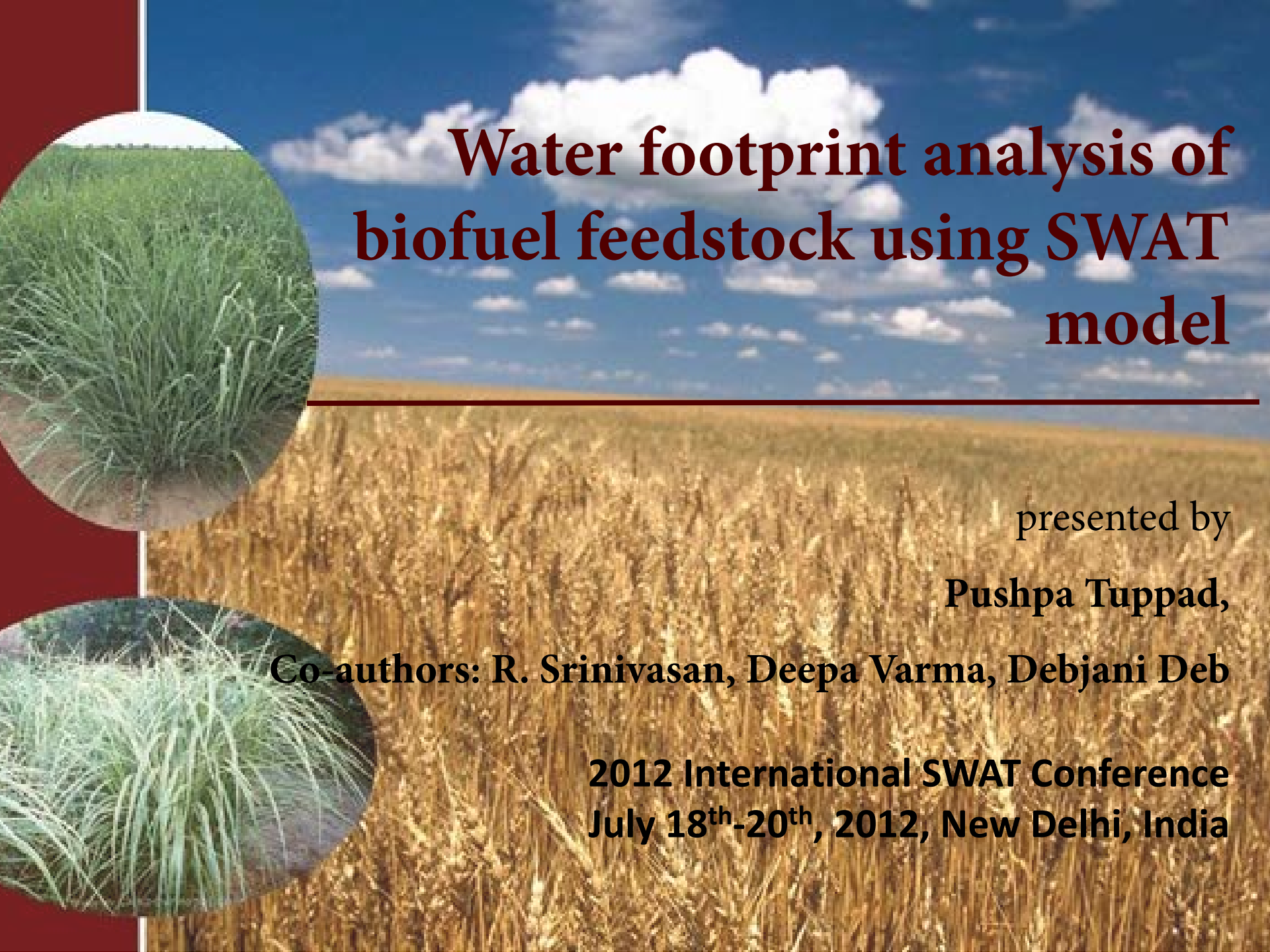

Water footprint analysis of biofuel feedstock using SWAT model

presented by

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Co-authors: R. Srinivasan, Deepa Varma, Debjani Deb

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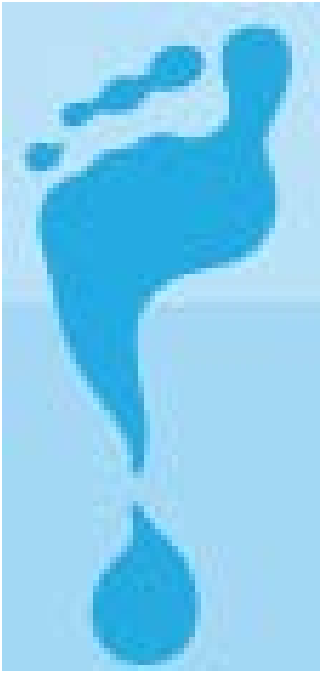
Background



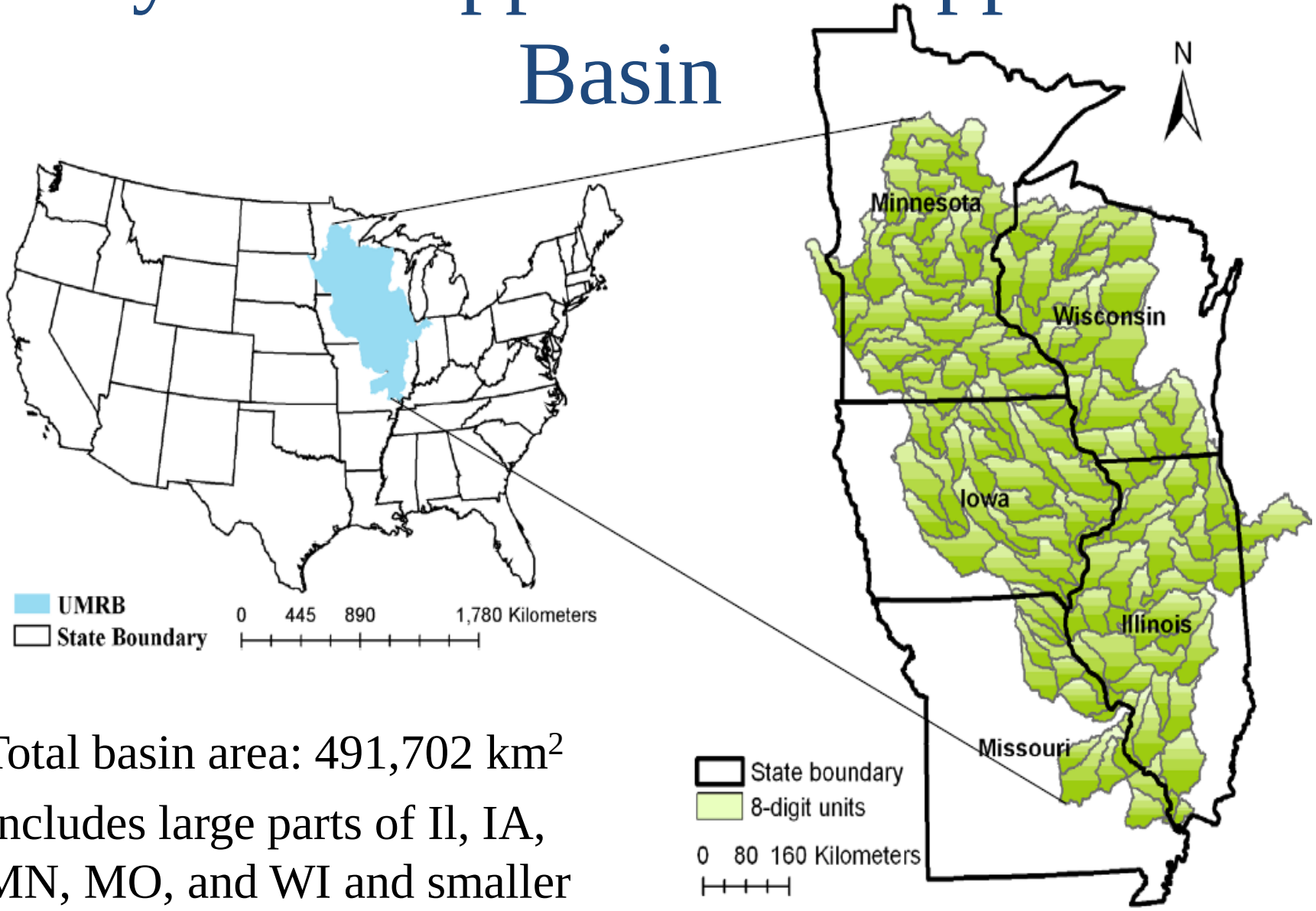
- A very large portion of WF → biomass production, linked to agriculture
- Water use and water availability is region specific and essentially linked to the hydrology of the region
- Understanding water variability and water accounting at watershed scale is considered appropriate
- How do biofuels expansion strategies impact water availability, consumption and discharge?

Objectives

- To demonstrate the link between SWAT hydrological variables and WF parameters – blue, green and grey water components

- Assess the hydrological WF of advanced biomass feedstock – mainly corn stover and switchgrass

Study area: Upper Mississippi River Basin



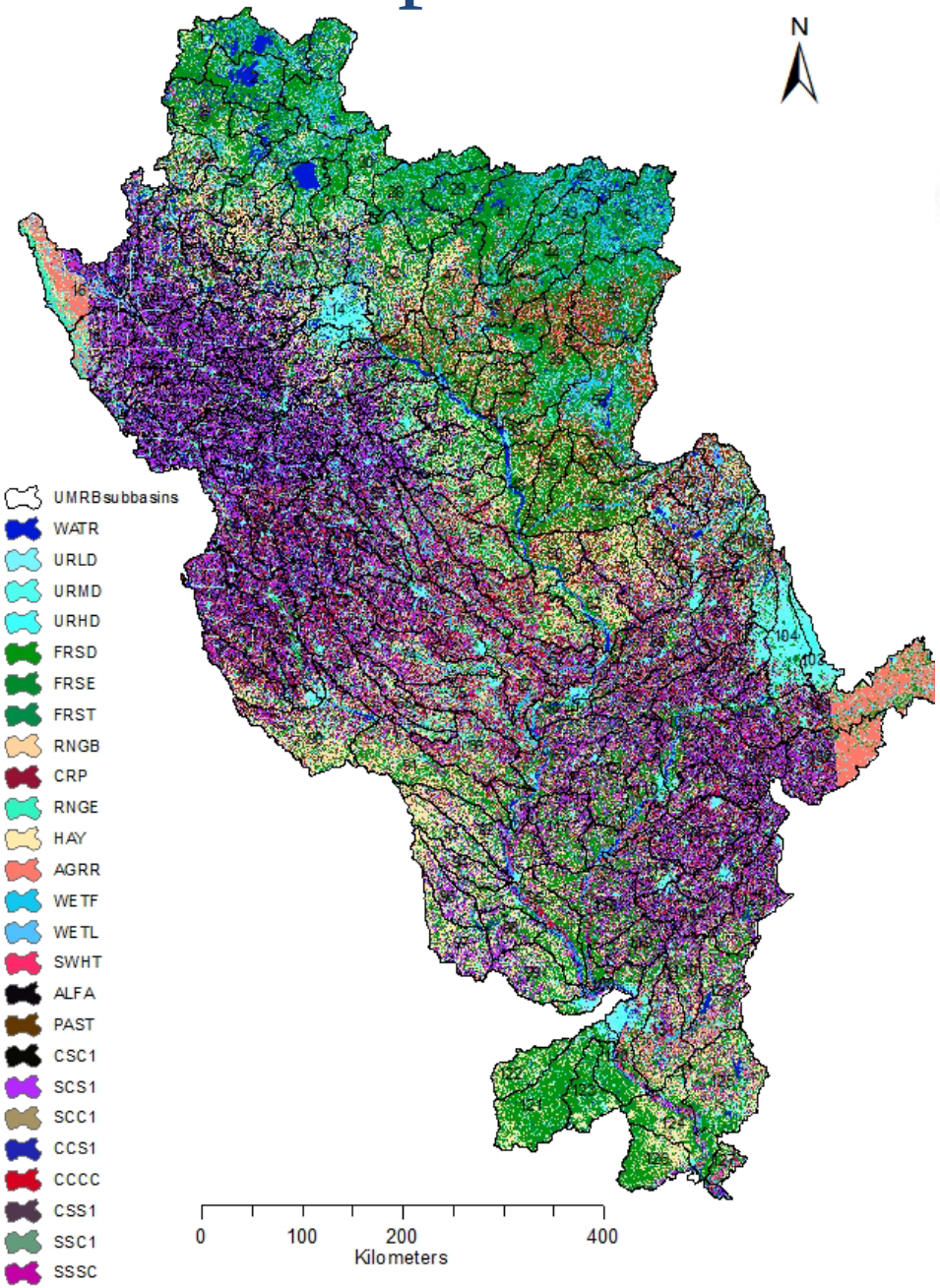
- Total basin area: 491,702 km^2
- Includes large parts of Il, IA, MN, MO, and WI and smaller portions of IN, MI, and SD

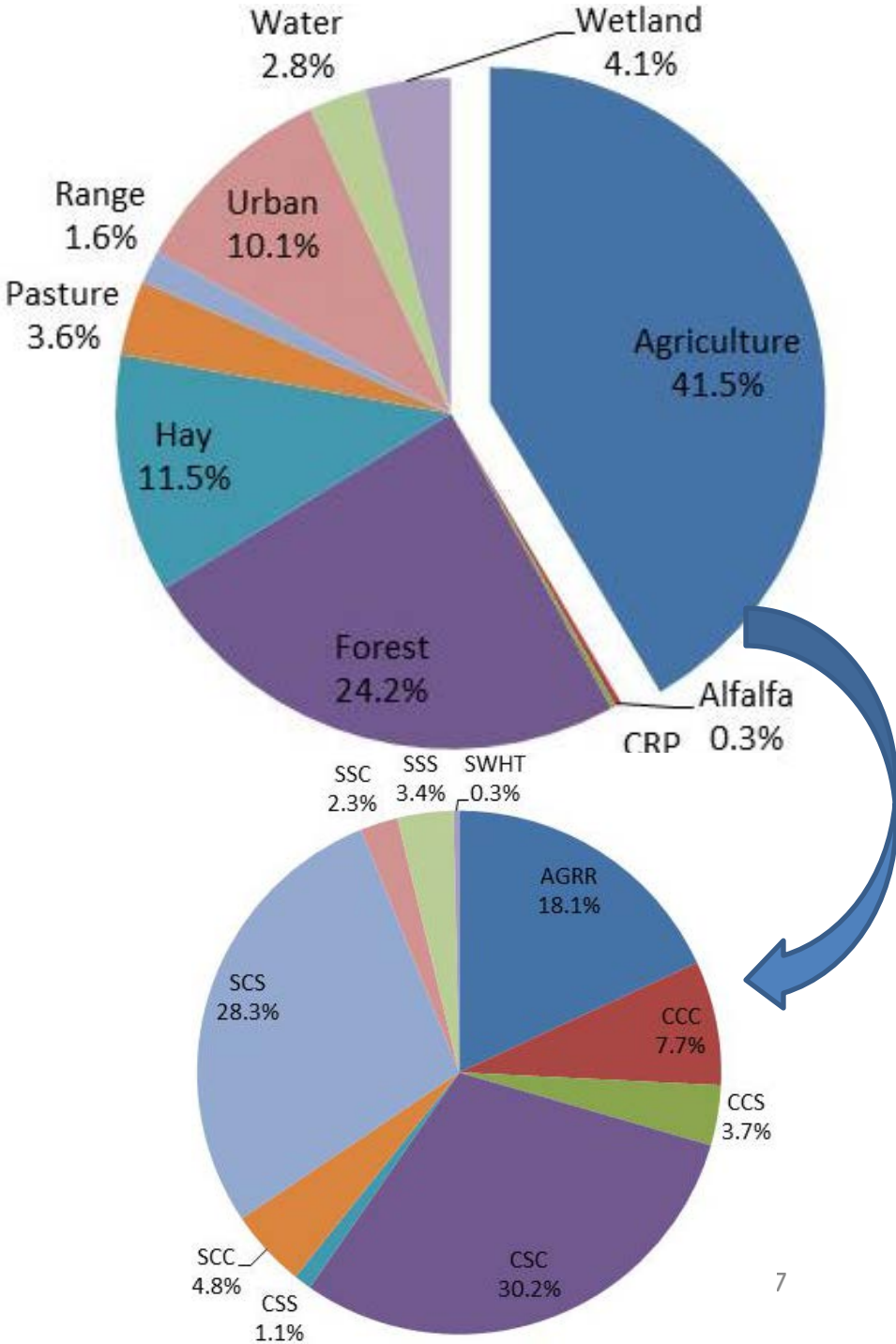
- The UMR (2100 km) extends from Lake Itasca in MN to a point just north of Cairo, Il (confluence with Ohio River).
- The UMR is the only water body in US recognized as both a “nationally significant ecosystem” and a “nationally significant commercial navigation system”
- >30 million people rely on UMR for public and industrial supplies, power plant cooling, wastewater assimilation, and other uses.

Watershed Characteristics/Model inputs

- DEM: 90 m (3 arc second)
- Stream: NHD
- LU: CDL & 2001 NLCD
- Soil: STATSGO (1:250000)
- Subbasin: 8-digit HUC (total of 131) (Subbasin area: 924 km^2 to 8,496 km^2; Avg - 3,753 km^2)
- HRUs: 14002 (5/10/5 % threshold for landuse/soil/slope)
- Fertilizer and Manure: chemical fertilizer through auto-fert for hay & row crops
- Weather: Interpolated NCDC daily precip & temp data values at 2.5 min (around 4 km) resolution and aggregated to 8-digit subbasin
- Crop mgmt: CTIC
- Number of years of analysis: 41 (1961-2001)

Model Inputs: LULC





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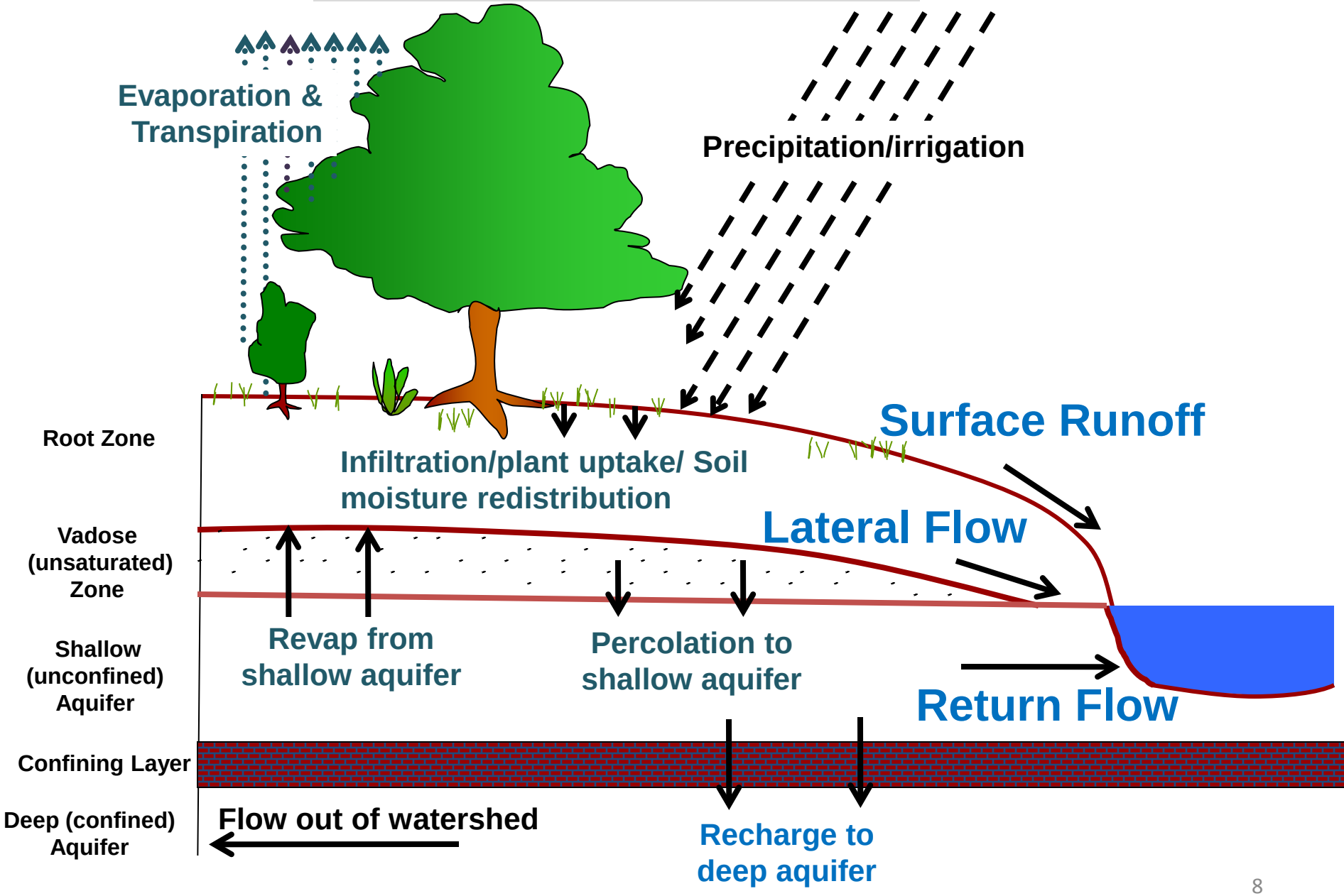
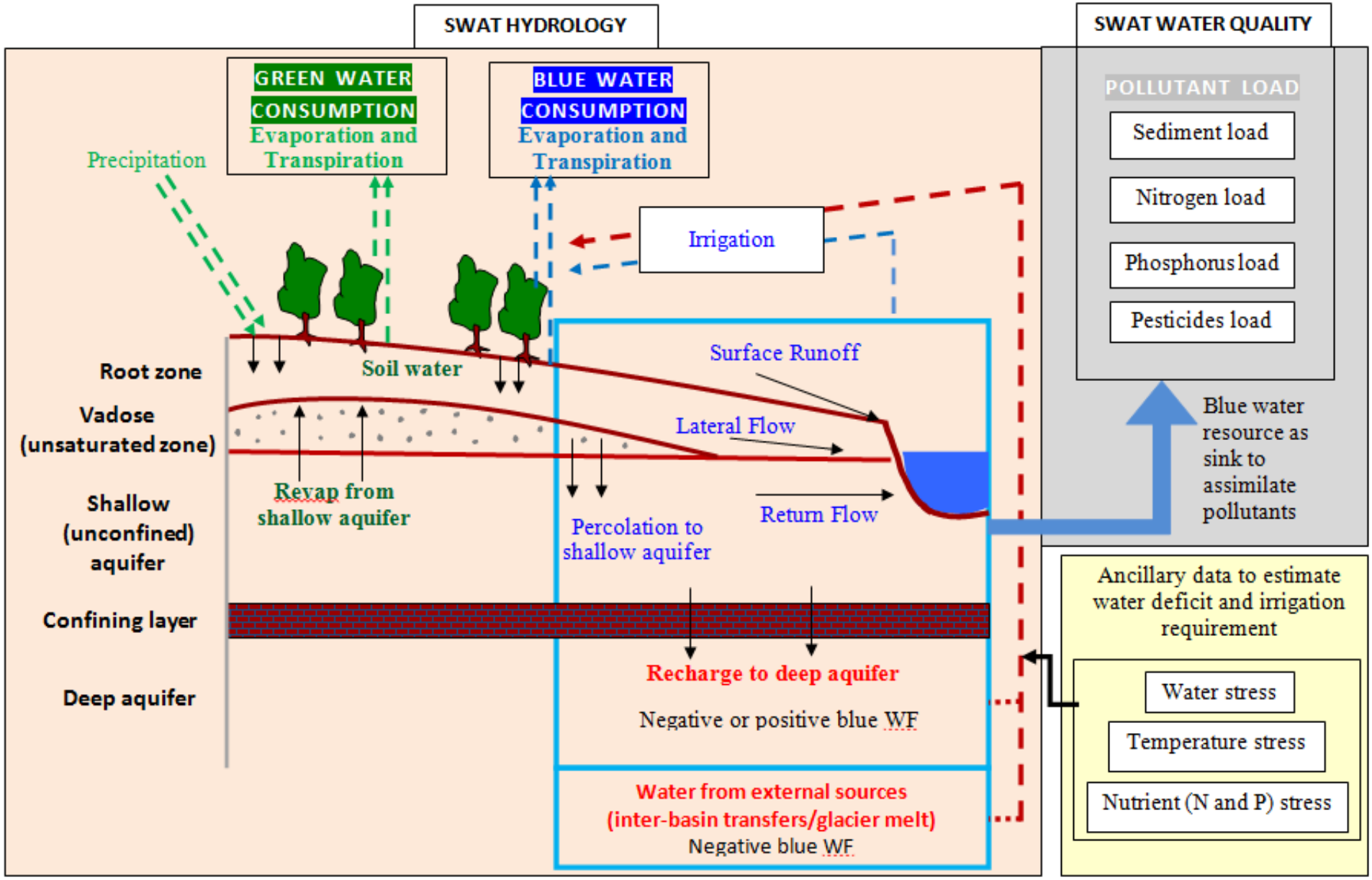
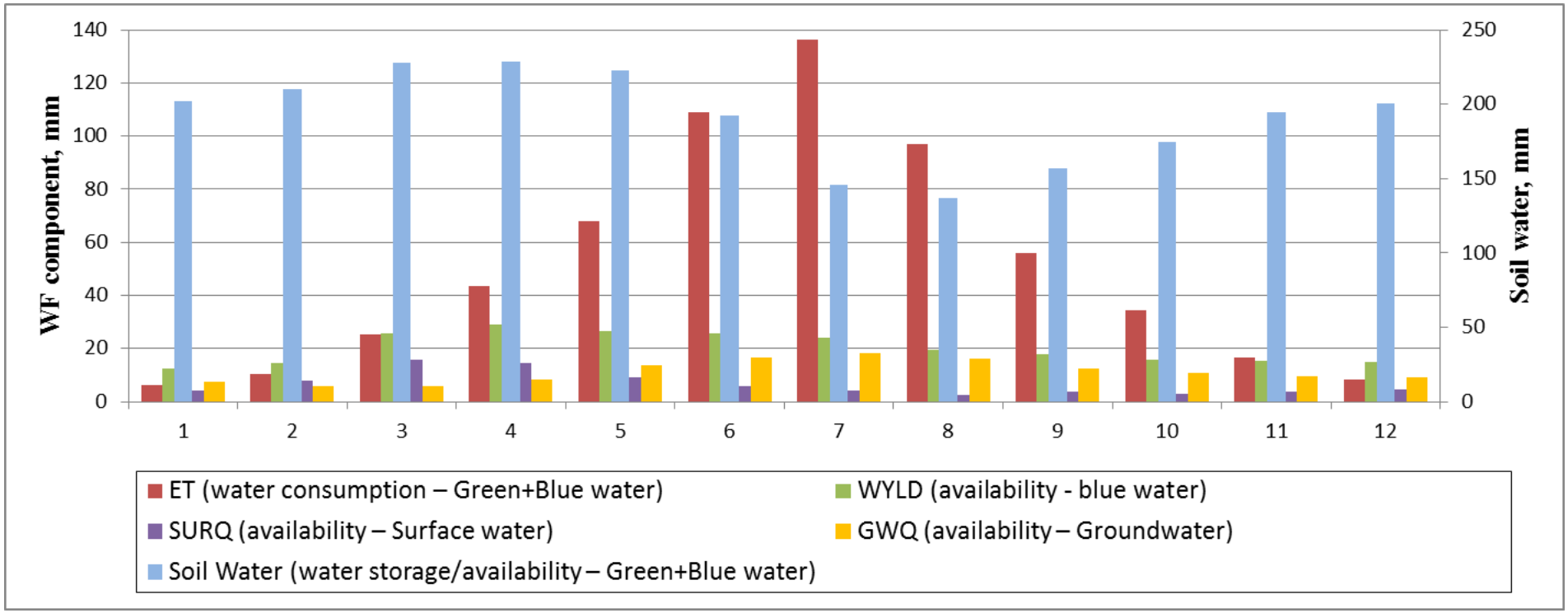
Hydrologic Balance

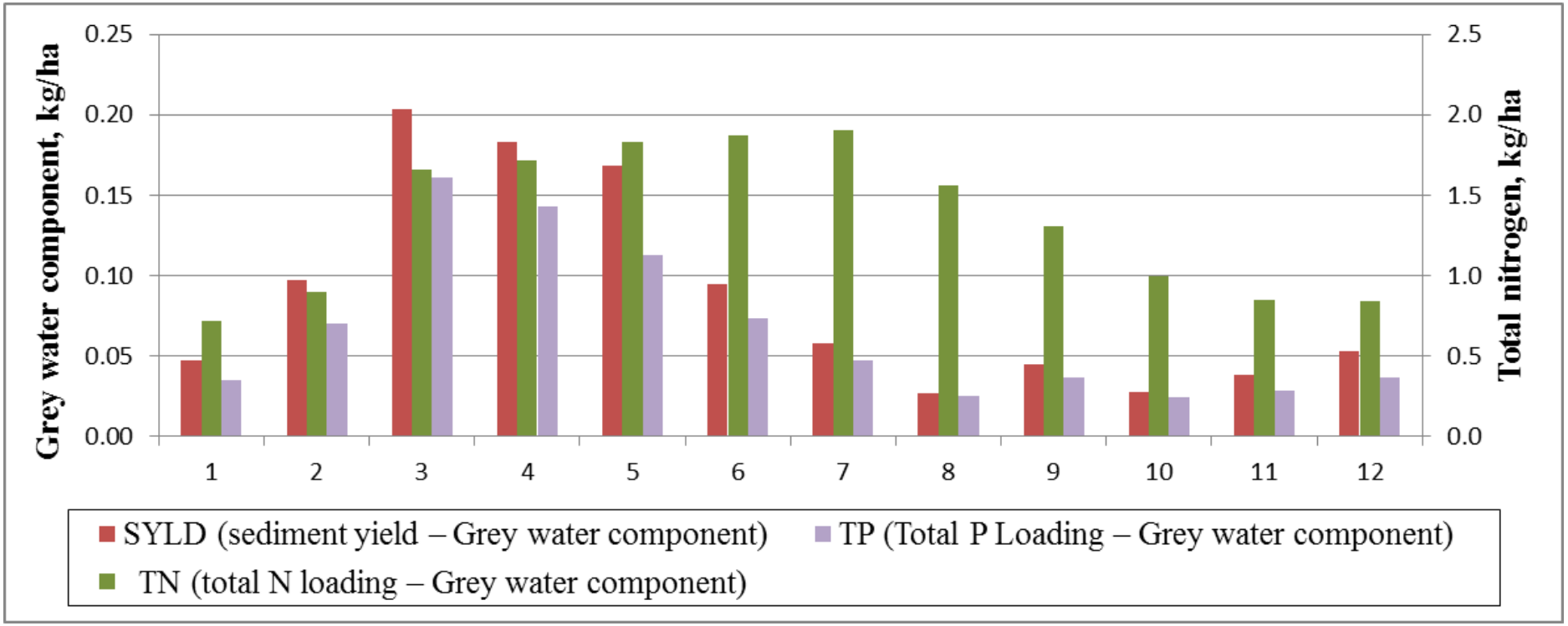


Basin Scale Watershed Accounting





SWAT Simulated Average monthly WF components for existing condition of UMRB (1961 to 2001)



SWAT Simulated Average monthly Grey water components for existing condition of UMRB (1961 to 2001)

Green Water Availability (Precipitation) mm

Blue Water (Water Yield) mm

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Grey Water (Sediment Yield) t/ha

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Scenarios

	Crop rotation	Stover harvest rate, %
Current (CS/CC/SS/CCS/CSS)	Corn-soybean	0
Scenario 1: Economic expansion – yield intensification		
CC	Continuous corn	0
Scenario 2: Environmental consideration – residue removal rates		
CC25	Continuous corn	25
CC50	Continuous corn	50
CC75	Continuous corn	75
Scenario 3: Environmental consideration – energy grass intervention		
Scenario	Percent cropland replaced with switchgrass	
SW25	25	
SW50	50	
SW75	75	
SW100	100	

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Scenarios

Scenarios	% Change WYld	% Change ET	%Change SYld	% Change TN
Scenario 1(a): Economic expansion – yield intensification				
CC	0.5	-0.2	-1.5	1.4
Scenario 2(a): Environmental consideration – residue removal rates				
CC25	6.2	-2.6	-3.0	8.7
CC50	7.9	-3.4	-6.0	12.0
CC75	9.2	-4.1	-27.0	4.1

Scenario 2(c): Environmental consideration – energy grass intervention

Scenarios	% Change WYld	% Change ET	%Change SYld	% Change TN
SW25	16.5	7.8	97.6	67.6
SW50	9.5	5.8	96.8	59.8
SW75	-8.1	7.2	96.8	65.9
SW100	-13.6	6.1	96.3	66.9

Switchgrass	Area in Sq km
swch25	31263
swch50	62575
swch75	94595
swch100	125048

Conclusions

- The UMRB is a region of relatively low water stress – however, within the basin there is considerable variability in rainfall– its Northern parts are drier than its southern parts.
- Continuous corn modified the hydrology variables by only 0.5 to <2% and therefore its impact is not significant.
- Introduction of switchgrass into the land use improved water flow in the watershed; the impact was felt mostly for groundwater resources (3-20%).Therefore, biofuels expansion in the UMRB is not expected to face water stress.
- High rainfall central-southern areas of the UMRB contribute most to nutrient discharge because of the larger share of area under corn to the total land use

Conclusions contd….

- Progressive stover removal rates of 25-50-75 percent increased sediment yield (erosion) from 3-6-27% from baseline respectively.

- Switchgrass increased water availability and reduced erosion/nutrient loading into the river.
  - With a 50% change from corn to switchgrass in the low-yielding corn areas, the impact can be significant - soil erosion decreased by 95% and N-loading in to the river also decreased by 70%.
  - Therefore, integrating switchgrass into the agricultural land use could serve the dual purpose of biomass expansion as well as reducing hypoxic conditions in the Gulf of Mexico.

- Although data intensive, SWAT emerged as a powerful tool to measure the impact of biomass expansion on the hydrology of the watershed at variable scales.

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Questions/comments?

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- The amount of stover that needs to remain in the field to maintain SOC depends on
  - crops and cropping pattern
  - tillage practices
  - soil type and erodibility
  - field characteristics (slope, climate)

- The SOC affects soil cation exchange capacity, aggregate stability, water holding capacity, and soil microbial activity

- The residue harvest rates need to account for both erosion potential and maintenance of SOC

- The USDOE considers switchgrass as a viable bioenergy feedstock because it is broadly adapted and has high yield potential on marginal croplands

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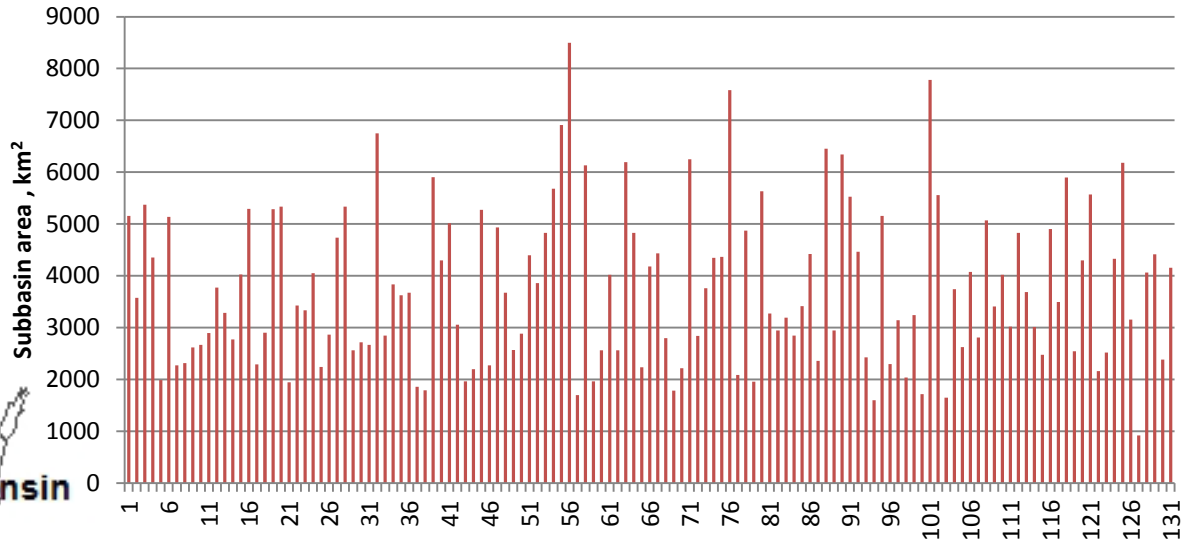

- Total basin area: 491,702 km2
- Total # of subbasins: 131
- Subbasin area ranges from 924 km2 to 8,496 km2; Avg - 3,753 km2

%change wyld	% change et	%change syld	%change tn
9.2%	-4.1%	-25.1%	4.1%

75% stover removal

%change wyld	% change et	%change syld	%change tn
-13.6%	6.1%	96.3%	66.9%

100% Switchgrass adaptation

Water requirement simulated by SWAT

Feedstock	Water requirement m^3/t	WF, L of water/L of ethanol
Corn grain	848	2005
Corn biomass	318	874
Switchgrass	299	818