Climate change impacts on potential evapotranspiration, drought, and runoff in eastern Australia

Submitted by

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Certificate of Original Authorship

I, Lijie Shi declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Life Science/Faculty of Sciences at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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Publications arising from this thesis

<u>Journal papers directly included in this thesis</u>

1. Lijie Shi, Puyu Feng, Bin Wang, De Li Liu, James Cleverly, Quangxiao Fang, and Qiang Yu. "Projecting potential evapotranspiration change and quantifying its uncertainty under future climate scenarios: A case study in southeastern Australia" Journal of Hydrology, 584 (2020), DOI: https://doi.org/10.1016/j.jhydrol.2020.124756. (Chapter 4)
2. Lijie Shi, Puyu Feng, Bin Wang, De Li Liu, and Qiang Yu. "Quantifying future drought change and associated uncertainty in southeastern Australia with multiple potential evapotranspiration models." Journal of Hydrology, 590 (2020), DOI: https://doi.org/10.1016/j.jhydrol.2020.125394. (Chapter 5)

<u>Peer-reviewed international conference proceedings</u>

1. Lijie Shi, Puyu Feng, Bin Wang, De Li Liu, Siyi Li, Qiang Yu. 'Modelling impacts of climate change on potential evapotranspiration in New South Wales, Australia' The 23rd International Congress on Modelling and Simulation (MODSIM), Canberra, Australia, 3-8 December 2019. (Extended Abstract, Accepted).

Contents

List of Figures

List of Tables

Abbreviations

BoM	Bureau of Meteorology
CR	Capillary rise
DP	Deep percolation
ET	Evapotranspiration
ETa	Actual evapotranspiration
ETp	Potential evapotranspiration
ET0	Reference evapotranspiration
H	Sensible heat of water
I	Irrigation water
G	Soil heat flux
GCMs	Global Climate Models
P	Precipitation
XAJ	Xinanjiang model
RCPs	Representative Concentration Pathways
Rn	Net radiation
RO	Runoff
R	Surface runoff
SILO	Science
SPEI	Standardized precipitation evapotranspiration index
λ	Latent heat of vaporization
△SF	Horizontal surface flow
△SW	Change in soil moisture

Abstract

As one of the most arid continents, Australia is exposed to drought and water scarcity. The changing climate is likely to intrigue more drought occurrence and make water scarcity more severe. In this context, it is important to investigate the influence of climate change on drought and water availability in Australia.

This study aimed to investigate the possible change of potential evapotranspiration (ETp), drought occurrence, and runoff under future climate scenarios, thus providing useful information to mitigate the adverse impacts of climate change on crop production and water resource management. In specific, four inter-related studies were carried out based on widely used empirical ETp models, random forest method, statistical indices, standardized precipitation evapotranspiration index (SPEI), Xinanjiang model, and a three-way analysis of variance. Findings from these studies suggested that: (1) radiation based models including Jensen-Haise, Abtew, modified Makkink, and Turc and temperature-based model Hargreaves were able to reasonably estimate ETp rates, capture its temporal evolution, and periodically oscillation; (2) random forest-based ETp models generally outperformed empirical ETp models which required the same climatic inputs; (2) ETp was likely to increase in the future and the increase could be mostly explained by the increase in temperature and solar radiation; (3) Droughts, especially for moderate and severe droughts were also likely to increase and the increases in spring and winter were larger than that in summer and autumn. The increase in ETp explained more of the change in drought than the decrease in rainfall did; (4) There were obvious decreases in spring and winter runoff whereas the mean changes in summer and autumn runoff were subtle. The changes in runoff were consistent with the pattern of changes in rainfall and the difference in ETp inputs barely influenced runoff projection; (5) GCMs, RCPs, or their interaction generally were the dominant factors resulting in uncertainty in the projections of ETp, drought, and runoff in future climate scenarios.

This study confirmed the increase in air evaporative demand, drought occurrence, and water scarcity in eastern Australia and highlighted the necessary to for farmers and policy makers take measures to adapt to the changing climate. The possible measures include cultivating drought-resistant varieties, adjusting the planting structure, improving the capability of drought forecast, and changing the seeding windows accordingly.

Keywords: climate change; potential evapotranspiration; random forest, drought; runoff; uncertainty; eastern Australia