Individual and coupled effects of future climate and land use scenarios on water balance components in Australia

Submitted by

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Certificate of Original Authorship

I, Hong Zhang declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Life Sciences/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

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Zhang, H., Wang, B., Li Liu, D., Zhang, M., Leslie, L. M., & Yu, Q. (2020). Using an improved SWAT model to simulate hydrological responses to land use change: a case study of a catchment in tropical Australia. Journal of Hydrology, 124822. (Chapter 5)

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Peer-reviewed International Conference proceedings:

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Glossary

AGRL	*agricultural land-generic*
ANOVA	*analysis of variance*
BOM	*Bureau of Meteorology*
CF	*change factor*
CMIP5	*Coupled Model Intercomparison Project phase 5*
CMIP6	*Coupled Model Intercomparison Project phase 6*
CSIRO	*Commonwealth Scientific and Industrial Research Organization*
DEM	*digital elevation model*
ENSO	*El Niño Southern Oscillation*
ET	*evapotranspiration*
FAO	*Food and Agriculture Organization*
FRSD	*forest-deciduous*
FRSE	*forest-evergreen*
FRST	*forest-mixed*
GCM	*global climate model*
GHG	*greenhouse gas*
GWQ	*groundwater*
HRU	*hydrologic response unit*
IPCC	*Intergovernmental Panel on Climate Change*
LAI	*leaf area index*
LAM	*limited-area model*
LATQ	*lateral runoff*
LU	*land use*
LUCC	*land use/cover change*
MK	*Mann-Kendall*
MLRM	*multiple Liner Regression Model*
MODIS	*Moderate Resolution Imaging Spectroradiometer*
NSE	*Nash-Sutcliffe Efficiency*
NSW	*New South Wales*
PBIAS	*percent bias*
PET	*potential evapotranspiration*
R^2	*coefficient of determination*
RC	*runoff coefficient*
RCM	*regional circulation model*
RCP	*Representative Concentration Pathway*
RMSE	*root mean square error*
RNGB	*range-brush*
RNGE	*range-grasses*
SCS CN	*Soil Conservation Service Curve Number*
SILO	*Scientific Information for Land Owners*
SURQ	*surface runoff*
SW	*soil water*

SWA	*south-western Australia*
SWAT	*Soil and Water Assessment Tool*
SWAT-CUP	*SWAT Calibration and Uncertainty Programs*
SWAT-T	*modified SWAT model for tropical areas*
SWWA	*Southwest Western Australia*
T_{max}	*maximum land surface temperature*
T_{min}	*minimum land surface temperature*
UB	*backward trend*
UF	*forward trend*
URBN	*urban*
WETL	*wetlands*
XAJ	*Xinanjiang*

Abstract

The hydrological cycle is influenced by both the climate change and variability and land use/cover change. Assessing the impacts of both climate change and variability and land use/cover change on hydrological variables is crucial for sustainable development of water resources and natural ecosystems. This thesis mainly assessed the effects of land use/cover change and future climate change and variability, both separately and in combination, on water resource availability in Australia. In specific, four inter-related studies were carried out based on statistical methods (Mann-Kendall trend test, Mann-Kendall abrupt test, wavelet analysis, linear regression, and climate elasticity), hydrological models, global climate models (GCMs), different land use/cover scenarios, and analysis of variance method.

The main findings of this thesis are: (1) As expected, rainfall is the factor that most affects runoff, and an increase of 10% in rainfall caused an increase of 24.4% in runoff according to the average of the four catchments. (2) Annual rainfall and runoff were projected to decrease slightly in 2021-2060 and increase in 2061-2100. A slight increase was predicted in annual actual evapotranspiration, while a decrease was projected in annual soil water in the future. (3) Urbanization increased surface runoff while decreased lateral runoff and groundwater, but produced no clear change in total runoff, actual evapotranspiration, and soil water. Additionally, afforestation decreased surface runoff and caused slight changes in other hydrologic variables. (4) For the combined impacts of climate and land use/cover changes, the results of different land use/cover change scenarios were only slightly different from the response of the original land use/cover. An uncertainty analysis shows that GCMs had the greatest contribution to hydrologic variables, followed by RCPs and land use/cover scenarios.

Overall, this thesis offers an improved understanding of the individual and coupled impacts of future climate and land use/cover scenarios on water balance components in Australian catchments. It is advisable for impacts analysis (non-extreme dry or wet studies) to use an ensemble of GCMs under different RCPs as this study or select “good” GCMs that can capture regional atmosphere physical processes as some other studies, to minimize the uncertainty of projected future hydrologic variables. This thesis can provide crucial information for the development of efficient adaptation strategies and future policy plans for sustainable land and water management in Australia.

Keywords: Climate elasticity; climate change and variability; land use/cover change; GCMs; MODIS LAI; XAJ model; SWAT model; SWAT-T model; Australia; runoff