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Evaluation of water distribution under pivot irrigation systems using remote sensing imagery in eastern Nile delta

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ABSTRACT

Traditional methods for center pivot evaluation depend on the water depth distribution along the pivot arm. Estimation and mapping the water depth under pivot irrigation systems using remote sensing data is essential for calculating the coefficient of uniformity (CU) of water distribution. This study focuses on estimating and mapping water depth using Landsat OLI 8 satellite data integrated with Heerman and Hein (1968) modified equation for center pivot evaluation. Landsat OLI 8 image was geometrically and radiometrically corrected to calculate the vegetation and water indices (NDVI and NDWI) in addition to land surface temperature. Results of the statistical analysis showed that the collected water depth in catchment cans is also highly correlated negatively with NDVI. On the other hand water, depth was positively correlated with NDWI and LST. Multi-linear regression analysis using stepwise selection method was applied to estimate and map the water depth distribution. The results showed R^2 and adjusted R^2 0.93 and 0.88 respectively. Study area or field level verification was applied for estimation equation with correlation 0.93 between the collected water depth and estimated values.

1. Introduction

One of the most populous countries in Africa is Egypt. More than 90 million inhabitants live near the banks of the Nile and the delta, in an area of about 5% of Egypt area. In other words, approximately only 5.5% of the total land area is used for different land use purposes. Nile River is the main water resources in Egypt. The climate is semi-arid with low precipitation rate only at the eastern and northern coasts reach 410 mm, with most of falling in winter season starts in October ends at the March. Egypt is therefore totally depended on Nile water entering Egypt at the southern border with Sudan (Droogers et al., 2009).

According to food and agriculture organization FAO Water Report No. 29, 2005, the main land cover/land use of the Egypt area is desert land. Moreover, the cultivated areas located in Nile delta and valley The Mediterranean coast had bearing low capacity only of few kilometers depth. The total cultivated areas in Egypt estimated by 3.4 million ha (2002).

Remote sensing data is essentially used as tools for yield prediction, water requirements and/or stress in addition to crop monitoring, (Idso et al., 1978, 1980), improving water use efficiency (Evett et al., 2006) precise irrigation managements (Wanjura et al., 1995). Infrared thermography and thermometry measurements can significantly use to drive information of water content, canopy moisture status and canopy surface temperature (O'Shaughnessy et al., 2011).

Evaluating the performance of irrigation system is significantly essential for sustainable water management. The ground survey is the most accurate way of evaluation and monitoring through field work. Which are cost effort and time especially when apply frequently and to cover large areas. The advantages of remote sensing data make its use is important for evaluation irrigation systems for large areas (Aman, 2003).

Irrigation plays an essential role in the agricultural productivity. When water applies spatially and temporally distributed matches with crop water demand high water use efficiency is achieved. Recently, new technologies have played an important role in improving irrigation processes. As precision agriculture technologies have significantly advanced irrigation scheduling. MODIS, Landsat, and GOES, and remote sensing technology can be used to estimate crop water requirements for better water management in irrigated areas (Fares et al., 2006; Cammalleri and Ciraolo, 2013; Hassan-Esfahani et al., 2014, 2015).

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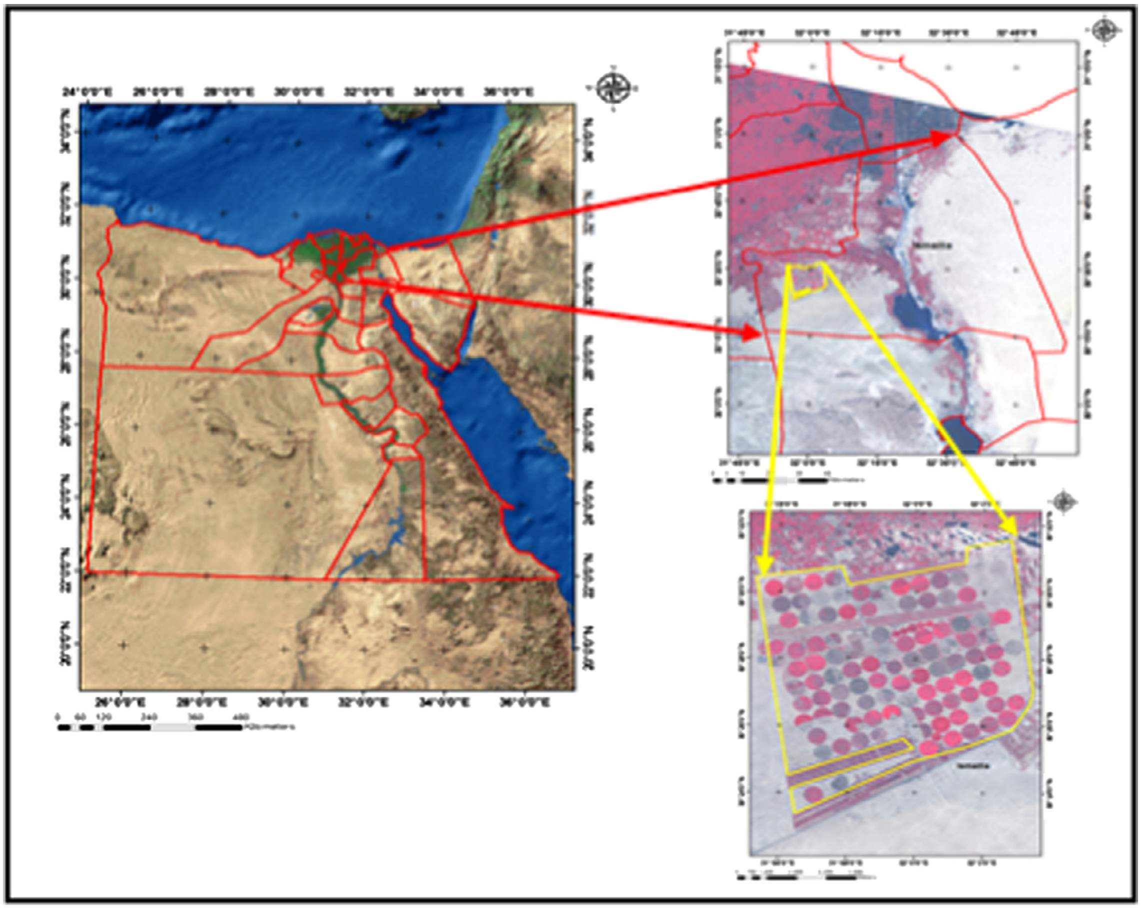

Fig. 1. Shows the study area location.

The thermal-based stress index has been calculated from spectral measurements is crop water stress index. That used to quantify plant water stress and irrigation schedule (O'Shaughnessy et al., 2012).

Different indices calculated from remote sensing sensors used to quantify many biophysical parameters of vegetation cover, such as leaf area index, vegetation cover surface temperature, leaf water content and chlorophyll pigment content. Remote sensing of VIs provides in situ time plant conditions. Moreover, crop water stress index (CWSI) used to schedule irrigation whenever a threshold criterion (trigger point) is reached. CWSI is estimated using remote sensing vegetation cover surface temperature (T_s) and meteorological data (Howell et al., 2012).The main objectives of this research were mapping water and vegetation indices calculated from remote sensing data. In addition to evaluation of the pivot irrigation system water distribution efficiency using remote sensing imagery.

2. Materials and methods

2.1. Study area

The study area is located in El-Salhiya, Ismailia governorate eastern Nile delta. The area is bounded by longitudes 31°59′17.55″E and Latitudes 30°27′29.81″N. The climate is an arid Mediterranean type with an average temperature 21.4 °C, The original land of El-Salhiya featured by dark yellowish brown (moist) and light yellowish (dry), sandy, single grains, non-sticky, non-plastic and friable or loose characteristics had been changed to dark brown (moist) and dark yellowish brown (dry), sandy loam, moderate medium sub-angular blocky structure, sticky, plastic and firm hard dry after 30 years of cultivation according to Gobran and El-Barbary (1998) see Figs. 1–4.

2.2. Data description

The data acquired for two different pivot systems. The field data were collected represented in the water depth mm to calculate the coefficient of uniformity (CU) using the Hermann and Hein modified equation. Set of Landsat OLI 8 satellite images were geometrically and radiometrically corrected and used to calculate Normalized Difference Vegetation Index (NDVI) and normalized difference water index (NDWI).

3. Methodology

Center pivot coefficient of uniformity (CU) calculated using the Heerman and Hein (1968) modified equation as Eqs. (1) and (2):

$$CU_H = CU_H = 100\left[1 - \frac{\sum_{i=1}^{n} S_i |V_i - \bar{V}_p|}{\sum_{i=1}^{n} V_i S_i}\right] \tag{1}$$

The weighted average of the volume of water caught is computed as Eq. (2):

$$\bar{V}_p = \frac{\sum_{i=1}^{n} V_i S_i}{\sum_{i=1}^{n} S_i} \tag{2}$$