

Supplementary Information for “Agricultural Irrigation Effects on Hydrological Processes in the United States Northern High Plains Aquifer Simulated by the Coupled SWAT-MODFLOW System”

Sijal Dangol¹, Xuesong Zhang^{2,*}, Xin-Zhong Liang^{1,3}, Fernando Miralles-Wilhelm^{4,5}

¹Department of Atmospheric and Oceanic Science, University of Maryland

College Park MD 20742 USA

²USDA-ARS Hydrology and Remote Sensing Laboratory, Beltsville, MD 20705 USA

³Earth System Science Interdisciplinary System, University of Maryland

College Park MD 20740 USA

⁴Department of Atmospheric, Oceanic and Earth Sciences, George Mason University

Fairfax VA 22030 USA

⁵The Nature Conservancy, Arlington VA 22203 USA

*Corresponding author:

Xuesong Zhang

USDA-ARS Hydrology and Remote Sensing Laboratory

Beltsville, MD 20705 USA

Email: xuesong.zhang@usda.gov

1. SWAT setup

1.1 Reservoir parameters and operation

Reservoir operations were simulated using the target release method with a specified minimum and maximum monthly discharge. The target release method represents the general rules of reservoir operation (water preservation and flood control) and simulates reservoir water release as a function of reservoir target storage. The reservoir target storage is set at the emergency spillway elevation for the non-flood season and at the primary spillway elevation for the flood season. The minimum and maximum monthly flow from each reservoir was estimated based on the discharge information obtained from US Army Corps of Engineers (USACE), US Bureau of Reclamation (USBR) and US Geological Survey (USGS) and converted to the SWAT input format. Reservoir parameters such as surface area and storage volume at the principal spillway and emergency spillway were obtained from the USACE and the USBR (USBR, 2019; USACE, 2013). The reservoirs simulated in the model and their corresponding parameters are listed in Table S1.

Table S1. Reservoir summary

S.No	Name	ESA ¹ (ha)	EVOL ² (10 ⁴ m ³)	PSA ³ (ha)	PVOL ⁴ (10 ⁴ m ³)
1	Bonny reservoir	2038.07	15889.69	133.96	88.32
2	Box butte reservoir	832.87	5638.24	649.54	3830
3	Calamus reservoir	2127.10	16354.71	1181.72	6439.38
4	Cedar Buff reservoir	4366.71	46549.81	2779.88	847.28
5	Enders dam	973.30	9193.13	266.29	1228.42
6	Grayrocks reservoir	1462.46	13283.35	798.47	4663.73
7	Guernsey reservoir	964.00	5525.99	542.30	1945.81
8	Harlan county lake	9232.42	102230.82	5397.89	39445.09
9	Harry strunk	1409.57	6502.29.29	368.6868	1788.67
10	Kanopolis lake	5648.80	45549.70	3660.51	6102.52
11	Kirwin reservoir	4305.60	38801.33	2052.23	12264.74
12	Lake Mcconaughey	12308.14	216636.09	8903.40	177312.75
13	Merritt reservoir	1303.94	10640.12	1177.27	9203.24

14	Milford lake	13446.60	93333.61	6357.43	47959.68
15	Norton	2151.39	16696.02	882.65	4456.19
16	Red willow/Hugh butler	1085.00	10493.21	289.36	1100.39
17	Trenton/Swanson dam	3231.53	30389.49	792.40	2571.93
18	Turtle creek lake	21732.39	278419.26	4998.05	41333.91
19	Waconda lake	13631.11	89179.12	5100.03	23828.74
20	Webster reservoir	3431.05	32159.66	1403.09	9543.43
21	Wheatland reservoir 2	3278.07	18528.35	2792.43	13868.76
22	Wilson reservoir	13712.05	205620.50	3660.51	29915.34

¹Emergency spillway area

²Emergency spillway volume

³Principal spillway area

⁴Principal spillway volume

2. SWAT-MODFLOW coupling

2.1 SWAT irrigation source assignment

To determine the appropriate irrigation source for cropland HRUs in SWAT, the grid based irrigation well locations from the Peterson et al. (2016) model were used to determine SWAT cropland HRUs irrigated with groundwater. Each MODFLOW well was mapped to the overlapping HRU (cropland) using ArcGIS. Then the irrigation source was assigned using the following framework: (i) if an irrigation well was mapped to the HRU classified as irrigated cropland, groundwater was assigned as the irrigation source (ii) if a HRU classified as irrigated cropland was not associated with any irrigation well, the river was assigned as the irrigation source, and (iii) if an irrigation well was mapped to the dry cropland, then the auto-irrigation function was used with groundwater as the irrigation source.

Results

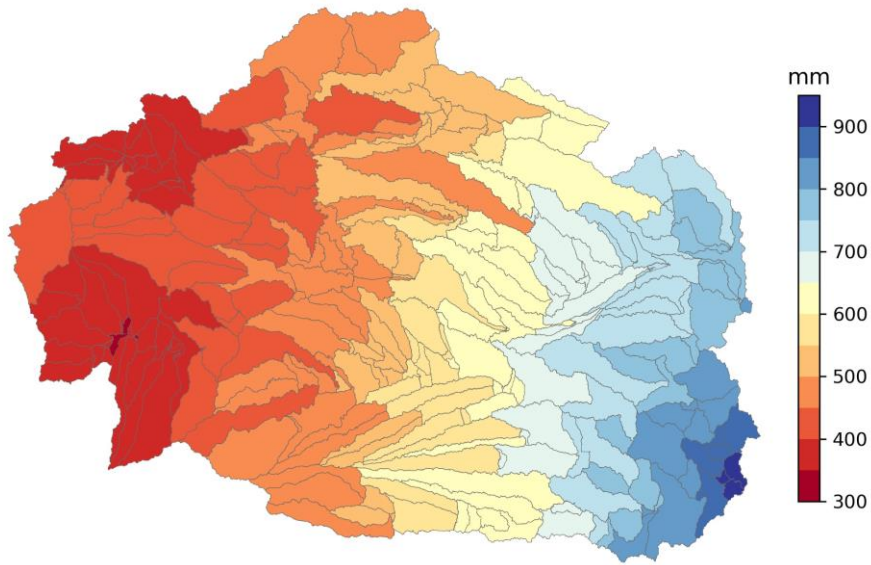


Figure S1. North American Regional Reanalysis (NARR) based average annual precipitation (1982-2008) at the sub-basin scale for SWAT domain.

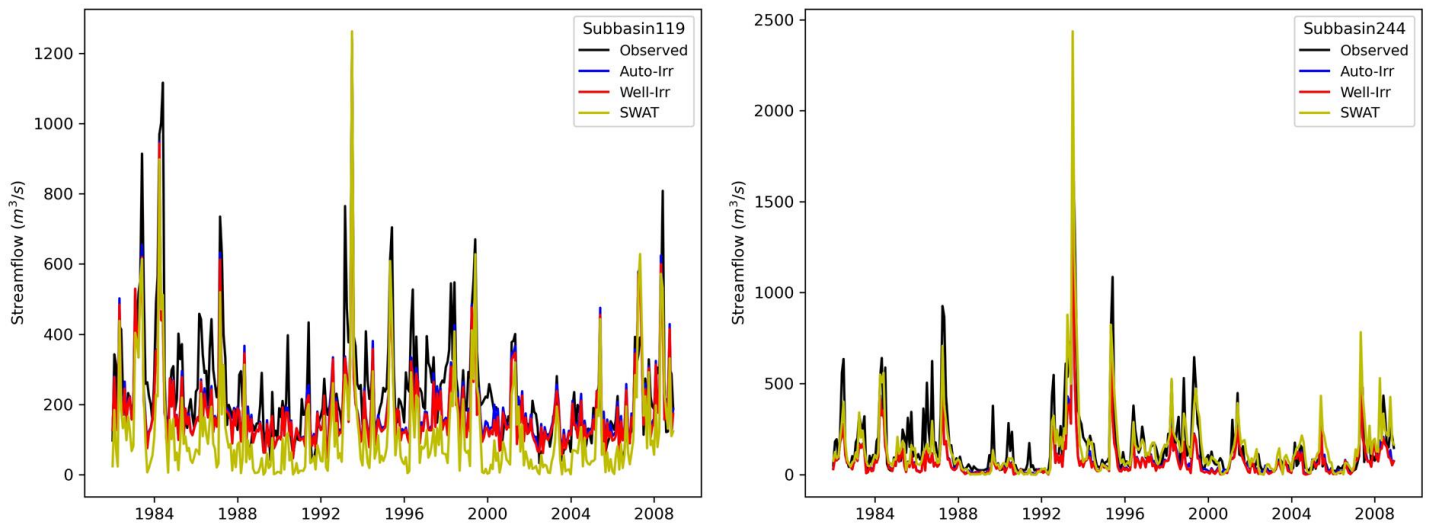


Figure S2. Monthly mean streamflow at the outlet of watersheds in Northern High Plains.

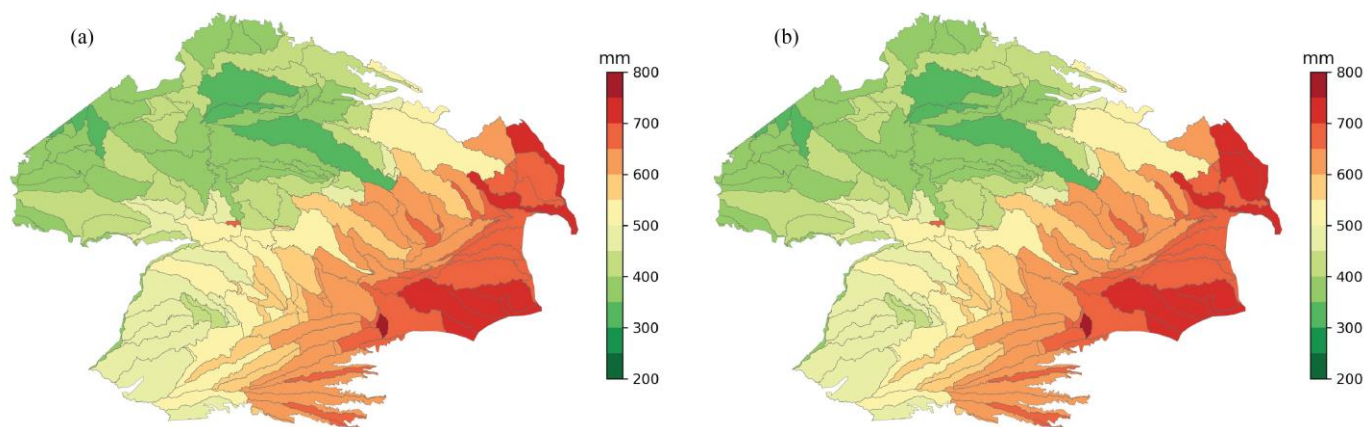


Figure S3. Sub-basin level mean annual evapotranspiration simulated by (a) SWAT only and (b) Well-Irr, for 2000-2008.

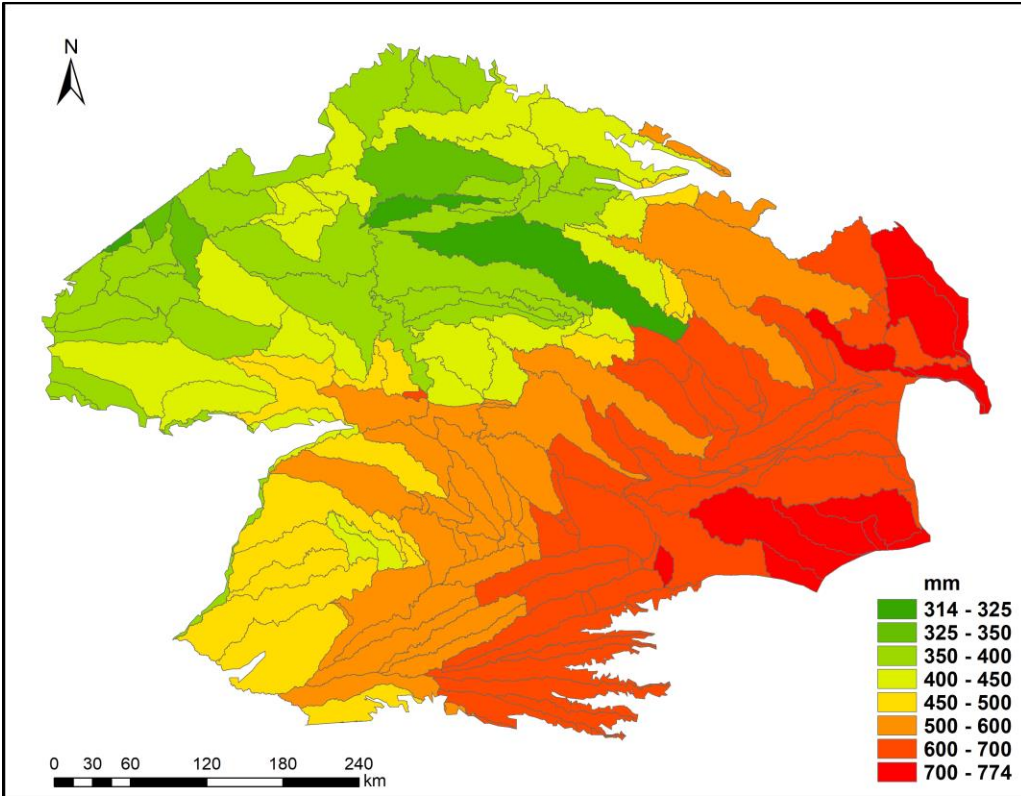


Figure S4. Sub-basin level mean annual evapotranspiration estimated from Moderate Resolution Imaging Spectroradiometer (MODIS) from 2000-2008.