Environmental Concerns/Limits on Withdrawal for Sustainable Irrigation in Alabama (and Georgia)

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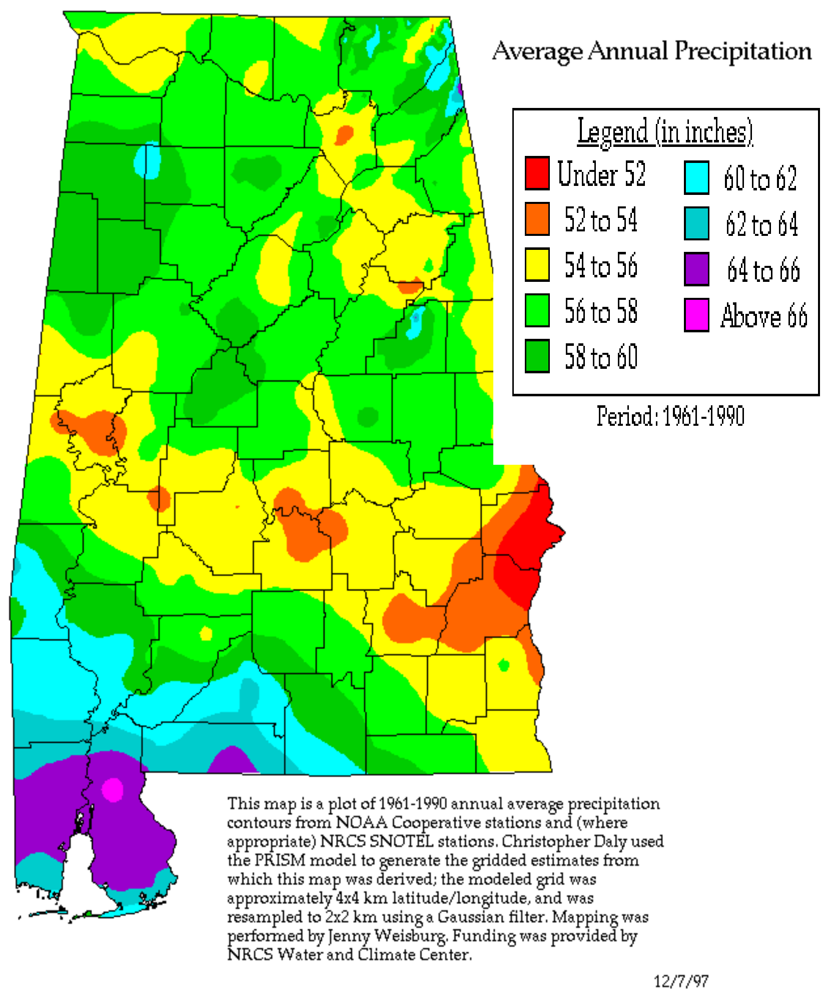
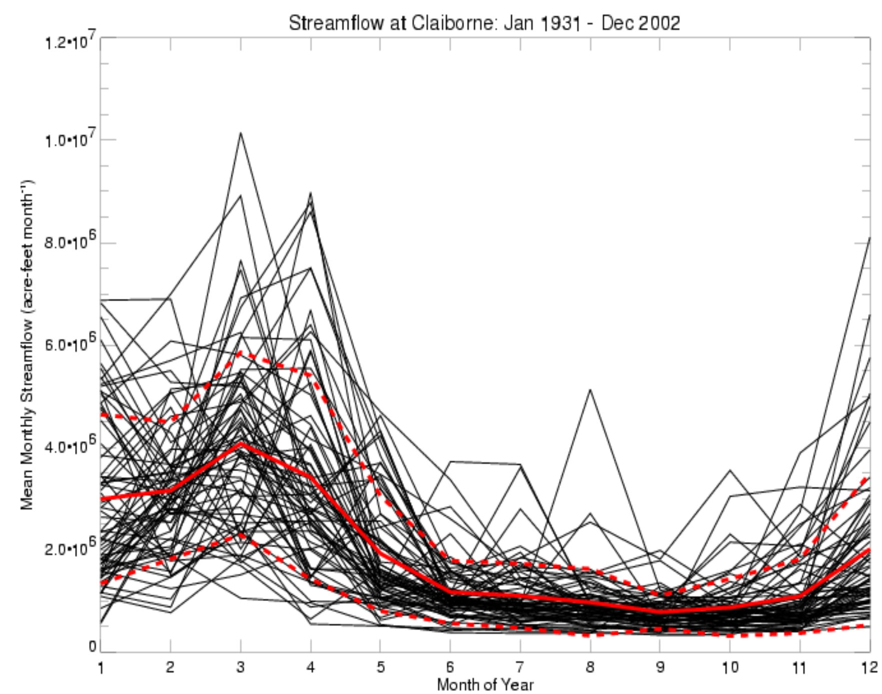
Climatology of the Southeast



- Average annual precipitation in Alabama 55 inches
- Water generally not available during growing period
- Intra- and inter-annual variability in rainfall and stream flows



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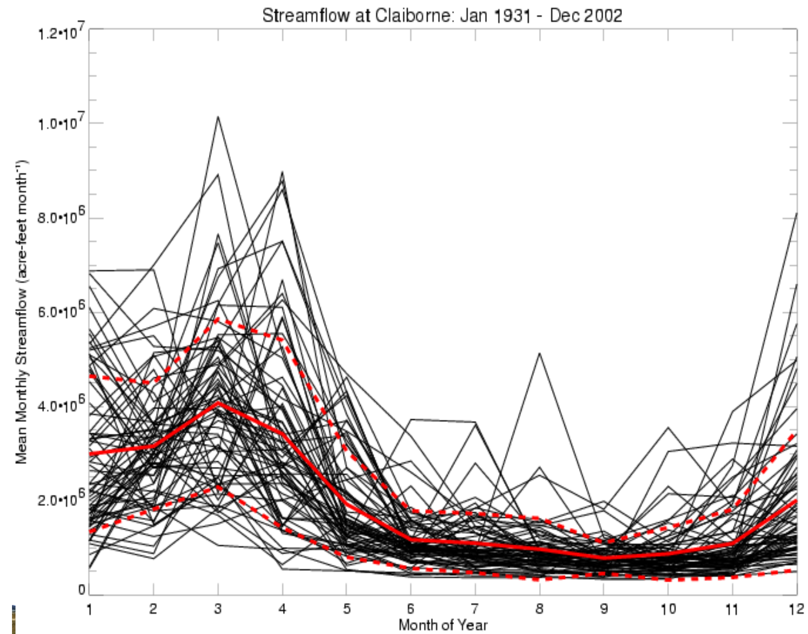
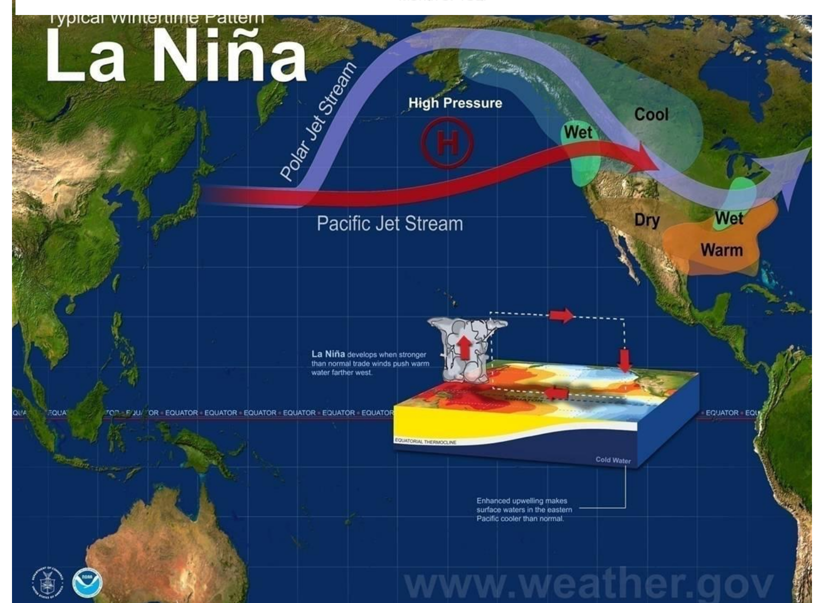
Climate Variability in the Southeast

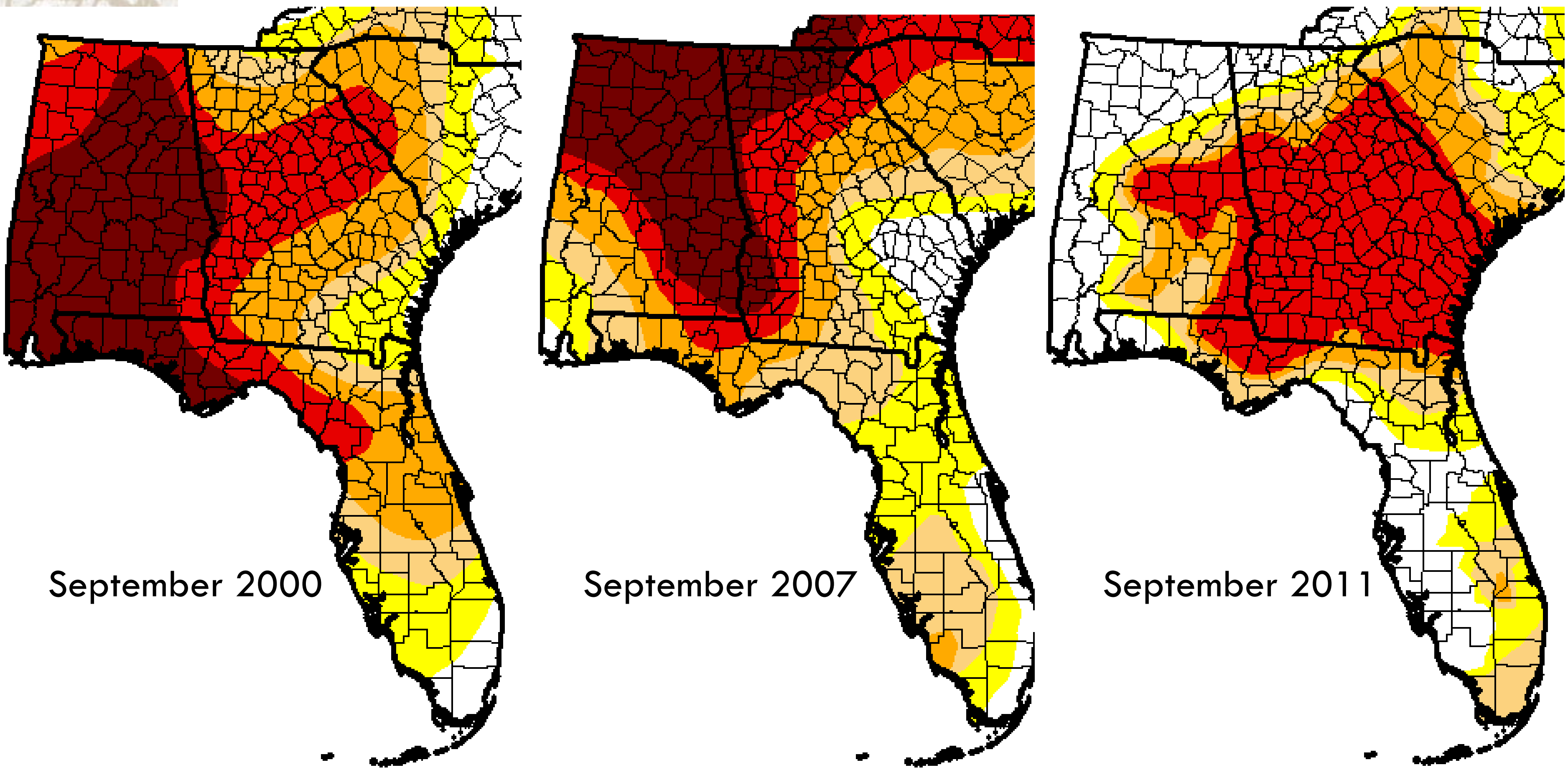
- Even in winter months, quite a bit of precipitation and temperature variability
- In the Southeast, precipitation, stream flow and consequently water availability is greatly affected by El Niño Southern Oscillation (ENSO)
- Short-term fluctuations (years to a few decades)

  ENSO, Pacific Decadal Oscillation (PDO), North Atlantic Oscillation (NAO), Atlantic Multi-decadal Oscillation (AMO)
- La Niña phase of ENSO brings warm and dry conditions (e.g., 1999 – 2001, 2007, 2010-2012) in the Southeast, especially in winter





Drought in the Southeast

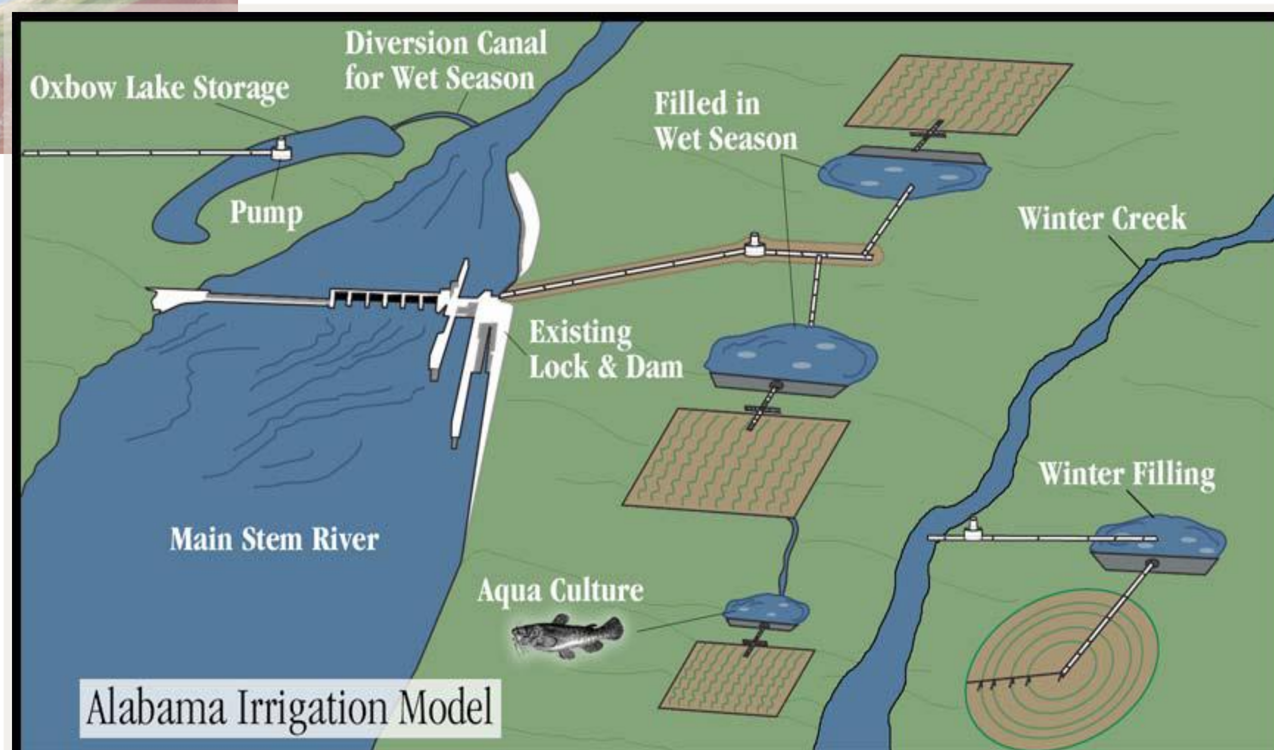


Drought is a recurring phenomenon in the Southeast

Conceptual framework – surface water withdrawal

- Withdrawal of water during the summer when stream flows are small can potentially harm stream ecology and reduce the dilution capacity of streams.
- Withdraw water in winter months to irrigate in summer months

In many areas a 15 acre pond ten feet deep can be constructed for less than $300,000.



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Criteria for Ecologically-Sustainable Flows

USEPA and U.S. Fish & Wildlife Service

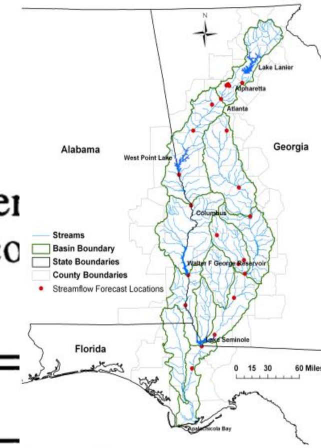
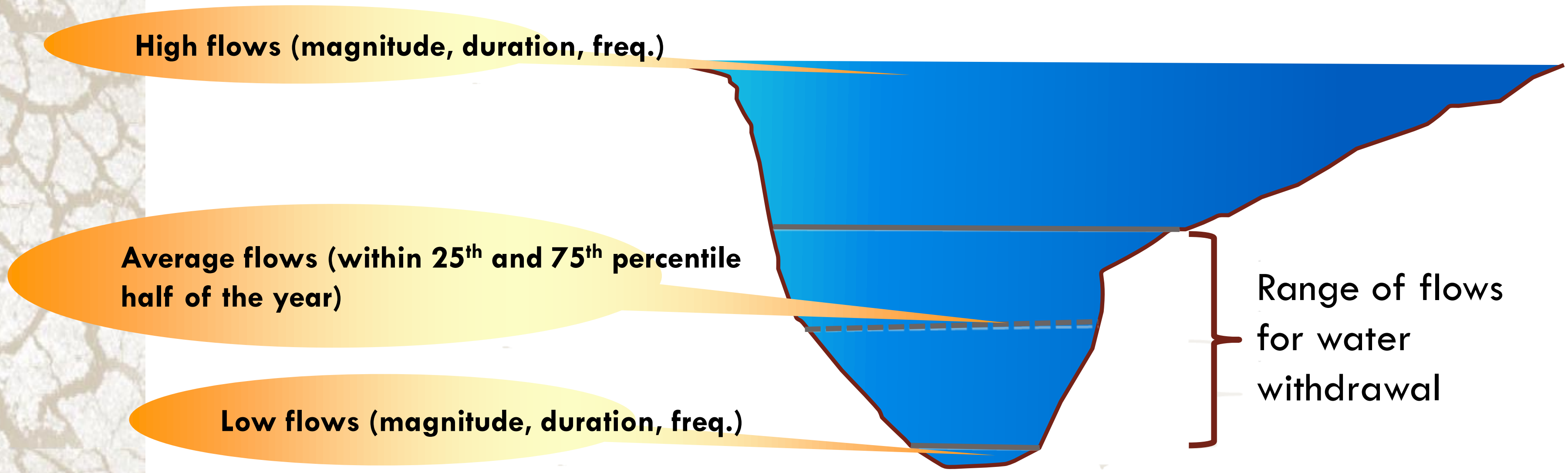


TABLE 1. Federal environmental agencies have defined ecosystem flow requiremen necessary to sustain viable populations of endangered species in the Apalachico hoochee–Flint River basin in Alabama, Florida, and Georgia.

Flow parameter	Guidelines based on pre-dam flows
Monthly 1-day minima	exceed the minimum in all years exceed the 25th percentile in 3 out of 4 years exceed the median in half of the years
Annual low-flow duration	do not exceed the maximum in all years do not exceed the 75th percentile in 3 out of 4 years do not exceed the median in half of the years
Monthly average flow	maintain the monthly mean flow within the range of the 25th and 75th percentile values in half of the years
Annual 1-day maxima	exceed the minimum in all years exceed the 25th percentile in 3 out of 4 years exceed the median in half of the years
Annual high-flow duration	exceed the minimum in all years exceed the 25th percentile in 3 out of 4 years exceed the median in half of the years

Ecologically-Sustainable Water Withdrawal



Limits on withdrawal for sustainable irrigation in Alabama

How much water can we withdraw while maintaining ecologically-sustainable flows?

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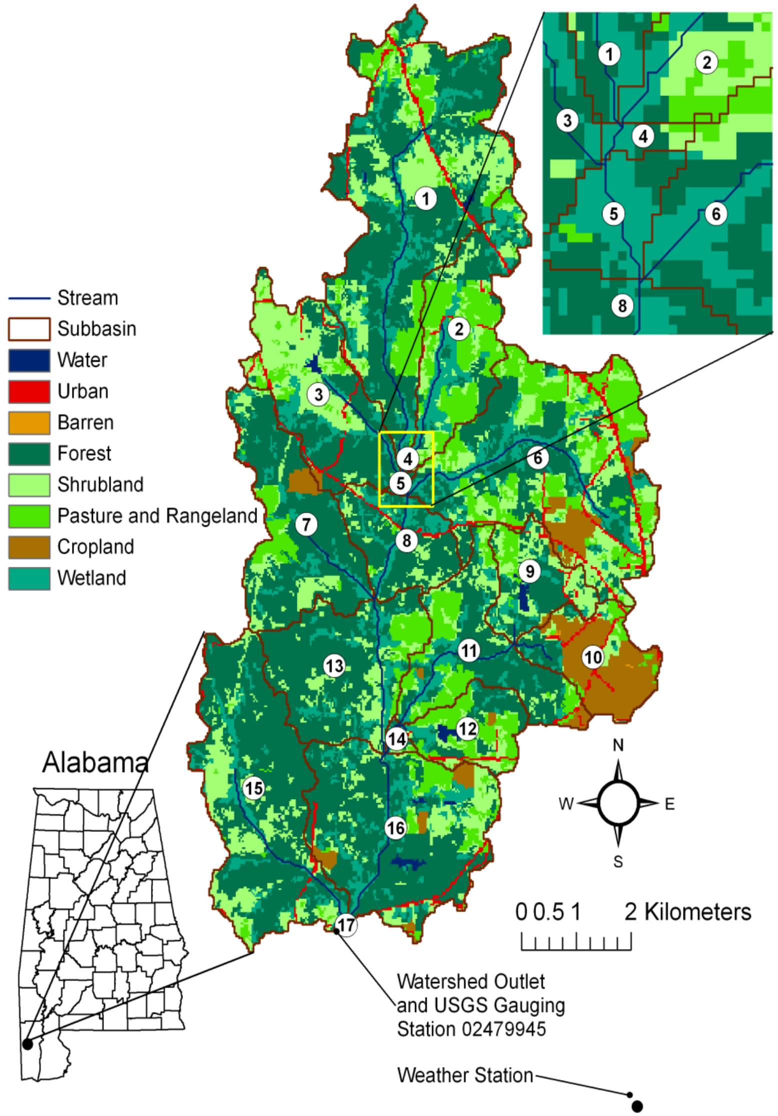
A case study of ecologically-sustainable water withdrawal

- Big Creek Watershed – a sub-watershed of Lake Converse Watershed located in Mobile County, South Alabama
- Area 31.5 sq. mi. (20,160 ac)
- Mostly in forest, pasture, and rangeland
- SWAT (Soil and Water Assessment Tool) was used for simulating stream flows at the sub-watershed outlets
- Daily flow simulations



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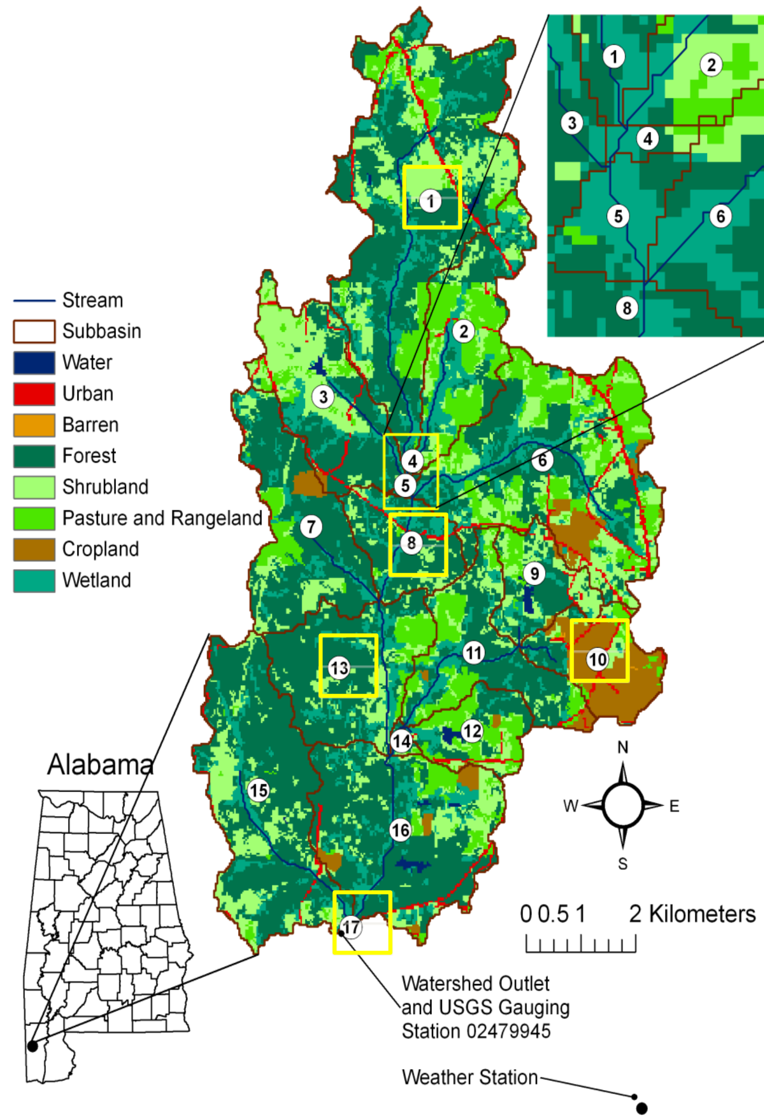
- Sub-basins evaluated
  - Sub-basins 1 and 10 – 1st order stream
  - Sub-basins 4, 8, and 13 – 2nd order stream
  - Watershed outlet – 3rd order stream
- Water needed for irrigation - 1.5 ac-ft (or 18 inches) for each acre of cropland



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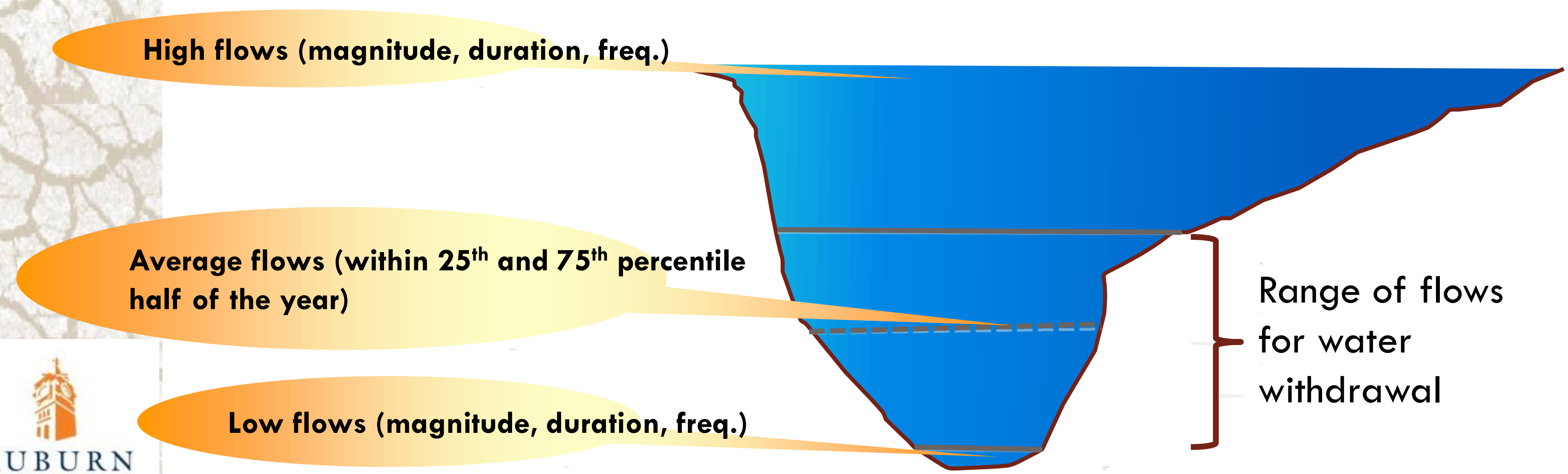
Strategy for Surface Water Withdrawal

- Withdrawal only in winter months (Dec – April)
- Do not withdraw when daily flows are at or below 25th percentile
- During generally high flows withdrawal on those days on which flows do not drop below 25th percentile
- During very high flows (about 95th percentile) withdraw 10-15% of the flow while not letting the flows drop below 25th percentile
- Withdrawal optimized to get potentially maximum withdrawal



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1st Order Streams 1 (3,455 ac) and 10 (770 ac)

Water year	Winter month precipitation[a] (mm)	Annual precipitation (mm)	Sub-basin 1			Sub-basin 10		
			Annual flow volume (million m^3)	Water withdrawn (million m^3)	Percentage of sub-basin irrigated[b]	Annual flow volume (million m^3)	Water withdrawn (million m^3)	Percentage of sub-basin irrigated[b]
1992	824.3	1653.0	10.3	1.2	18.7	2.3	0.2	15.9
1993	872.2	2122.2	13.5	1.6	24.3	3.4	0.3	20.8
1994	551.2	1508.6	8.2	0.3	4.2	2.0	0.2	13.7
1995	837.8	1743.2	11.2	1.4	21.6	2.6	0.3	18.7
1996	1141.4	2012.9	14.3	1.8	27.9	3.4	0.4	27.9
1997	697.7	1520.5	8.3	0.4	5.6	1.8	0.1	9.5
1998	853.9	1955.6	13.7	1.4	21.5	2.9	0.3	18.6
1999	469.9	1042.0	7.4	0.4	5.5	1.5	0.2	12.3
2000	390.2	911.4	4.4	0.1	1.6	0.4	0.0	2.7
2001	426.5	1327.9	7.4	0.2	3.5	1.3	0.1	7.3
2002	368.2	989.0	4.8	0.1	1.5	0.7	0.0	2.1
2003	565.2	1852.3	10.9	0.5	8.1	2.7	0.2	13.1
2004	516.6	1471.7	8.8	0.4	5.6	2.0	0.2	15.0
2005	722.7	1888.8	12.2	0.6	8.9	2.9	0.2	15.4
2006	359.1	923.3	5.3	0.1	1.7	0.9	0.1	6.3
2007	451.1	1263.6	7.2	0.3	3.9	1.3	0.1	8.8
Average	628.0	1511.6	9.2	0.7	10.2	2.0	0.2	13.0

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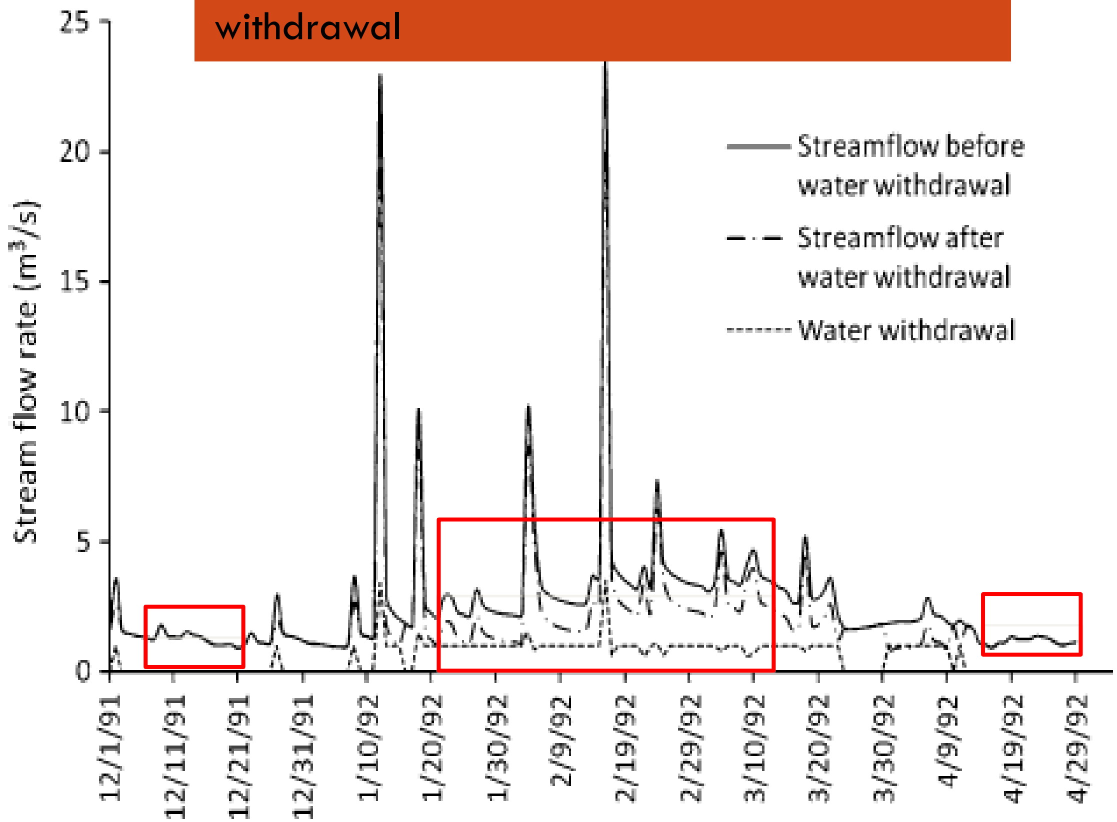
- Similar results for 2nd order streams [4 (4,720 ac), 8 (9,687 ac), and 13 (12,490 ac)] and 3rd order stream at the watershed outlet (20,160 ac)

Sub-basin	Percentage of sub-basin irrigated	Percentage of annual flow withdrawn
1	10.2	7.6
10	13.0	10.0
4	10.2	7.0
8	10.2	7.0
13	10.5	7.3
Watershed Outlet	10.6	7.4

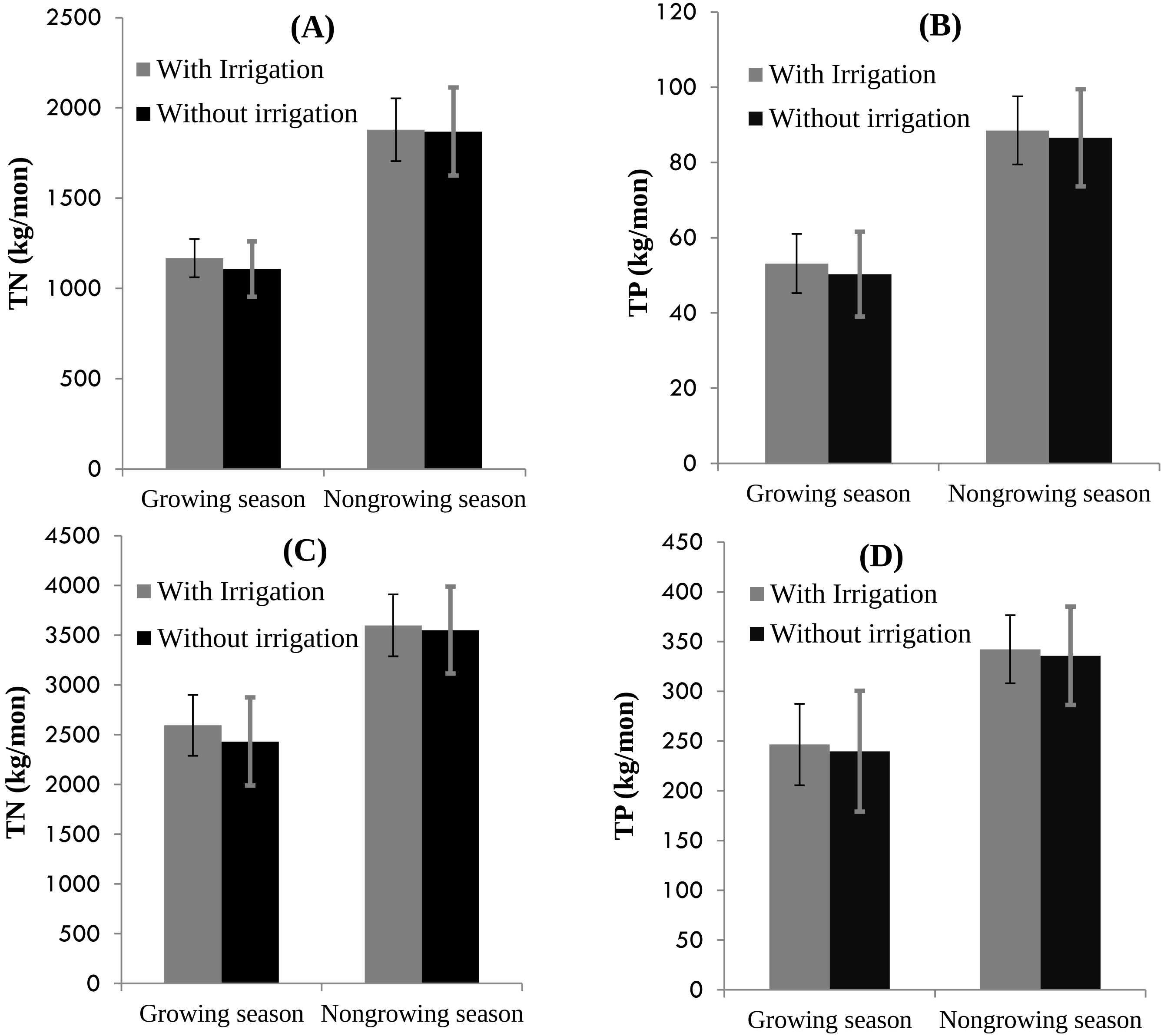
Mean daily stream flow rate before and after water withdrawal and water withdrawal



Water Quality Impacts of Increased irrigation

(A) and (B) – Current watershed condition

(C) and (D) – increased cropland



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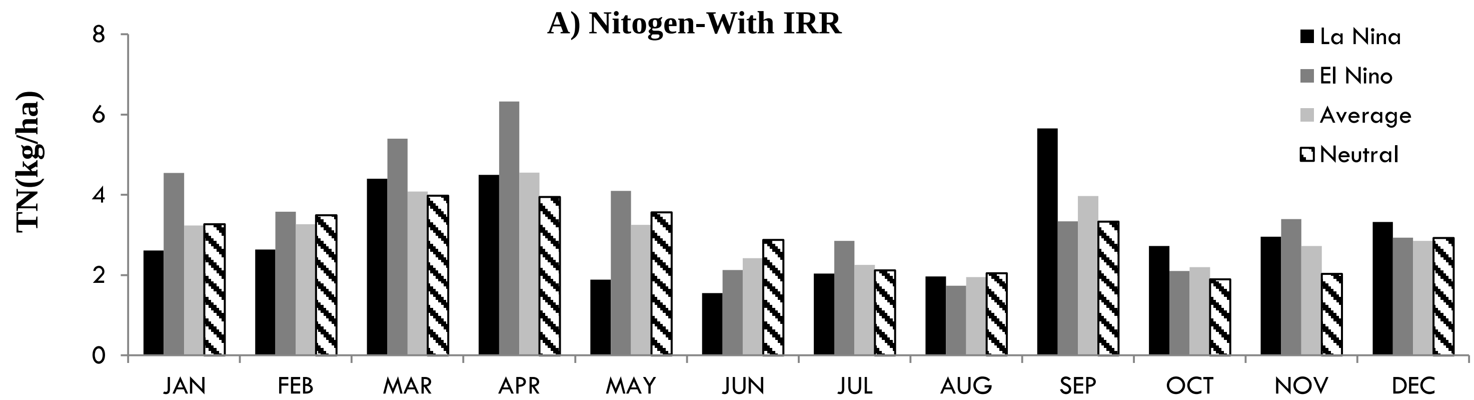
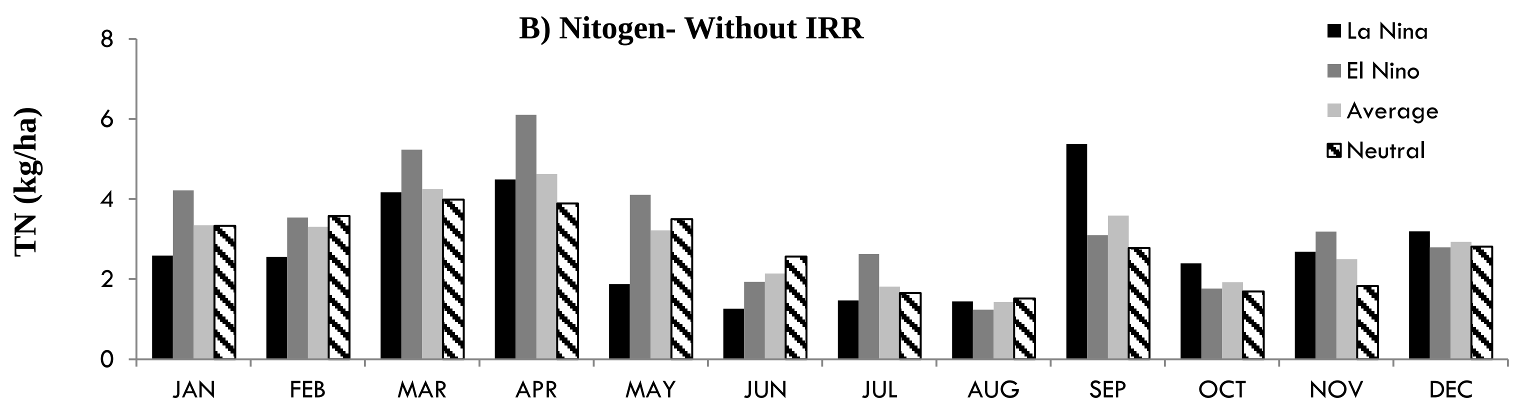
Water Quality Impacts of Increased irrigation





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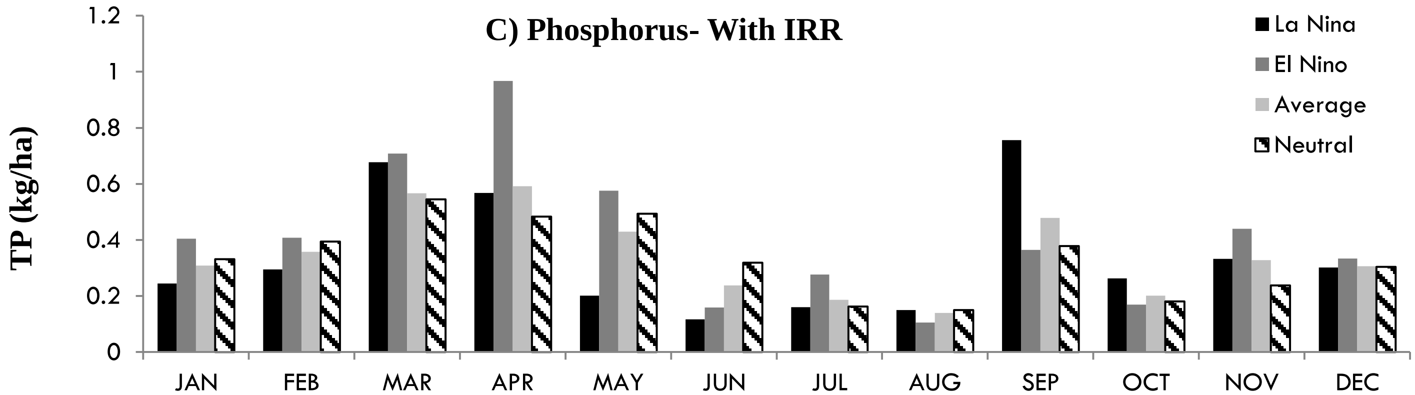
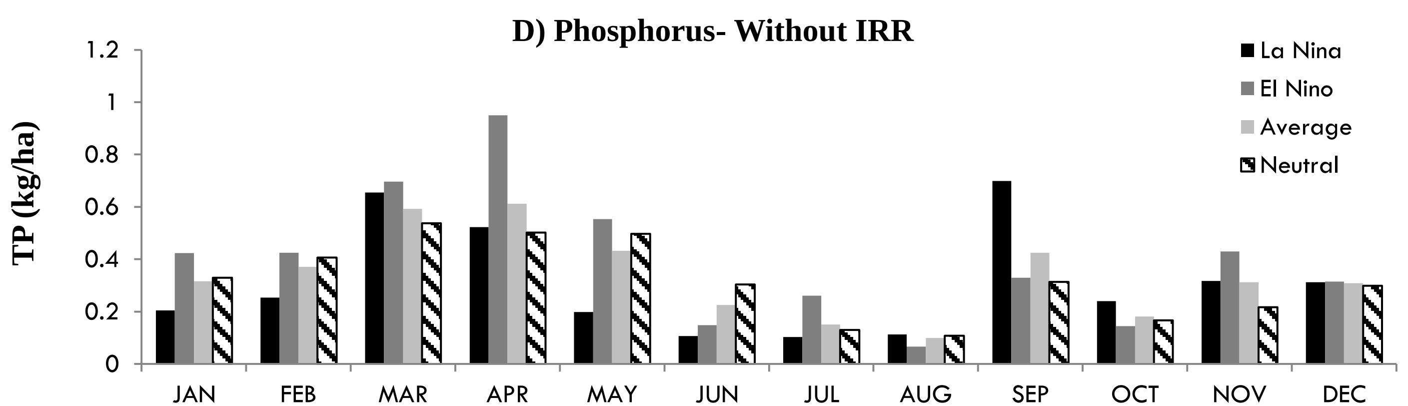
Water Quality Impacts of Increased irrigation





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A case study of ecologically-sustainable water withdrawal

Conclusions

- On an average, through ecologically-sustainable surface water withdrawal during winter about 10% area of a watershed (16 year average) can be irrigated (18 in per acre rate).
- In wet years, up to 28% of a watershed area can be irrigated.
- In dry years (La Niña), which are fairly common in Alabama, very little or no water can be withdrawn for irrigation.
- Water cannot be withdrawn at a constant rate throughout the winter months.

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Conclusions

- Interesting result – stream order is less important
  - You would be able to irrigate only about 10% of watershed area.
- Reservoirs should be designed to hold more than required water, to store more water in wet years for use in dry years.
- Nitrogen and phosphorus loads will increase – mainly because of increased cropland acreage.
- Nutrient loads followed the precipitation and stream flow trends in different ENSO phases.
- Application of nutrients can be modified using ENSO forecasts to reduce nutrient transport.

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- What about year around water withdrawal (not just winter months) while considering climate variability?

- Can we ecologically-sustainably withdraw more water?

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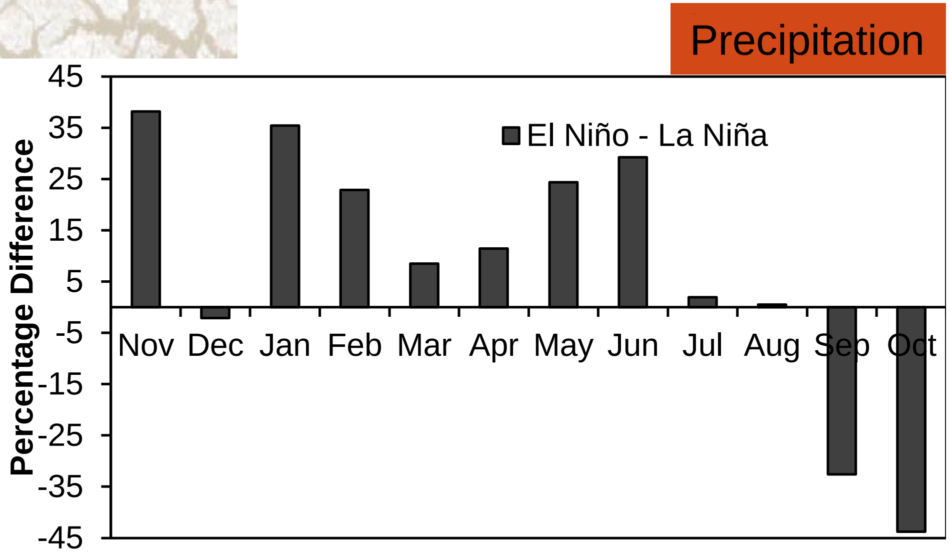

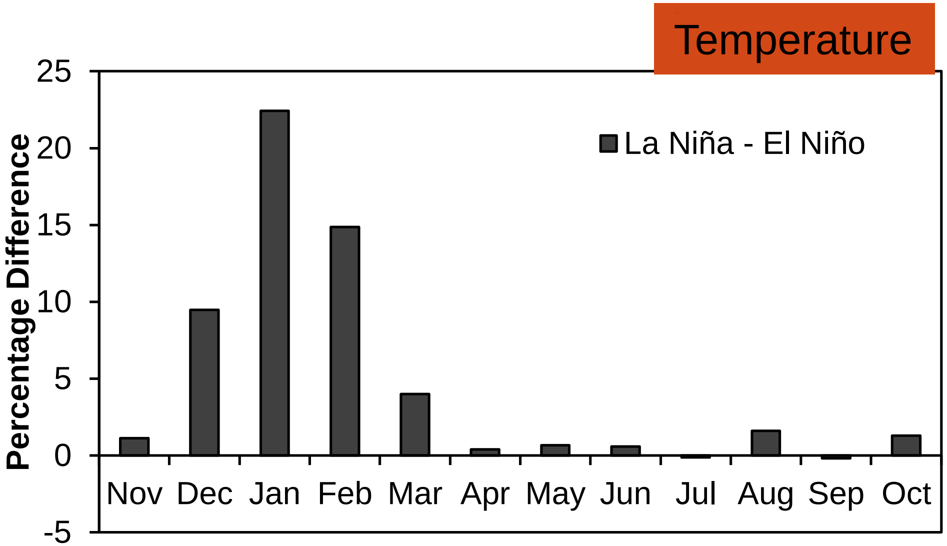

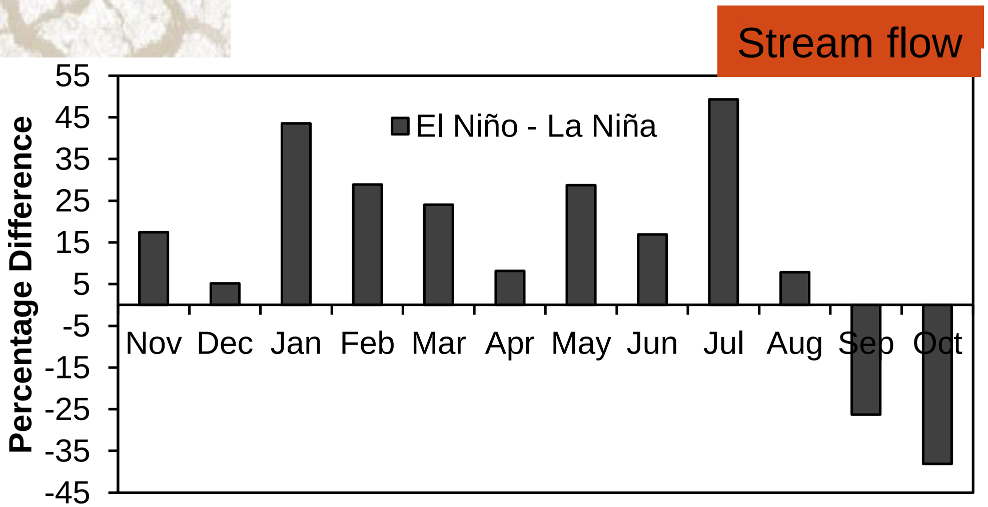

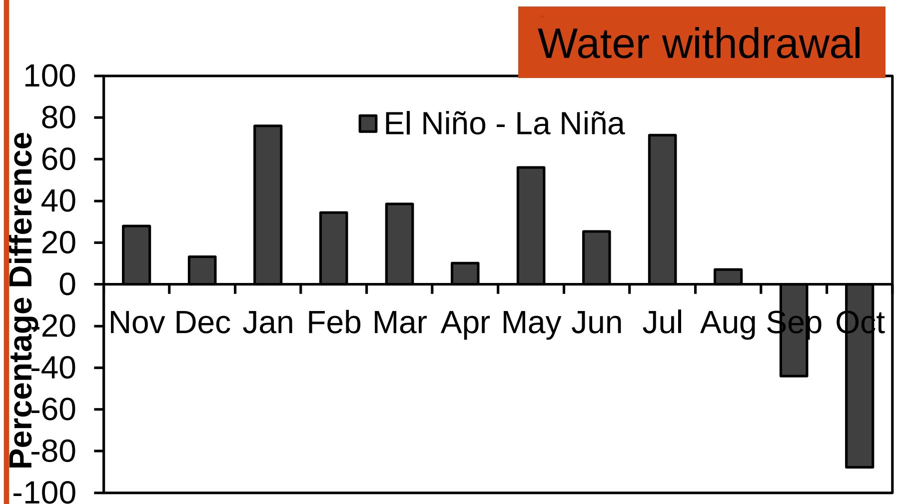

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Year around ecologically-sustainable water withdrawal

Sub-basin	Stream Order	Drainage Area (ac)	Mean Annual Flow Volume 10^6 m^3 (10^3 ac-ft)	Mean Annual Water Withdrawn 10^6 m^3 (10^3 ac-ft)	Mean Percentage of Annual Flow Withdrawn	Mean Percentage of Sub-basin Irrigated*
1	First	3,455	8.3 (6.7)	1.5 (1.2)	16.2	23.0
4	Second	4,270	11.4 (9.2)	1.7 (1.4)	14.0	19.9
8	Second	9,687	23.3 (18.9)	3.5 (2.8)	13.9	19.6
13	Second	12,490	30.4 (24.6)	4.7 (3.8)	14.6	20.5
17	Third	20,160	51.7 (41.9)	8.1 (6.6)	14.6	21.7
				Average	**14.7**	**20.9**

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A case study of ecologically-sustainable water withdrawal

Conclusions

- In this watershed, and most likely in much of South Alabama, El Niño months result in more precipitation than La Niña months in much of the year except July to October.
- Correlation of ENSO with stream flow is more prominent than precipitation.
- Watershed area that can be irrigated in any given water year ranged from as high as 45.3% to as low as 1.8%.
- On an average about 20% of a watershed area can be irrigated.
- This finding is also independent of stream order.

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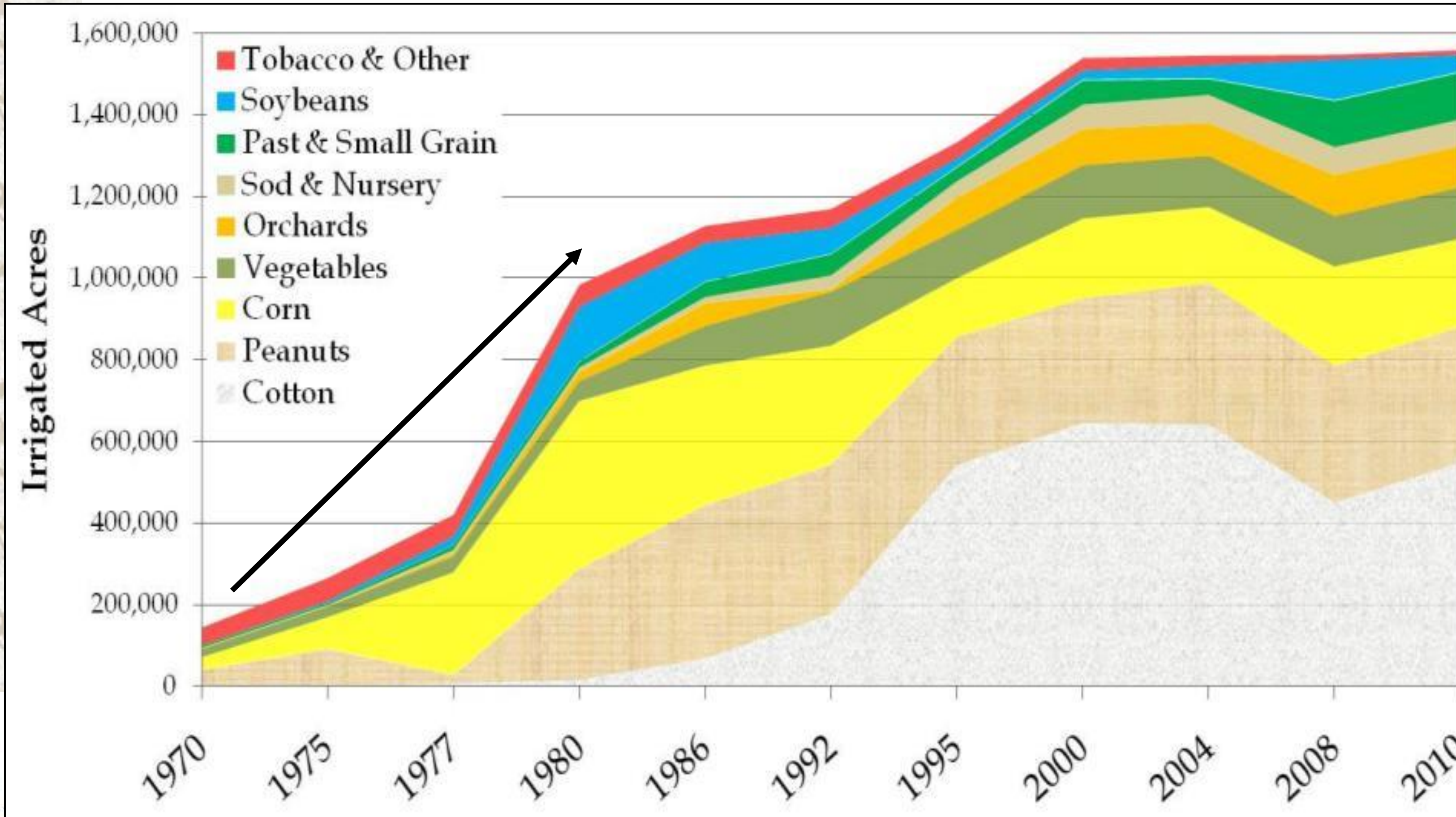
Impact of Uncontrolled Irrigation in Southwest Georgia

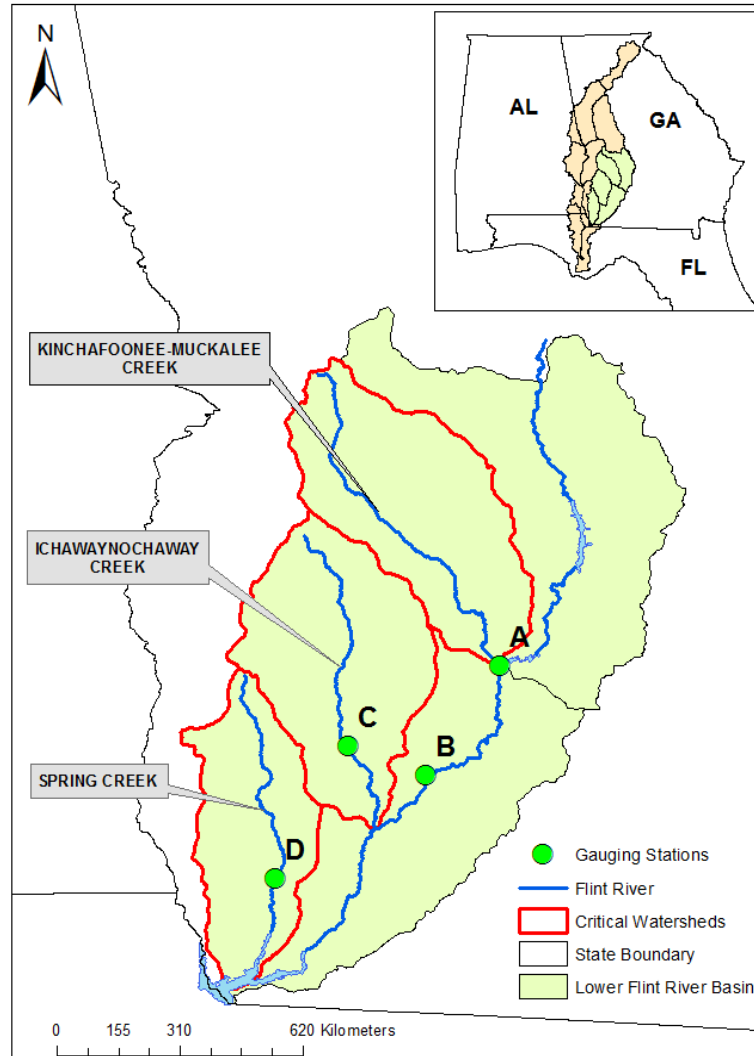
Extensive implementation of center pivot irrigation system occurred between 1970 and 1980 in SW Georgia



Impact on Streamflows

USGS Station ID	Location	Given Name	Data Range (Year)
02352500	Flint River, Albany, GA	A	1930-2014
02353000	Flint River, Newton, GA	B	1957-2014
02353500	Ichawaynochaway Creek, Milford, GA	C	1940-2014
02357000	Spring Creek, Iron City, GA	D	1938-2070 and 1983-2014

- Monthly streamflow data were sorted according to irrigated (from 1976) and non-irrigated period (before 1976).
- The JRFit procedure was used to test and quantify significant difference.



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Impact on Streamflows

Non-Irrigation (before 1976) and Irrigation Analysis (after 1976)

Station ID	NI (m^3/s)	IR (m^3/s)	% difference NI to IR	p- value
A	124.48	103.89	-17	0.000
B	150.48	120.59	-20	0.000
C	17.23	13.87	-19	0.000
D	7.50	6.58	-12	0.036

ENSO and Irrigation Analysis

Station ID	El Niño				La Niña			
	NI (m^3/s)	IR (m^3/s)	% change NI to IR	p-value	NI (m^3/s)	IR (m^3/s)	% change NI to IR	p-value
A	135.81	135.00	-1	0.901	104.96	92.06	-12	0.01
B	144.03	148.43	3	0.479	162.32	106.56	-34	0.00
C	17.27	17.77	3	0.543	15.63	11.68	-25	0.00
D	8.25	10.28	25	0.126	4.20	3.56	-15	0.30

Non-Growing Period Analysis

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Streamflow Analysis

Station ID	Non-Growing			
	NI	IR	% change NI to IR	p-value
A	180.58	169.77	-5.99	0.093
B	208.86	182.46	-12.64	0.073
C	23.81	22.06	-7.36	0.013
D	11.12	12.12	9.02	0.279

ENSO

Station ID	El Niño				La Niña			
	NI	IR	% change NI to IR	p-value	NI	IR	% change NI to IR	p-value
A	195.04	216.79	11.15	0.055	123.71	125.87	1.75	0.823
B	192.09	217.12	13.03	0.215	205.81	151.98	-26.15	0.101
C	22.21	25.56	15.09	0.019	17.75	15.79	-11.08	0.086
D	12.54	21.23	69.28	0.006	3.95	5.33	34.96	0.173

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Growing Period Analysis

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Streamflow Analysis

Station ID	Growing			
	NI	IR	% change NI to IR	p-value
A	105.83	79.66	-24.74	0.000
B	130.12	96.82	-25.59	0.000
C	14.97	10.86	-27.47	0.000
D	6.31	4.55	-27.86	0.001

ENSO

Station ID	El Niño				La Niña			
	NI	IR	% change NI to IR	p-value	NI	IR	% change NI to IR	p-value
A	101.62	88.71	-12.71	0.026	93.69	63.34	-32.40	0.000
B	120.00	106.70	-11.08	0.067	155.01	75.36	-51.39	0.000
C	13.12	11.71	-10.76	0.127	14.65	8.07	-44.90	0.001
D	5.68	5.98	5.29	0.606	4.40	2.07	-52.97	0.001

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Conclusions

- The analysis of non-irrigation (NI) and irrigation (IR) period showed that since 1970's overall streamflow and baseflow levels have reduced substantially in the lower Flint River and its tributaries.
- Due to irrigation, tributaries have changed from perennial stream to intermittent which suggests that groundwater withdrawal has intensified the extreme low flows in this region.
- Leads to concerns related to flow and habitat requirements for the endangered mussel species in the Flint and Apalachicola River Basins
- Reduced flows also lead to salinity and oyster fisheries issues in the Apalachicola Bay.

Overall Conclusions

- With irrigation water withdrawals in winter monthly only, about 10% of the watershed area can be ecologically sustainably irrigated.
- Independent of stream order.
- Water quality will be impacted mainly because of increased cropland acreage not because of increased irrigation.
- Through year-around water withdrawal following ENSO phases, 20% of watershed area can be ecologically sustainably irrigated.
- Again, increased cropland area would leave some water quality impact.
- Uncontrolled irrigation will leave impacts similar to what is observed in southwest Georgia (endangered mussel species, salinity, oyster fisheries, etc.)

Take home

- Limits on water availability will be put on by climate and environmental flow needs.

- Dealing with climate, environmental and, subsequently, water availability issues should not be an afterthought.

- For a sustainable solution to food and energy security, these issues need to part of the solution from the very beginning.

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