Supplementary material

SWAT-Simulated Streamflow Responses to Climate Variability and Human Activities in the Miyun Reservoir Basin by Considering Streamflow Components

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Supplementary Table S1. The information of the reservoirs in the watershed.

No	Name	Drainage area(km^2)	Total storage capacity(10^{9}m^3)	Completed year	Dam Height(m)
1	Yunzhou Reservoir	1170	1.02	1973	43
2	Baihepu Reservoir	2657	0.90	1983	42
3	Banchengzi Reservoir	66.1	0.10	1977	29
4	Yaoqiaoyu Reservoir	178.2	0.19	1984	54

Supplementary Table S2. Hydrology stations, rainfall gauges and meteorological stations used in the watershed.

No.	Station Name	Latitude(°N)	Longitude(°E)	Elevation(m)	Category
1	Anchunmengou	40.87	117.20	450	R[1]
2	Baicao	41.12	116.08	990	R
3	Dage	41.18	116.68	620	R
4	Dengjiashanzi	41.23	116.33	1060	R
5	Diaoe	40.72	115.82	830	R
6	Dongwankou	41.00	116.07	830	R
7	Dushikou	41.32	115.72	1270	R
8	Heidaziying	40.92	116.18	740	R
9	Heilongshan	41.25	116.08	1180	R
10	Hushenha	40.88	116.97	350	R
11	Liangjiafang	40.73	117.38	340	R
12	Longguan	40.78	115.57	1070	R
13	Maying	41.15	115.65	1130	R
14	Nanbazi	40.82	116.07	830	R
15	Nanguan	41.25	116.77	650	R
16	Sandaohe	41.13	116.45	730	R
17	Sandaoying	40.78	116.38	540	R

18	Shanghuangqi	41.45	116.67	870	R
19	Shipozi	40.90	116.82	460	R
20	Shirengou	41.07	117.02	480	R
21	Tuchengzi	41.30	116.60	740	R
22	Xiaobazi	41.45	116.37	1045	R
23	Yunzhoushuiku	41.03	115.77	980	R
24	Zhenanbao	41.12	115.88	1150	R
25	Zhenningbao	40.98	115.67	1070	R
26	Chicheng	40.88	115.83	868	W[1]
27	Chongli	40.97	115.28	1249	W
28	Fengning	41.22	116.63	661	W
29	Guyuan	41.67	115.67	1413	W
30	Huairou	40.37	116.63	76	W
31	Luanping	40.93	117.33	530	W
32	Miyun	40.38	116.87	72	W
33	Miyunshangdianzi	40.65	117.12	293	W
34	Xinglong	40.40	117.47	633	W
35	Zhangjiafen	40.62	116.78	193	H[1]
36	Xiahui	40.62	117.17	198	H

Note: The alphabets of H, R and W stand for hydrological station, rain gauge and meteorological station, respectively.

Supplementary Table 3S. Calibrated parameters and their initial range and calibrated value in the watershed.

Parameters	Descriptions	Initial range	The best simulation		Final parameter ranges	
			Chao River	Bai River	Chao River	Bai River
v_SURLAG.bsn	Surface runoff lag coefficient (days)	(1, 10)	1.5	2.9	0, 3.6	1.5, 4.3
v_ESCO.hru	Soil evaporation compensation factor	(0, 1)	0.48	0.54	0.26, 0.69	0.42,0.65
v_EPCO.hru	Plant uptake compensation factor	(0.5, 1)	0.55	0.88	0.4, 0.70	0.76,1.01
v_CANMX.hru	Maximum canopy storage (mm H_2O)	(1, 20)	19.71	12.77	17.2,22.3	11.3,14.1
v_CH_K1.sub	Effective hydraulic conductivity in tributary channel alluvium (mm/h)	(0, 120)	33.9	12.9	3.5,64.3	0,38.05
v_CH_N1.sub	Manning's "n" value for tributary channel	(0.014, 0.15)	0.06	0.11	0.03, 0.1	0.07, 0.14
v_ALPHA_BF.gw	Baseflow alpha factor (1/days)		0.021	0.011		
v_RCHRG_DP.gw	Deep aquifer percolation fraction	(0, 0.2)	0.12	0.08	0.07,0.17	0.03, 0.14
v_GW_DELAY.gw	Groundwater delay time (days)	(0, 460)	232.8	271.8	120,349.9	177.7, 365.9
r_CN2.mgt	Initial SCS runoff curve number for moisture condition II	(-0.3,0.3)	0.11	0.26	0.01, 0.20	0.11, 0.40
r_SOL_AWC.sol	Available water capacity for the soil layer (mm H_2O/mm soil)	(-0.5,0.5)	-0.098	-0.43	-0.27, 0.07	-0.50,-0.25
r_SOL_K.sol	Saturated hydraulic conductivity (mm/h)	(-0.5,0.5)	0.23	0.06	0.07 ,0.39	-0.05, 0.19
r_SOL_BD.sol	Moist bulk density (Mg/m^3)	(-0.5,0.5)	0.4013	-0.33	0.19, 0.5	-0.49,-.17
v_CH_N2.rte	Manning's n value for main channel	(0.014,0.15)	0.113	0.12	0.09, 0.13	0.09, 0.14
v_CN_K2.rte	Effective hydraulic conductivity in main channel alluvium (mm/h)	(0,25)	11.3	24.9	7.4, 14.6	18.6,31.2

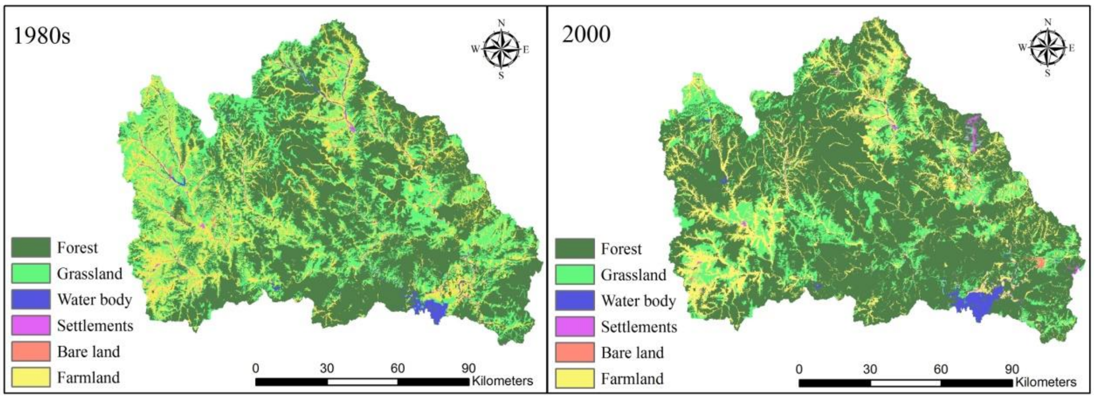
Notes: The extension (e.g., bsn) refers to the SWAT input file where the parameter occurs.

The qualifier (v) refers to the substitution of a parameter by a value from the given range.

The qualifier (r) refers to the relative change in the parameter where the value from the SWAT dataset is multiplied by 1 plus a factor in the given range.

The value of ALPHA_BF was estimated using the automatic baseflow filter tool.

Further description of each parameter may be found in the SWAT user manual (Neitsch, Arnold et al. 2005).



Supplementary Figure S1. The land use of the MRB in 1980s and 2000

2.Technical Details of the heuristic segmentation algorithm

For a given time series, a sliding pointer is moved step-by-step from left to right along the time series. Thus, the overall time series was divided into two sub-series of time series. The average of the subset of the series to the left of the pointer u_1 and to the right u_2 is calculated.

For two Gaussian distributed random series, the statistical significance of difference between the averages of these two sub-series u_1 and u_2 is estimated by Student's t-test statistic as follows:

$$t = \left|\frac{u_1 - u_2}{S_D}\right| \tag{1}$$

Where S_D is the pooled variance and calculated according to Equation (2).

$$s_D = \left(\frac{(N_1-1)S_1^2+(N_2-1)S_2^2}{N_1+N_2-2}\right)^{1/2}\left(\frac{1}{N_1}+\frac{1}{N_2}\right)^{1/2} \tag{2}$$

S_1 and S_2 stand for the standard deviations of these two sub-series ($u_1$and u_2), and N_1 and N_2 are the number of points from these two sub-series, respectively. Moving the pointer along the given time series step-by-step, then statistic t is calculated to estimate the difference between the averages of these two sub-series. Lager t means that the average values of the two sub-series tend to be more significantly different. The largest t value is regarded as a good candidate for the break point. Then, the statistical significance $P(t_{max})$ is approximately computed as follows:

$$P(\mathrm{t_{max}}) \approx \left\{1 - I_{\left[\frac{v}{v+t_{max}^2}\right]}(\delta v, \delta)\right\}^{\eta} \tag{3}$$

where $\eta = 4.19\, ln\, N - 11.54$ and $\delta = 0.40$ are estimate from Monte Carlo simulations, N is the number of the time series, $\mathrm{v = N - 2}$, and $I_x(a,b)$is the incomplete beta function.

If the difference in average is not statistically significant (i.e., smaller than a specified threshold), then this time series is not divided; otherwise, the time series is divided into two segments (sub-series). If the time series is split, the iteration of the above procedure on each new segment (sub-series) continues until the acquired significance value is less than the threshold, or the length of the acquired sub-series is less than presupposed minimum segment length ℓ_0. In this study, the threshold is set to 0.95 and ℓ_0 is set to 25 according to proposal from [1, 2].

3. Technique details of the dynamic baseflow separation of the SWAT-CUP software

In order to simultaneous calibration of parameters related to the baseflow and quickflow simulation, the dynamic flow separation function of the SWAT-CUP software was selected for the SWAT model calibration for the streamflow, baseflow and quickflow in the Miyun Reservoir Basin. The main steps for dynamic flow separation are listed as follows:

Step 1: Data preparation

For the dynamic flow separation，a baseflow separation program (automatic baseflow filter tool used in this study) should be used to separating the baseflow from the streamflow. Both observed streamflow and filtered baseflow are needed for the SWAT model calibration. In SWAT-CUP model setup, both observed streamflow and baseflow data must appear as two separate columns (column 3 and column 4) in the **observed.txt** file in **SUFI2.IN** directory.

Step 2: Parameter setting

Parameters setting for running dynamic flow separation of the SWAT-CUP software refers to the weight setting for the baseflow and quickflow variables. There are formulas to calculate the weights in the user manual [3]. But if you want to have exactly the same contribution you need to run. The initial weight values of baseflow and quickflow variable are set to 1, and then look at the **Echo_goal_fn.txt** file in the **Echo** directory. At the end of this file the contribution of all variable to the goal function will be found. You can calculate the weight from these numbers for the next iteration. If baseflow has a contribution of X and quickflow a contribution of Y, and you want them to have equal contribution, then new weight of v1 is equal to Y/X for the next iteration.

After the above-mentioned two steps, the SWAT-CUP software is carried out for the SWAT calibration. The details of dynamic flow separation of the SWAT-CUP software is available on the user manual of SWAT-CUP4 software [3]. Furthermore, the corresponding examples are provided via the SWAT-CUP Google group (http://groups.google.com/forum/#!forum/swat-cup).

Reference:

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