Spatial and Temporal Evaluation of Hydrological Response to Climate and Land use Change in South Dakota Watersheds

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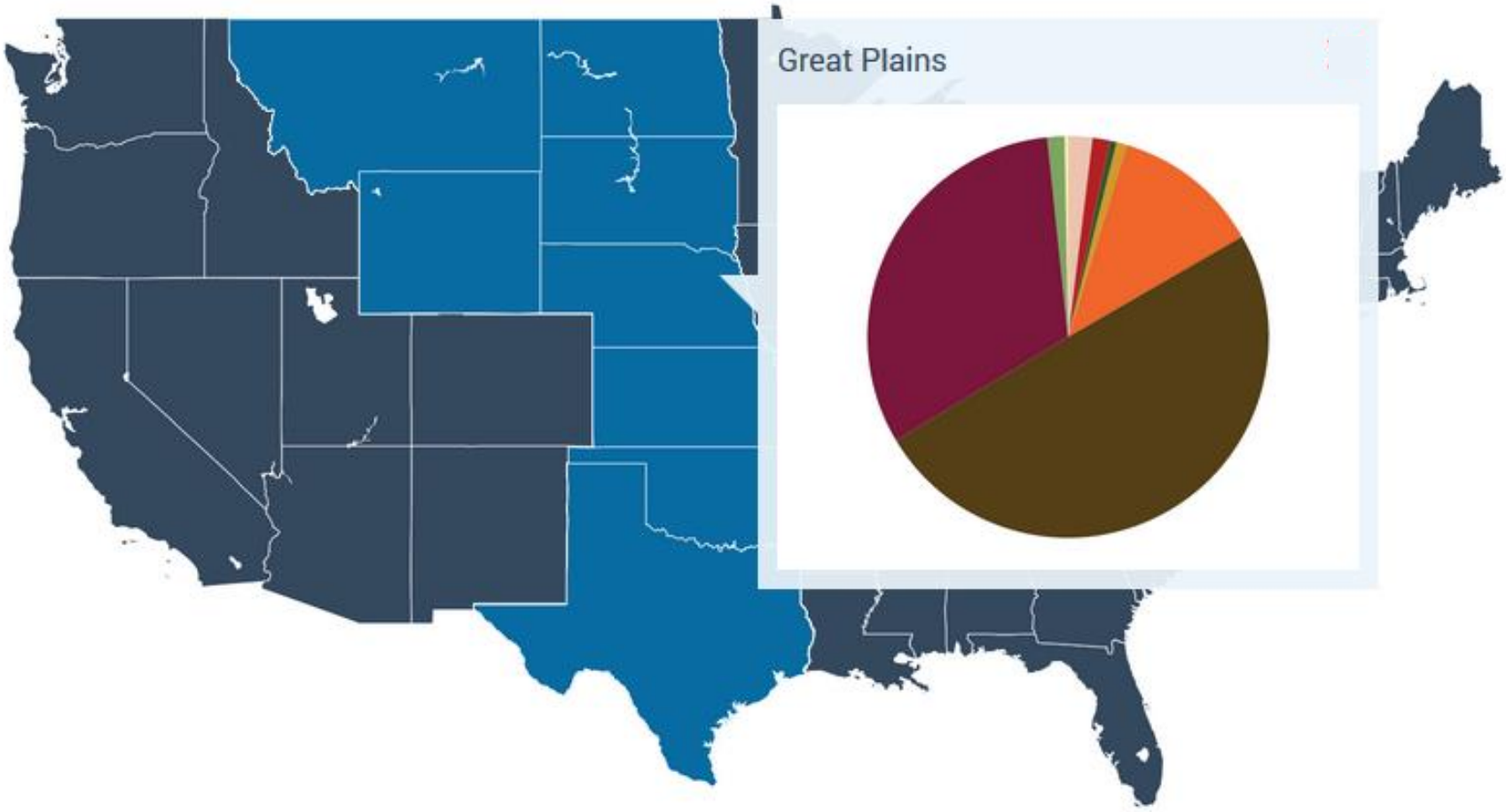
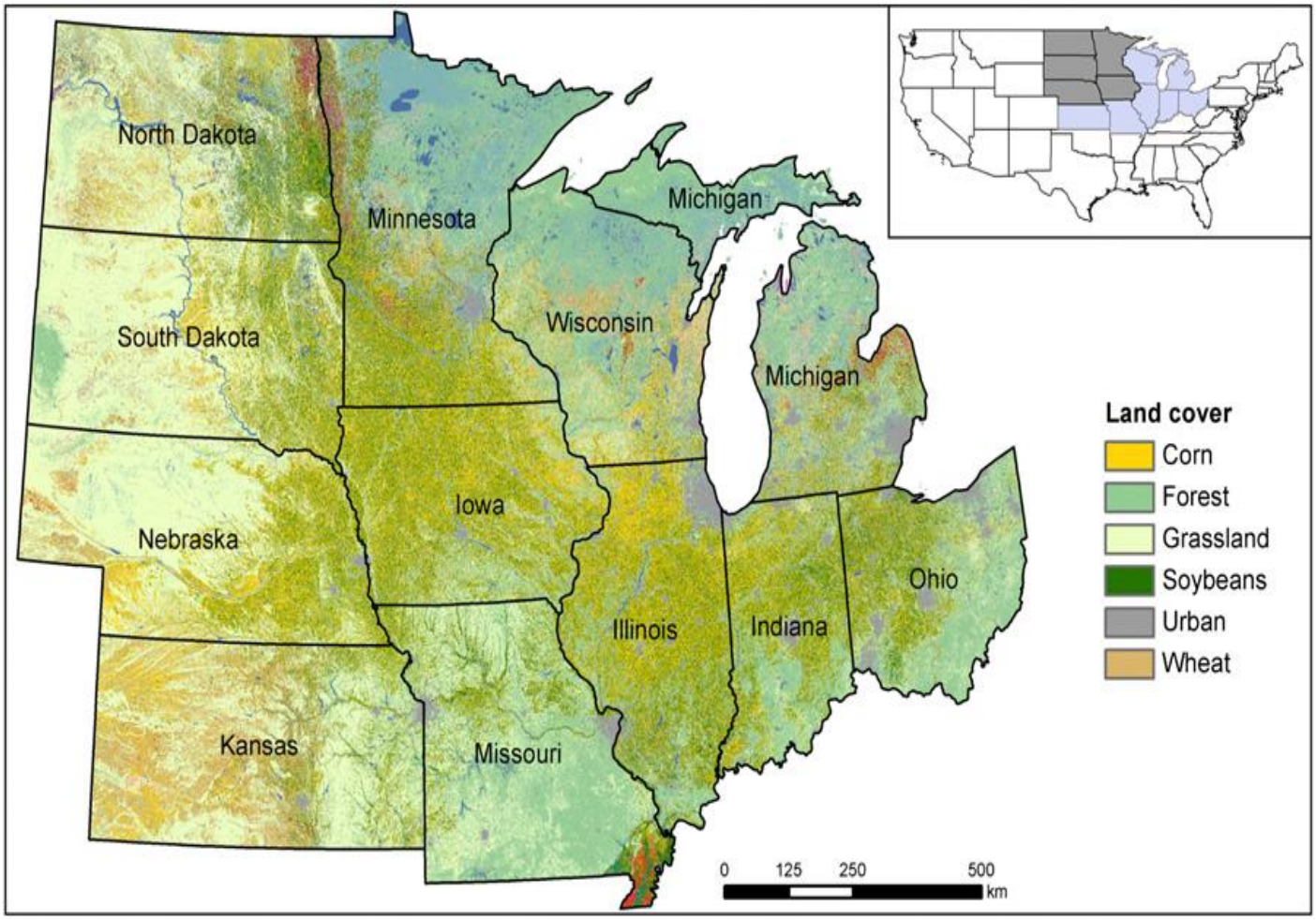
Introduction



Source: U.S. EPA Integrated Climate and Land Use Scenarios

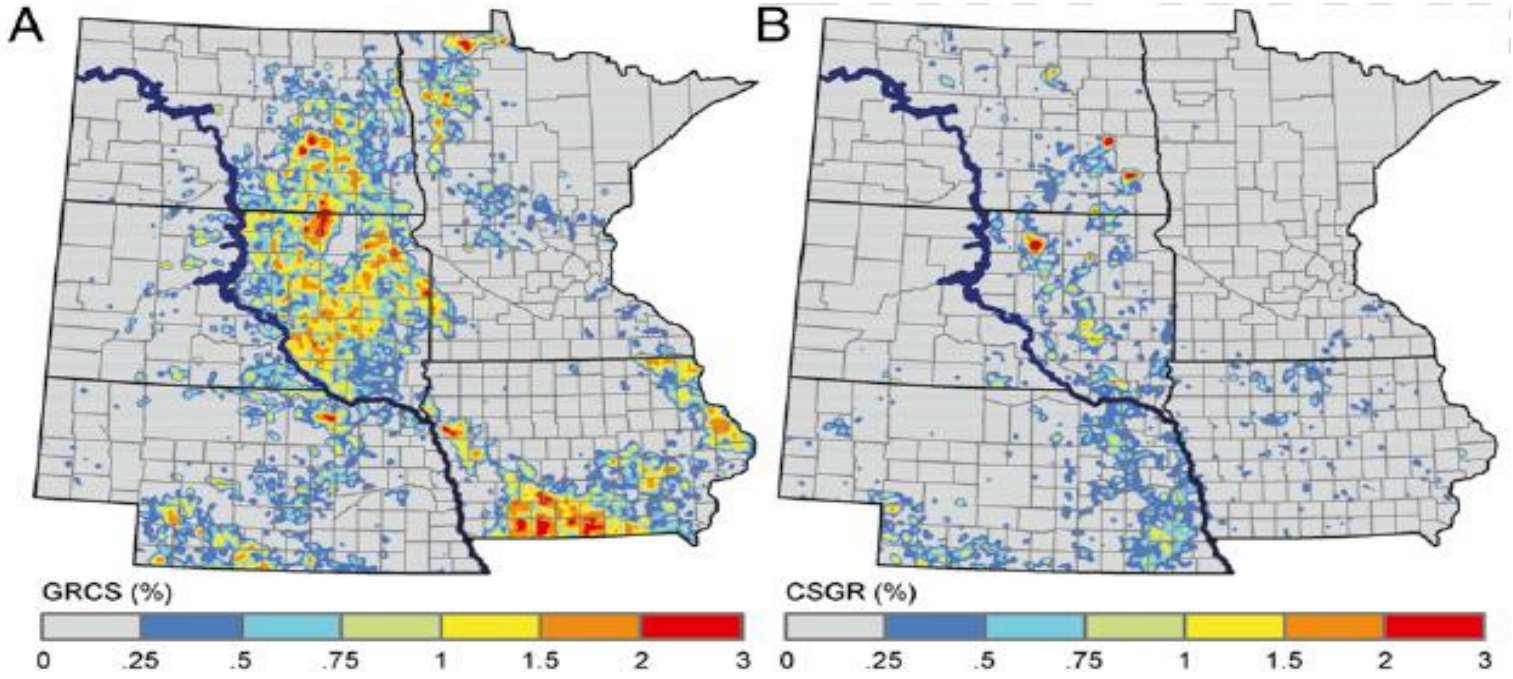
Introduction (Cont.)

- Recent data revealed annually 1 to 5.4% of grassland is being converted to cropland in the Western Corn Belt (WCB).
- Across WCB, more than 99% of pre-settelement tallgrass prairie has been converted to other lands, mostly to agricultural land.
- This land cover conversion in the WCB can present critical ecosystem issues.



Wright and Wimberly, 2013

Introduction (Cont.)



Area of LCLUC from 2006 to 2011

State	Area, ha * 10^3 (acres * 10^3) Grassland to corn/soy	Corn/soy to grassland	Grassland net loss
North Dakota	129 (320)	40 (100)	89 (220)
South Dakota	256 (632)	73 (181)	182 (451)
Minnesota	92 (228)	13 (31)	80 (196)
Iowa	195 (481)	42 (104)	152 (376)
Nebraska	125 (309)	100 (247)	25 (62)
Sum	797 (1,969)	268 (663)	528 (1,306)

Wright and Wimberly, 2013

Objective

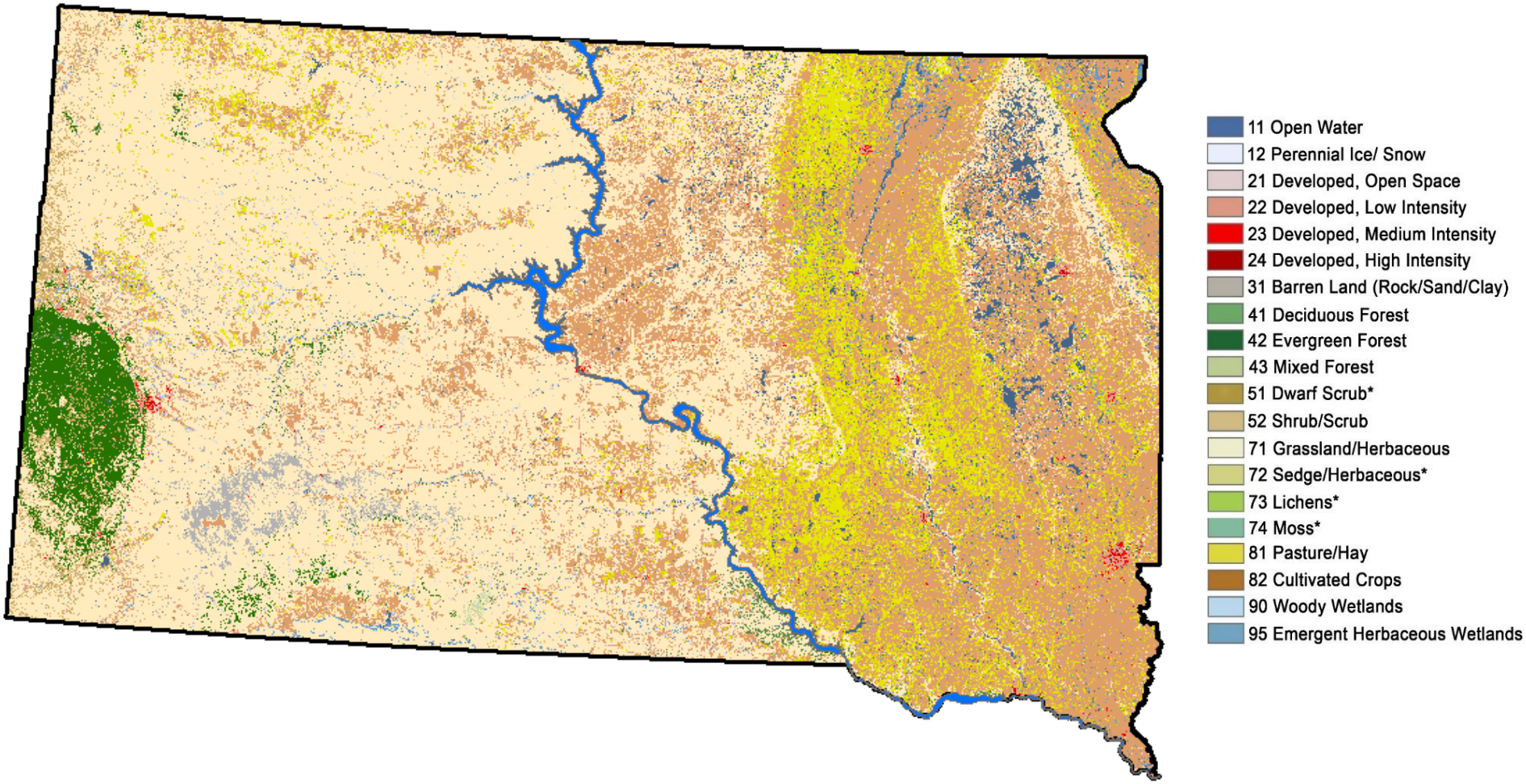
To characterize hydrologic changes that possibly occurred in South Dakota between two recent decades (the 1980s and 2000s).

Methodology

Data Use	Study Period	Model	Statistical Analysis

• Daily Precipitation (National Oceanic and Atmospheric Administration (NOAA))
• Daily Maximum and Minimum Temperature (National Oceanic and Atmospheric Administration (NOAA))
• Daily Streamflow (U.S. Geological Survey (USGS))
• Land Use and Land Cover Data (National Land Cover Dataset 1992 (NLCD 1992) and (NLCD 2011)
	• 1981-1990
	  • NLCD 1992
	• 2005-2014
	  • NLCD 2011
		• Soil and Water Assessment Tool (SWAT)	• Nash-Sutcliffe Efficiency (NSE)
			• Coefficient of Determination (R^2)
			• Percent Bias (PBIAS)
			• Wilcoxon change test

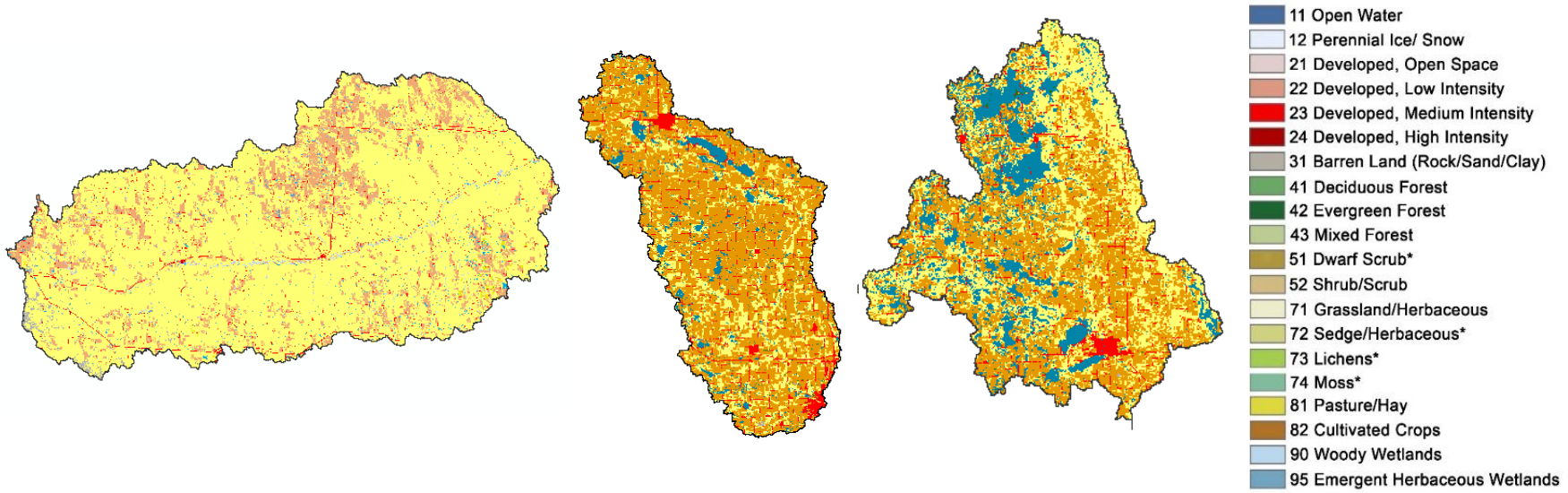
Natinal Land Cover Data (NLCD 2011)



Study Area

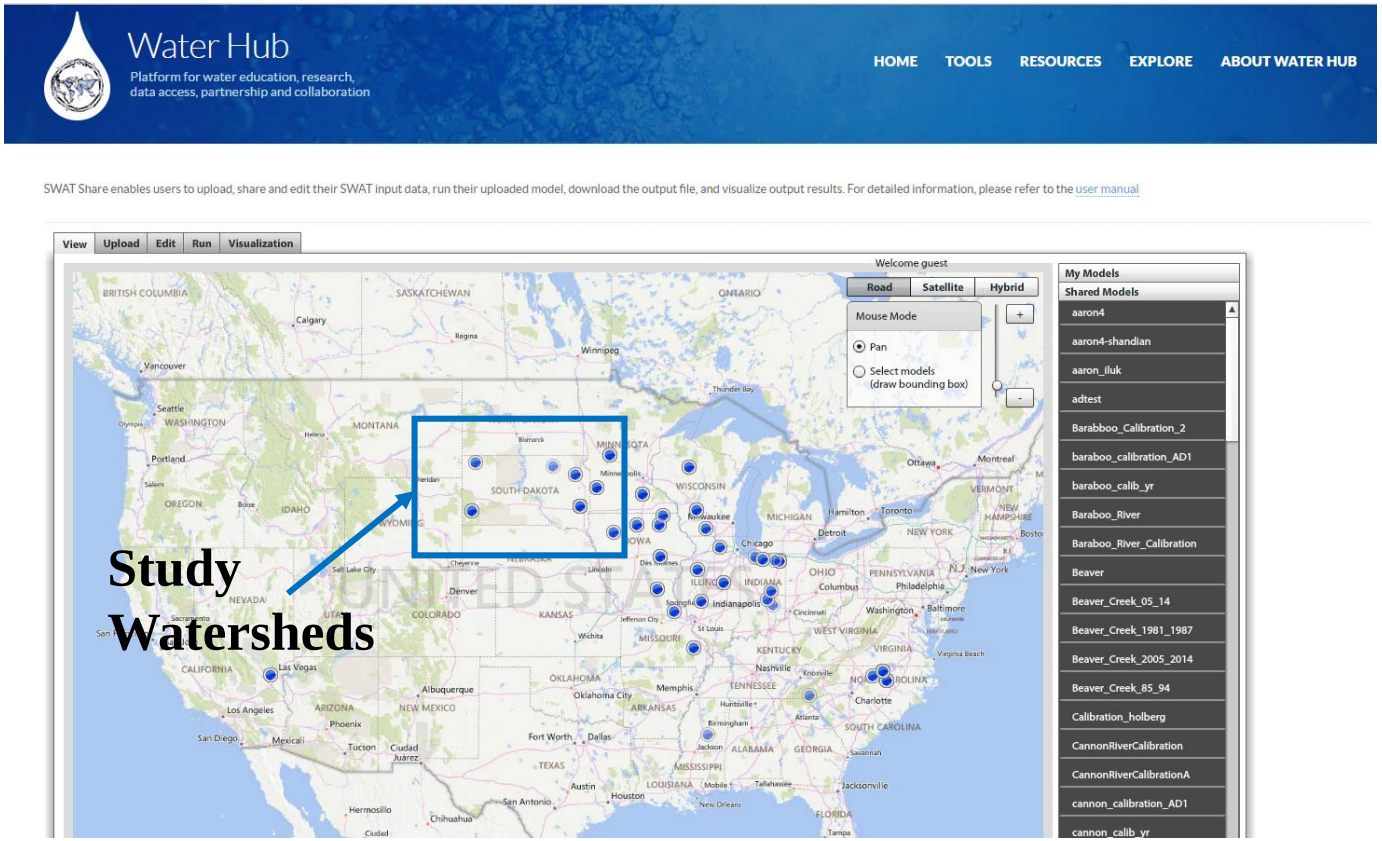
N
W
E
S
Upper Big Sioux
River Watershed
Bad River
Watershed
Skunk Creek
Watershed
Streamflow Gauge Station
Weather Station
Missouri River
Watershed Outline
0
50
100
200 Kilometers

Study Area (Cont.)



NLCD Land Cover Data	Bad River Watershed (Area- 8119 sq. km)	Skunk Creek (Area- 1604 sq. km)	Upper Big Sioux (Area- 3803 sq. km)
1992	**Grassland – 85%** **Agricultural Land- 13.5%** Water- 0.7% Urban- 0.7% Forest- 0.2%	**Grassland – 26%** **Agricultural Land- 64.3%** Water- 7.8% Urban-1.3% Forest-0.6%	**Grassland – 39.4%** **Agricultural Land- 46.7%** **Water- 11.9%** Urban-1.1% Forest-1.0%
2011	**Grassland – 81.7%** **Agricultural Land- 14.8%** Water- 1.5% Urban- 2.1% Forest-0.1%	**Grassland – 22.2%** **Agricultural Land- 64.3%** Water- 6% Urban- 6.5% Forest-0.6%	**Grassland – 36.8%** **Agricultural Land- 41.3%** **Water- 16.6%** Urban-4.7% Forest-0.5%

Calibration Parameter		
Streamflow Calibration	ALPHA_BF	Baseflow alpha factor
	ESCO	Evaporation compensation coefficient
	EPCO	Plant uptake compensation factor
	CANMX	Maximum canopy storage
	CN2	Initial SCS runoff curve number for moisture condition II
	Ch_N2	Manning's "n" value for the main channel
	Ch_K2	Effective hydraulic conductivity in main channel alluvium (mm/hr)
	GW_DELAY	Groundwater delay time (days).
	GW_REVAP	Groundwater "revap" coefficient
	Gwqmn	Threshold depth of water in the shallow aquifer required for return flow to occur (mm H20)
	Revapmn	Threshold depth of water in the shallow aquifer for revap or percolation to the deep aquifer to occur (mm H2O)
	Surlag	Surface runoff lag coefficient
	SFTMP	Snowfall temperature
	SMTMP	Snow melt base temperature
	SMFMX	Melt factor for snow on June 21
	SMFMN	Melt factor for snow on December 21
	TIMP	Snow pack temperature lag factor



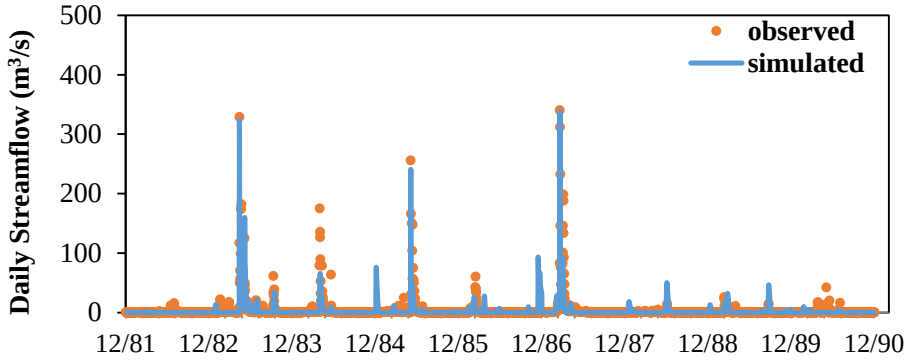
https://mygeohub.org/groups/water-hub/swatshare

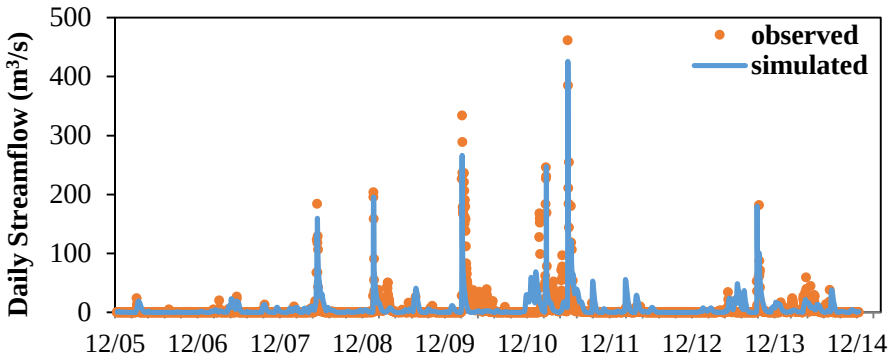
SWAT models are calibrated in SWATShare

SWATShare is a cyber-infrastructure, being developed in Purdue University
To enable online parallel calibration jobs, sharing and visualization of SWAT model.

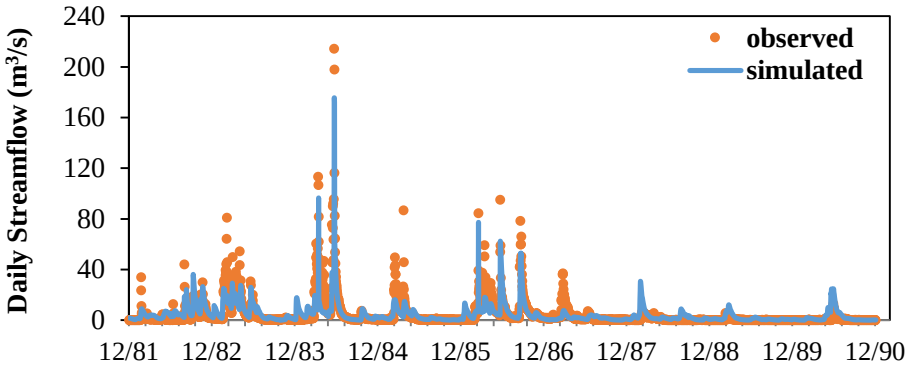
Calibration and Validation

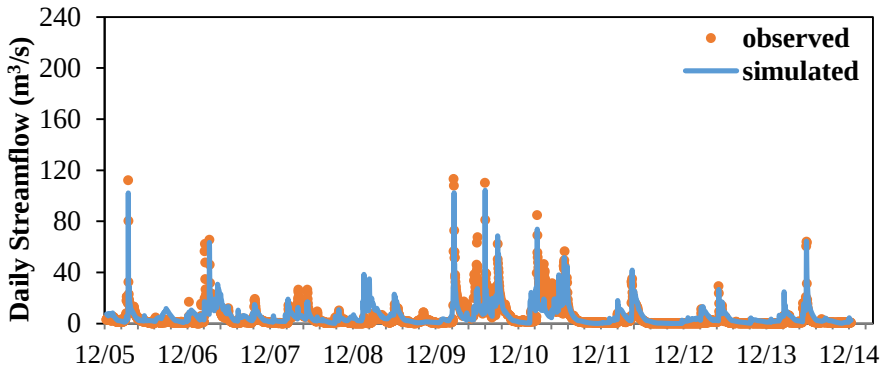
a) Bad River Watershed



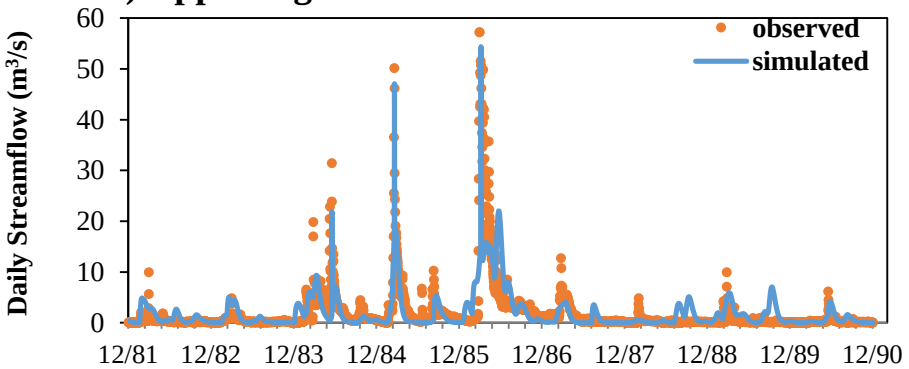


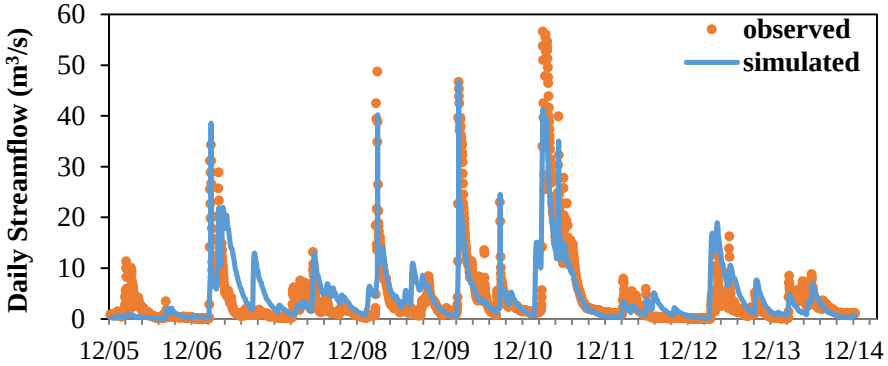
b) Skunk Creek Watershed





c) Upper Big Sioux River Watershed





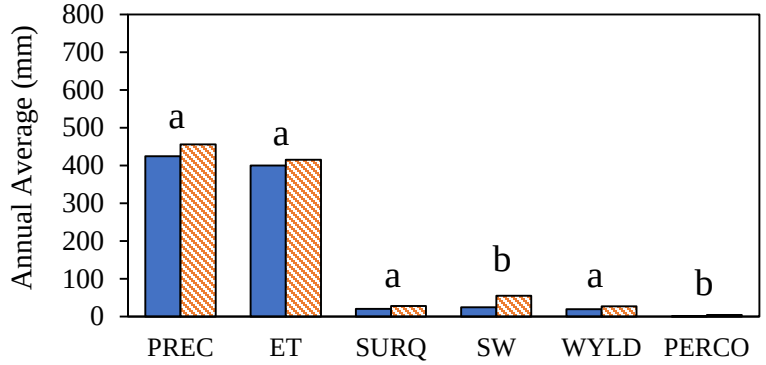
Calibration and Validation Period

Warm- up period 1981 and 2005

		Statistics	Calibration	Validation	Study period
Bad River watershed	1981-1990	R^2	0.59	0.38	0.50
		NSE	0.59	0.38	0.50
		PBIAS	- 0.3	15.6	5.7
	2005-2014	R^2	0.47	0.67	0.5
		NSE	0.47	0.55	0.48
		PBIAS	- 20.4	- 46.5	- 37.9
Skunk Creek watershed	1981-1990	R^2	0.57	0.65	0.63
		NSE	0.55	0.63	0.62
		PBIAS	- 20.8	0.85	- 11.2
	2005-2014	R^2	0.56	0.75	0.52
		NSE	0.56	0.48	0.5
		PBIAS	- 7.6	- 42.6	- 21.6
Upper Big Sioux River watershed	1981-1990	R^2	0.48	0.55	0.50
		NSE	0.48	0.54	0.50
		PBIAS	- 17.2	- 6.1	- 13.2
	2005-2014	R^2	0.43	0.73	0.60
		NSE	0.40	0.72	0.59
		PBIAS	- 23.9	- 11.4	- 17.8

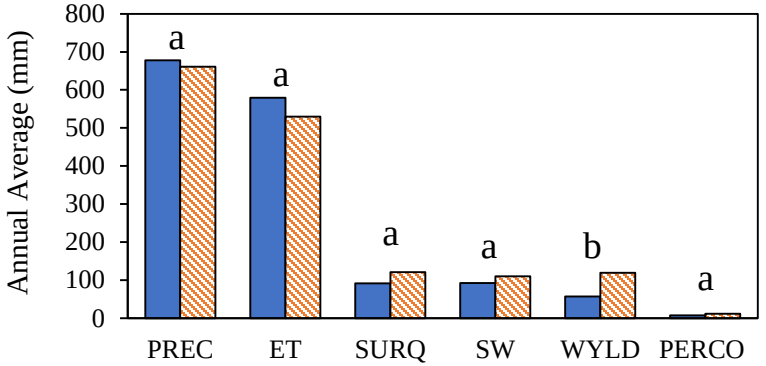
Results

BRW



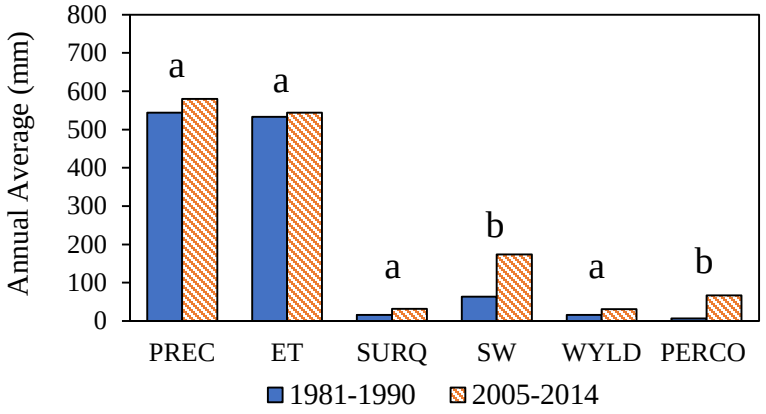
	Difference (mm)	% change	p- value
Precipitation	31.5	7.5	0.605
Surface Runoff	7 .0	34	0.546
Soil Water Content	31.0	127	**0.008**
ET	15.0	4	0.605
Water Yield	7.0	36	0.436
Percolation	3.5	331	**0.001**

SCW



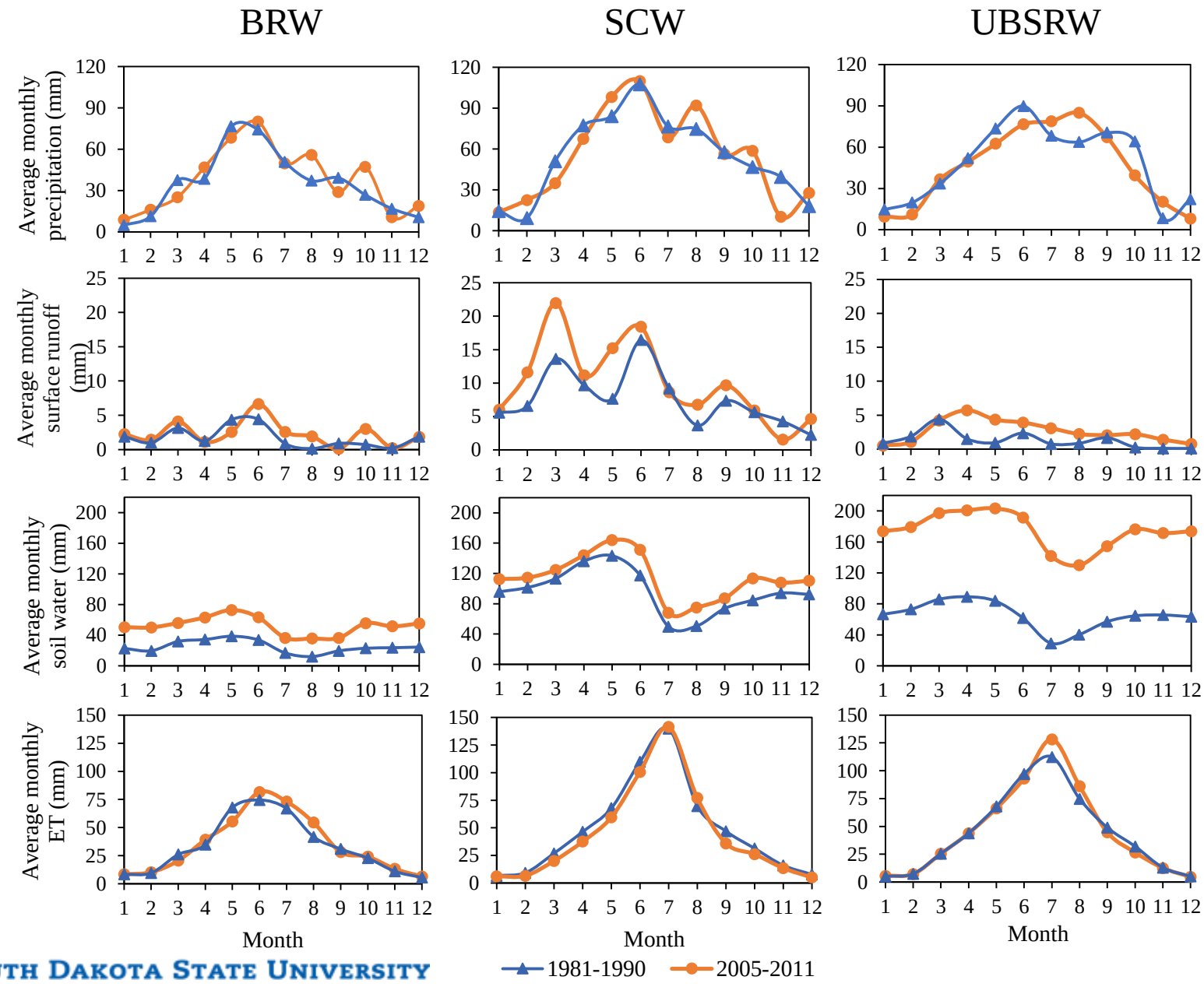
	Difference (mm)	% change	p- value
Precipitation	-16.7	-2.5	0.730
Surface Runoff	30.0	32.5	0.222
Soil Water Content	18.0	19.5	0.436
ET	-49.0	-8.5	0.050
Water Yield	62.0	108	**0.003**
Percolation	4.5	63	0.546

UBSRW

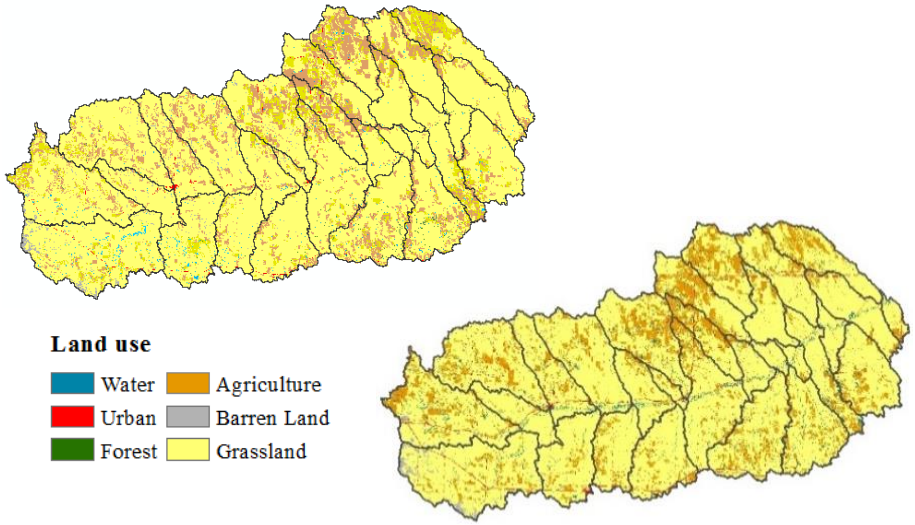


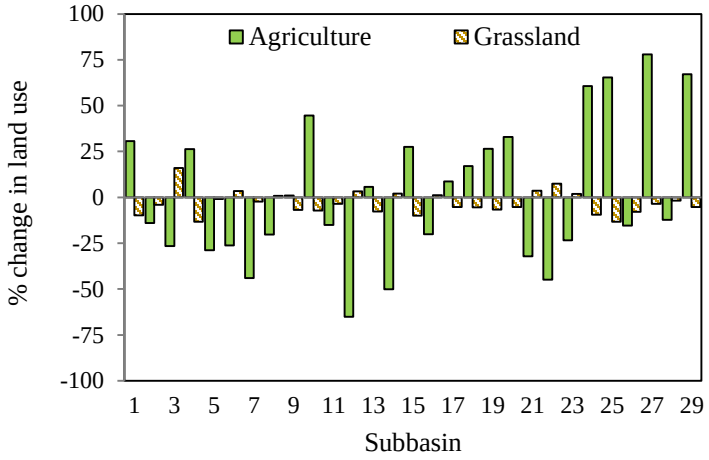
	Difference (mm)	% change	p- value
Precipitation	36.0	6.5	0.436
Surface Runoff	16.0	101	0.114
Soil Water Content	110.5	174	**0.00004**
ET	11.0	2	0.258
Water Yield	15.0	97.5	0.114
Percolation	61.0	930	**0.0003**

a - no change (at α= 0.05)
b - significant change (at α= 0.05)

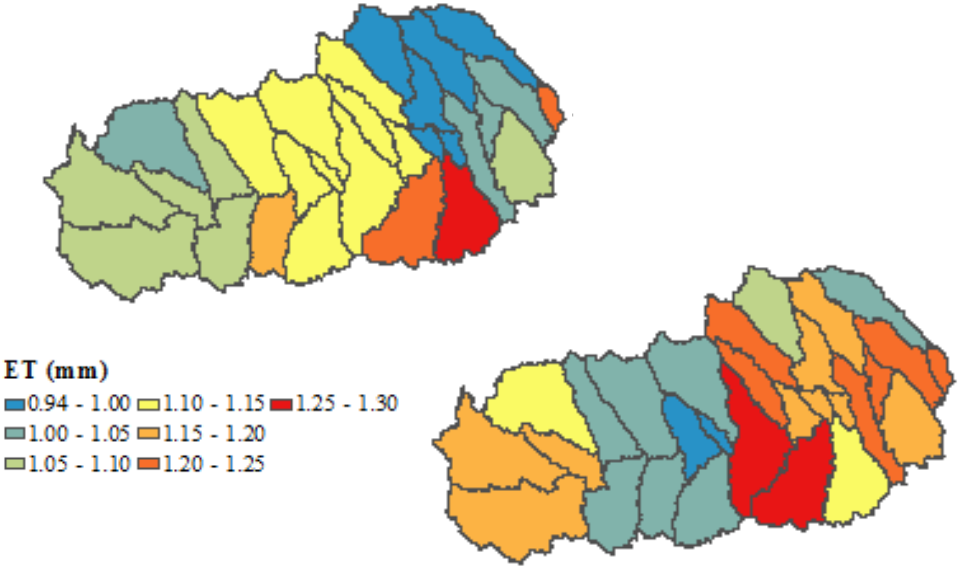

BRW
SCW
UBSRW
Average monthly precipitation (mm)
Average monthly surface runoff (mm)
Average monthly soil water (mm)
Average monthly ET (mm)
Month
Month
Month
1981-1990
2005-2011

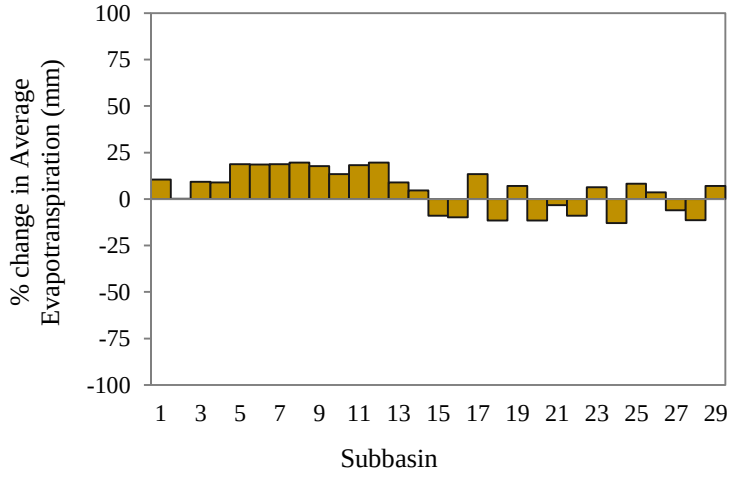
(1981-1990) (2005-2014)



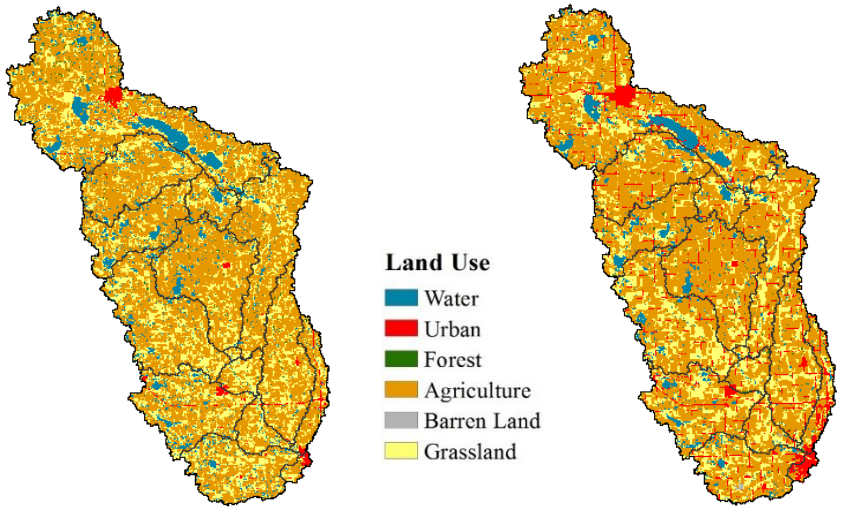


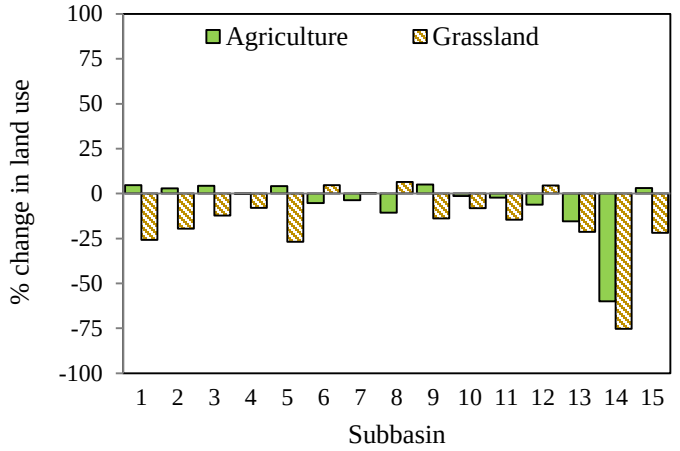
Evapotranspiration



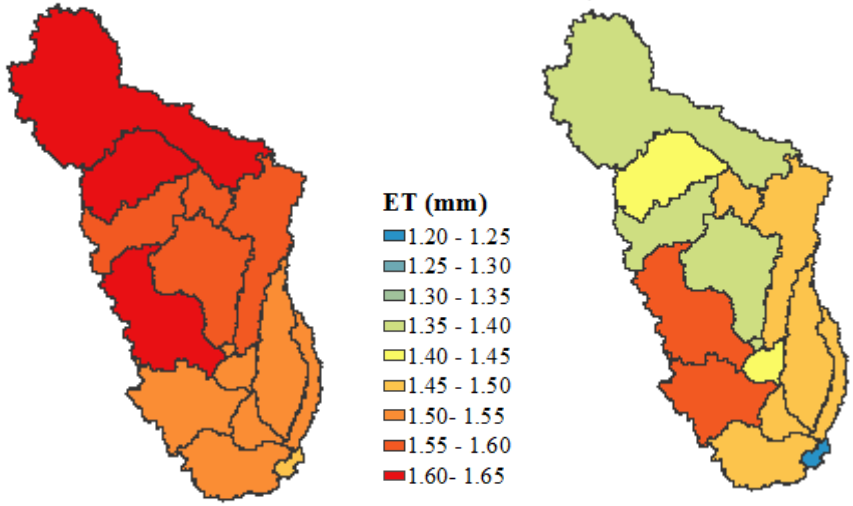


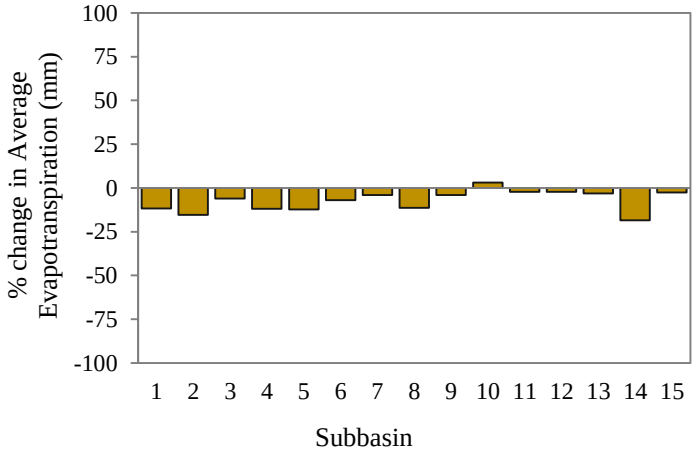
(1981-1990) (2005-2014)



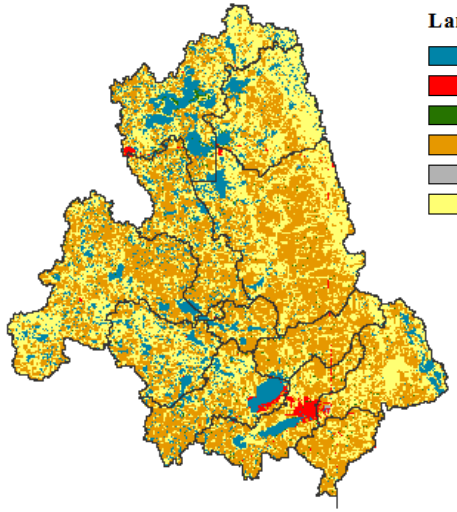


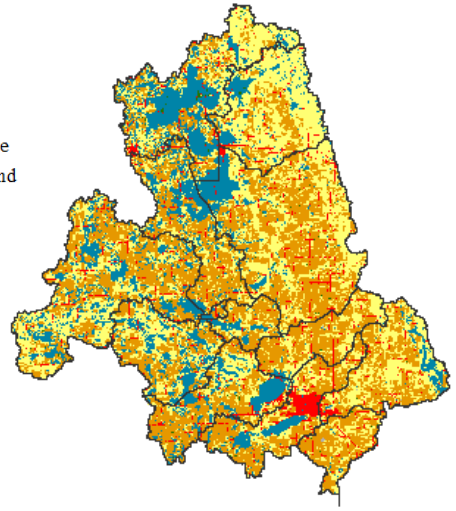
Evapotranspiration

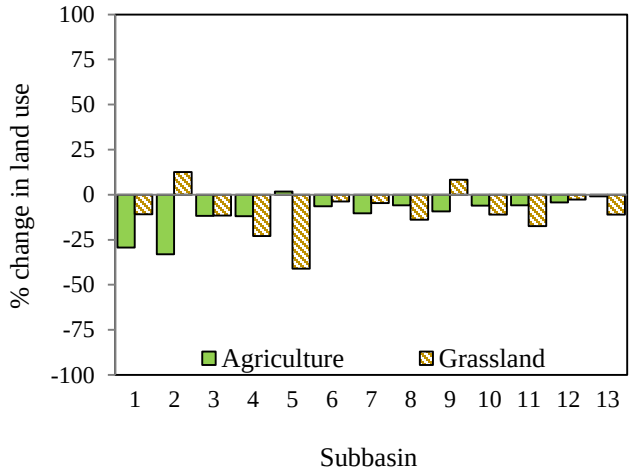




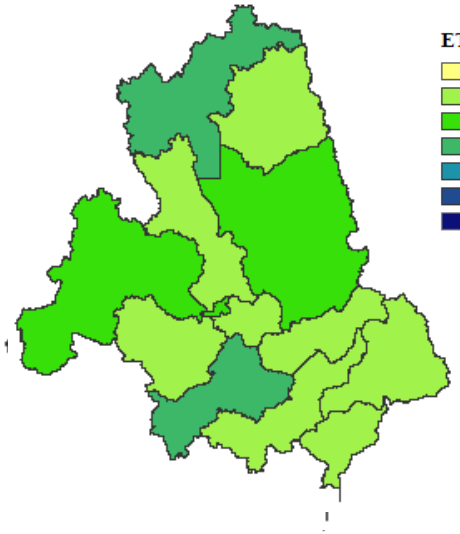
(1981-1990) (2005-2014)

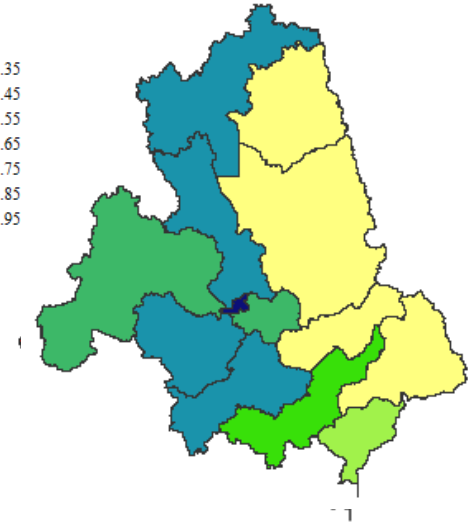


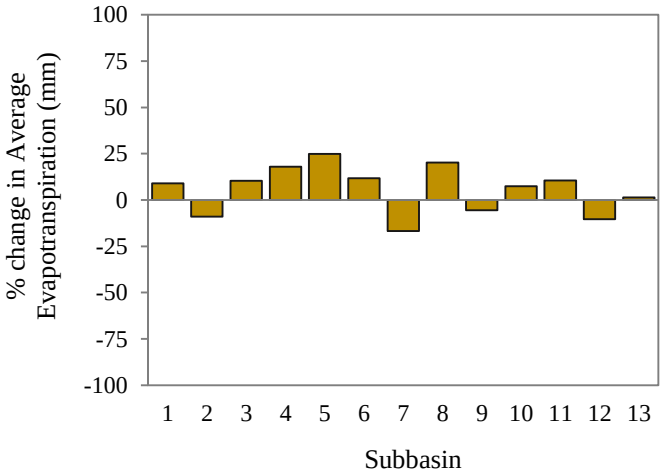




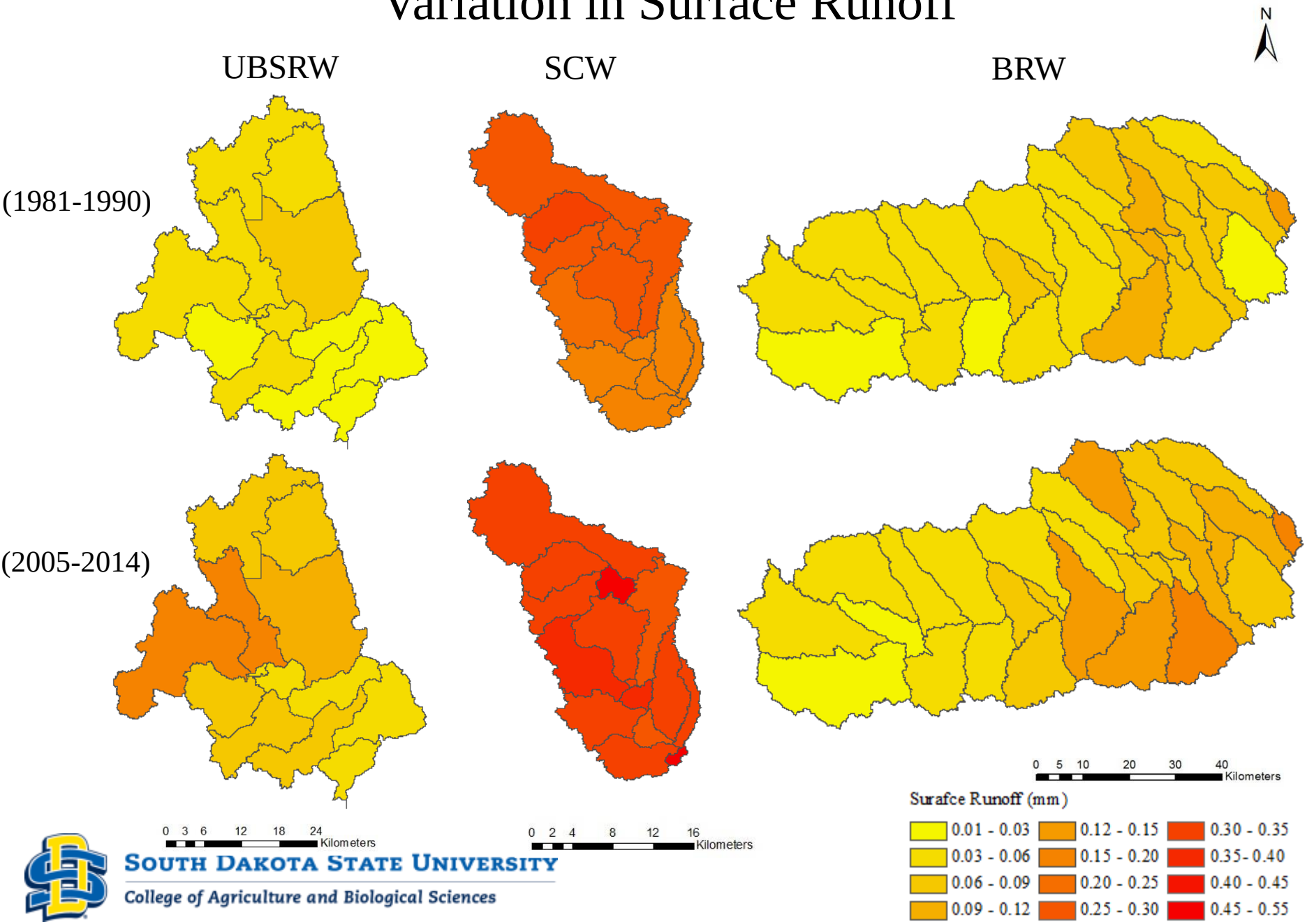
Evapotranspiration







Variation in Surface Runoff



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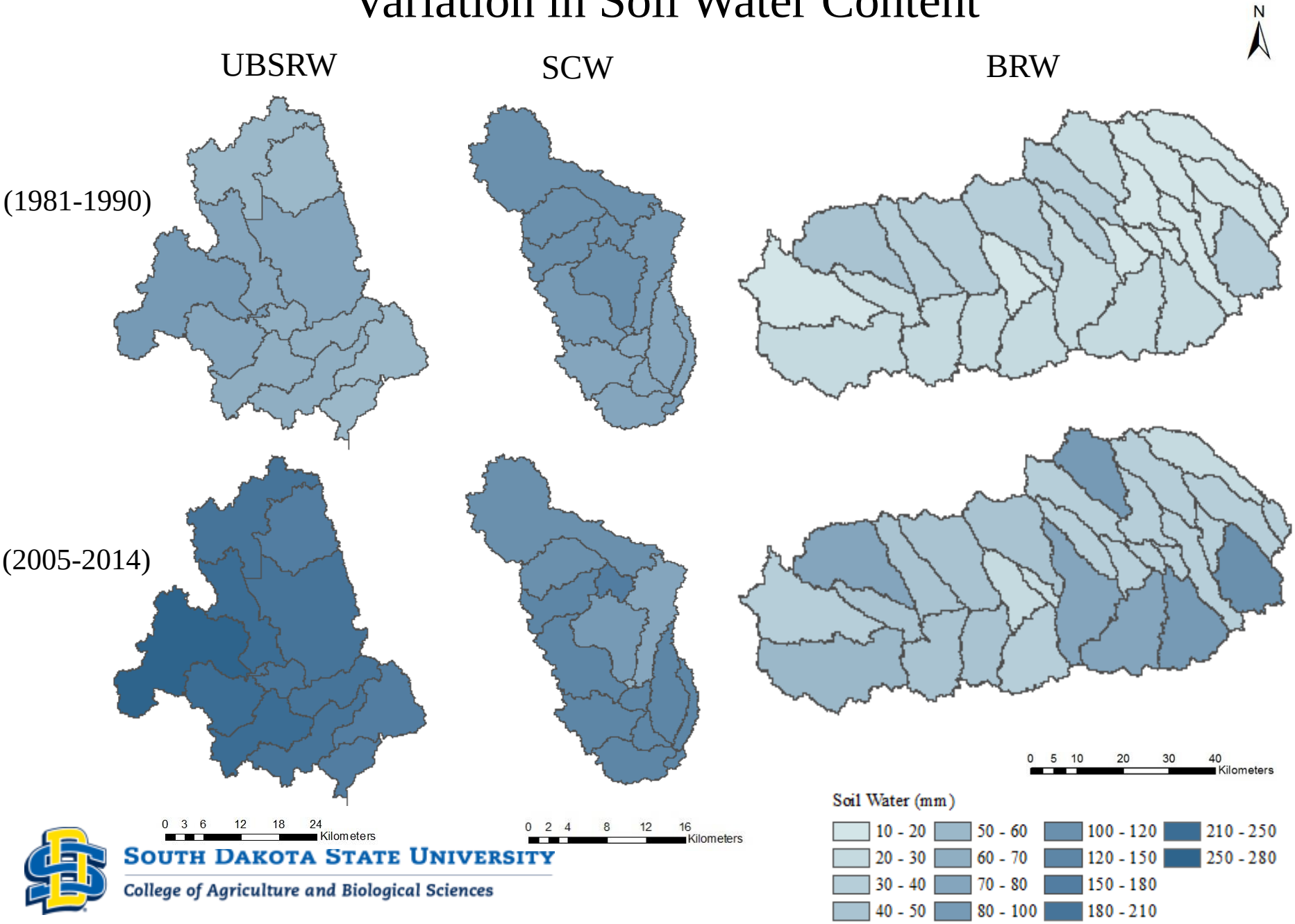
Variation in Soil Water Content



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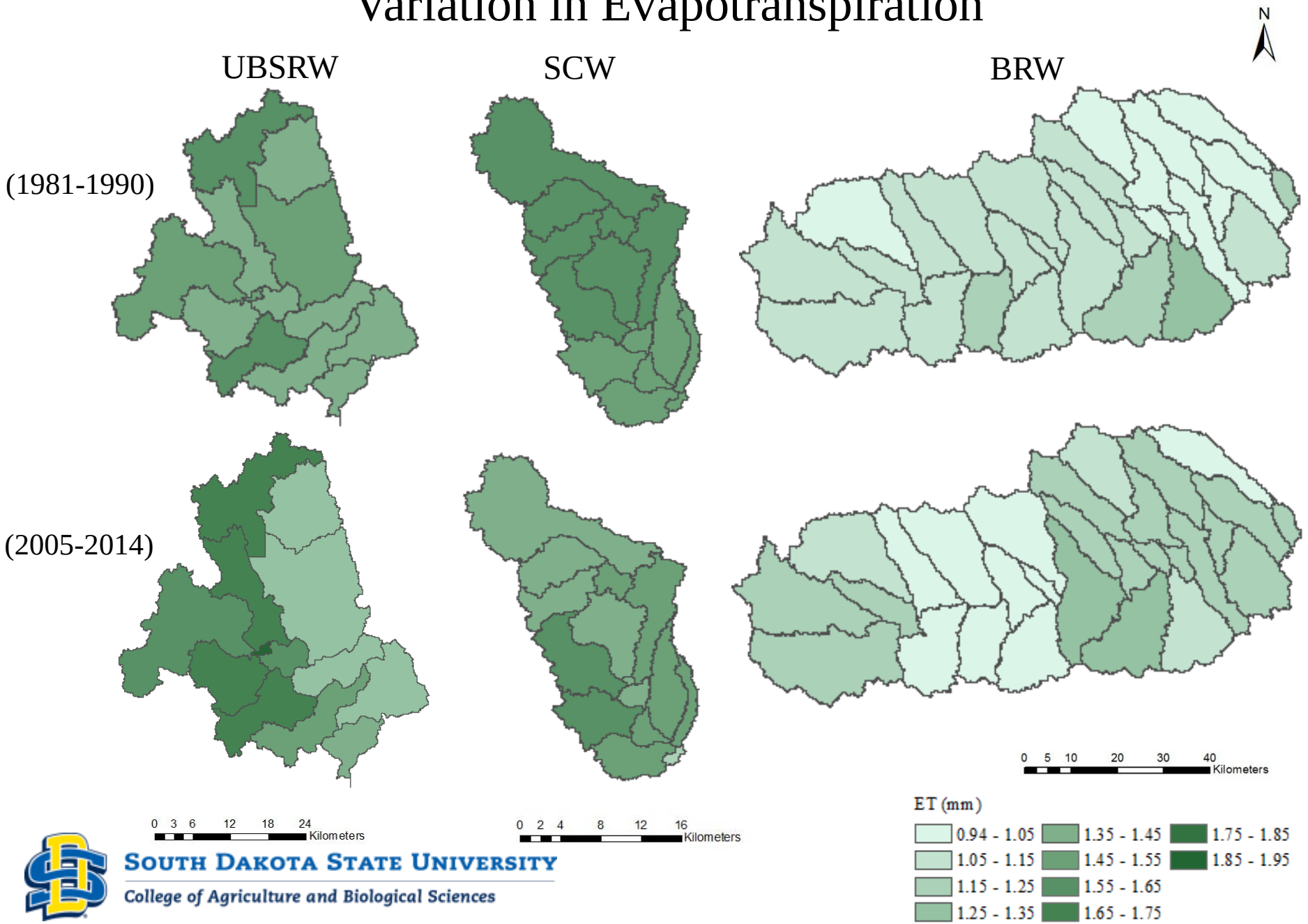
Variation in Evapotranspiration



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Conclusion

- BRW and SCW experienced grassland loss with the expansion in agricultural and urban areas (1.4% and 5.2%, respectively) and in the UBSRW was mostly derived from expansion of wetlands (4.8%).
- Climate variability appears with a slight precipitation increase in BRW and UBSRW, and slightly decreased in the SCW during 2005-2014 relative to 1981-1990.
- Comparison of watershed-scale average annual water budget components between the two decades indicates significant increase in soil water content and percolation in BRW and UBSRW and water yield in SCW.
- Analysis of seasonal variability between the two time periods revealed a notable shift in surface runoff in SCW from June to March and in UBSRW from March to April.
- ET shows a distinctive change in the summer growing season for all three watersheds.
- Based on the sub-basin scale spatial evaluation, downstream parts of BRW and SCW, and the western part of UBSRW experienced more changes in hydrology.

Future Plan

- Analyze the effects of projected climate change scenarios with existing land use on water resources.
- Analyze the effects of projected land use change scenarios with existing climate condition on water resources.
- Analyze the combined effects of climate change and land cover change on water resources in South Dakota.

Acknowledgement

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Thank You

Questions