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Spatio-temporal distribution of groundwater recharge under climate change in the Namngum++ River Basin

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Groundwater contributes to one-third of the global water consumption and is critical for supplying global ecological, economic and societal needs. The burgeoning population has escalated groundwater demand for groundwater abstraction for industrial, domestic and irrigation consumption. In contrast to surface water, climate change, though it does not directly impact groundwater resources, influences groundwater in different ways: infiltrating water through soil, deep percolation, and increasing the evaporative demands of land, altering the groundwater recharge. The main objective of this study is to quantify the current groundwater recharge and assess the impact of climate change on its spatio-temporal distribution in the Namngum ++ river basin of the Lower Mekong Region (LMR). Namngum++ is a transboundary river basin that transcends Laos and Northern parts of Thailand, where groundwater is garnering wider attention in recent days. Thus, it is imperative to understand the impact of climate change on groundwater recharge for sustainable and progressive groundwater planning and management as erratic rainfall and prolonged droughts have made surface water unpredictable in this region. In order to quantify the current groundwater recharge, a physically semi-distributed Soil and Water Assessment Tool (SWAT) model for Namngum++ basin has been used. Hydrological simulation in SWAT is based on water balance, as given in equation 1.

$$\mathrm{SW_t} = \mathrm{SW_0} + \sum_{i=1}^{t} \left(\mathrm{R_{day}} - \mathrm{Q_{surf}} - \mathrm{W_{seep}} - \mathrm{ET_a} - \mathrm{Q_{gw}}\right) \quad 1$$

where SW_t is soil water (mm), SW_0 is the base soil water (mm), t is time (days), R_{day} is rainfall (mm), Q_{surf} is surface runoff, ET_a is actual evapotranspiration (mm), W_{seep} is seepage of water through soil into deeper layers, Q_{gw} is groundwater runoff (mm).

Recharge on a given day in SWAT is calculated using equation 2,

$$r_{rchrg,i} = \left(1 - \exp[-1/\delta_{gw}]\right) \cdot r_{\mathrm{seep}\,+\exp[-1/\delta_{gw}]} \cdot r_{rchrg,i-1} \quad 2$$

where $r_{rchrg,i}$ and $r_{rchrg,i-1}$ are the recharges reaching aquifers on day i and i-1 respectively, δ_{gw} is time delay posed by underlying geological section (days), r_{seep} is total water exiting bottom of soil layer on day i (mm H2O).

In this study, the SWAT model is calibrated (1997-2010) and validated (2011-2015) to the observed monthly streamflow (figure 1) prior to recharge estimation for present and future climate stress periods. The model performance was good with the coefficient of determination (R^2), Nash-Sutcliffe Efficiency (NSE), and percentage bias (PBIAS) values of 0.72, 0.70 and 9.2% for the calibration period and 0.80, 0.77 and 4.9 % for the validation period, respectively. The simulated recharge at the hydrologic response unit (HRU) level was processed for spatio-temporal representation.

The study linearly bias-corrected 3 climate variables(precipitation, minimum and maximum temperature) of four global circulation models (GCMs: BCC-CSM2-MR, Canesm5, GFDL-CM4 and MRI-CSM2-0) of the sixth phase of the Coupled Model Intercomparison Project (CMIP6) against the available observed (1985-2015) datasets to project the impact of climate change on groundwater recharge, this study The projections are computed for three future climate stress periods (2016-2045 as near future, 2046-2075 as mid future and 2076-2100 as far future) under two Shared Socioeconomic Pathways scenarios -

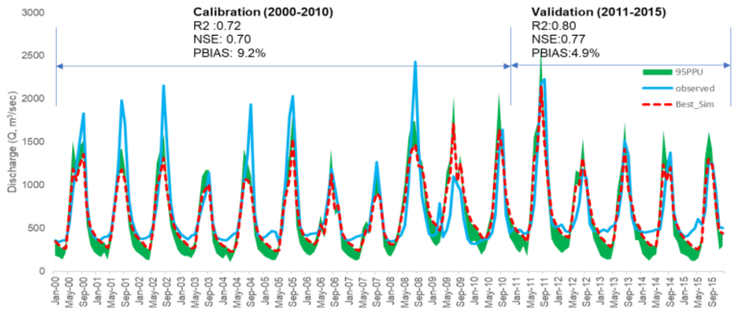

Figure 1: Monthly hydrographs of SWAT model during calibration and validation

(SSP2-4.5 and SSP 5-8.5). The bias-corrected hydrometeorological variables are then used as an input to SWAT. Considering the time scale at which SWAT runs, 8 SWAT models (for 4 GCM models and 2 SSP scenarios) were developed to assess the impact of climate change on groundwater recharge of Namngum++ basin (Lacombe et al., 2017). Groundwater recharge from each model for the future run was later averaged to obtain ensemble mean housing uncertainties of all models. As presented in figure 2, the lower flank of the basin shows the decline in groundwater recharge in ssp585 for all future stress periods while the northern region mostly demonstrated increased recharge for all stress periods.

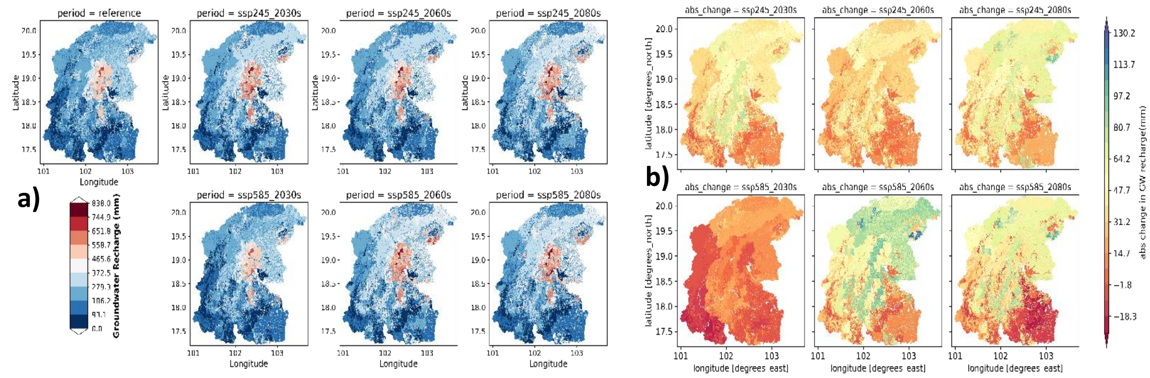

Figure 2: Groundwater recharge in Namngum++ basin a) comparison of different future scenarios with reference period b) absolute change in groundwater recharge for ssp245 and ssp585 scenarios for 2030s, 2060s and 2080s

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