-Hammar Lake (Yacoub *et al.*, 1985).

The goal of this study is to detect changes in water bodies of Al-Hammar and Central marshes by using Modified Normalized Difference Water Index (MNDWI) via Google Earth Engine (GEE) cloud considering what GEE offers support fast, interactive exploration and analysis of spatial data.

Several studies dealt with the study area through geological, hydrological, and environmental points of view but no one has used GEE to detect changes in the study area. So, this study came to fill the gaps of knowledge regarding the use of GEE.

STUDY AREA

Al-Hammar Marshes is situated entirely south of the Euphrates River, extending from near Al-Nasiriyah in the west to the outskirts of Al-Basrah city along the Shatt Al-Arab in the east. Roughly located in a triangle between Nasiriyah, and Basrah cities. To the south, the marsh is bordered by a sand dune belt of the southern desert. The marshes area covers about (2,800) Km² of contiguous permanent marsh and lake, while the Central Marshes are formed between the Tigris and Euphrates rivers (Al-Hmedawy, 2008; Fig.1).

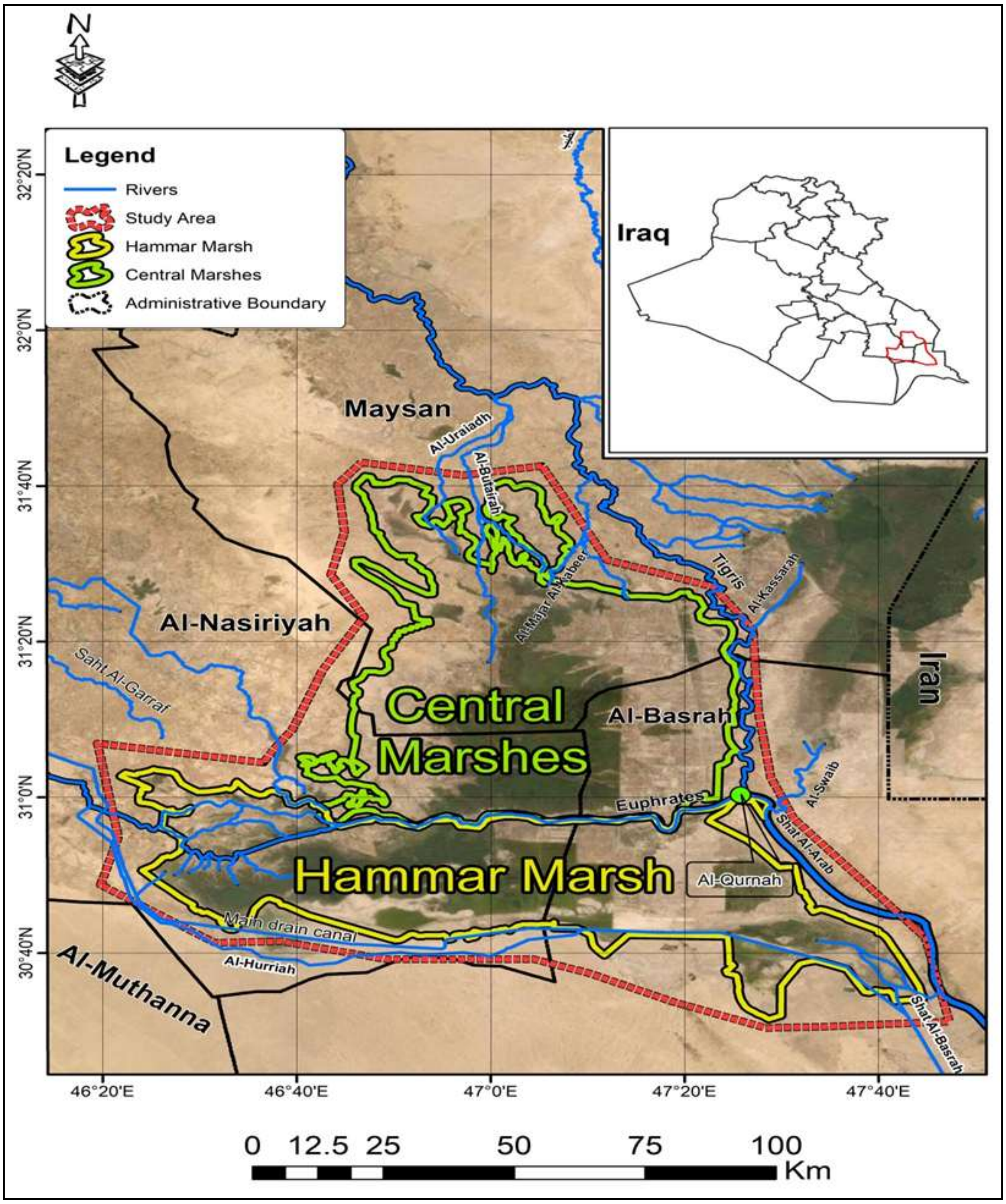

Fig.1: The location of the study area shows Al-Hammar and Central marshes

MATERIALS AND METHODS

- **Methodology**

The present study includes many steps namely the images of Landsat 5,7, and 8 were processed on GEE servers on the cloud with conditions of spatial filters and cloud filter applied the code inside the GEE environment by using java scripts to obtain results compared with the hydrological data as shown in the flowchart (Fig.2).

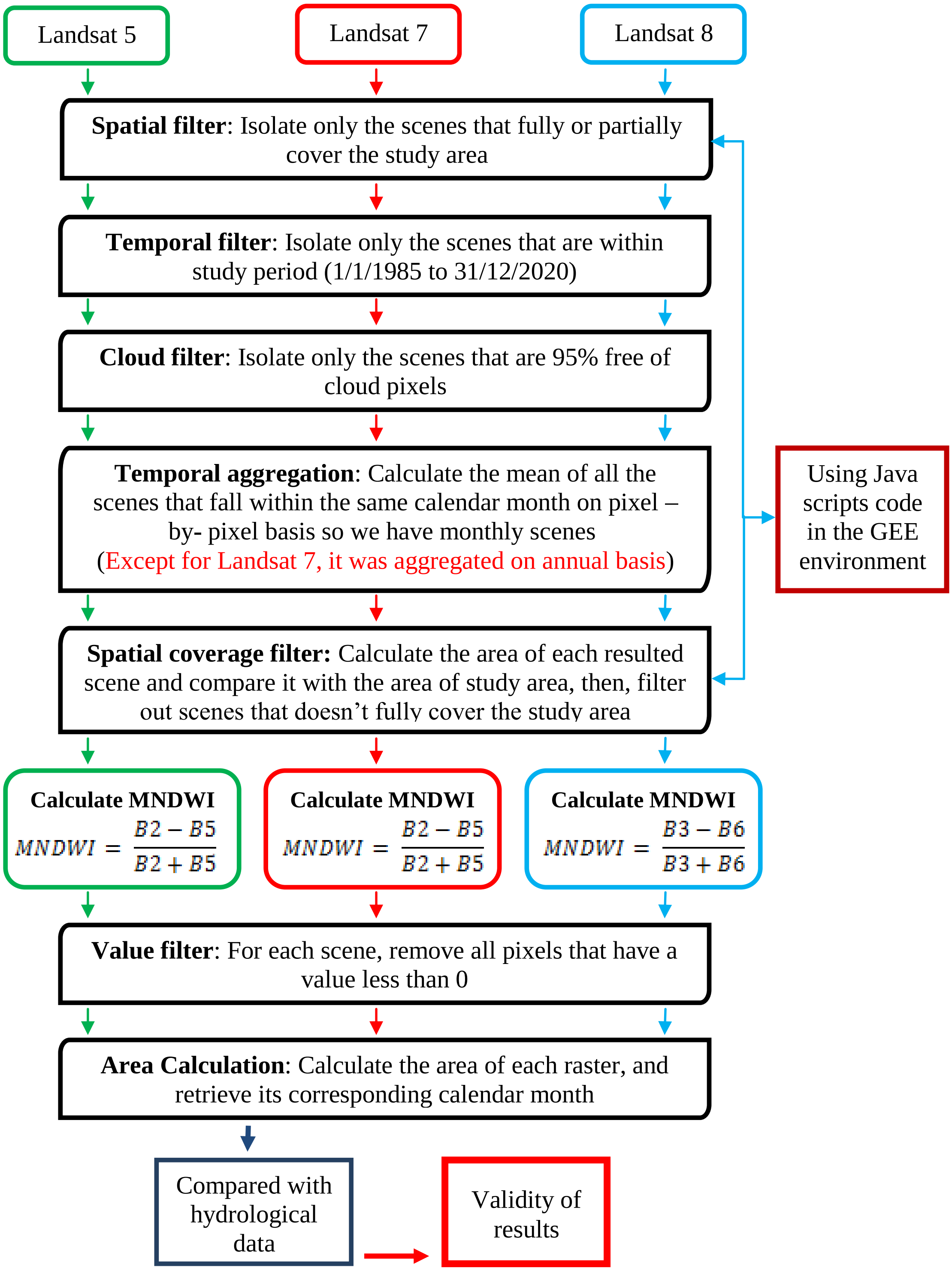

Fig.2: Shows the methodology of the current study

- **Data Acquisition**

Multi-temporal data dated from 1/1/1985 till 31/12/2020 for (L5), (L7), and (L8) cover Al-Hammar and Central Marshes.

The pre-processing phase included the acquisition of every scene that fully or partially covers the study area within the above-mentioned period. This can be achieved by setting spatial and temporal filters on each sensor image during collection. In addition, a cloud filter was also set to exclude any scene that has a cloud cover of more than 5%. Up to this point, the number of filtered satellite images is 10802 scenes. For practicality and elimination of noise, which usually accompanies fine resolution data, the scenes were aggregated on monthly basis by calculating the mean of all scenes; band-by-band that fall within the same month on a pixel-by-pixel basis. All used data were atmospherically and geometrically corrected. (https://developers.google.com/earth engine/datasets/catalog/LANDSAT_LT05_C01_T1_SR). As the Table (1).

Table 1: frequently used datasets in the earth engine data catalog

Dataset	Spatial Resolution	Temporal Resolution	Coverage
Landsat 5	30 m	16 days	1984 – 2012
Landsat 7	30 m	16 days	2000 – Now
Landsat 8	30 m	16 days	2013 – Now

- **Google Earth Engine (GEE) Platform**

GEE is used to source, generate, and analyze surface water maps that were derived from imagery. GEE is an online coding environment enabling relatively rapid, server-based analysis of large spatial datasets (Gorelick *et al*., 2017). As we mention earlier 10802 scenes were analyzed (Fig.3).

Monitoring the inundation area of Al-Hammar and Central marshes over the past 35 years requires a massive amount of satellite images to be analyzed. The only computational power freely available at the current time to achieve this goal exists within the GEE service. The GEE is a service provided by Google that let users programmatically utilize Google servers to do heavy remote sensing (RS) related computations on the cloud and to download the final product “if needed". The GEE is also preloaded with almost every known RS sensors to the most recent dates, which makes it convenient in terms of data availability (Fig.4).

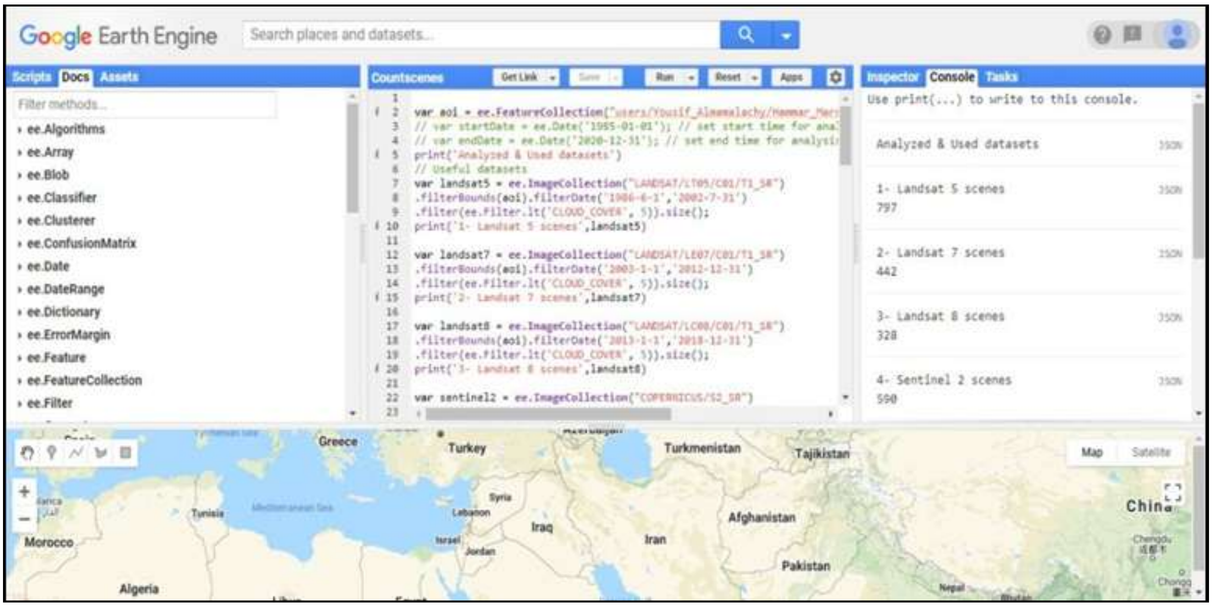

Fig.3: The scene number of different satellites

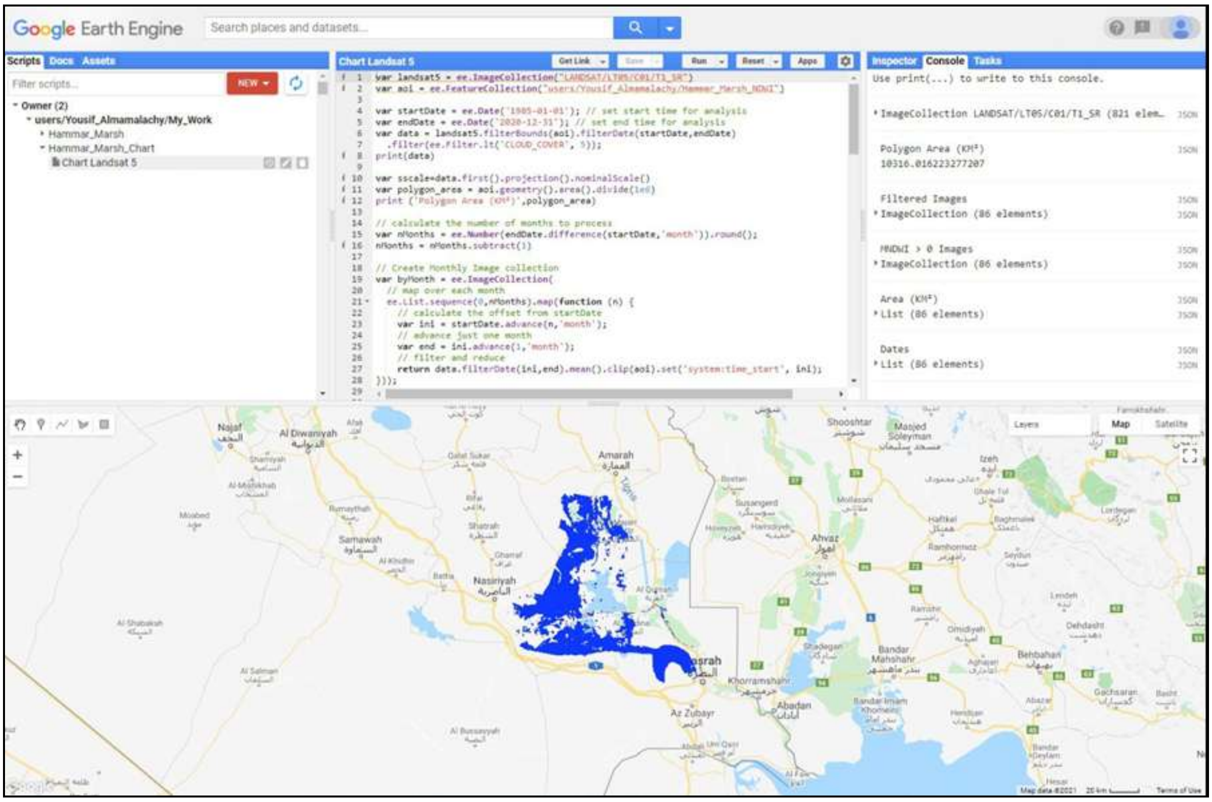

Fig.4: Google Earth Engine Environments

- **Extraction of Inundation from Modified Normalized Difference Water Index (MNDWI)**

The real-time monitoring of water bodies on the Earth's surface is an essential work to protect ecological environments and control surface water pollution (Yang and Du, 2017). Due to the advantages of fast information updates and the ability to produce near real-time observations over large geographic areas, RS has been widely applied in investigating and monitoring surface water resources. The MNDWI is a water index and is developed by Xu (2005). It uses the green (GREEN) and the short-wave infrared (SWIR) bands, as in equation (1).

$$MNDWI= (GREEN-SWIR) / (GREEN+SWIR) \;\ldots\ldots\; (1)$$

After the MNDWI was produced, water bodies can then be mapped by the simple segmentation algorithm using a suitable threshold value. In general, the threshold is often set to zero to produce map water bodies from MNDWI. Any pixel, which is larger than zero, is considered water. In practice, however, multispectral images acquired by different satellite platforms and at different times always have different characteristics. Thus, the threshold should be determined according to the feature of water index values themselves in each scene. Figure (5) represents water bodies for the study area at different times, it represents water surplus for the years (1988, 2019) and water deficit for the years (2000, 2018).

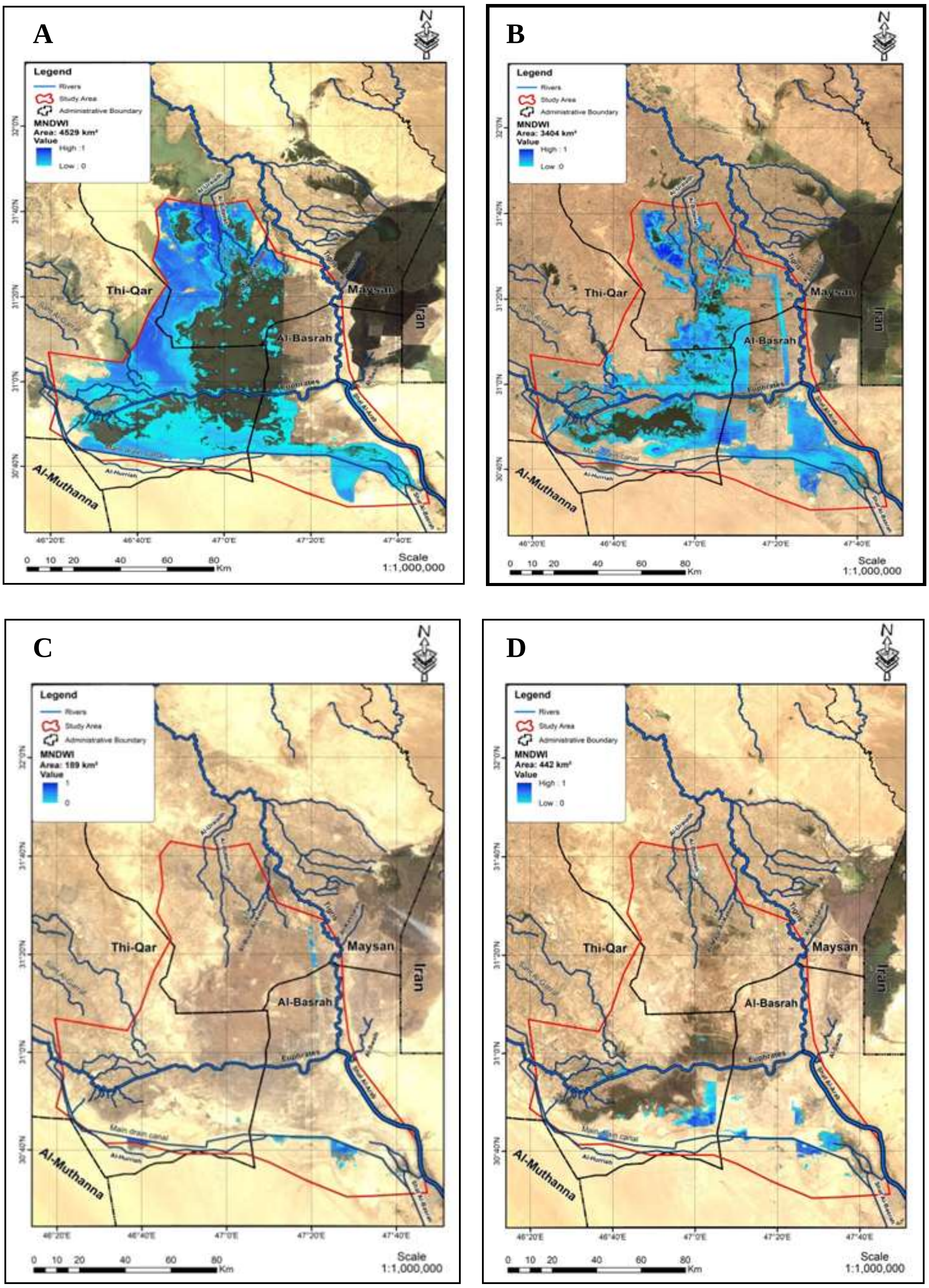

Fig.5: MDNWI in the study area in the time of water surplus (1988 and 2019) and water defect (2000 and 2018) A, B, C, and D, respectively

RESULTS AND DISCUSSION

- **Data Analysis**

The GEE platform was used to configure and calculate the MNDWI index; as a result, we obtained a list of data that included the date and areas of each satellite. There were areas of overlap that were removed based on the accuracy and availability of the image data. Python was used to draw the interpolation line and the used of cubic spline method to get the figure. Figure (6) shows analysis data for the study area at different times and on different satellites.

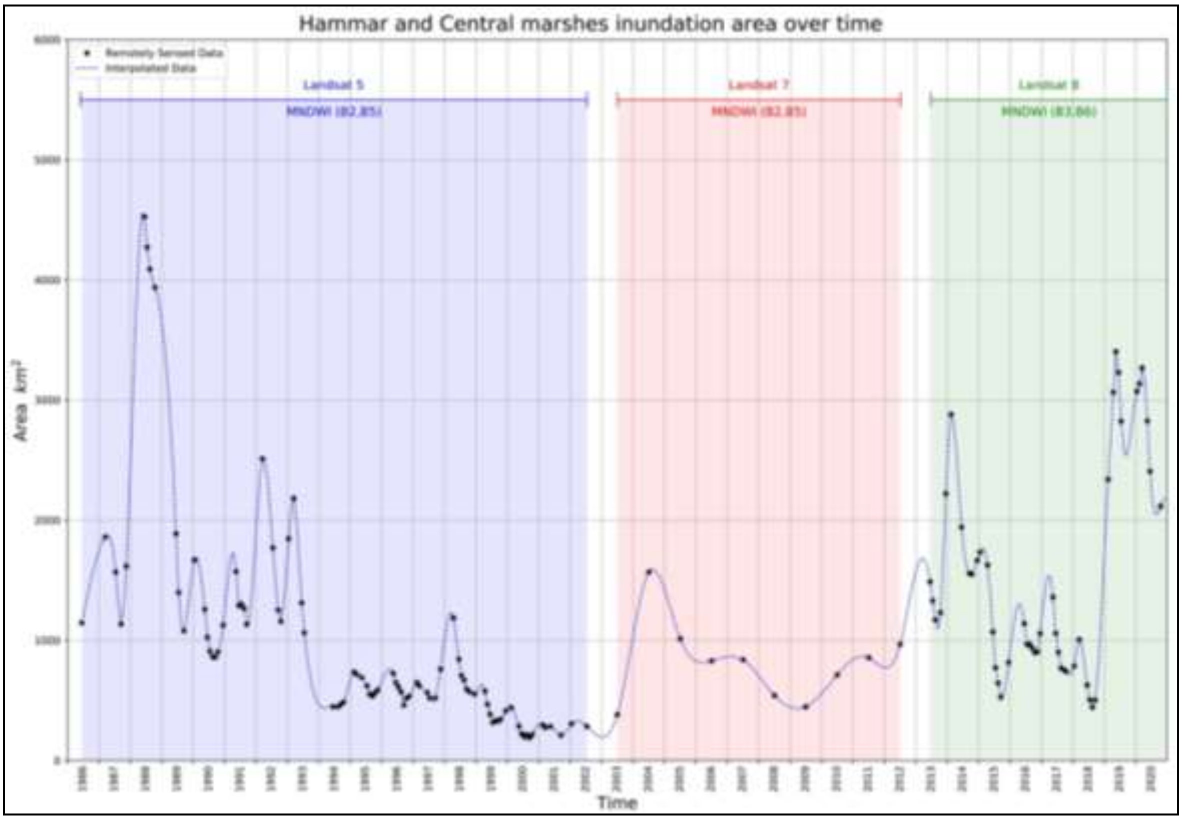

Fig.6: Analyzed data of the study area at different times from (1986 – 2020) and different satellites (L5, L7, and L8)

- **Validity of the Results**

The water resources in Iraq are largely related to the amount of rain and snow in the main river basins (Tigris and its tributaries and the Euphrates), as well as to the operating policy of dams and reservoirs built on the shared rivers in Turkey, Syria, and Iran. The study area is a part of the Iraqi basin whether it is the Euphrates or Tigris basins, and consequently, it affected the scarcity of flood records during historical years.

Iraq has experienced floods and scarce years, and among the flood years are 1946, 1954, 1963, 1968, 1969, 1988, 1993, 1995, and 2019. For the years of scarcity, 1934, 1935, 1961, 1999, 2000, 2001, 2008, and 2009; while the year 2018 was the scariest year for Iraq (Hydrological center station, 2020). The available discharge data is from 1986 to 2020 represents in Figure (7).

We have used all obtained data by analyzing the areas of inundation of Al-Hammar and Central marches, besides the annual discharge of Euphrates and Tigris rivers, and accordingly, we got the data presented in Figure (8).

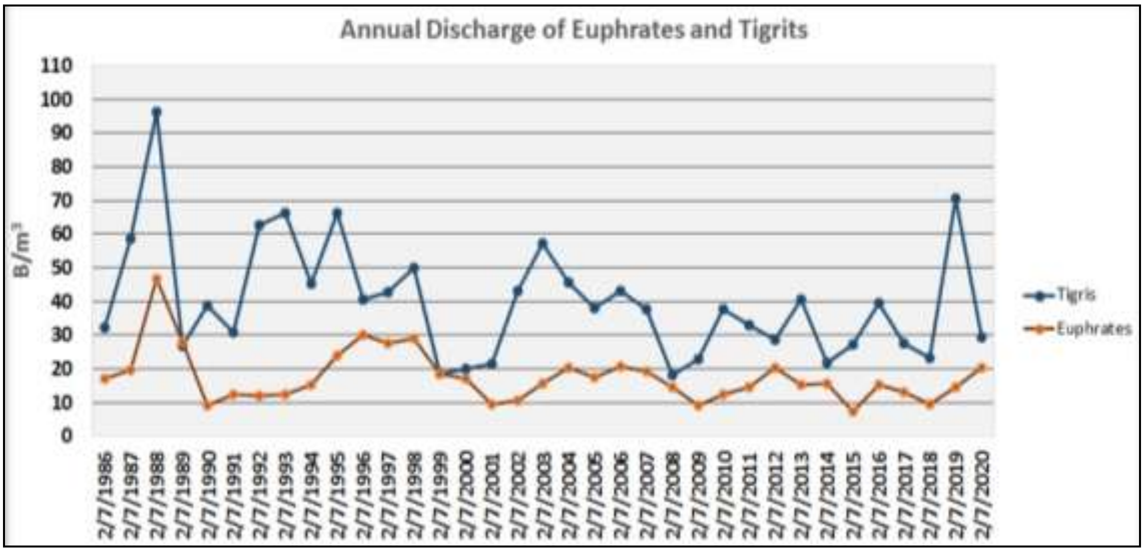

Fig.7: Annual discharge of the Euphrates and Tigris rivers
(Hydrological center station, 2020)

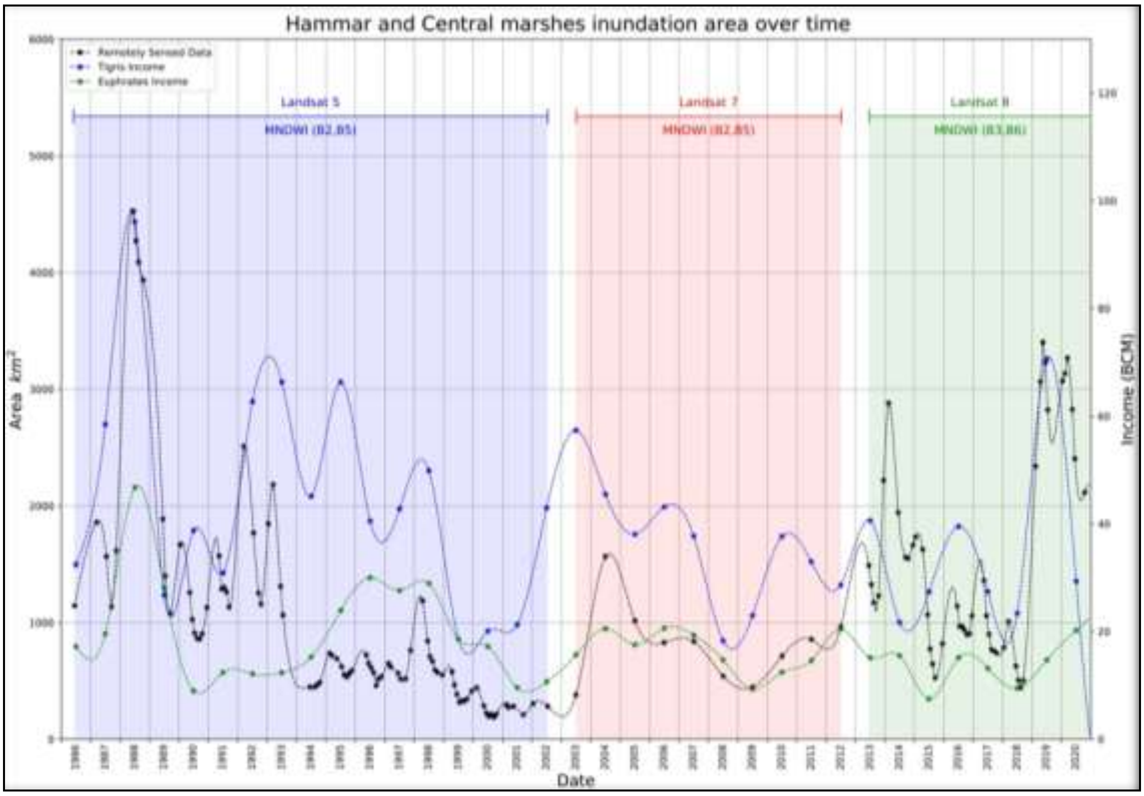

Fig.8: A comparison of inundation of Al-Hammar and Central marshes with the annual discharge of the Euphrates and Tigris rivers

In Figure (8), the y-axis on the left represents areas in a square kilometer, while the y-axis on the right represents the income of water into the Iraqi territory in billion cubic meters. The x-axis represents data in years, the Pearson correlation measures the strength of the linear relationship between two variables. It has a value between -1 to 1, with a value of -1 meaning a total negative linear correlation, 0 being no correlation, and + 1 meaning a total positive correlation. To know the R^2, excel was used, for the Tigris River it was $R^2 = 0.5$ and for the

Euphrates River, it was $R^2 = 0.4$. The fluctuations in curves (Figure 8) are due to many factors that affect the study area, such as its location downstream of Iraq, geological setting because it is a depression area, as well as the long path of the Euphrates and Tigris rivers, and the existence of tens of regulators along the rivers, and agricultural lands.

CONCLUSION

The main conclusions regarding the current study area are listed as follows:

- To viably oversee marshes, we require modern data almost their location, extent, inundation dynamics, and drivers of alteration; the GGE dataset provides the most spatially and categorically detailed data about marshes mapping using moderate spatial resolution satellite images (e.g., Landsat, Sentinel).
- Sensors Landsat 5, 7, and 8 were used and 10802 scenes were analyzed and filtered to get normalized difference water index MNDWI by special code under the GEE environment.
- Many factors affect the inundation of the study area, such as the amount of rain and snow falls in the main river basins (Tigris River and its tributaries and the Euphrates River), the operating policies of dams and reservoirs, which were built along the shared rivers in Turkey, Syria, and Iran, its location downstream of Iraq, geological setting because it is a depression area, as well as the long path of the Euphrates and Tigris rivers and the existence of tens of regulators and agricultural lands. By applying the Pearson equation between data of years and areas of inundation within the study area, we got the R values of the Tigris and Euphrates rivers to be $R^2 = 0.5$ and 0.4, respectively.

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