Proceeding Paper

Application of Satellite Remote Sensing Data to Manage Groundwater in Irrigated Canal Zone of Punjab [†]

Aamir Shakoor [1,*], Muhammad Ali [1], Zahid Mahmood Khan [1], Hafiz Umer Farid [1] and Muhammad Abubakar Aslam [2]

1   Department of Agricultural Engineering, Bahauddin Zakariya University, Multan 60800, Pakistan
2   National Center of Industrial Biotechnology (NCIB), PMAS Arid Agriculture University,
    Rawalpindi 46000, Pakistan
*   Correspondence: aamirskr@bzu.edu.pk
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Abstract: Irrigated agriculture is highly dependent on groundwater resources in Pakistan. Due to the fiber and food requirements, the reliance on groundwater has been increasing during the past two decades. This research work was conducted at the canal command area of the Dera Ghazi Khan (D.G Khan) canal for years 2017–2019. There were two products of the satellite i.e., AQUA (EOS PM) and TERRA (EOS AM), which were used in this research for determining groundwater demand in the area. For Rabi seasons 2017–2018 and 2018–2019, cropping areas of the major crops i.e., wheat and sugarcane, were 98,712.5 and 131,856.2 ha, and 100,568.7 and 132,743.7 ha, respectively. For the Kharif seasons of 2018 and 2019, cropping areas of major crops i.e., rice, cotton, and sugarcane, were 82,093.7, 74,150, and 98,712.5 ha, and 75,687.5, 79,275, and 132,743.7 ha, respectively.

Keywords: groundwater demand; NDVI; AQUA; TERRA; Dera Ghazi Khan

1. Introduction

In Pakistan, groundwater has been used for irrigating agriculture for a long time. Earlier, the abstraction of groundwater was made through open wells with the help of rope and buckets, reciprocating pumps, and hand pumps. In Pakistan, for irrigation for agriculture, groundwater is the second-largest source because of arid climatic conditions [1]. Due to the meeting of fiber and food requirements in Pakistan, the reliance on groundwater has been increasing during the past two decades [2–4].

In Pakistan, groundwater is a very important resource because its demand is increasing day by day for agricultural, domestic, and industrial purposes. Across the country, the contribution of groundwater for agriculture purposes is about 60%, for drinking it is 90%, and for industry it is 100% [5]. As most of the climatic zone of Pakistan is an arid climate zone where average annual rainfall is less than 20 mm and groundwater is limited in these areas [6]. In the Punjab province of Pakistan, the installation rate of private tubewells has been increasing at the rate of 60% from 1991–2000. In Pakistan, 1.20 million tubewells are installed that have a discharge rate of 0.015–0.56 m^3/s, having a depth of 30–85 m and a diameter of 15–30 cm out of this, and almost 86% of tube wells are installed in Punjab province. The groundwater has great importance for the farmers of tail ends of distributaries and watercourses because groundwater supplies are not enough there [7–9]. The advances in remote-sensing availability of images and image acquisition are helpful for geoscientists to prepare maps quickly and explore and evaluate the geo-characteristics of any area on the globe.

The investigation of groundwater demand is one of the main components of the management of these resources. Thus, the remote sensing data, one of the latest techniques,

was used to determine the crop water requirements and groundwater abstraction need in the study area.

2. Materials and Methods

2.1. Data

This research work was conducted at the canal command area of Dera Ghazi Khan (D.G Khan) canal, located at latitude 29.731° to 29.862° N and longitude 70.314° to 70.487° E. Elevation level of the study area is 129 m (423 ft) above the sea level. The canal network of the D.G. Khan Irrigation zone is 2679.64 miles long, and the command area under cultivation is about 0.84 million ha. The Chashma and Taunsa barrages provide irrigation water to the DG Khan canal.

The hottest month in this area is June, which has a maximum average temperature of 42 °C, and the coldest month is January, which has minimum average temperature of 6 °C. The average annual rainfall of this area is about 236.3 mm/year, having arid climate and erratic rainfall pattern. There are two seasons of crops, Kharif and Rabi. The Kharif season started in winter and is also named after monsoon crops because these crops are cultivated in the monsoon season. Sowing of Kharif crops started in April and harvesting started in October/November. Crops of the Kharif season are cotton, rice, and sugarcane. The Rabi season is sowing in November/December and harvesting in April/May. Major crops of the Rabi season are wheat, mustard, sugarcane, and barley.

2.2. MODIS Satellite Data

The remote sensing data were collected from the source of earth data, and its components were satellites AQUA (MYD13Q1) and TERRA (MOD13Q1), having a resolution of 250 m. The temperature data for the study area were collected from TERRA (MOD11A2), and rainfall data were collected online from weatheronline.com/dera-ghazi-khan for the time duration of 2017–2019. The discharge data of the canal were collected daily from the Punjab Irrigation Department for the time duration of 2017–2019. The MODIS satellite data set were acquired from its two sensors (AQUA and TERRA) and used for further processing. The data downloaded from these products have a difference of 8 days, and each product provides data after every 15 days.

2.3. Selection of Tiles of the Study Area

The selection of tiles in MODIS was very important because, in this method, the required tiles were selected in the study area that they lie in. The tiles were viewed from the app Google Earth that created a grid shape in Google Earth software around the globe, which was seen in red lines covering the area.

The interface of MODIS tiles is shown in Figure 1. The study area lies in horizontal tile h24 and two vertical tiles, v5 and v6. Therefore, the complete study area of research was covered by h24, v5, h24, and v6 tiles. Images through the satellite were easy for the graphical study of an area because tiles cover large areas, and Punjab (Pakistan) was completely covered by 2 tiles.
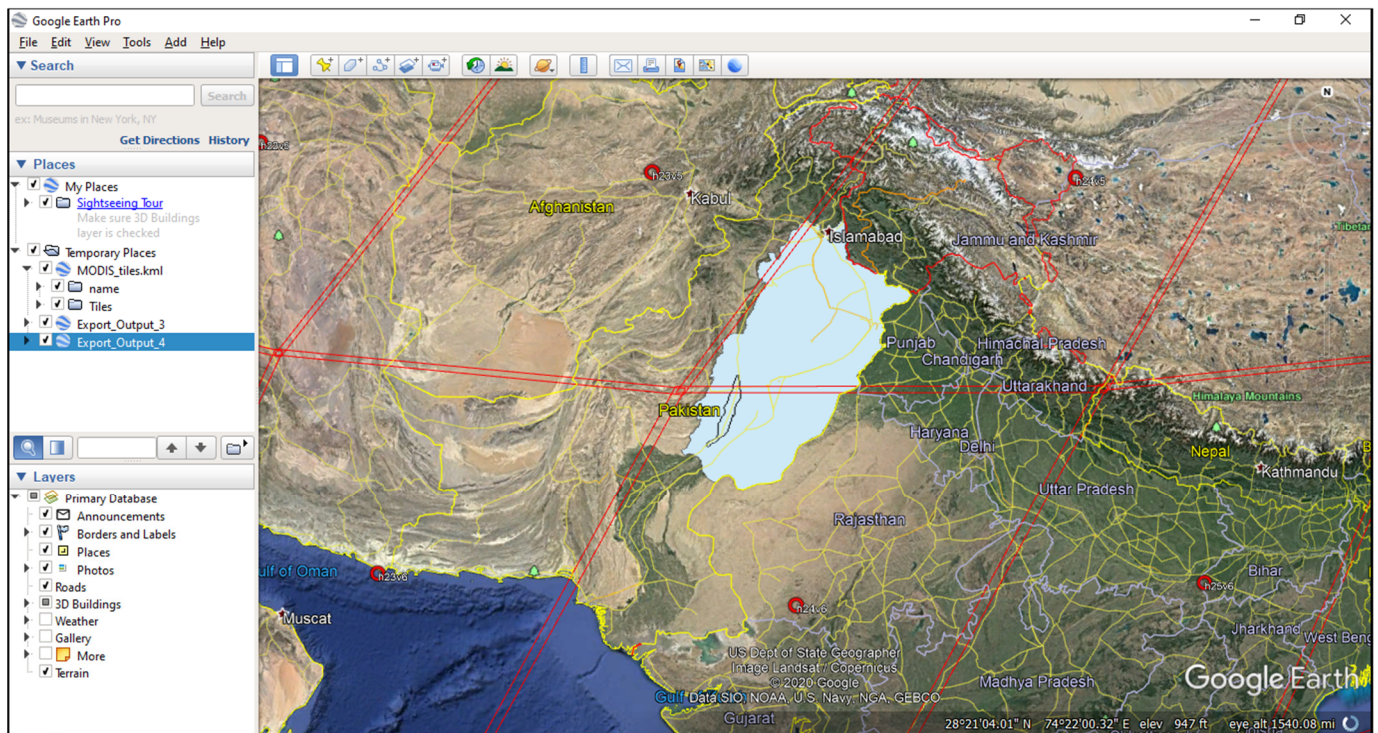
Figure 1. Selection of MODIS tiles of command area.

3. Results and Discussion

3.1. Seasonal Crop Water Requirement

The volume of seasonal crop water requirements for Rabi and Kharif is shown in Figure 2. The volume of crop water requirement ranged between 353.76 and 353.04 Mm^3 (million cubic meter) for the wheat crop during the season 2017–2018 and 2018–2019, respectively. The volume of crop water requirement ranged from 445.42 and 445.1 Mm^3 for the sugarcane crop for seasons 2018 and 2019, respectively. It was observed that the crop water requirement was high in 2017–2018 for Rabi and 2018 for Kharif, as compared to 2018–2019 and 2019, respectively.
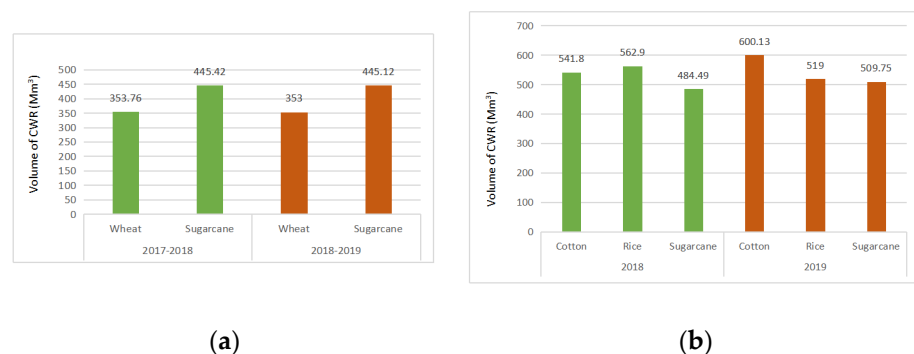

(**a**)

(**b**)

Figure 2. Seasonal crop water requirements (CWR): (**a**) Rabi (**b**) Kharif.

3.2. Seasonal Groundwater Demand

The groundwater demand was calculated for each cropping season, as shown in Figure 3. The volume of groundwater demand for Rabi 2017–2018 and 2018–2019 was 642.24 and 661.57 Mm^3 and for Kharif 2018, 2019 was 165 and −101.18 Mm^3, respectively. The highest value of groundwater was required for season Rabi 2018–2019, and the lowest value for Kharif was in 2018. It was observed that Kharif 2019 showed a negative value in

the graph, representing that there was no need for groundwater for this season and that canal water was enough to meet crop water requirements.
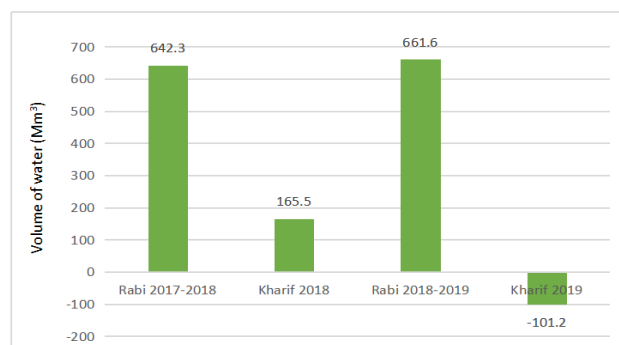

Figure 3. Seasonal groundwater demand.

4. Conclusions

In this research, AQUA and TERRA remotely sensed datasets were used to determine crop water requirements of the major crops in the study area for the year 2017–2019. The groundwater demand was calculated by subtracting the CWR from the actual canal water supplies. It was found that the seasonal volume of CWRs of wheat and sugarcane for season 2017–2018 were 353.76 and 445.42 Mm^3 and for season 2018–2019 were 353 and 445.12 Mm^3, respectively. The seasonal volume of CWRs for rice, cotton, and sugarcane for season 2018 were 562.9, 541.8, and 484.5 Mm^3, and for season 2019 they were 518.9, 600, and 509 Mm^3 respectively. The results showed that volume of groundwater demands for Rabi 2017–2018 and 2018–2019 were 642.24 and 661.57 and for Kharif 2018 was 165 Mm^3, respectively. For Kharif 2019, the negative values (-101.18 Mm^3) represent the surplus canal water supplies. The groundwater demand in the Rabi season was relatively higher than Kharif season. It is recommended that the maximum number of crops should be observed for a better understanding of the crop water requirements in the area.

Author Contributions: A.S. and M.A. conceptualize the research objectives. M.A., H.U.F. and M.A.A. collected the data. A.S. and Z.M.K. supervised the procedure and method adopted. All the authors contributed to analyzing the results and writing the manuscript. All authors have read and agreed to the published version of the manuscript.

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