Changes in the fate of pesticides used in cotton production systems under potential climate change

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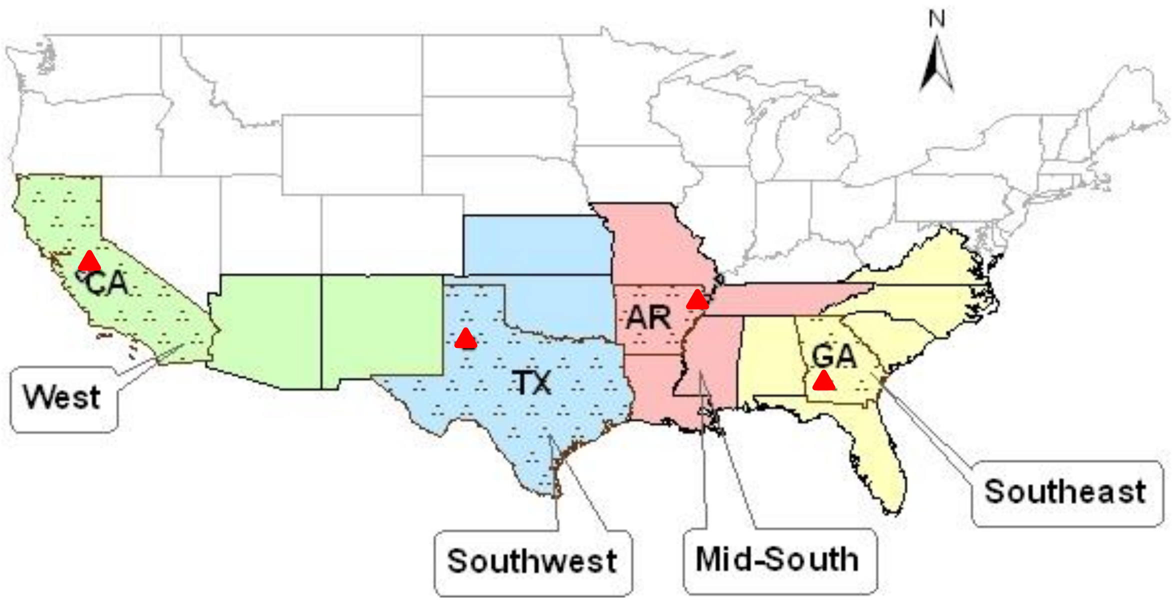
Cotton is One of the Highest Pesticide Use Systems

The following is a sample of acaricides, insecticides & herbicides used on cotton:

2, 4-D (H)	Endothall (H)	Monocarbamide (H)
Abamectin (I)	Ethephon (H)	MSMA (H)
Acephate (I)	Etoxazole (A)	Novaluron (I)
Acetamiprid (I)	Fipronil (I)	Oxamyl (I)
Aldicarb (I)	Flonicamid (I)	Paraquat (H)
Bacillus aureus (I)	Flumioxazin (H)	Pendimethalin (H)
Bifenthrin (I)	Fomesafen (H)	Profenofos (I)
Carfentrazone-ethyl (H)	Glyphosate (H)	Pyraflufen-ethyl (H)
Chlorpyrifos (I)	Glufosinate (H)	Pyrithiobac-sodium (H)
Cyclanilide (PGR)	Imidacloprid (I)	S-Metolachlor (H)
Cyfluthrin (I)	Indoxacarb (I)	Sodium chlorate (H)
Cypermethrin (I)	Lambda-cyhalothrin (I)	Thiamethoxam (I)
Dicamba (H)	Malathion (I)	Thidiazuron (PGR)
Dicofol (A)	Mepiquat chloride (PGR)	Tribufos (I)
Dicrotophos (I)	Methyl parathion (I)	Trifluralin (H)
Diuron (H)	Metolachlor (H)	Zeta-cypermethrin (I)

Objectives

- Evaluate the potential environmental impact of cotton production systems under climate change:
  - Develop EPIC simulations for four cotton production regions using data collected by and in collaboration with Cotton Incorporated staff.
  - A representative area was chosen from each region
  - Three representative soils were chosen for each area



Input Data Source

Data type	Source
Soils	Soils_5 database, National Soil Survey Laboratory
Crop Management	USDA-Economic Research Service, Natural Resource Survey Regional Summary, USDA Ag Census, Farm and Ranch Survey, and numerous regional cotton specialists and producers.
Weather (precipitation and temperature)	Geophysical Fluid Dynamics Laboratory's CM2 climate model under the pessimistic SRES-A2 emissions scenario
Pesticide properties	USDA-NRCS/UMass Extension pesticide properties database (Plotkin et al., 2012)

Plotkin, S., J. K. Bagdon, and E. S. Hesketh. 2012. USDA-NRCS/UMass Extension pesticide properties database. Amherst, Mass.: USDA Natural Resources Conservation Service. Available at: www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/landuse/crops/npm/?cid=stelprdb1044769

Soil Characteristics

West (California)	Southwest (Texas)	Mid-South (Arkansas)	Southeast (Georgia)
Alamo clay (BD=1.54)	***Randall*** clay (BD=1.45)	***Alligator*** clay (BD=1.40)	***Alviso*** clay loam (BD=1.42)
Merced silty loam (BD=1.57)	***Acuff*** loam (BD=1.50)	***Commerce*** silty loam (BD=1.48)	***Izagora*** silty sand (BD=1.55)
Atwater sand (BD=1.45)	***Amarillo*** fine sandy loam (BD=1.34)	***Crevasse*** sandy loam (BD=1.42)	***Orangeburg*** sandy loam (BD=1.53)

Soil albedo

Hydrologic soil group

Soil attributes by layer:
- depth
- field capacity, wilting point, bulk density
- % sand, % silt, % clay, % organic carbon
- soil pH
- saturated conductivity
- water holding capacity

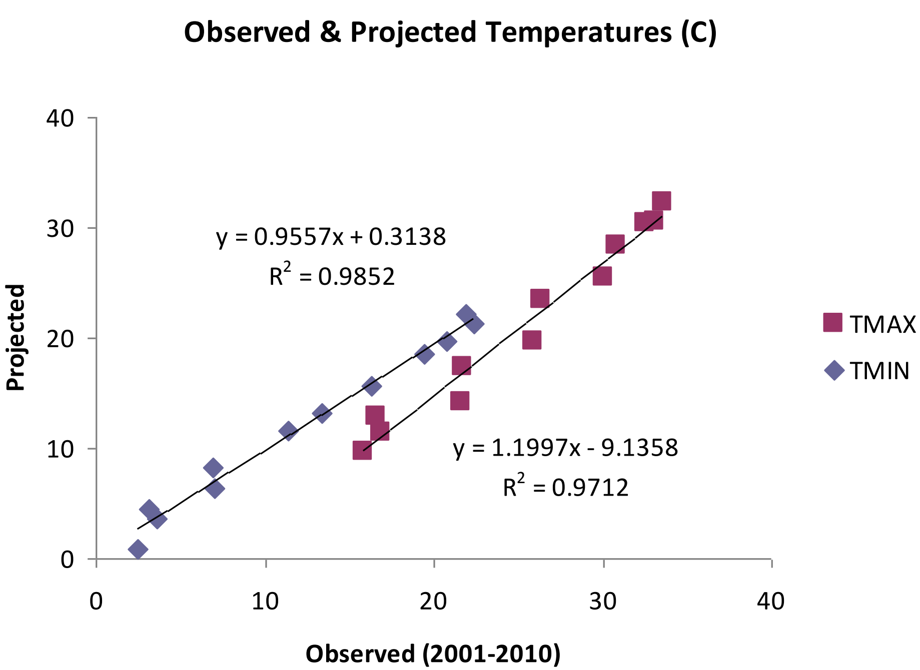
Cotton Management Practices

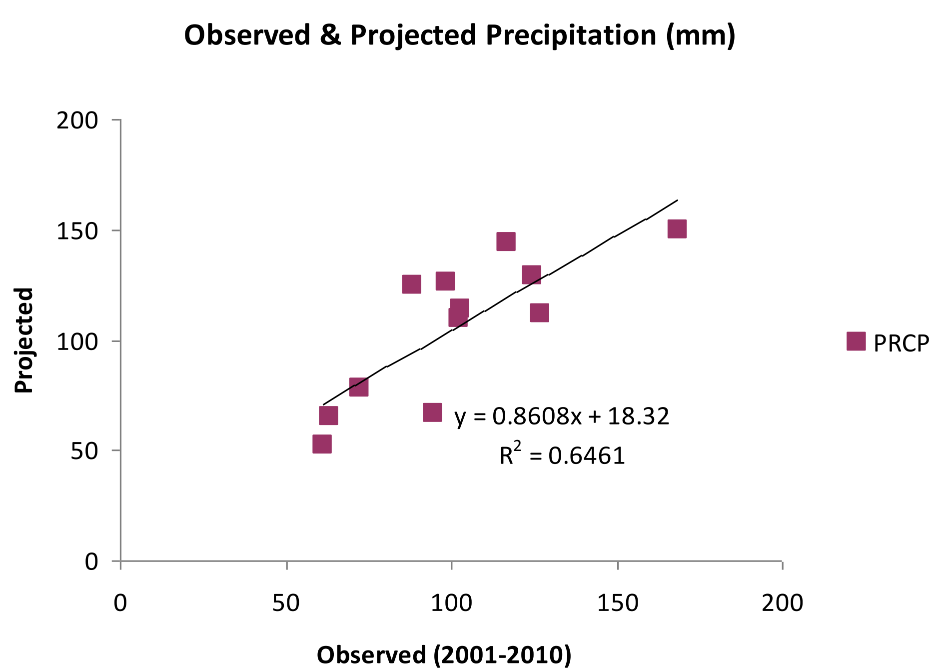
Location	Tillage	Irrigation	Fertilizer
Keiser, AR 35.7°N, 90.1°W, 70m	Disk, Bedder	Furrow Irrigated	March: 11.2 kg N/ha 14.7 kg P/ha June: 106.4 kg N/ha
Merced, CA 37.3°N, 120.5°W, 52m	Heavy disk, Five-bottom plow, Land plane, Lister, Disk, Bedder	Furrow Irrigated	Dec: 11.20 kg N/ha 13.20 kg P/ha
Albany, GA 31.6°N, 84.2°W, 60m	No-till	Dryland	March: 11.2 kg N/ha 21.5 kg P/ha June: 82.9 kg N/ha
Lubbock, TX 33.7°N, 101.8W, 992m	Disk, Bedder, Row cultivator	Pivot Irrigated Dryland	March: 11.8 kg N/ha 11.8 kg P/ha June: 112.6 kg N/ha March: 11.8 kg N/ha 11.8 kg P/ha June: 44.2 kg N/ha

Comparison of Observed and Projected Climate at Albany, GA from 2001 to 2010

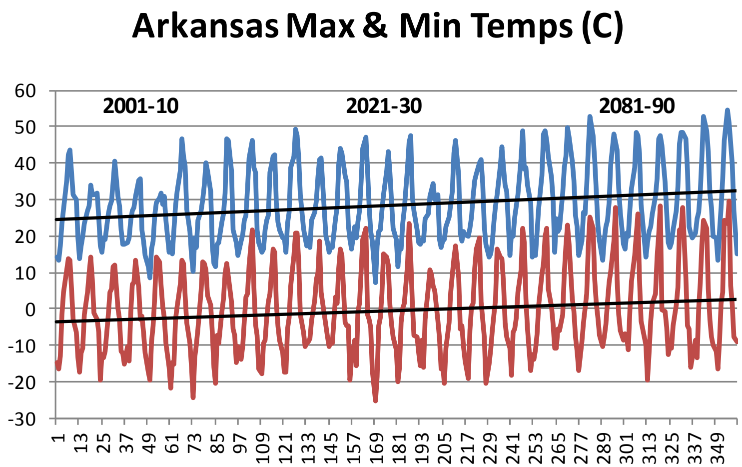
Projected and observed maximum & minimum temperatures are highly correlated but with maximum temperature slightly overestimated; month by month estimates differing by only 10%.

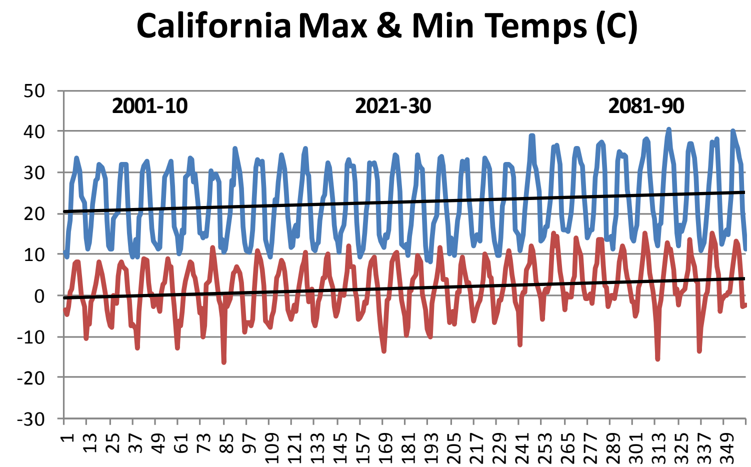
The temporal sequence of projected and observed precipitation are moderately well correlated although the projected and observed total annual precipitation differ by only 10% (projected 1131 mm vs 1258 mm observed).

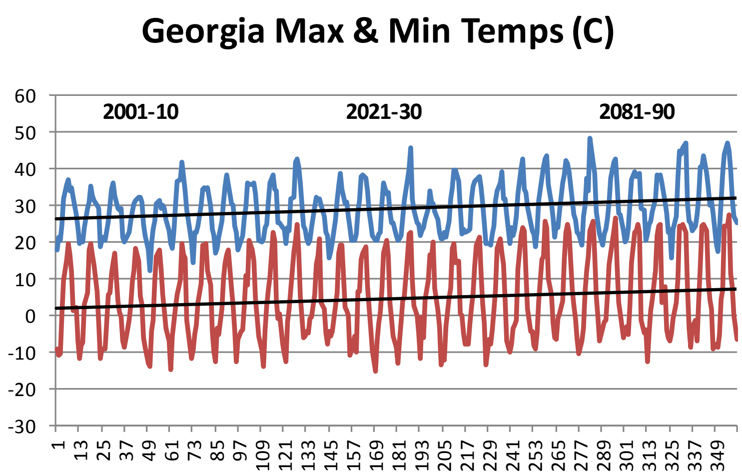


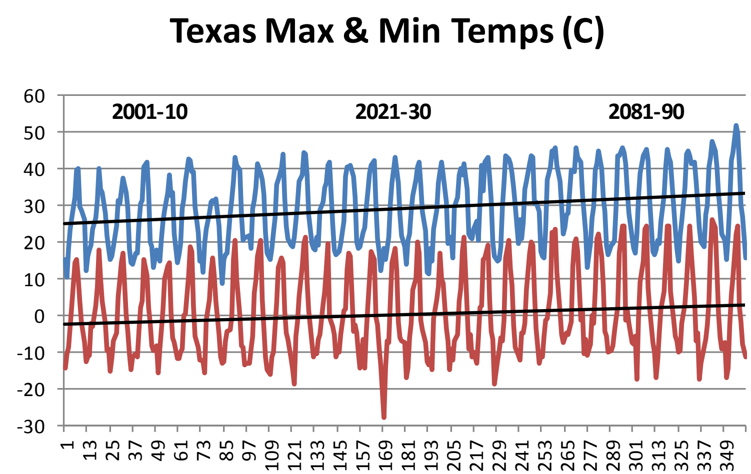


Monthly Temperatures

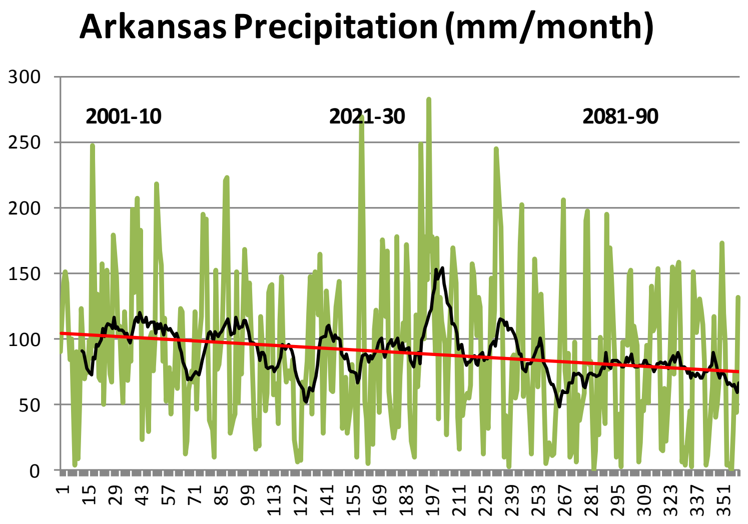


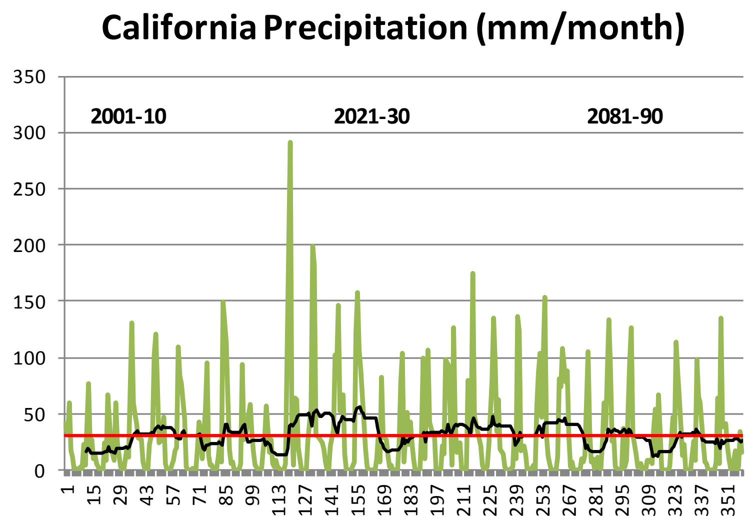


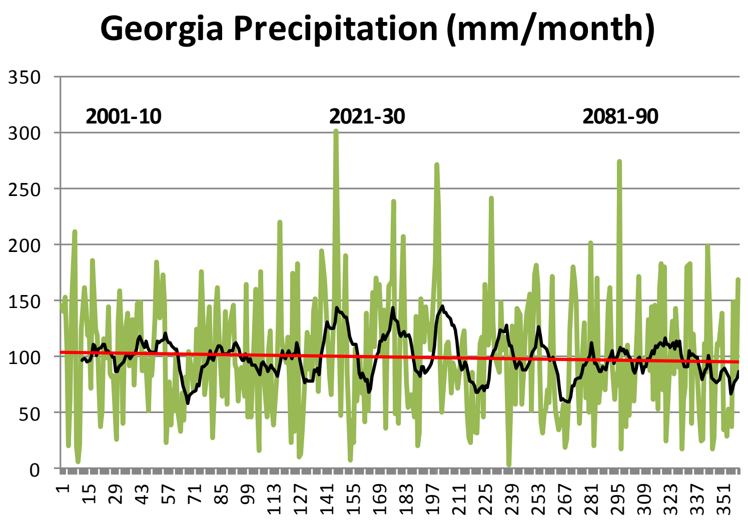


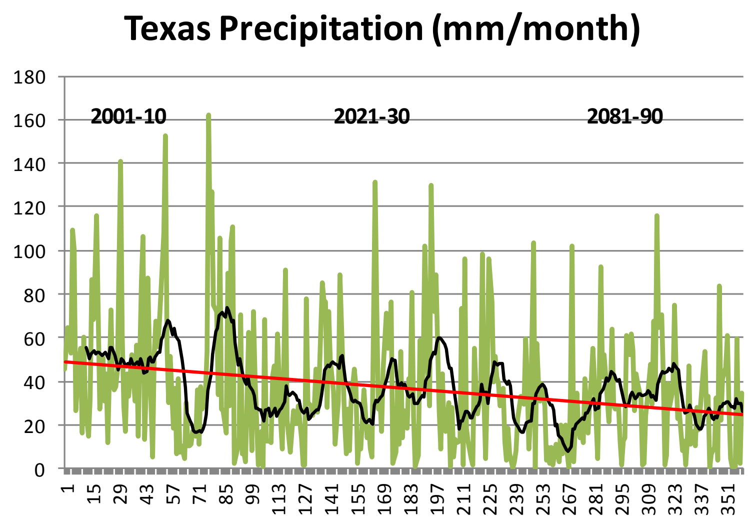


Monthly Precipitation









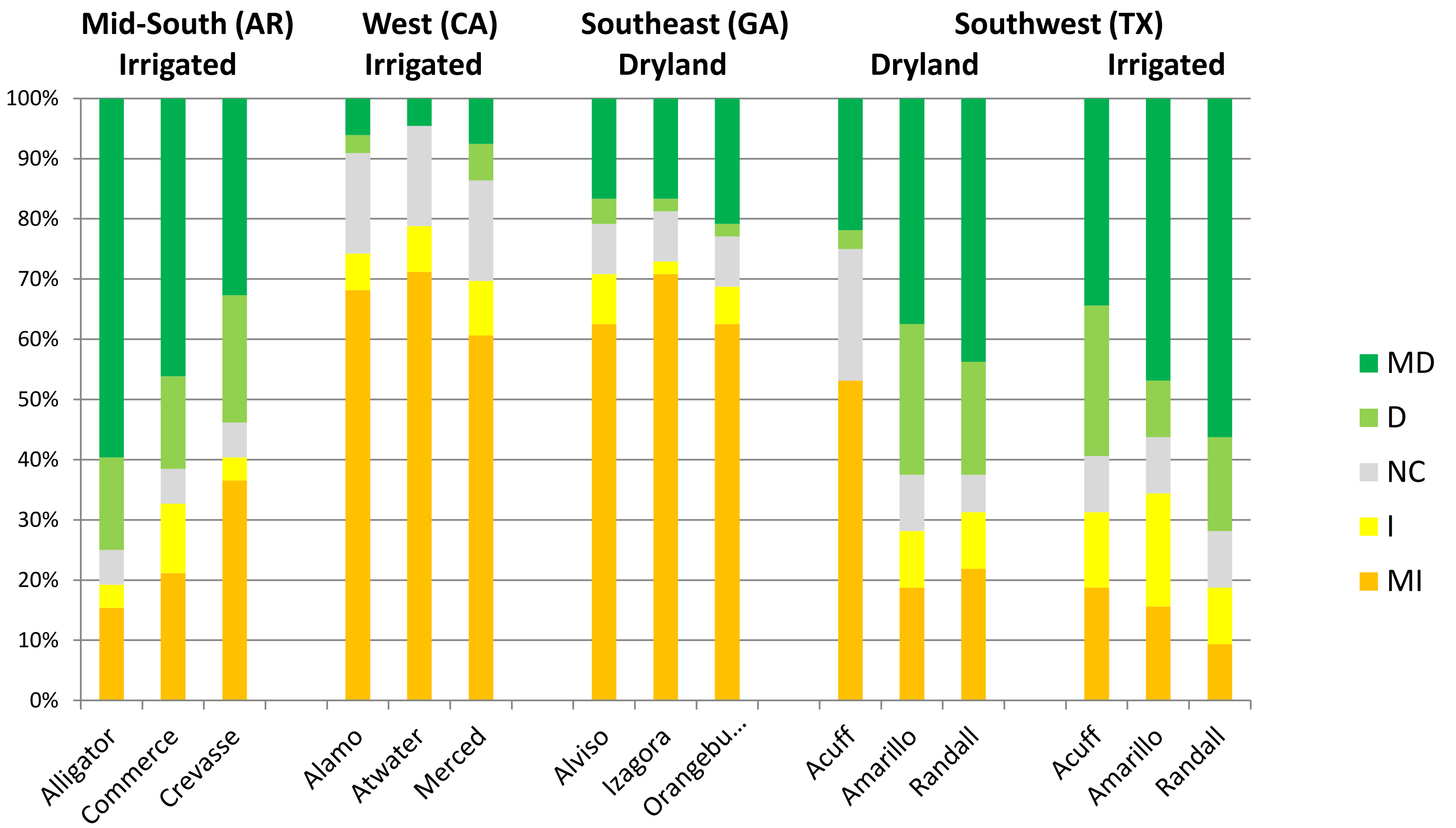
Analysis of Pesticide Runoff

- Changes in pesticide surface runoff losses were scored for analysis.

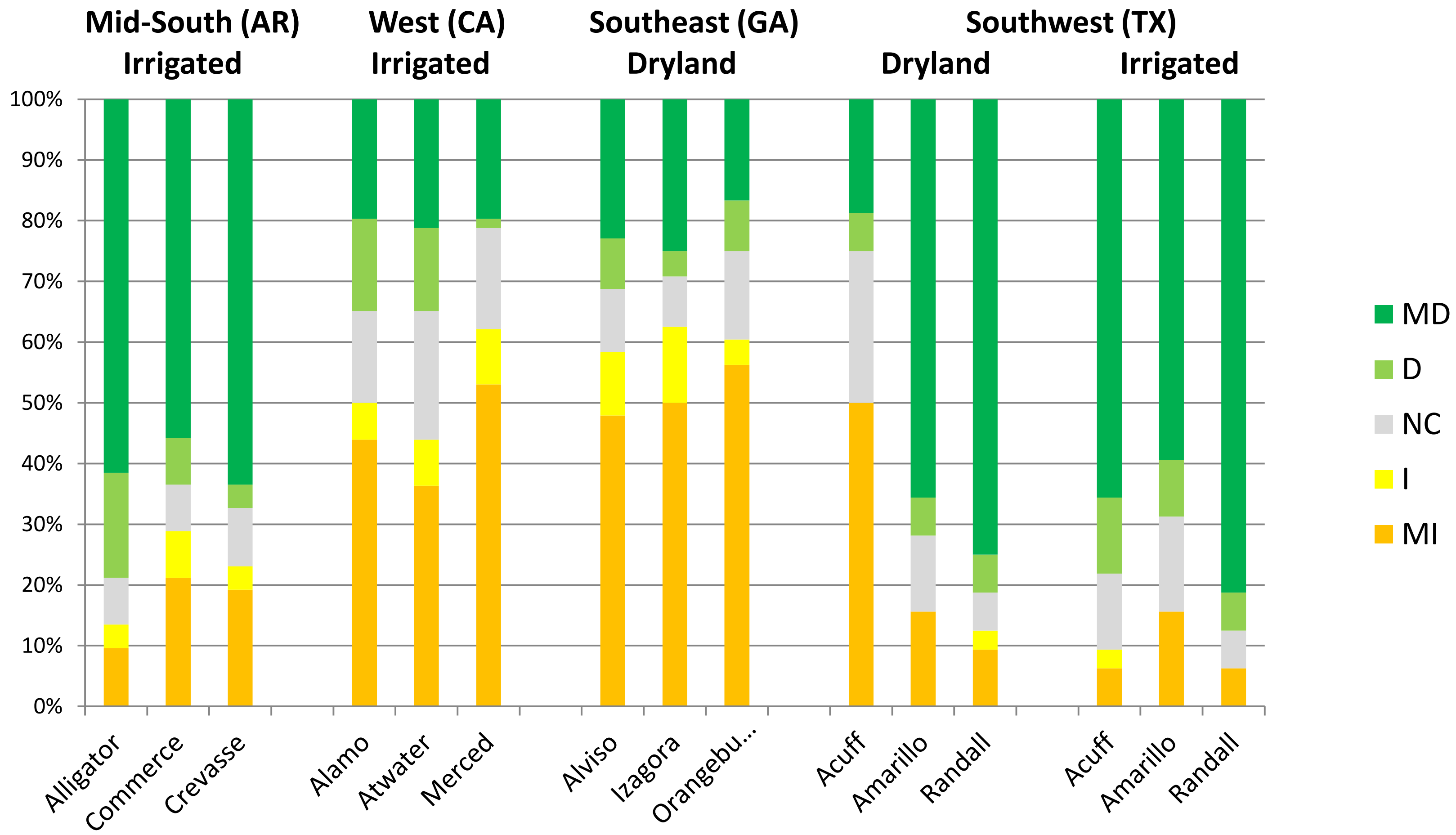
1. Change from the 1st decade (2001-10) to the 3rd decade (2021-30)
2. Change from the 1st decade (2001-10) to the 9th decade (2081-90)

- > -50% (halving) = -2 (Major Decrease)
- -5% to -50% = -1 (Decrease)
- -5% to +10% = 0 (No Change)
- +10 to +100% = 1 (Increase)
- > +100% (doubling) = 2 (Major Increase)

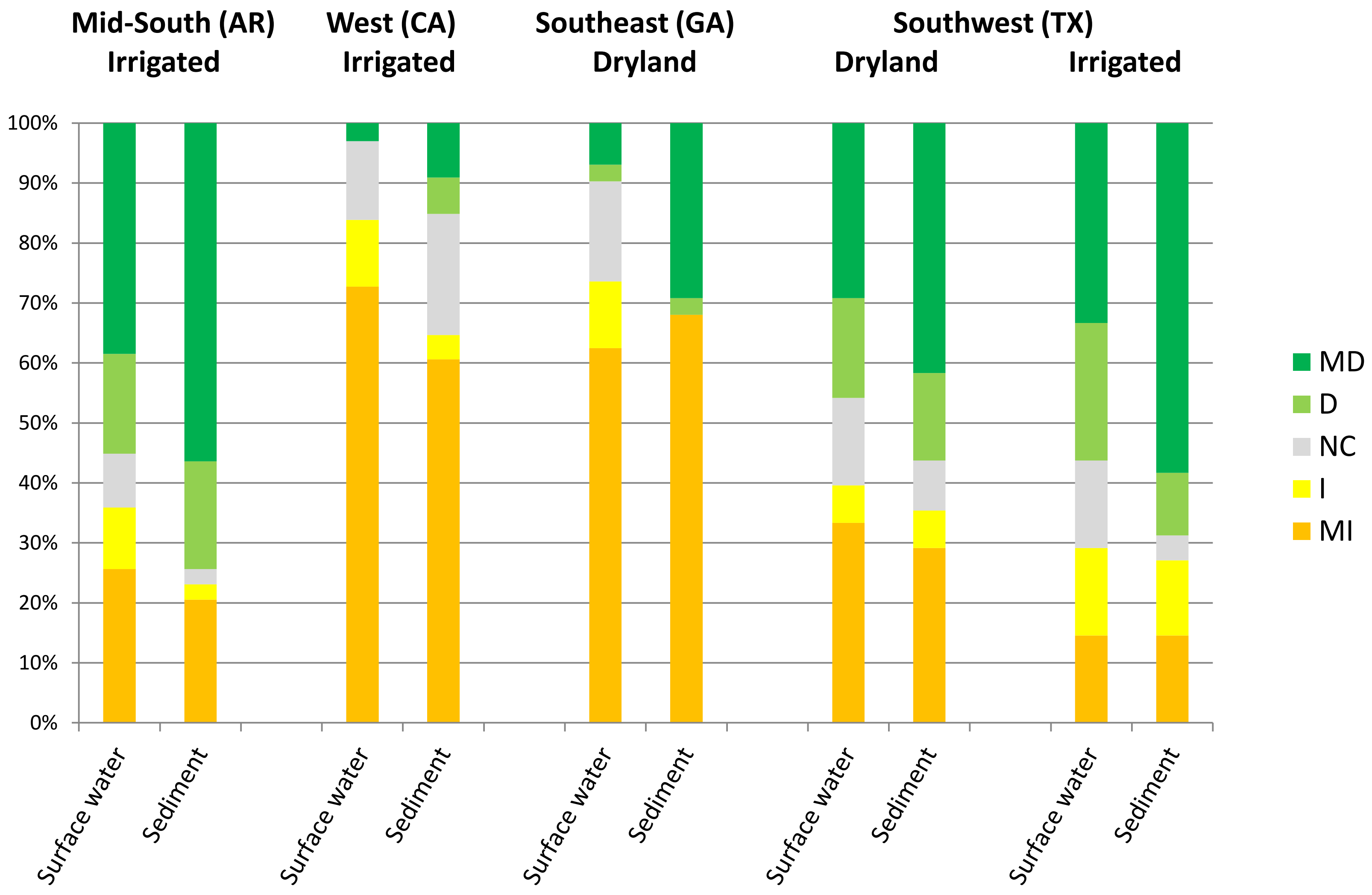
Pesticide Runoff by Soil - Change from Decade 1 to Decade 3



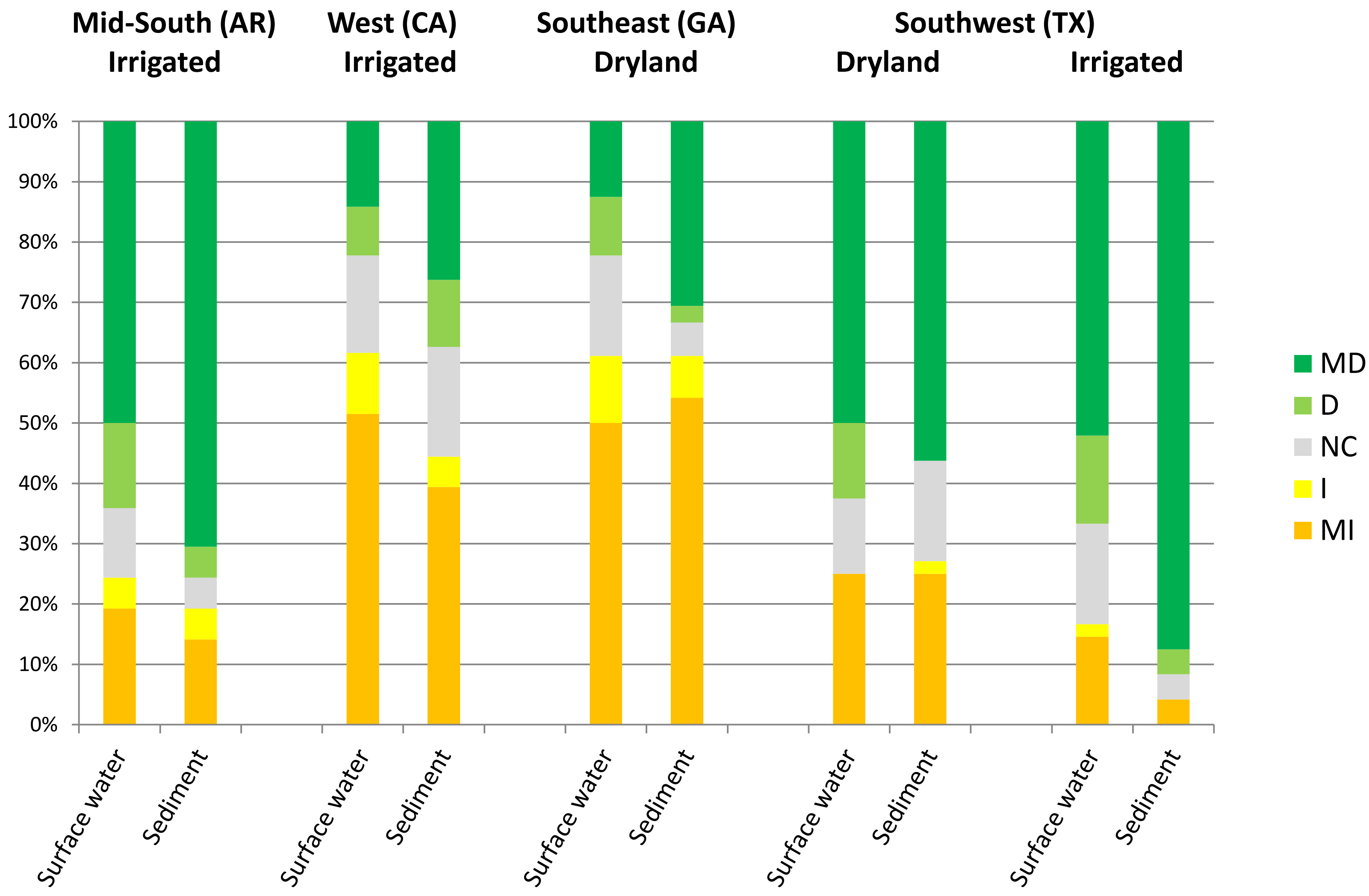
Pesticide Runoff by Soil - Change from Decade 1 to Decade 9



Pesticide Runoff by Site - Change from Decade 1 to Decade 3



Pesticide Runoff by Site - Change from Decade 1 to Decade 9



Factors Affecting Changes in Pesticide Fate - 1

Variable	Correlation	
Log[Solubility (ppm)]	-0.2243	ns
Log[KOC (Tm^3)]	0.1976	ns
Half-life on Foliage (d)	0.0501	ns
Half-life in Soil (d)	-0.0551	ns
Wash-off Fraction (%)	-0.1972	ns

Change Scores are unrelated to Chemical Properties

- Pesticide fate (surface water and sediment) depends on pesticide chemical properties, but climate change will not change the relationship.

Factors Affecting Changes in Pesticide Fate - 2

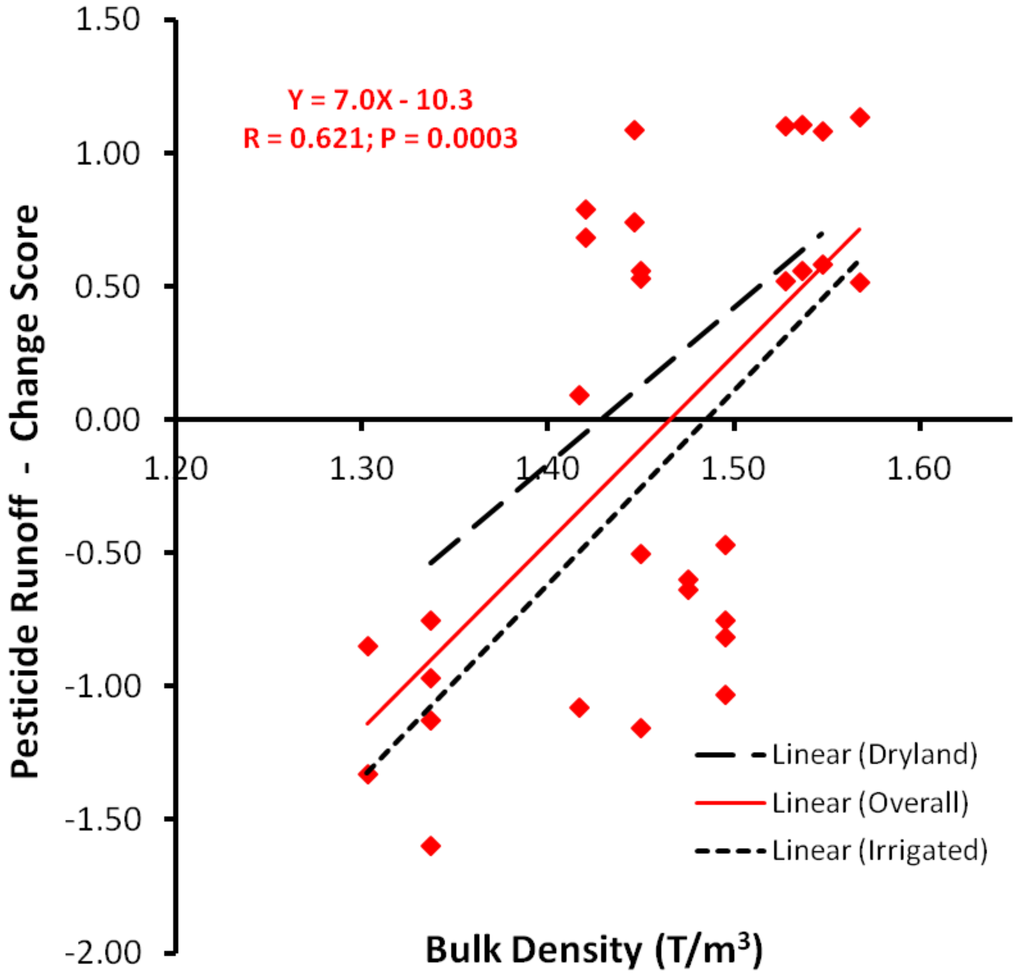
Variable	Dryland		Irrigated	
Wilting Point (m/m)	-0.5850	*	-0.0877	ns
Field Capacity (m/m)	-0.7020	**	-0.1444	ns
Saturated Conductivity (mm/h)	0.5559	*	0.0454	ns
Bulk Density (T/m^3)	0.5355	*	0.6628	**

Change Scores are related to Soil Properties

- Change scores increase with conductivity and decrease with soil water holding capacity in rainfed but not irrigated cotton
- Change scores increase with to bulk density in both rainfed and irrigated cotton

Change Score vs. Bulk Density

- Bulk density is the best predictor of pesticide fate under climate change.
- There's a small difference between dryland and irrigated.
- May be important as precipitation declines, increasing the need for irrigation to maintain productivity.



Summary

- Pesticide runoff from cotton will change as climate warms – *both increases and decreases.*
- Runoff changes will not depend on pesticide physico-chemical properties - *unless there are temperature-dependencies we are unaware of.*
- Soil characteristics will have the biggest influence on changes in pesticide runoff as climate warms - *in particular Bulk Density*.