remote sensing

MDPI

Article

Satellite-Based Determination of the Water Footprint of Carrots and Onions Grown in the Arid Climate of Saudi Arabia

Khalid A. Al-Gaadi [1,2], Rangaswamy Madugundu [2,*], ElKamil Tola [2], Salah El-Hendawy [3,4] and Samy Marey [5,6]

[1] Department of Agricultural Engineering, College of Food and Agriculture Sciences, King Saud University, Riyadh 11451, Saudi Arabia
[2] Precision Agriculture Research Chair, Deanship of Scientific Research, King Saud University, Riyadh 11451, Saudi Arabia
[3] Department of Plant Production, College of Food and Agriculture Sciences, King Saud University, Riyadh 11451, Saudi Arabia
[4] Department of Agronomy, Faculty of Agriculture, Suez Canal University, Ismailia 41522, Egypt
[5] Agricultural Engineering Research Institute (AEnRI), Agricultural Research Centre, Giza 12618, Egypt
[6] Science & Technology and Innovation Unit, King Saud University, Riyadh 11451, Saudi Arabia
* Correspondence: rmadugundu@ksu.edu.sa; Tel.: +966-11-4691943

Abstract: Increasing demand for food, climate change, and other human interventions are leading to significant increases in water consumption by the agricultural sector. This requires rationalizing the water used for the production of agricultural crops through improved irrigation management practices. Therefore, this study aimed to estimate the water footprint (WF) of onion (*Allium cepa* L.) and carrot (*Daucus carota*) crops using the CROPWAT model and the SSEB (Simplified Surface Energy Balance) algorithm. Experiments were carried out at two center-pivot irrigated fields belonging to Tawdeehiya Commercial Farms in the southeastern region of the Riyadh governorate, Saudi Arabia. Individual bands and vegetation indices (VIs) were retrieved from Sentinel-2 satellite data, including the normalized difference vegetation index (NDVI), soil adjusted vegetation index (SAVI), optimized soil adjusted vegetation index (OSAVI), renormalized difference vegetation index (RDVI), and enhanced vegetation index (EVI), and the land surface temperatures (LST) extracted from Landsat-8 data were used to estimate crop productivity (CP), crop water use (CWU) (i.e., evapotranspiration—ET_a), and crop WF. Crop growth/phenology stages and georeferenced biophysical parameters were recorded during the growth period, and crop yield samples were collected randomly from predetermined sampling locations. It was found that the NIR band was appropriate for predicting onion yield (R^2 = 0.68; $p > F$ = 0.02) and carrot yield (R^2 = 0.77; $p > F$ = 0.02). The results also showed the feasibility of using the RDVI and EVI to estimate the yields of onion and carrot crops, with bias values of 15% and –17%, respectively. The CWU has also been successfully estimated using the SSEB algorithm, with an overall accuracy of 89%. The SSEB-estimated CWU was relatively high compared to the applied amounts by 10.6% (onions) and 12.6% (carrots). Finally, the crop WF was successfully estimated at 312 m^3 t^{-1} and 230 m^3 t^{-1} for carrots and onions, respectively, with an overall accuracy of 71.11%. The outcomes of this study can serve as a reference for crop irrigation management practices in the study region and areas with similar environmental conditions.

Keywords: crop water use; crop yield; satellite images; vegetation indices; water footprint

Citation: Al-Gaadi, K.A.; Madugundu, R.; Tola, E.; El-Hendawy, S.; Marey, S. Satellite-Based Determination of the Water Footprint of Carrots and Onions Grown in the Arid Climate of Saudi Arabia. *Remote Sens.* **2022**, *14*, 5962. https://doi.org/10.3390/rs14235962

Academic Editor: Guido D'Urso

Received: 8 November 2022
Accepted: 21 November 2022
Published: 25 November 2022

1. Introduction

The demand for water has increased dramatically around the world, with particular attention being paid to the water used for the irrigation of agricultural crops and related industries. Therefore, the sustainable use of water in agricultural production, particularly in arid regions such as Saudi Arabia, has become one of the key priorities of modern agricultural strategies. Due to the drastic shortage of freshwater resources and harsh