Journal of Cleaner Production 434 (2024) 140194

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

A new factorial sensitivity model for analyzing the impacts of climatic factors on crop water footprint

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ARTICLE INFO

Handling Editor: Cecilia Maria Villas Bôas de Almeida

Keywords:
Crop water footprint
Spatio-temporal changes
Standardized precipitation evapotranspiration index (SPEI)
Factorial analysis
Climatic factors

ABSTRACT

The impact of climate change on the crop water footprint (WF) is highly uncertain, hindering effective agricultural water use in response to climate change. This study proposes a factor sensitivity analysis method, which can screen out statistically significant climatic factors and interactions on crop WF under various uncertainties and determine water resource management measures to mitigate drought for different crops. A special case study was conducted in Heilongjiang Province, China. The results showed that (1) the annual change in crop WF showed a downward trend from 1988 to 2018. The crop WF was dominated by green water footprint (WF_{green}), and the average occupancy rate of WF_{green} in crops was 58.7%–74.1 %; the spatial distribution of WF has latitude zonality. (2) Drought has different effects on WF of different crops, and WF of soybean is susceptible to drought. Wind speed, sunshine hours, and humidity have a greater impact on crop WF in most growth stages. (3) The effect of climatic factors on crop WF varies in different months. The rice WF is mainly affected by the climate in May, and there is an interaction between May humidity and May rain. The WF of maize and soybeans are affected primarily by the climate in July, especially sunshine hours. The proposed approach attempts to analyze that crop WF is affected by not only an individual climatic factor but also their interactions. Crop water management practices should be adjusted based on the results to mitigate the adverse impact of climatic conditions on crop WF during different growing months.

1. Introduction

Water is an indispensable ingredient in agricultural production, and without water, farmers cannot grow crops and feed animals (Fitton et al., 2019). Therefore, water insecurity means food insecurity. Climate change has brought huge risks and uncertainties to food production and agricultural water security (Elnashar and Elyamany, 2023; Mirón et al., 2023; Zhu et al., 2019). Climate change not only affects the process of the hydrological cycle processes by changing hydrological elements such as precipitation and evaporation (Oki and Kanae, 2006; Vörösmarty et al., 2010), but also affects the spatiotemporal distribution of regional water resources (Guevara-Ochoa et al., 2020), which directly affects agriculture. The increased frequency of extreme events such as heavy rainfall and drought poses a direct threat to crop yields (Heinicke et al., 2022; Webber et al., 2018). Meanwhile, as one of the most affected industries, agriculture is highly sensitive to climate change (Tao et al., 2022; Wang et al., 2009). For example, climate warming may increase the potential evapotranspiration, affecting crop water requirements and deficits during the crop growing season (Cooper et al., 2022).

The crop water footprint (WF) is an effective method for assessing water resource utilization and pollution intensity in crop growth, providing a comprehensive assessment for decision-making and optimizing agricultural production systems (Mekonnen and Hoekstra, 2011). The WF includes green, blue, and grey WF, green water refers to the precipitation absorbed by crops during growth. Blue water refers to the volume of water taken for irrigation from surface or groundwater

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https://doi.org/10.1016/j.jclepro.2023.140194
Received 2 July 2023; Received in revised form 27 October 2023; Accepted 12 December 2023
Available online 25 December 2023
0959-6526/