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Estimation of Evapotranspiration ET_c and Crop Coefficient K_c of Wheat, in south Nile Delta of Egypt Using integrated FAO-56 approach and remote sensing data

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Vegetation indices

Abstract Crop water requirements are represented by the actual crop evapotranspiration. Estimation of crop evapotranspiration (ET_c) and crop coefficient using remote-sensing data is essential for planning the irrigation water use in arid and semiarid regions. This study focuses on estimating the crop coefficient (K_c) and crop evapotranspiration (ET_c) using SPOT-4 satellite data integrated with the meteorological data and FAO-56 approach. Reference evapotranspiration (ET_o) were estimated using FAO Penman-Monteith and tabled single crop coefficient values were adjusted to real values. SPOT-4 images geometrically and radio metrically corrected were used to drive the vegetation indices (NDVI and SAVI). Multi linear regression analysis was applied to develop the crop coefficient (K_c) prediction equations for the different growth stages from vegetation indices. The results showed R^2 were 0.82, 0.90 and 0.97 as well as adjusted R^2 were 0.80, 0.86 and 0.96 for developing, mid-season and late-season growth stage respectively.

1. Introduction

The importance of water resources management is due to the increase of the population and water demand especially in the Middle East and North Africa, which are classified as arid and semi-arid regions. These are threatened by the water crisis in the future. Egypt is classified among the regions that are facing high-water shortages. This is mainly due to the combination of persistent drought and the increase of water demand effects, especially in the irrigation sector.

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The importance of wheat crop, that returns to its strategic value in the Egyptian diet commodities, is that it provides more than one-third of the daily caloric intake of Egyptian consumers and 45 percent of their total daily protein consumption (Rosen, 1993; Rowntree, 1993; Abdel Ghaffar, 1994).

Grain yield is affected by both the magnitude of water deficit, and the stage of growth subjected to the deficit (Salter and Good, 1994). Insufficient water supply caused by prolonging irrigation intervals, and or decreasing the available moisture in the soil clearly inhibits plant growth in terms of leaf area and plant height (Porro and Cassel, 1986).

The most common and practical approach widely used for estimating crop water requirement, and the operational monitoring of soil-plant water balance is the FAO-56 method. In the FAO-56 approach, crop evapotranspiration is estimated by the combination of a reference evapotranspiration (ET_o) and crop coefficients. There are two different FAO-56 approaches: single and dual crop coefficients. The single crop coefficient approach is used to express both plant transpiration and soil evaporation combined into a single crop coefficient (K_c). The dual crop coefficient approach uses two coefficients to separate the respective contribution of plant transpiration (K_{cb}) and soil evaporation (K_e), each by individual values (Allen et al., 1998).

Crop coefficients K_c primarily depended on the dynamics of canopies (cover fraction, LAI, greenness). Remote sensing data can be used to estimate some key-variables related to vegetation phonology (Bastiaanssen et al., 2000), which offer opportunities for monitoring the space and time variability of K_c. Use of remotely-sensed vegetation indices as the Normalized Difference Vegetation Index (NDVI) and the Soil Adjusted Vegetation Index (SAVI), has been tested to predict crop coefficients at field and regional scales (Rosue et al., 1974; Huete, 1988; Duchemin et al., 2002).

The remotely sensed spectral reflectance may provide an indirect estimate of crop coefficient or basal crop coefficients. Indeed, several authors have tested similarity between the seasonal patterns of different vegetation indices and transpiration over annual crops (Jackson et al., 1980; Bausch and Neale, 1987; Bausch, 1993, 1995; Hunsaker et al., 2003, 2005; Duchemin et al., 2006; Er-Raki et al., 2007). In addition K_c can be estimated from spectral vegetation indices since both are related to leaf area index and fractional ground cover (Heilman et al., 1982; Neale et al., 1989; Choudhury et al., 1994).

The main objectives of this study are: (1) Estimating the crop coefficient (K_c) and the crop evapotranspiration (ET_c) for the wheat crop in Egypt through the different growth stages from vegetation indices (NDVI, SAVI) derived from the SPOT-4 satellite images. (2) Mapping the crop coefficient and crop evapotranspiration within the entire field for different growth stages.

2. Materials and methods

2.1. Study area

The study area is located in south Nile Delta, Egypt. Where the soil is clay loam, has a relatively heavy texture permeable. The climate is arid Mediterranean type with an average annual precipitation of about 0.65 mm and temperature 25.7 co.31.5 acres are cultivated with wheat crop sub-species Bani-suief 1. The investigation was applied only on 10.5 acres (see Fig. 1).

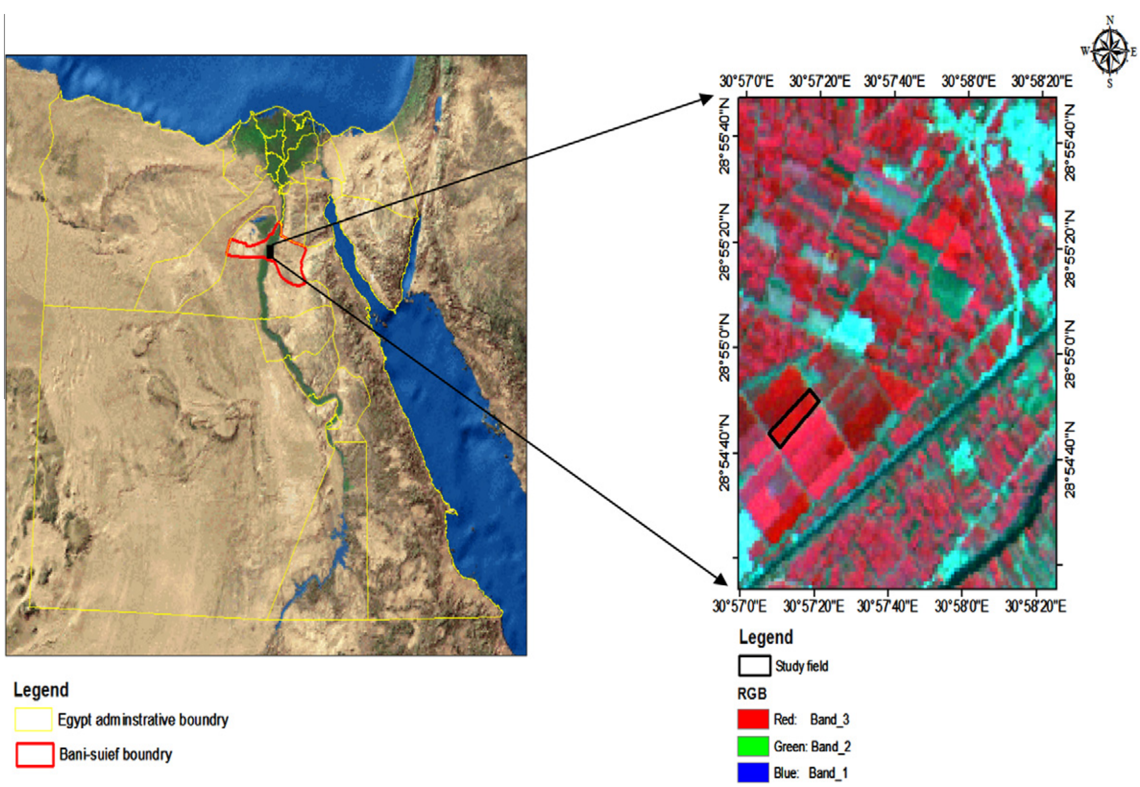

Figure 1 Location of study area SPOT-4 image in false color composition.