**Effects of land-use and climate variability on the main the stream of the Songhua River, Northeast China**

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**For Review only**

**Water Evaluation and Planning (WEAP)**

The water balance for uniform climate over the catchment area, represented as *j* (Yates et al. 2005) is shown in equation.

- (S1)

where *z1, j* represents the relative soil water storage (dimensionless); *Swj* represents the soil water capacity (mm); *Pe(t)* represents the effective precipitation (mm), and *PET (t)* is the Penman–Monteith evapotranspiration (mm/day). The crop coefficient is *Kc, j(t)*, and *LAIj* is the leaf area index. is the surface runoff, and  is the first soil layer interflow; *fj* is the partition coefficient related to the topography, soil, and land cover type, which determines whether water moves horizontally or vertically; ks,*j* represents the saturated hydraulic conductivity (mm/time) of the root zone layer.

**Statistical Analysis**

 The nonparametric rank sum test (Mann–Kendall) and Sen’s slope tests (Kendall 1975; Kendall and Gibbons 1990; Sen 1968) were used to obtain the monotonic trend and slope of the historical hydro-climatic variables and predicted PP and SAT.

**Detail of future scenarios used in the Study**

1. *Climate Change*: The model was run with predicted climate variables (temperature and precipitation) and recycled base line climatic conditions (same as in 1964 to 1995) to assess the impact of climate change on stream flow during the selected time periods. In this scenario, the water use and land cover conditions were assumed to be constant (as in the historical time period)
2. *Domestic, agricultural water use and wet-dry conditions*: In this scenario, a combination of two assumptions was considered. Firstly, the wet and dry conditions were taken into account based on predicted precipitation and calculated by standardized precipitation index (McKee et al. 1993). Secondly, for the 2006 to 2030 period of (domestic water consumption 500 m3per day; agricultural water use 7500 m3/hm2 per hectare; 60 s (2031-2060) (domestic water consumption 800 m3per day; agricultural water use 6445 m3/hm2 per hectare, and 90 s (2061-2099) (domestic water consumption 1000 m3per day; agricultural water use 8000 m3/hm2 per hectare. In this study, the predicted values of agricultural water use and domestic water use were taken from (Liu and He 2000; Wang and Shen 1997). In order to assess a small variation in stream flow due to domestic, agricultural water use and wet-dry conditions; a minimum consumption of domestic and agricultural water use was also assumed in this study. For example, for the period of 30 s (2006-2030) (domestic water consumption 200 m3per day; agricultural water use 3500 m3/hm2 per hectare; 60 s (2031-2060) (domestic water consumption 300 m3per day; agricultural water use 2445 m3/hm2 per hectare, and 90 s (2061-2099) (domestic water consumption 500 m3per day; agricultural water use 4000 m3/hm2 per hectare. A similar approach has already used in previous study (Pulido-Velazquez et al., 2011), in which the author performed sensitivity analysis under different hypothesis. Moreover, in this scenario, the land cover and land use conditions were assumed the same as in the historical time period.
3. *land cover and land use areas*: In this scenario land cover and land use classes were assumed fixed (i.e. the same as from 1992 to 2015) for the period of 30 s (2005-2030), urban area increased up to 10%, cropland area increased up to 20%, while forest and grassland areas both decreased up to 20% for the period of 60s (2031-2060), and for the period of 90s (2061-2099) the urban area increased up to 20% and cropland area increased from up to 40%. The percentage variation of land cover and land use classes were equally distributed for the selected time period. The water use conditions were assumed the same as during the historical time period (1964-2015).

**Table S1**: List of CMIP5 models for which RCPs (RCP 2.6, RCP 4.5 and RCP 8.5) outputs were available.

|  |  |  |  |
| --- | --- | --- | --- |
| **GCM** | **Model** | **Source** | **Spatial Resolution (Lon. × Lat.)** |
| 1 | ACCESS1.0 | Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia and Bureau of Meteorology (BOM), Australia | 1.875∘ × 1.25∘ |
| 2 | ACCESS1-3 |
| 3 | BCC-CSM 1.1(m) | Beijing Climate Center, China Meteorological Administration, China | 1.125∘ × 1.125∘ |
| 4 | BNU-ESM | Beijing Normal University, China | 2.812∘ × 2.812∘ |
| 5 | CanESM2 | Canadian Centre for Climate Modelling and Analysis, Canada | 2.812∘ × 2.812∘ |
| 6 | GFDL-CM3 | Geophysical Fluid Dynamics Laboratory, USA | 2.5∘ × 2∘ |
| 7 | CCSM4 | National Center for Atmospheric Research (NCAR), USA | 1.25∘ × 1.25∘ |
| 8 | GISS-E2-H | NASA Goddard Institute for Space Studies, USA | 2.5∘ × 2∘ |
| 9 | IPSL-CM5A-LR | Institute Pierre-Simon Laplace, France | 3.75∘ × 1.875∘ |
| 10 | MIROC-ESM | AORI, NIES, JAMSTEC, Japan | 2.812∘ × 2.812∘ |
| 11 | MIROC-ESM-CHEM | AORI, NIES, JAMSTEC, Japan | 2.812∘ × 2.812∘ |
| 12 | MPI-ESM-LR | Max Planck Institute for Meteorology, Germany | 1.875∘ × 1.875∘ |
| 13 | MPI-ESM-MR | Max Planck Institute for Meteorology, Germany | 1.875∘ × 1.875∘ |
| 14 | FGOALS-g2 | Institute of Atmospheric Physics, Chinese Academy of Sciences, China | 2.812∘ × 3.0∘ |
| 15 | CSIRO-Mk3.6.0 | Australian Commonwealth Scientific and Industrial Research Organization, Australia | 1.875∘ × 1.875∘ |
|  |  |  |

Table S2: Calibration parameters value range

|  |  |  |
| --- | --- | --- |
| **Parameters** |  | Range |
| Deep water capacity | mm | 250-420 |
| Runoff Resistance factor (includes LAI) |  | 1.2-3.8 |
| Root zone conductivity  | mm/month | 210-410 |
| Deep conductivity  | mm/month | 300-750 |
| Preferred flow direction (f) |  | 0-1 |

**Table S3:** Trend analysis for precipitation and temperature by 2099

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Precipitation(mm)** | **Temperature (°C)** |
| **Scenarios** | **Time Period** | **Kendall's tau** | **Sen's Slope****(mm×year-1)** | **Kendall's tau** | **Sen's Slope****(mm×year-1)** |
| **RCP 2.6** | **Annual** | 8.76 | 0.505 | 5.65 | 0.012 |
| **DJF** | 0.78 | 0.016 | 3.27 | 0.008 |
| **MAM** | 2.77 | 0.150 | 4.48 | 0.007 |
| **JJA** | 2.12 | 0.197 | 5.23 | 0.007 |
| **SON** | 3.38 | 0.162 | 6.29 | 0.011 |
| **RCP 4.5** | **Annual** | 9.30 | 0.967 | 11.34 | 0.026 |
| **DJF** | 3.29 | 0.086 | 9.19 | 0.029 |
| **MAM** | 5.73 | 0.289 | 9.00 | 0.022 |
| **JJA** | 3.85 | 0.472 | 10.36 | 0.023 |
| **SON** | 1.92 | 0.087 | 10.75 | 0.029 |
| **RCP 8.5** | **Annual** | 11.9 | 1.56 | 13.18 | 0.062 |
| **DJF** | 7.04 | 0.227 | 12.03 | 0.073 |
| **MAM** | 6.17 | 0.374 | 12.03 | 0.052 |
| **JJA** | 5.81 | 0.794 | 12.79 | 0.058 |
| **SON** | 2.71 | 0.194 | 13.01 | 0.065 |

Under lines indicate that the trend is non-significant



**Fig. S1**: Assessment of stream flow change point during the period of 1964-2013.



**Fig. S2**: Stream flow simulation using WEAP for future scenarios, in the SRB during 30 s, 60 s, and 90 s under all RCPs and base line climatic conditions.

**References**

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