

# Agricultural Virtual Water Trade and Water Footprint of U.S. States

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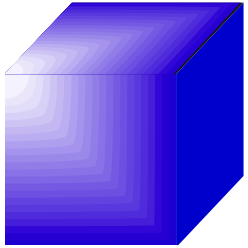
University of Texas at El Paso

Acknowledgements:

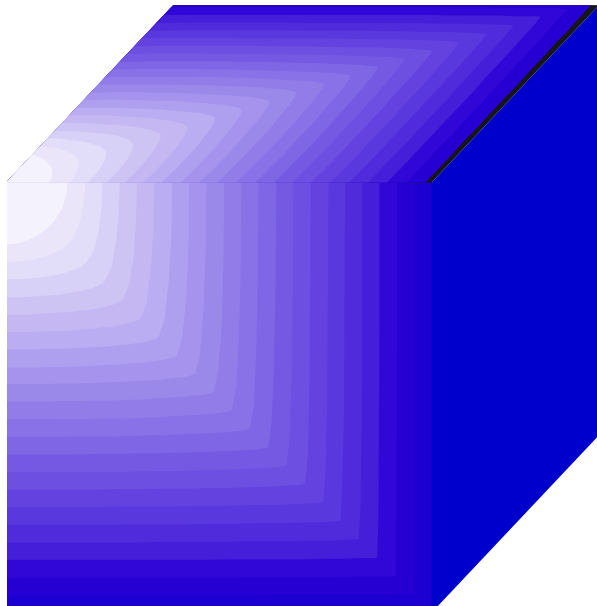
Doctoral dissertation committee at SIUC

# What is virtual water?

## Water footprint



1,000 liters  
(1,000 kg)



15,000 liters  
(15,000 kg)



## Virtual water trade/transfer

# Research questions

1. How much virtual water flows among the 48 contiguous states?
2. What component of this is blue vs green water?
3. Which commodities make up the largest part of virtual water flows?
4. Which states are large net and gross virtual water importers and exporters?
5. What are the water management and policy implications?

# Scope of the study & data

- 48 contiguous states
- Agriculture: major water use sector- 9 crops and 9 livestock groups.

## EPA livestock categorization

Type of livestock establishment	Percent of establishments	Percent of sales	Crop	Percent cultivated area harvested	Cumulative percentage
Cattle ranching and farming	78	60	Corn for grain	25.79	25.79
Hog and pig farming	4	14	Soybeans	22.89	48.68
Poultry and egg production	4	23	Hay	19.97	68.65
Sheep and goat farming	3	<1	Wheat	16.86	85.52
Animal aquaculture	<1	<1	Cotton	3.80	89.32
Other animal production	11	2	Corn for silage	2.06	91.38
			Sorghum	1.98	93.36
			Barley	1.10	94.46
			Rice	0.92	95.38
			Others	4.63	100

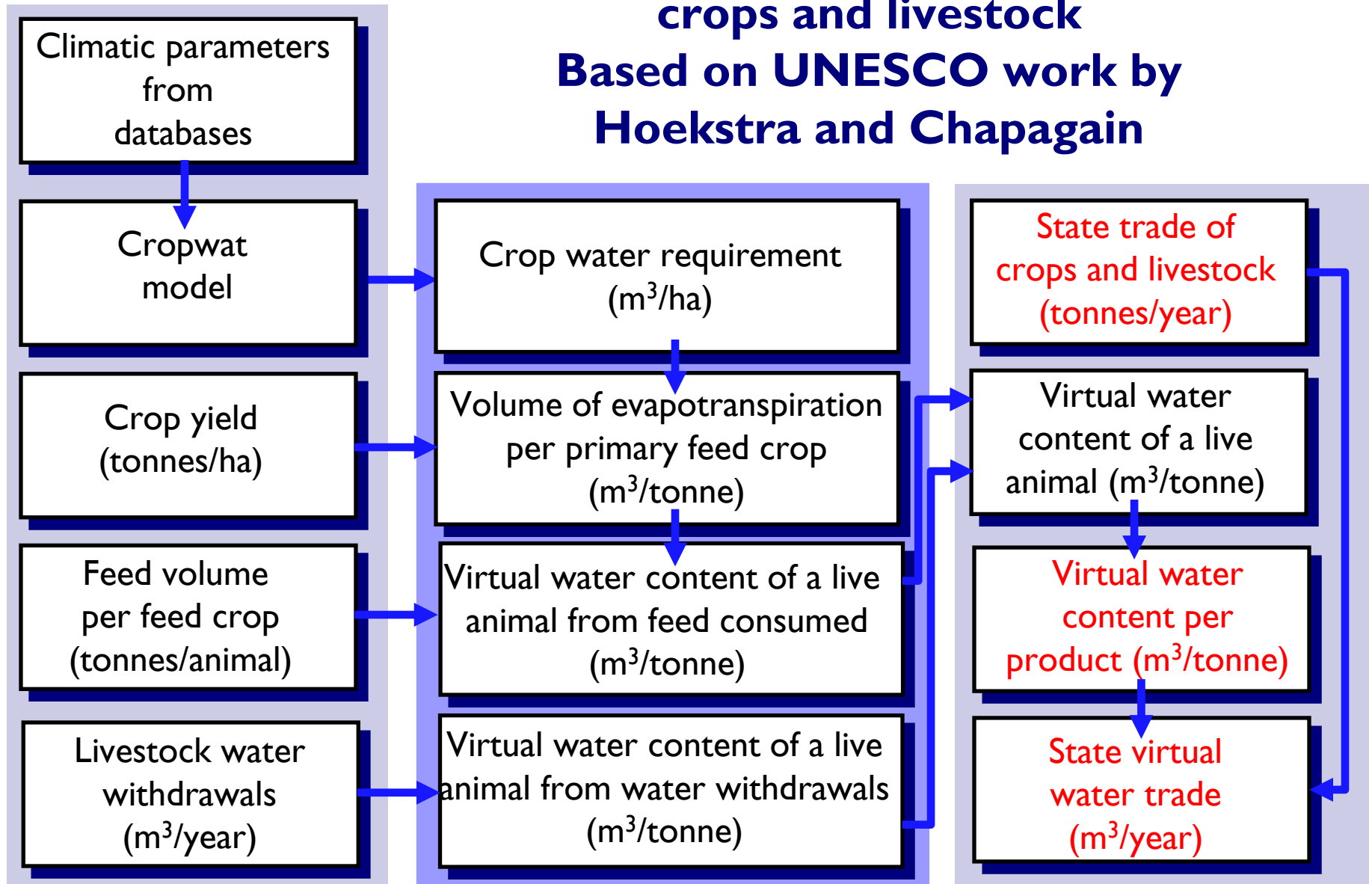
## USDA major crop categorization

- Year 2008 data, various sources.

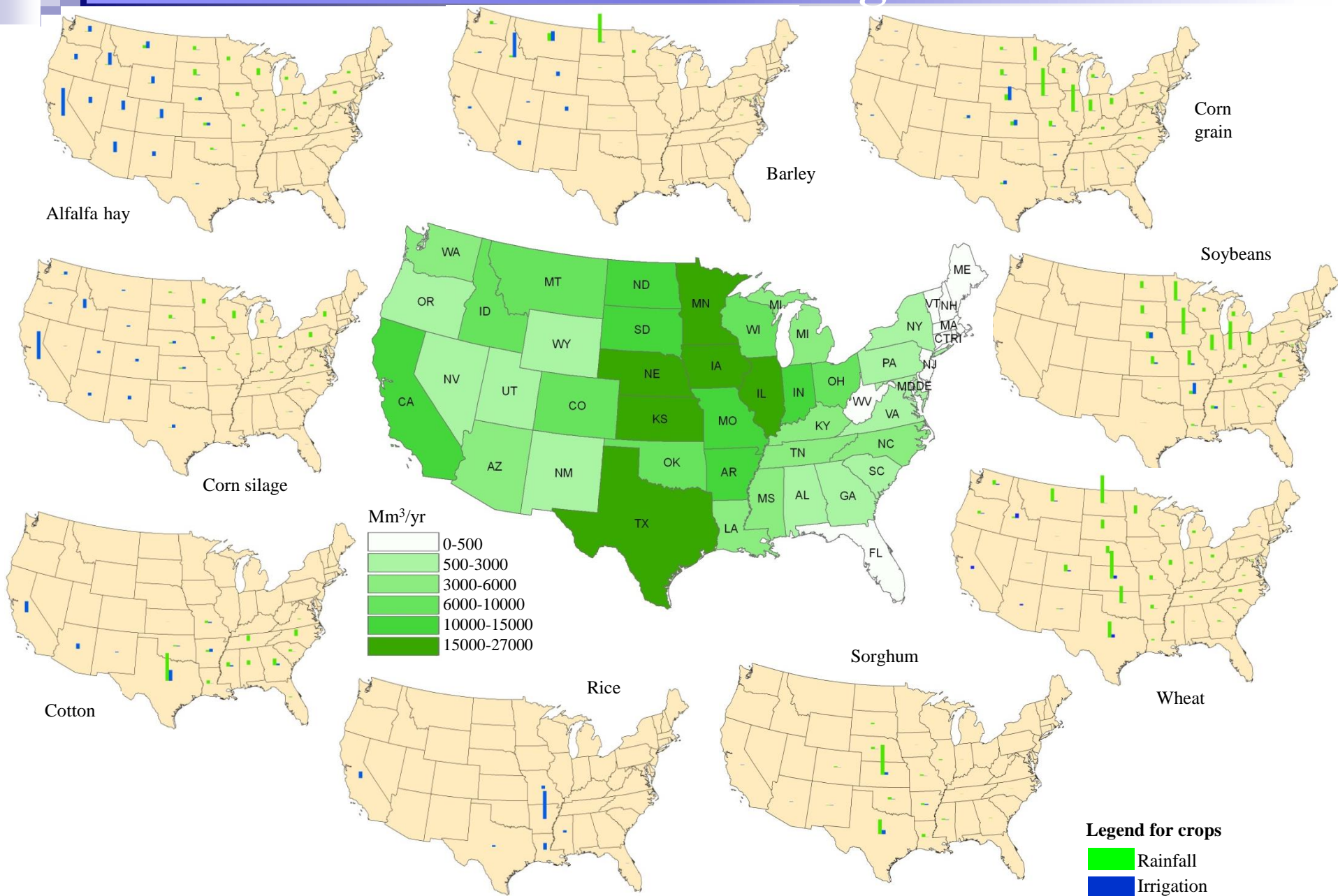
# Method

## VW volumes related to primary crops and livestock

Based on UNESCO work by  
Hoekstra and Chapagain



# Results : EVT of rainfall and irrigation water



# Results

Virtual water content of primary crops in selected states (m<sup>3</sup>/tonne).

Crop/ State	Corn grain	Soybeans	Alfalfa hay	Wheat	Cotton	Corn silage	Sorghum	Barley	Rice
AR	379	1398	828	1884	1930	102	520	-	1613
CA	775	-	955	1440	5672	207	1458	1468	848
IL	278	745	400	1390	-	67	640	1124	379
ND	289	655	301	1257	-	73	-	713	-
LA	338	948	449	1578	3722	46	551	-	1638
TX	480	939	451	1890	3455	96	482	927	1001
U.S.	538	1081	678	1394	5185	101	756	991	1036

Comparison of U.S. virtual water content estimates for crops.

Primary Crop	Hoekstra & Hung (2002)	Oki and Kanae (2004)	Chapagain & Hoekstra (2004)	Aldaya et al. (2008)	Hanasaki et al. (2011)	This study
Corn	377	466	489	466	621	538
Corn silage	-	-	-	-	-	108
Sorghum	595	-	-	-	-	756
Barley	1118	-	-	-	-	991
Wheat	1302	1911	849	1707	1359	1394
Cotton	3551	-	-	-	-	5185
Rice	1331	-	-	-	-	1036
Soybeans	1380	1718	1869	1413	1921	1081
Alfalfa hay	377	-	-	-	-	678

# Results

Virtual water content ( $\text{m}^3/\text{tonne}$  of animal) for selected producing states.

State	% of AU	Prdn rank*	Beef cattle	Milk cows	Swine	Broiler chickens	Laying hens	Turkeys	Sheep	Goats	Horses
TX	11.9	1	7979	63779	3232	1702	11708	2096	4523	3985	4505
IA	7.2	2	6792	50137	3022	1155	7945	1419	3588	3292	3579
NE	5.9	3	6838	54089	3027	1263	8692	1554	3611	3221	3591
KS	5.7	4	7591	58988	2541	1510	10387	1857	4345	3882	4429
OK	5.0	5	9268	72989	4202	2170	14926	2674	5152	4462	5326
U.S. average			8916	74256	3198	1488	10232	1829	5452	4453	5369

\*Production rank out of the 48 contiguous states. 1 Animal Unit (AU) = 450 kg (1000 pounds) of live animal.

VWC of livestock ( $\text{m}^3/\text{animal}$ ).

State	% of AU	Prdn rank*	Beef cattle	Milk cows	Swine	Broiler chickens	Laying hens	Turkeys	Sheep	Goats	Horses
TX	11.9	1	3726	23255	381	4	23	26	181	139	1802
IA	7.2	2	3184	18563	357	3	16	18	144	115	1432
NE	5.9	3	3205	19841	357	3	17	19	144	113	1436
KS	5.7	4	3536	21376	300	3	21	23	174	136	1772
OK	5.0	5	4346	26834	496	5	30	33	206	156	2131
U.S. average			4149	26749	377	3	20	23	218	156	2148
U.S. (Chapagain & Hoekstra 2003)			5484	39443	398	3	18	-	303	114	2350

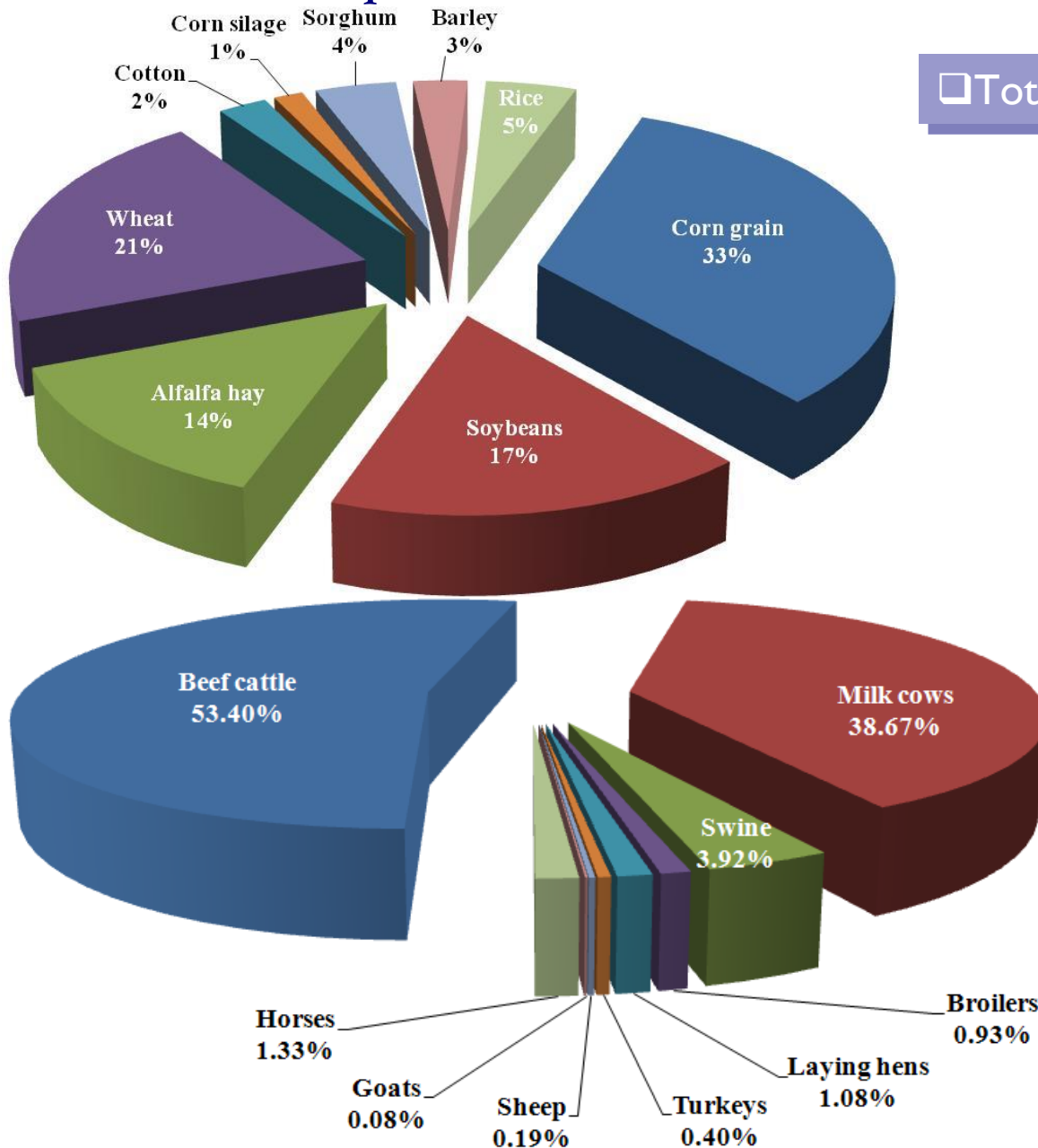


# Results

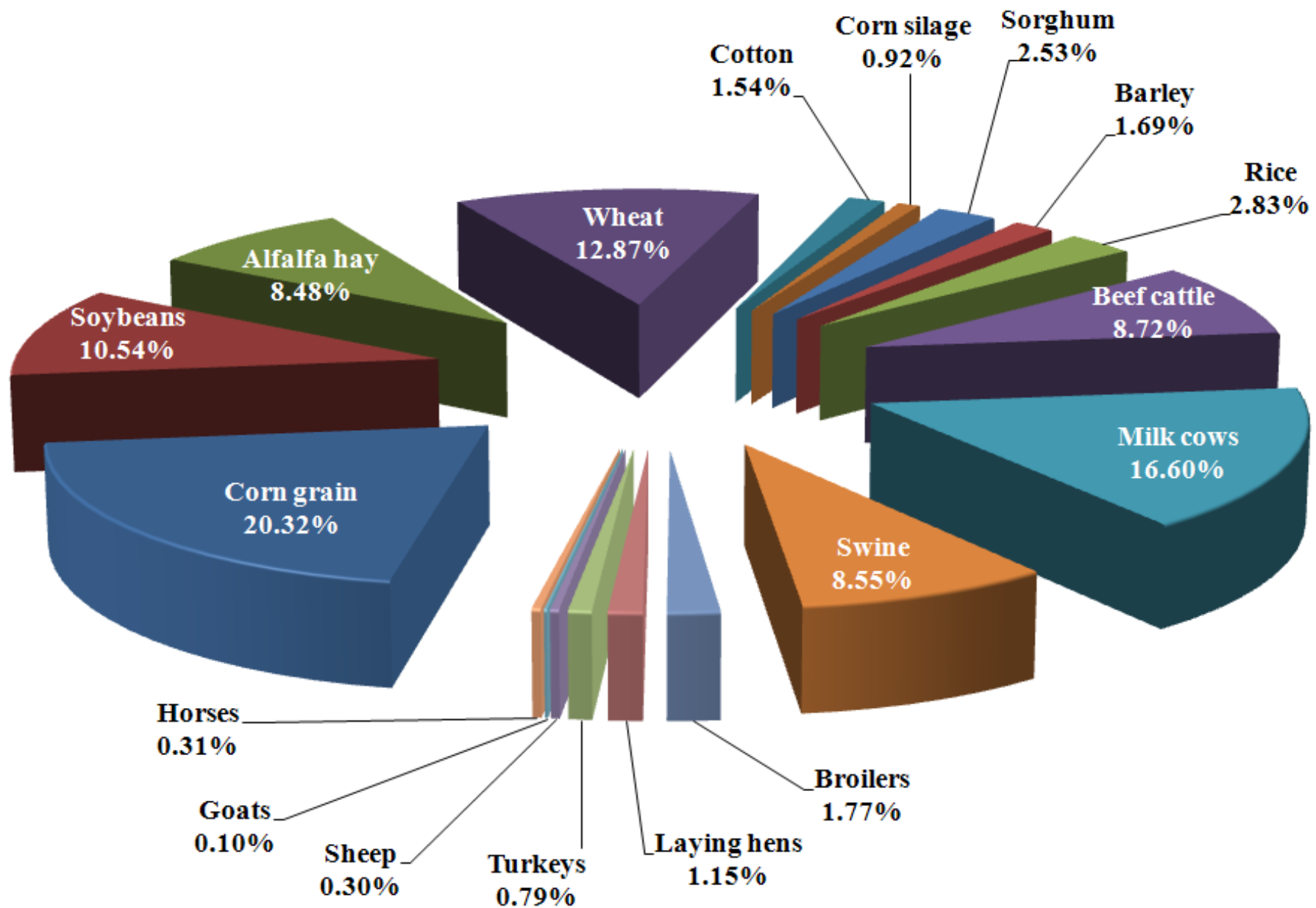
## Impact of individual commodities on water use

□ Total water use = 332 Gm<sup>3</sup>/yr.

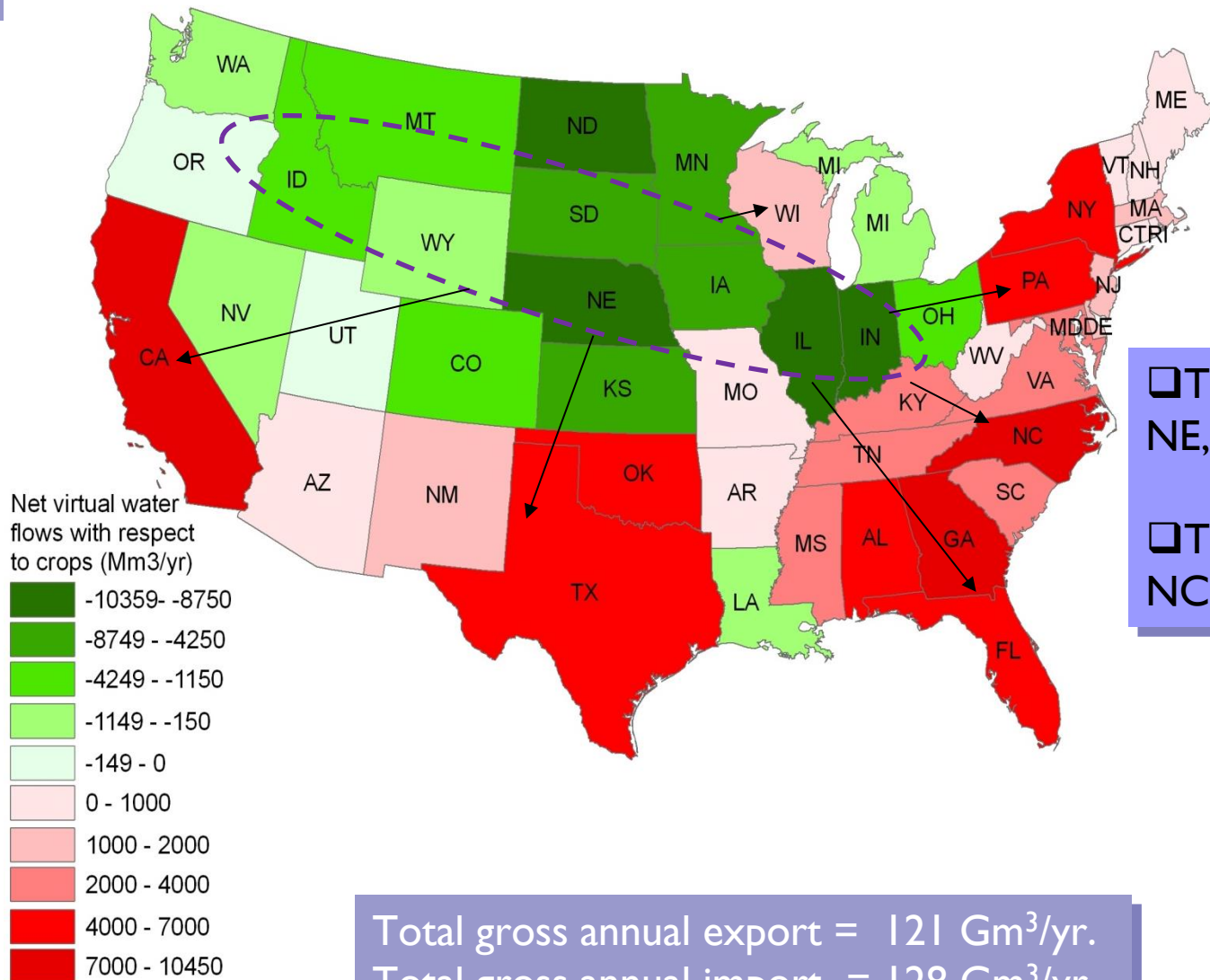
□ Total water use = 636 Gm<sup>3</sup>/yr.



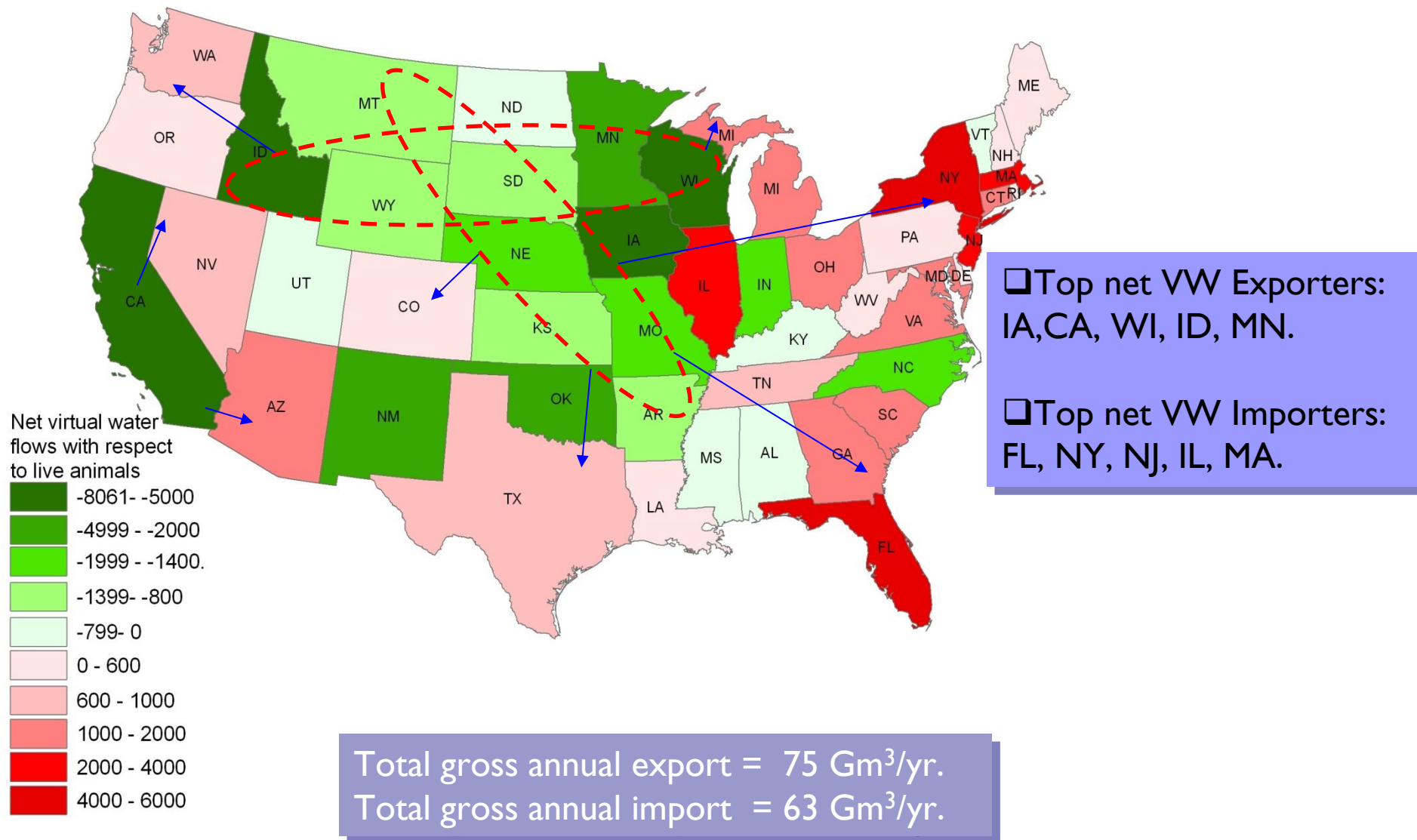
# Results and analysis: VW flow by commodity



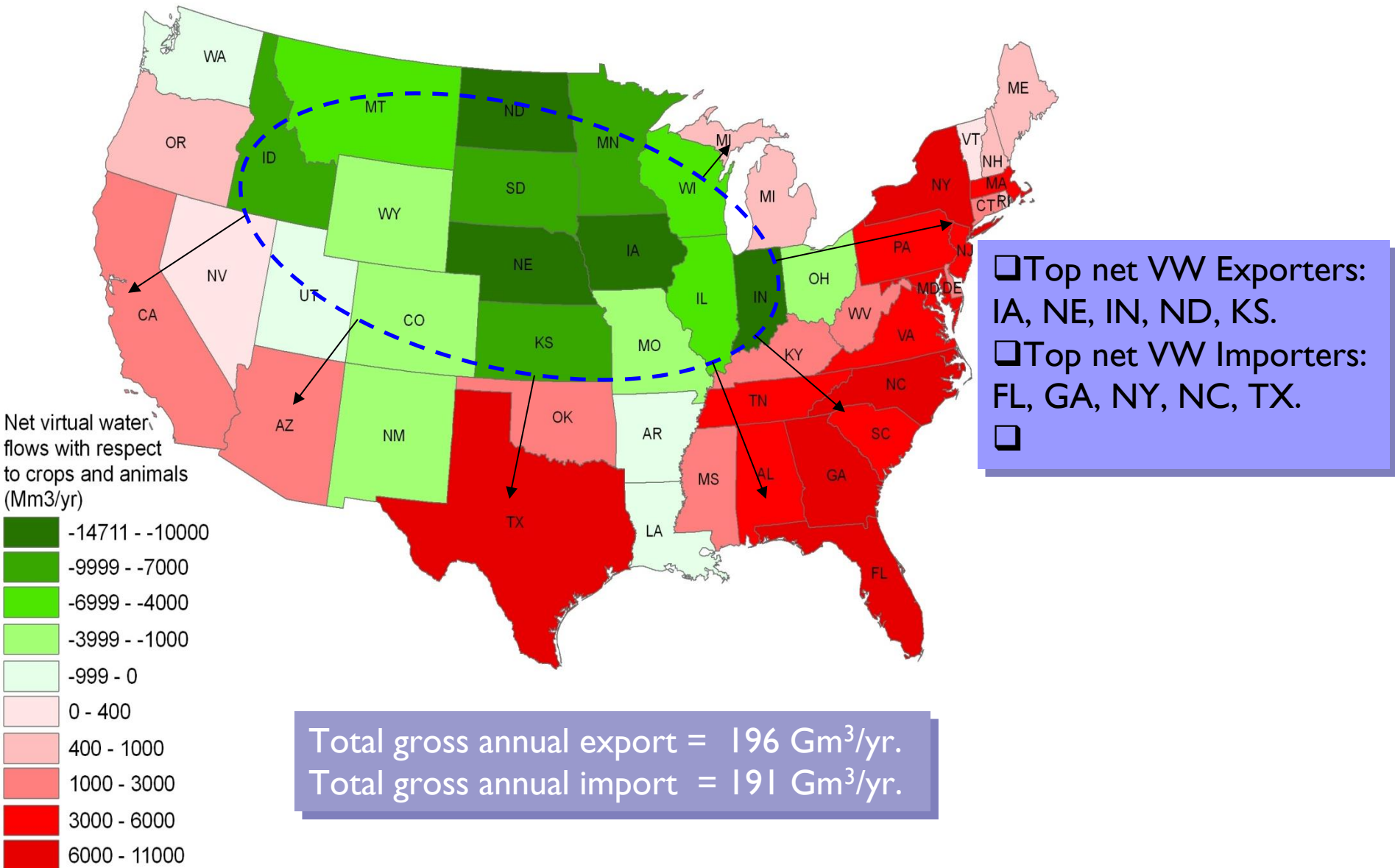
# Results: Net virtual water flows-Crops



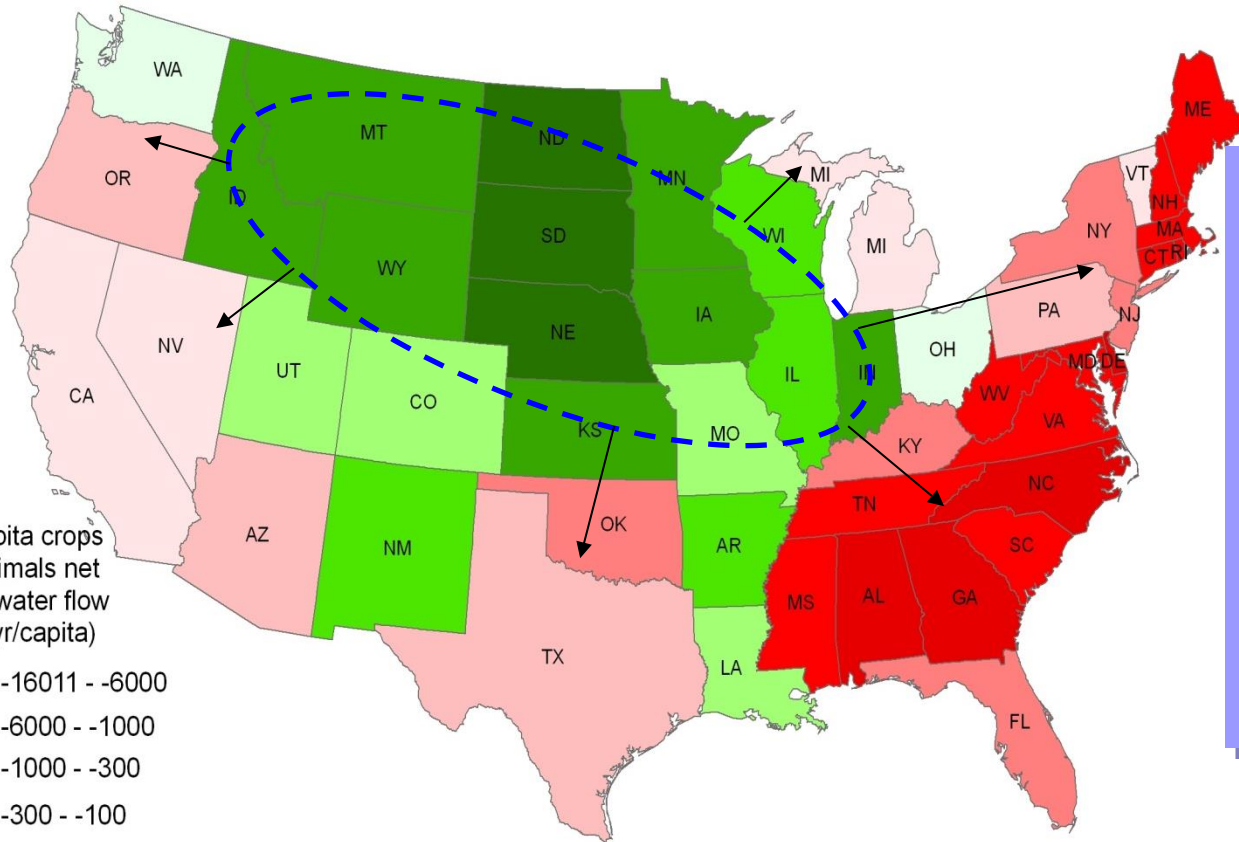
# Net virtual water flows-Animals



# Results: Net VWF-crops and animals



# Results: NVWF per capita-crops and animals



□ Top agricultural per capita NVWE: ND, SD (0.2% and 0.3% national population).

□ Top agricultural per capita NVWI: DE, AL (0.3% and 1.5% national population).

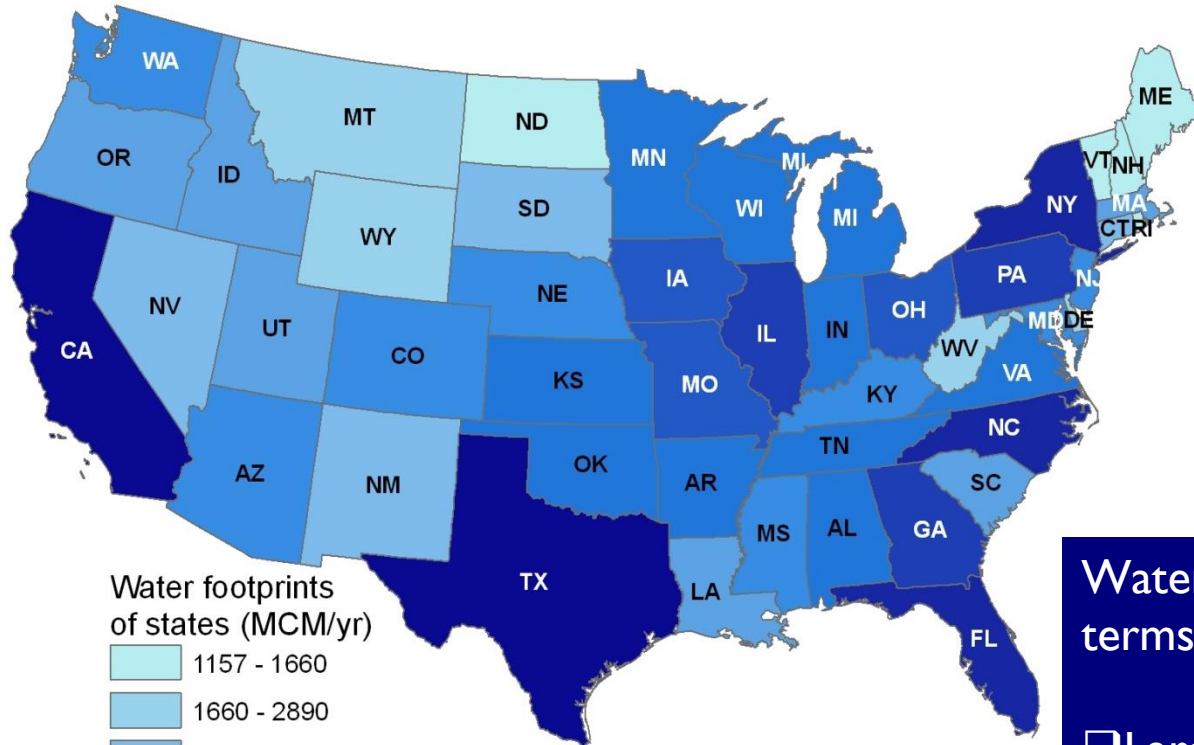


# Water footprints (WF) of U.S. States

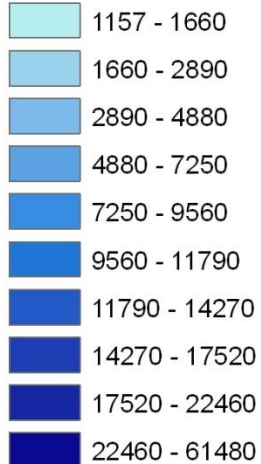
State	WF (Mm <sup>3</sup> /yr)	Rank	State	Per capita WF (m <sup>3</sup> /yr)	State	WF (Mm <sup>3</sup> /yr)	Rank	State	Per capita WF (m <sup>3</sup> /yr)
CA	61471	1	NE	4872	NE	8682	25	CA	1680
TX	42816	2	IA	4675	CO	8516	26	OR	1648
FL	22460	3	SD	4291	WA	8495	27	IN	1635
NY	21081	4	WY	4016	MD	8097	28	TN	1599
NC	19939	5	ID	3570	MS	7983	29	WV	1519
GA	17518	6	KS	3563	MA	7250	30	SC	1518
IL	16824	7	AR	3468	SC	6835	31	LA	1506
PA	16287	8	OK	3089	LA	6705	32	VA	1481
MO	14270	9	MT	2976	OR	6234	33	MD	1431
IA	13997	10	MS	2715	UT	5871	34	AZ	1395
OH	13554	11	DE	2456	ID	5453	35	IL	1310
MI	11786	12	NM	2454	NM	4876	36	NV	1310
MN	11785	13	MO	2396	CT	3978	37	PA	1296
VA	11546	14	AL	2299	SD	3452	38	WA	1294
WI	11468	15	ND	2267	NV	3428	39	ME	1254
OK	11256	16	MN	2253	MT	2881	40	FL	1219
AL	10752	17	VT	2212	WV	2756	41	MI	1178
IN	10445	18	NC	2156	DE	2152	42	OH	1176
TN	9976	19	UT	2152	WY	2140	43	NH	1167
KS	9968	20	KY	2039	ME	1655	44	CT	1136
AR	9946	21	WI	2038	NH	1542	45	MA	1108
NJ	9551	22	GA	1806	ND	1454	46	NJ	1102
AZ	9064	23	TX	1762	VT	1374	47	RI	1098
KY	8742	24	CO	1726	RI	1157	48	NY	1083

U.S.  
agricultural  
water  
footprint =  
509 Billion  
m<sup>3</sup>/yr = 1688  
m<sup>3</sup>/yr/capita.

## Water footprint of U.S. states in $\text{Mm}^3/\text{yr}$



### Water footprints of states (MCM/yr)



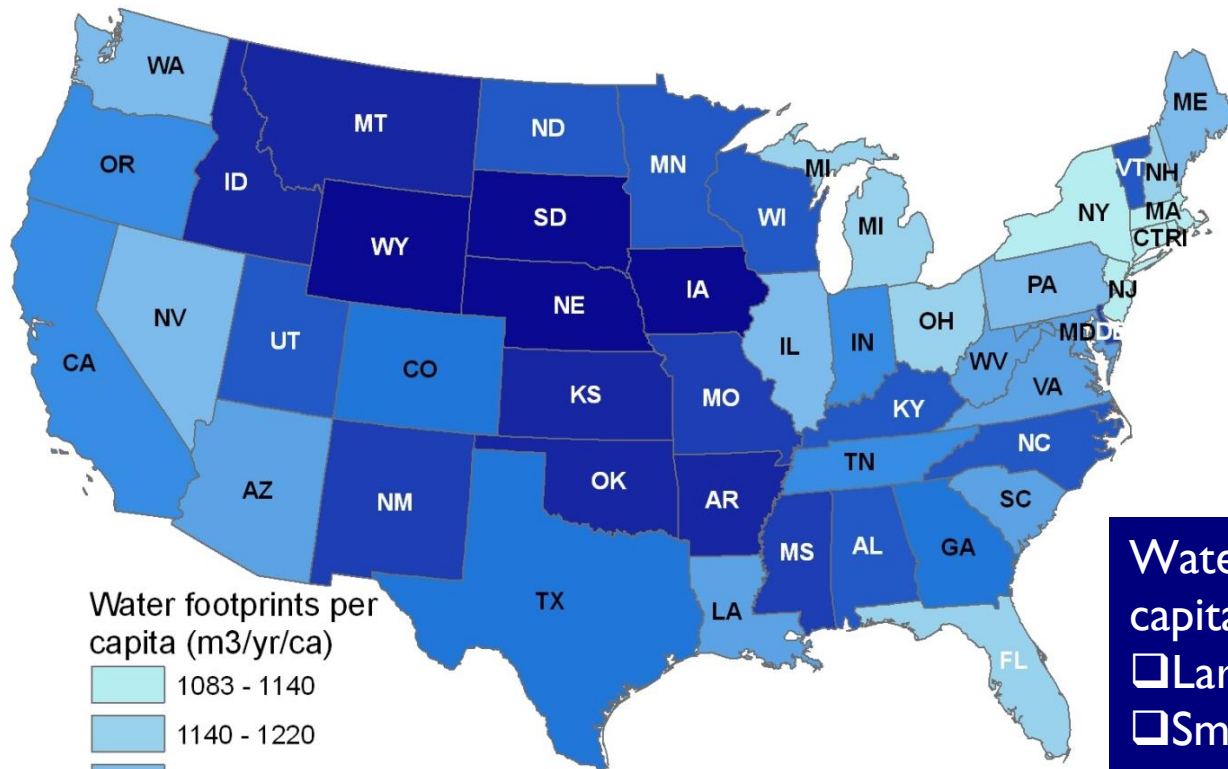
## Water footprint in absolute terms.

□ Largest: CA, TX, FL, NY, NC, GA

❑Least: ME, NH, ND, VT, RI.



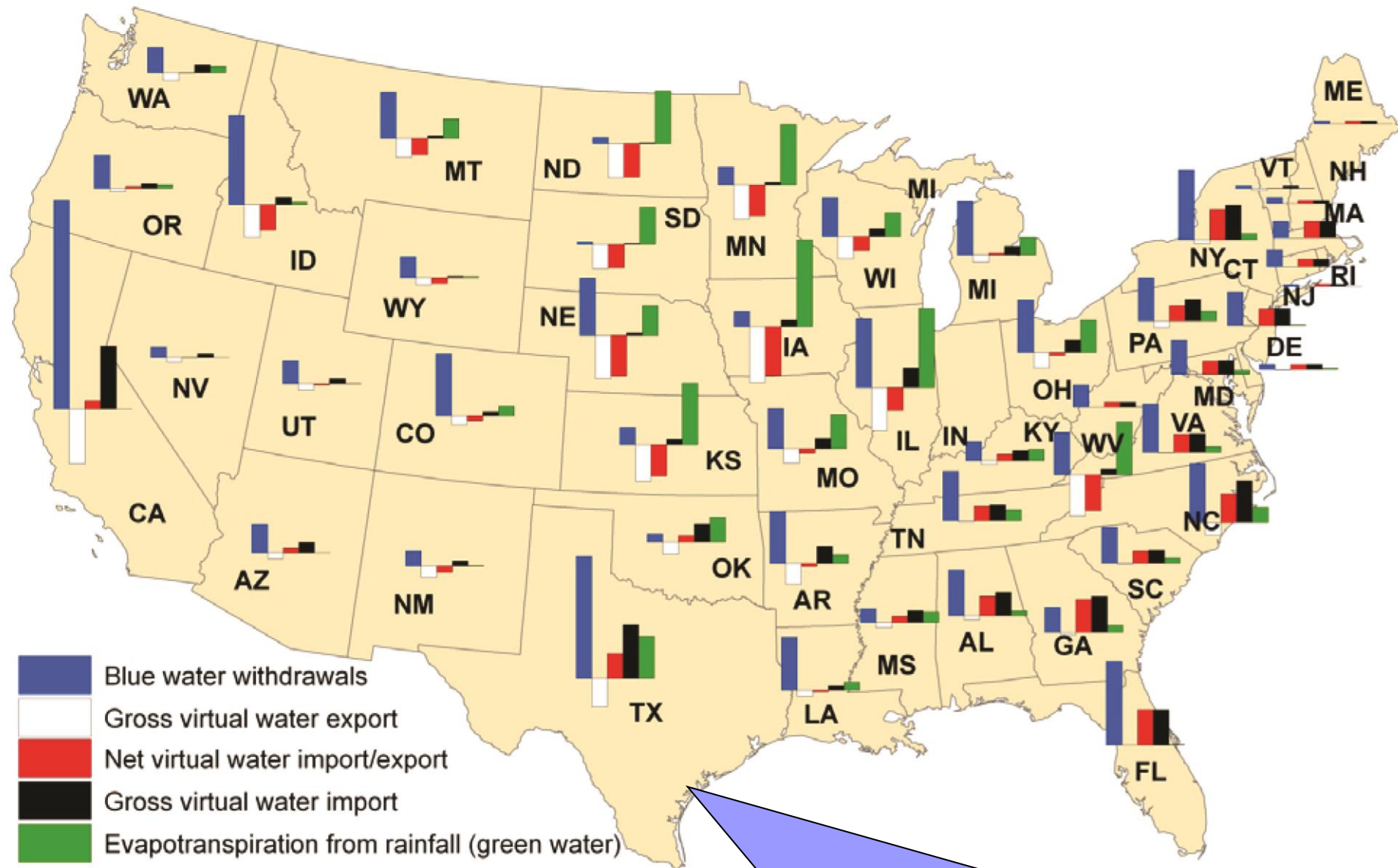
# Water footprint of U.S. states in $\text{Mm}^3/\text{yr}/\text{ca}$



Water footprint per year per capita

□ Largest : NE, IA, SD, WY, ID  
□ Smallest: CT, MA, NJ, RI, NY.

# VW volumes vs Blue & Green water



**Total U.S. NVWE:** <1% withdrawals; <2% green water use; <1% total water footprint→ national totals dwarfed by illustrated interstate VWFs



# Research questions

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2. What component of this is blue vs green water?
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# What are the implications?

1. Despite its large water footprint per capita ( $1688 \text{ m}^3/\text{yr}$ ), the U.S. is the leading net virtual water exporting country (5 billion  $\text{m}^3$ ), but this masks interstate flows of 191 billion  $\text{m}^3$  per year of virtual water, larger than withdrawals in many states.
2. VW flows primarily from the rural, agricultural north-central region, to populous urban Atlantic coast states. This mirrors international trends and can be explained partly as comparative advantage, with soil as a complementary resource to water.
3. The southwest is nearly VW neutral, but could become a major net VW importer, like Atlantic coast states, by scaling back irrigation and increasing food imports. This would reduce water footprint as well and is a viable option for dealing with increasing water scarcity, population growth, and climate change.

# End – Thank You.

## Selected References

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