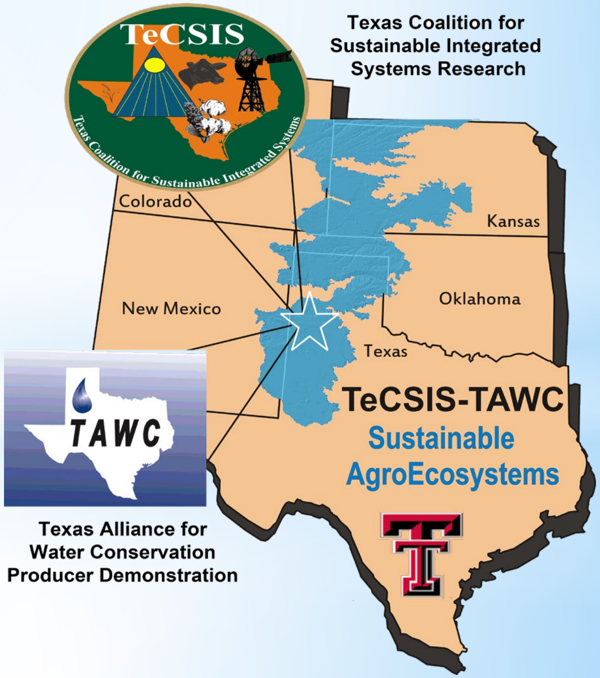
Role of Forage Crops and Grazing in the Water-Limited Texas High Plains

Leu Distinguished Lecture, November 12, 2018



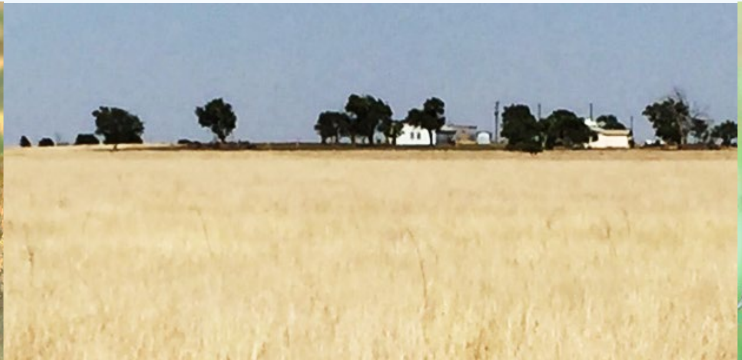
Chuck West

CASNR Water Center
Plant & Soil Science Department
Texas Tech University

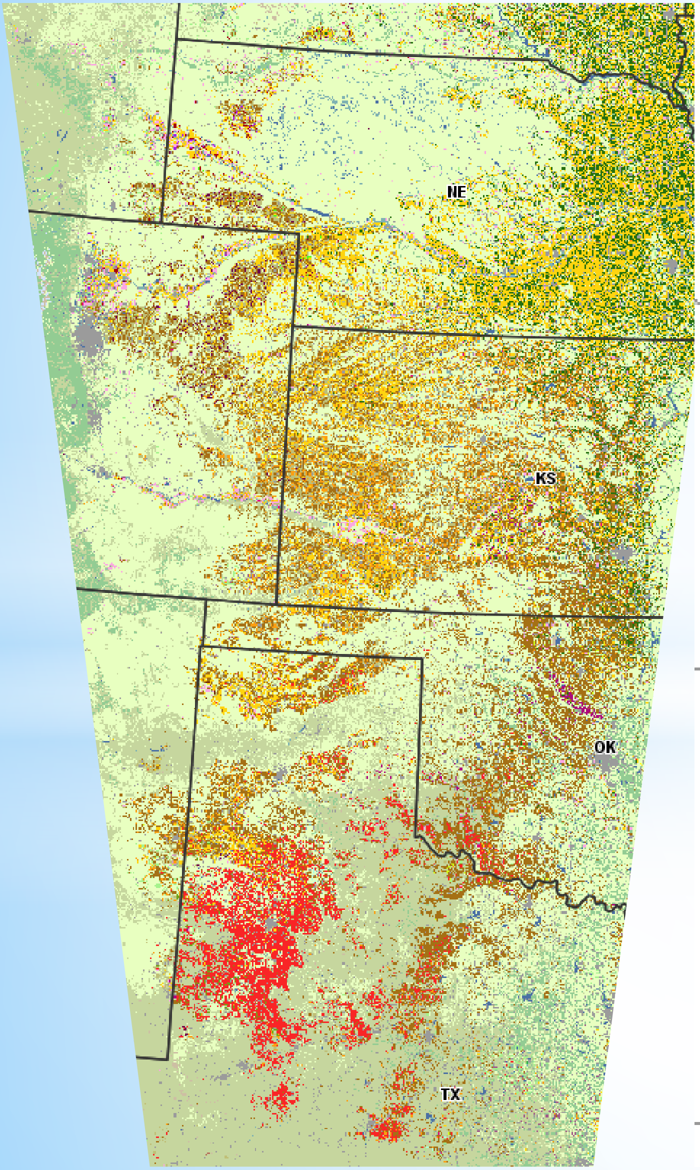
TEXAS TECH UNIVERSITY
College *of* Agricultural Sciences & Natural Resources™

Main Topics

- ✓ The water situation
- ✓ Forage options
- ✓ Water footprint
- ✓ Graduate student research
- ✓ The future


Great Plains agriculture



Ogallala Aquifer

- Ogallala Aquifer supports ~30% of U.S. crop and livestock production
- Increases U.S. agricultural production by more than $12 billion annually

USDA-NASS, 2016

Hotspots of groundwater depletion

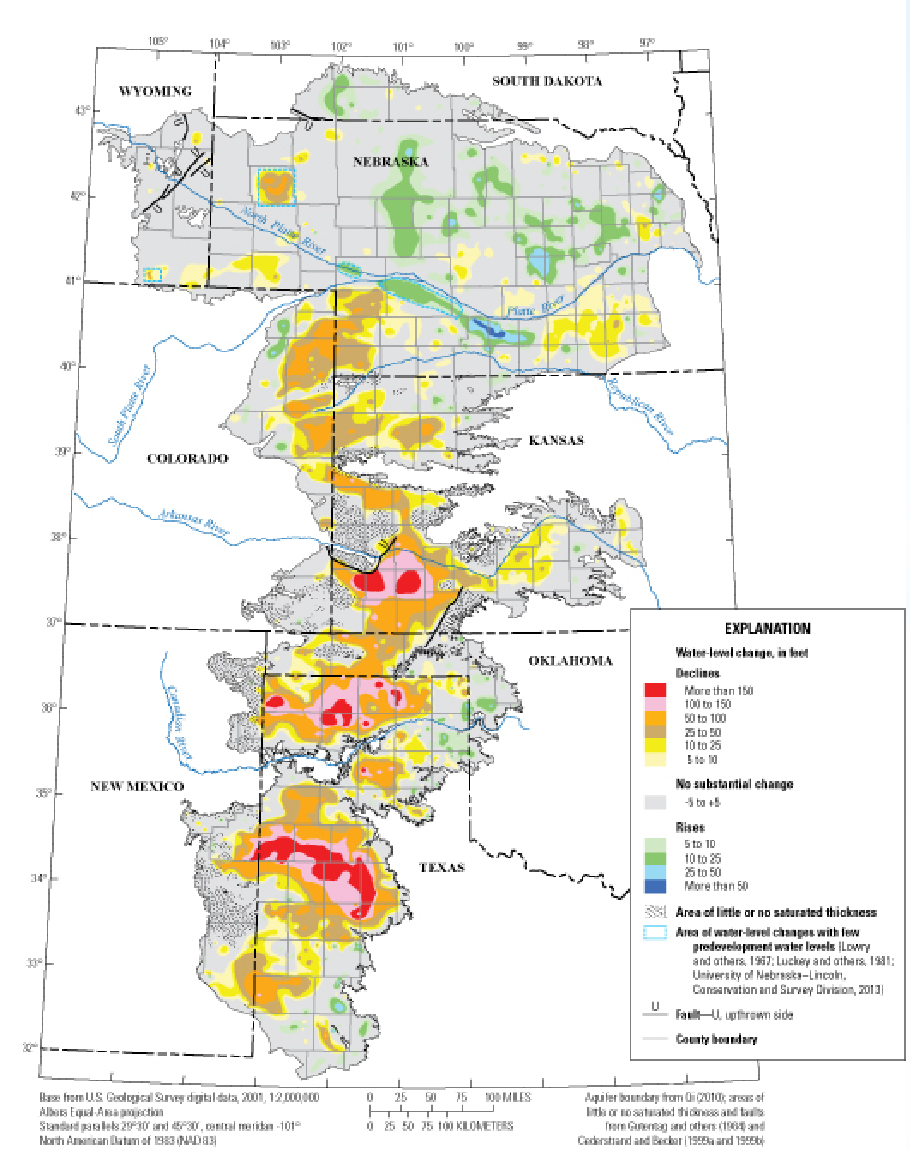
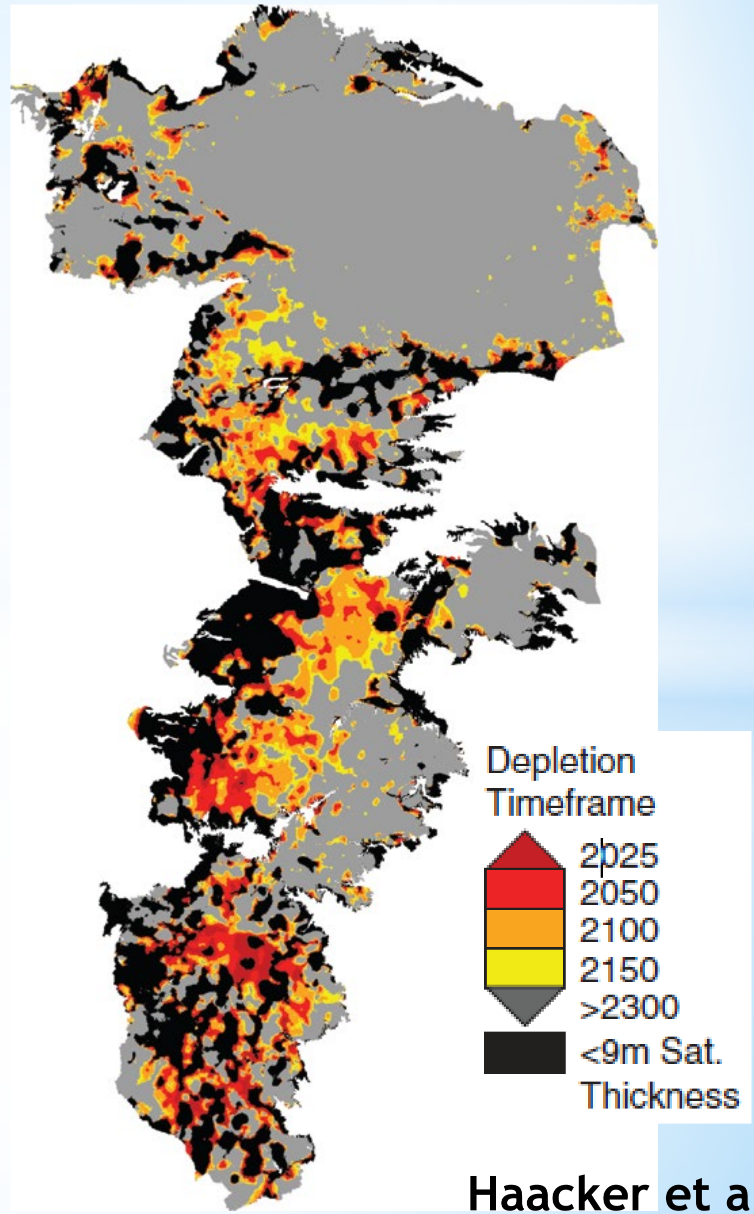


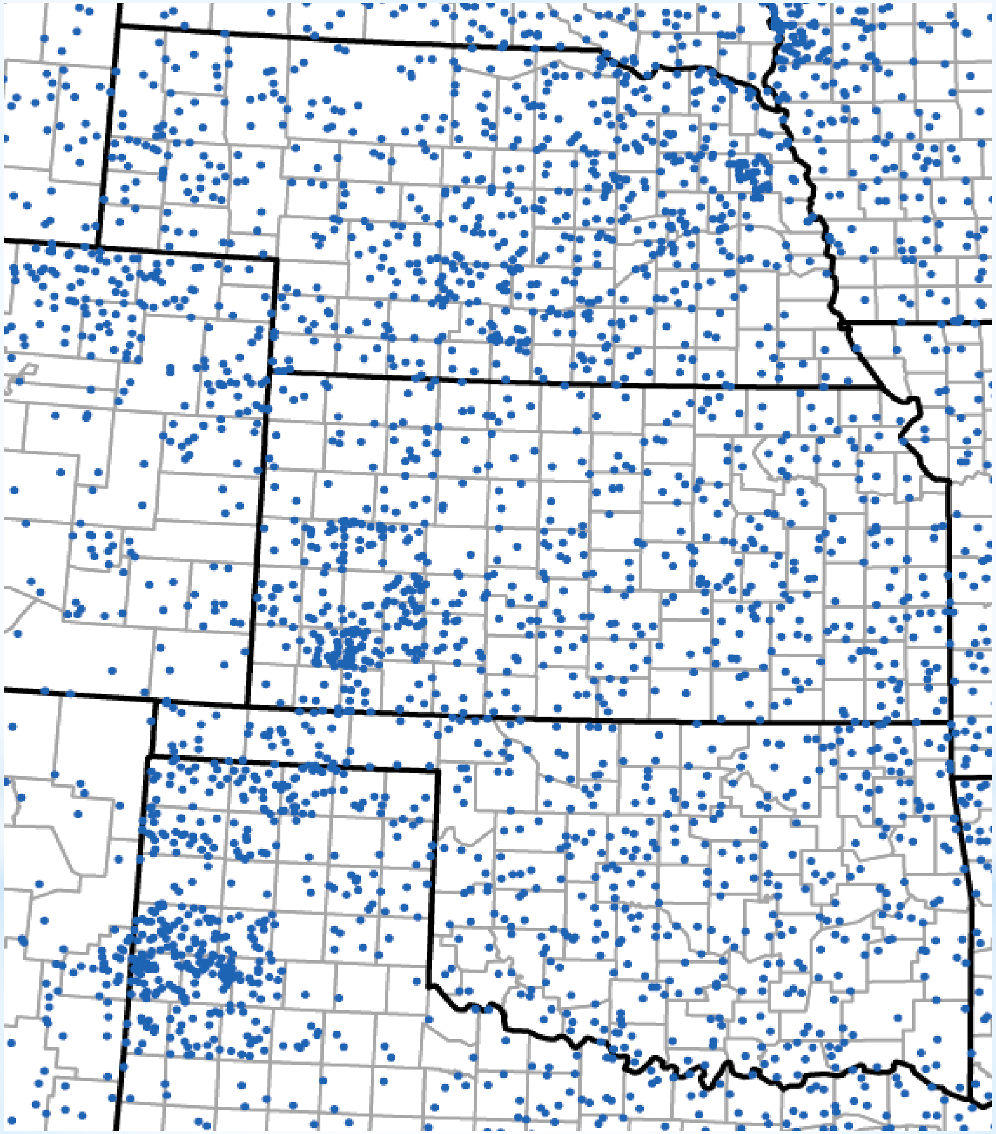
Figure 11. Water-level changes in the High Plains aquifer, predevelopment (about 1950) to 2013.

McGuire, 2014

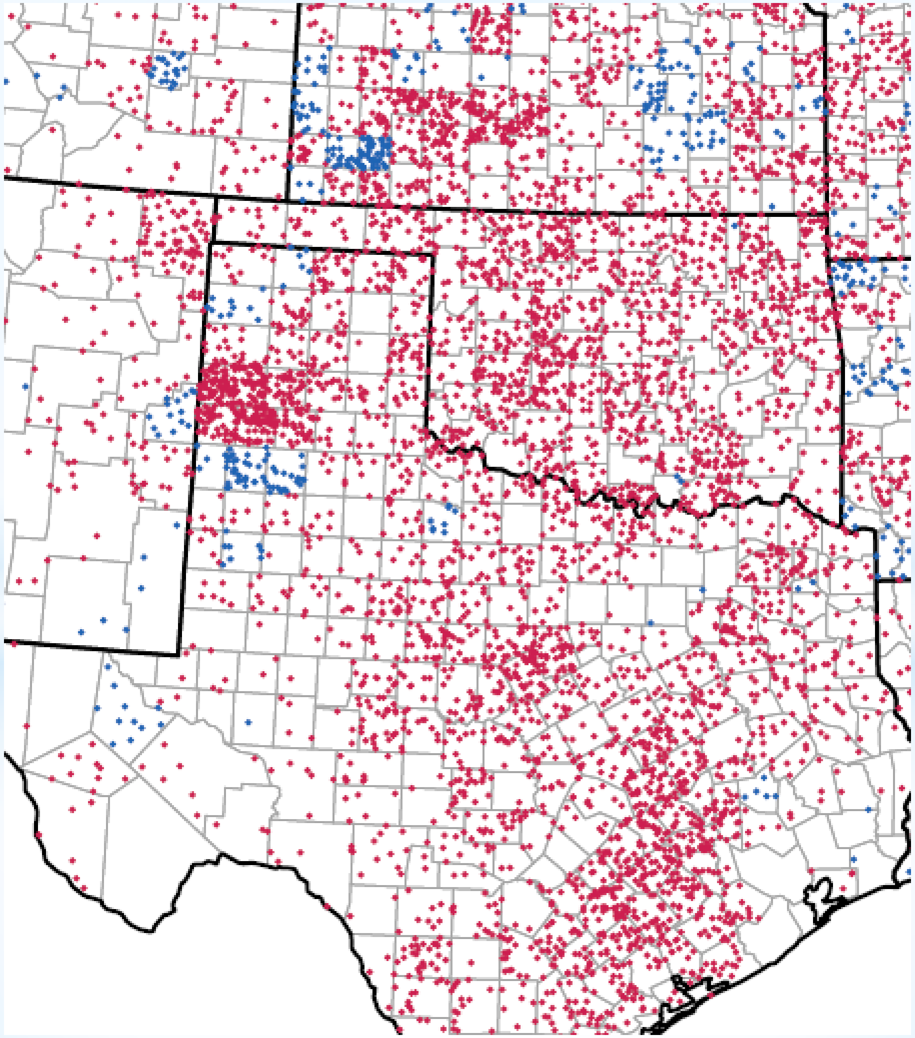


Haacker et al., 2015

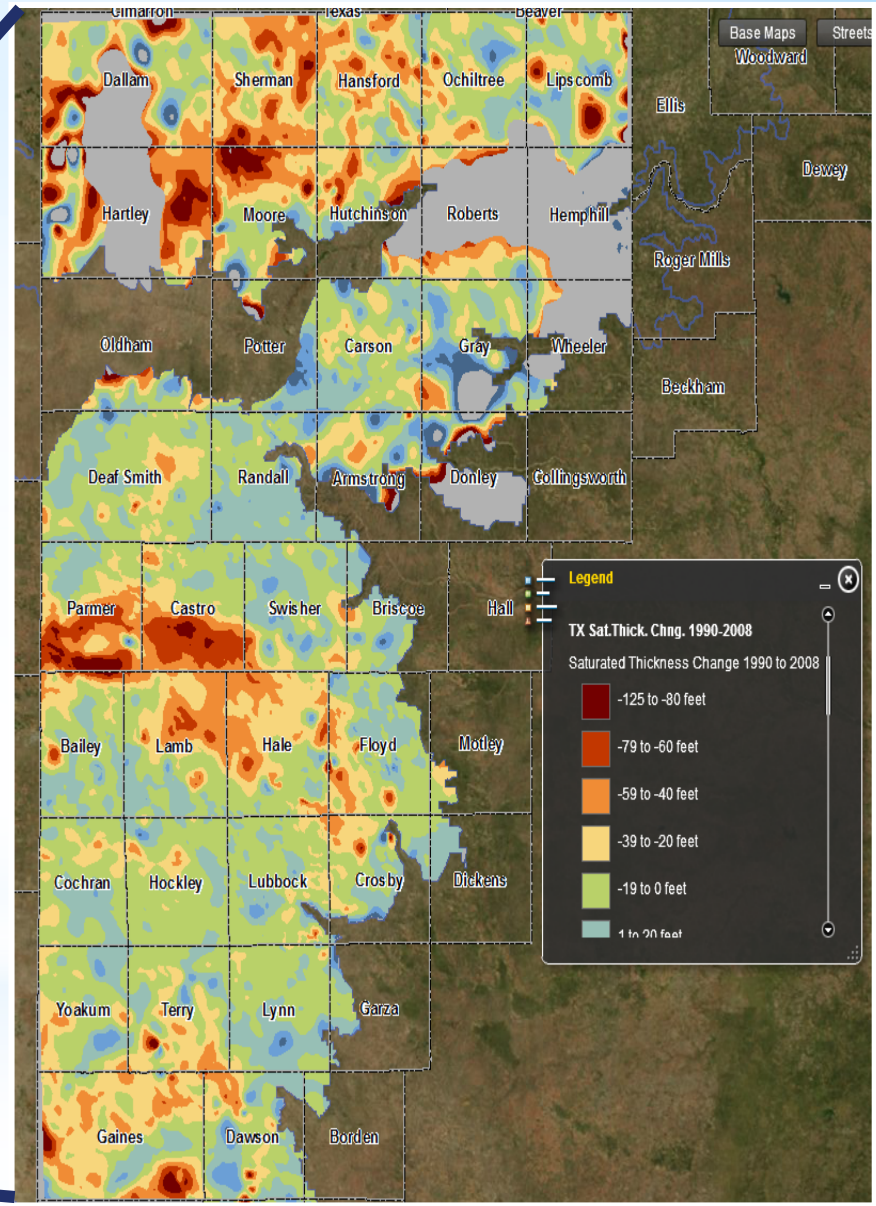
Map of all cattle and calves.
1 Dot = 10,000 head (USDA-NASS, 2012)



Change in all cattle and calves, 2007-2012

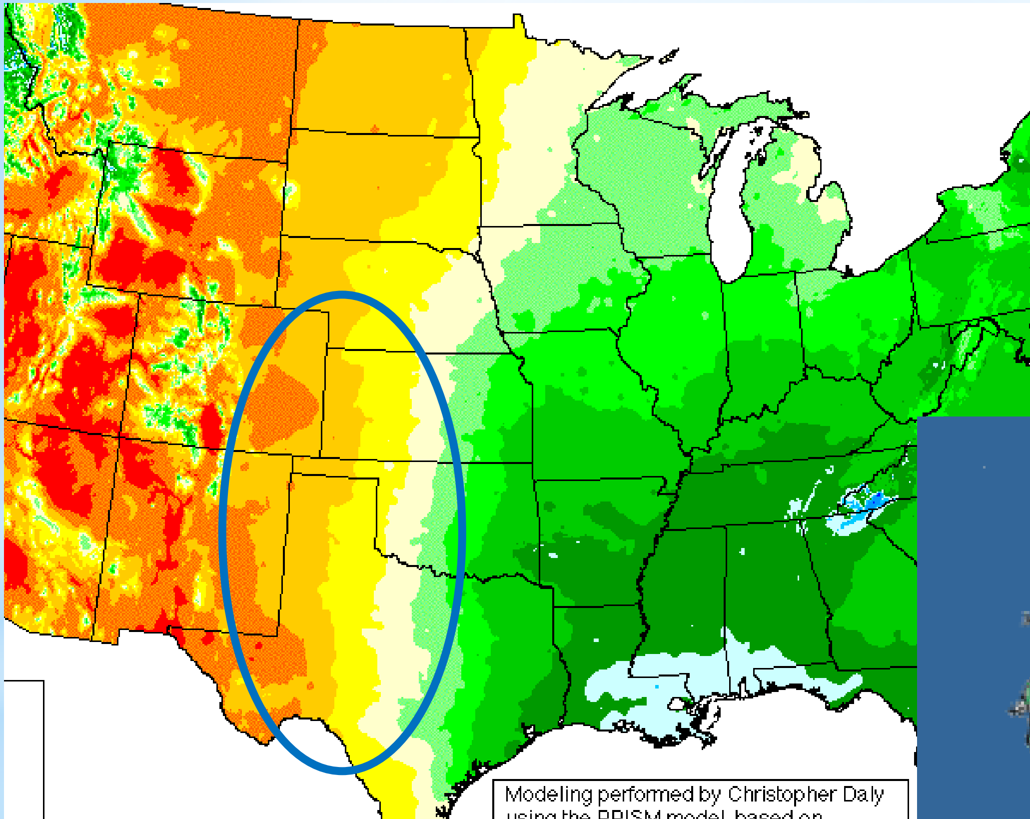


OGALLALA AQUIFER
Wyoming
South Dakota
Nebraska
Colorado
Kansas
New Mexico
Oklahoma
Texas
Panhandle
South Plains



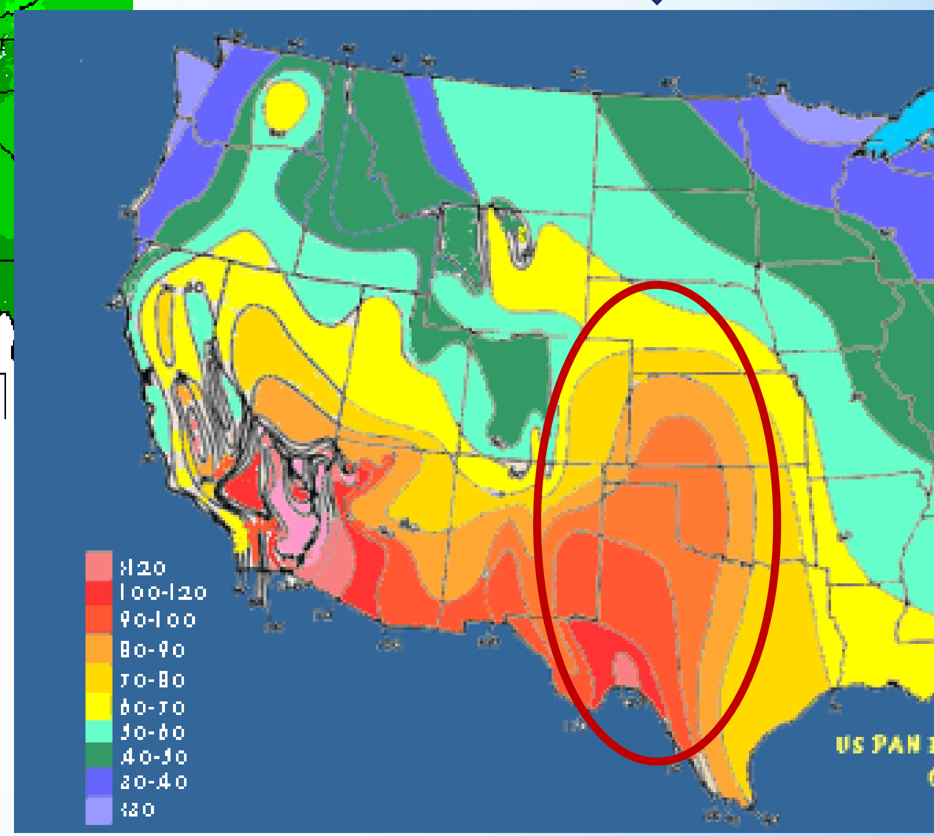
Base Maps
Woodward
Dallam
Sherman
Hansford
Ochiltree
Lipscomb
Ellis
Dewey
Hartley
Moore
Hutchinson
Roberts
Hemphill
Roger Mills
Oldham
Potter
Carson
Gray
Wheeler
Beckham
Deaf Smith
Randall
Armstrong
Donley
Collingsworth
Parmer
Castro
Swisher
Briscoe
Hall
Bailey
Lamb
Hale
Floyd
Motley
Cochran
Hockley
Lubbock
Crosby
Dickens
Yoakum
Terry
Lynn
Garza
Gaines
Dawson
Borden
Legend
TX Sat.Thick. Chng. 1990-2008
Saturated Thickness Change 1990 to 2008
-125 to -80 feet
-79 to -60 feet
-59 to -40 feet
-39 to -20 feet
-19 to 0 feet

Southern Great Plains has chronic water deficit:

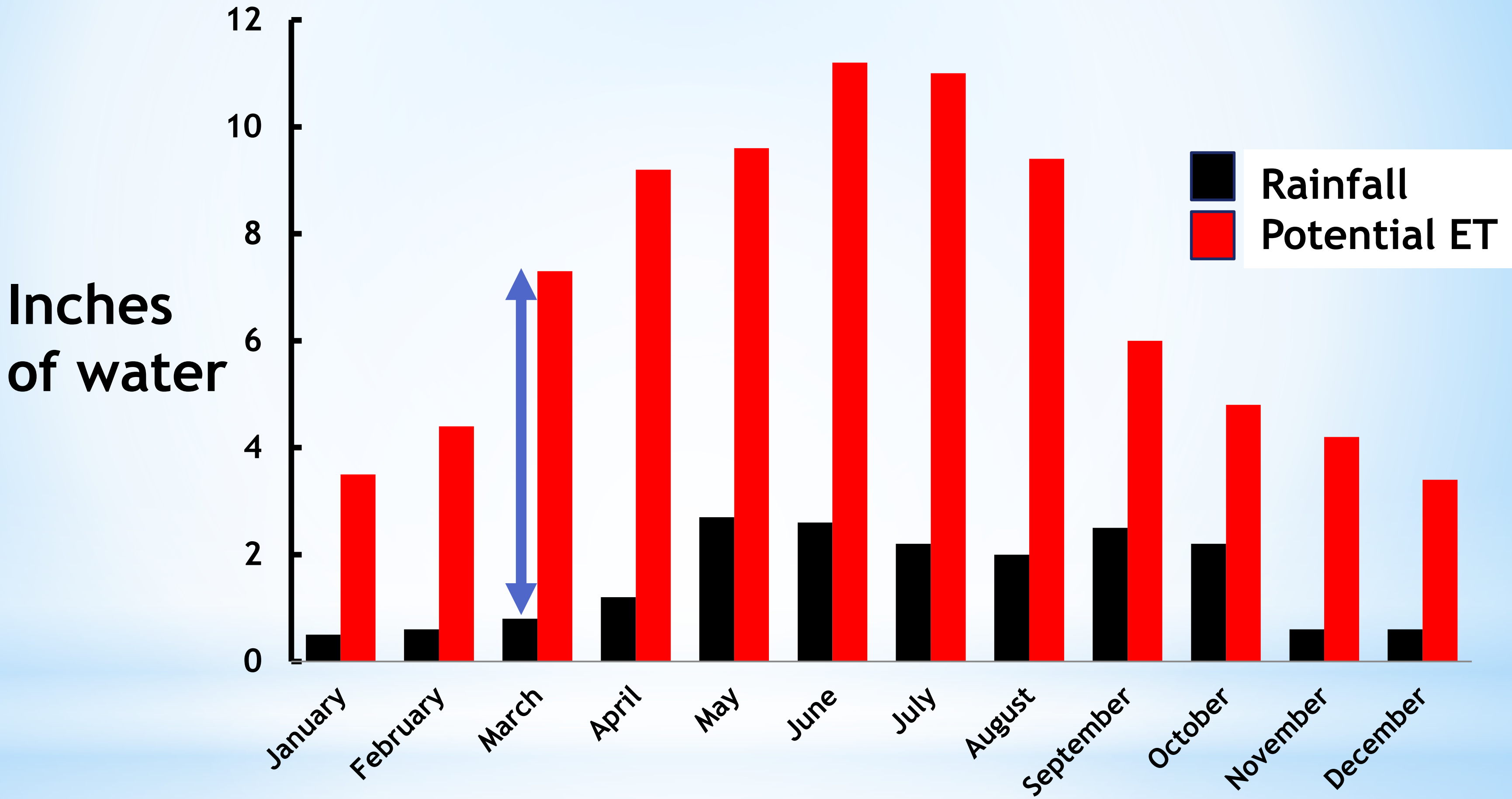


Low precipitation

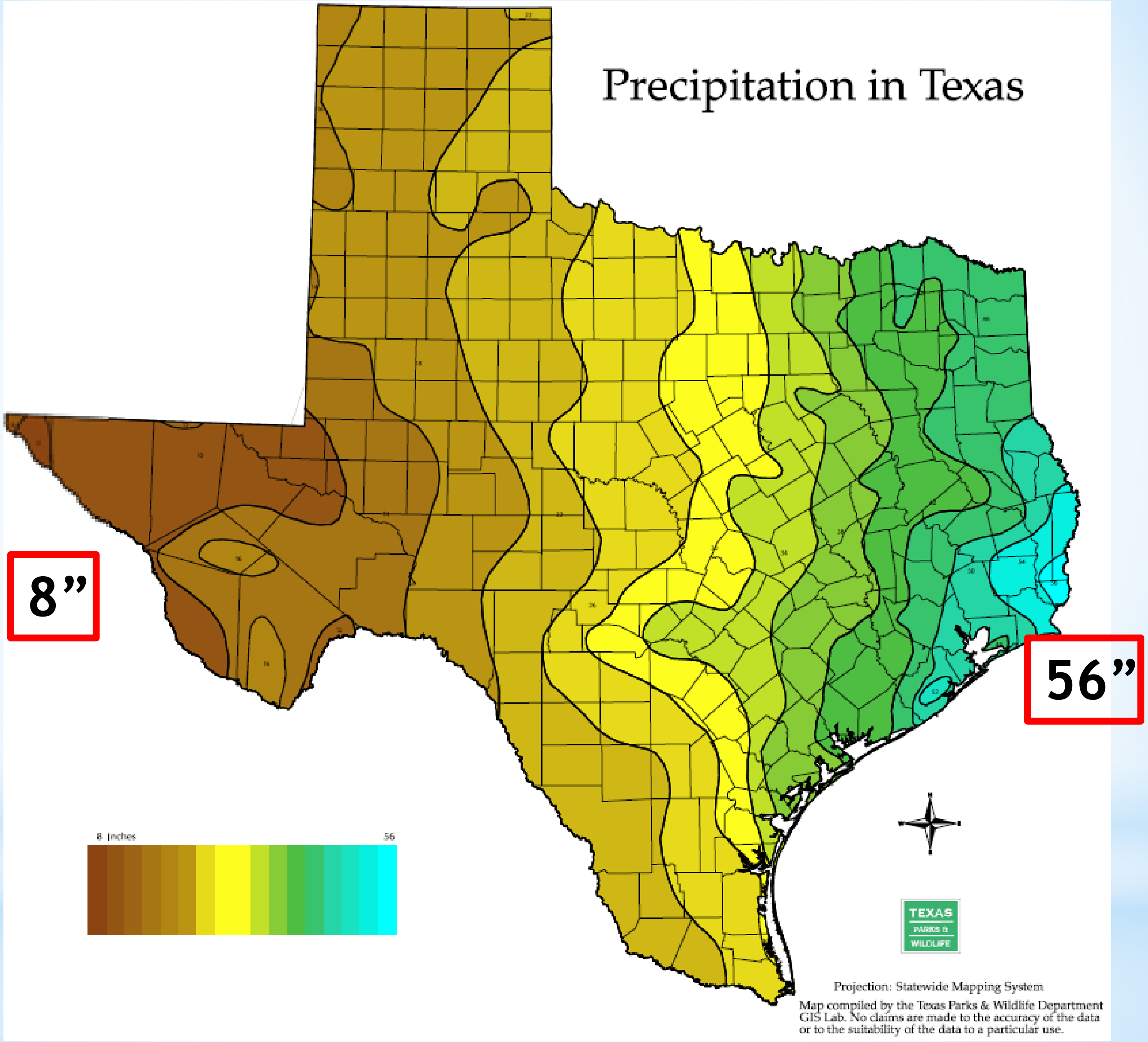
High evaporative demand



In Lubbock, PET exceeds rainfall in every month.



Lubbock: Rain and PET by month


Precipitation in Texas
8”
56”
8 Inches
56
TEXAS PARKS & WILDLIFE
Projection: Statewide Mapping System
Map compiled by the Texas Parks & Wildlife Department GIS Lab. No claims are made to the accuracy of the data or to the suitability of the data to a particular use.

Why forages and cattle?

- **Native ecosystem is grassland.**
- **Perennials build soil organic matter, reduce soil erosion.**
- **Beef cattle and hay are high-value commodities.**
- **Require modest water inputs.**

***Hypothesis*: Forages/livestock production provides profitable means of transitioning to low water-input and dryland agriculture in the Texas High Plains.**

Capitalize on using high-quality forages with low resource inputs.

Forage Options – Largely warm-season grasses

Cool-season grasses limited by dry winters, hot summers

Rangeland **– native species, short grasses, mesquite**
'Improved' grasses: old world bluestems, lovegrass, kleingrass

Dryland cropping area **– Old world bluestems, wheat graze-out, sorghum, millets**

Irrigated area **– Silage crops, wheat, triticale, crop residue, teff, old world bluestem in transition to dryland, alfalfa**

Alfalfa **– declined area, in pockets, very profitable if enough water.**
Used for dairy calves and heifers, receiving feeder cattle,
Largely replaced by co-products in diets.
I am emphasizing alfalfa for grazing.

cv WW-B.Dahl
Bothriochloa bladii

Crop Monocultures → Integrated Systems

Complementarity

Diversification

Allen et al. 2012. Agron. J. 104:1625

Integrating livestock in Texas High Plains

Monoculture Cotton

Rye
↓
Cotton
↓
Wheat

Integrated Crop-Livestock

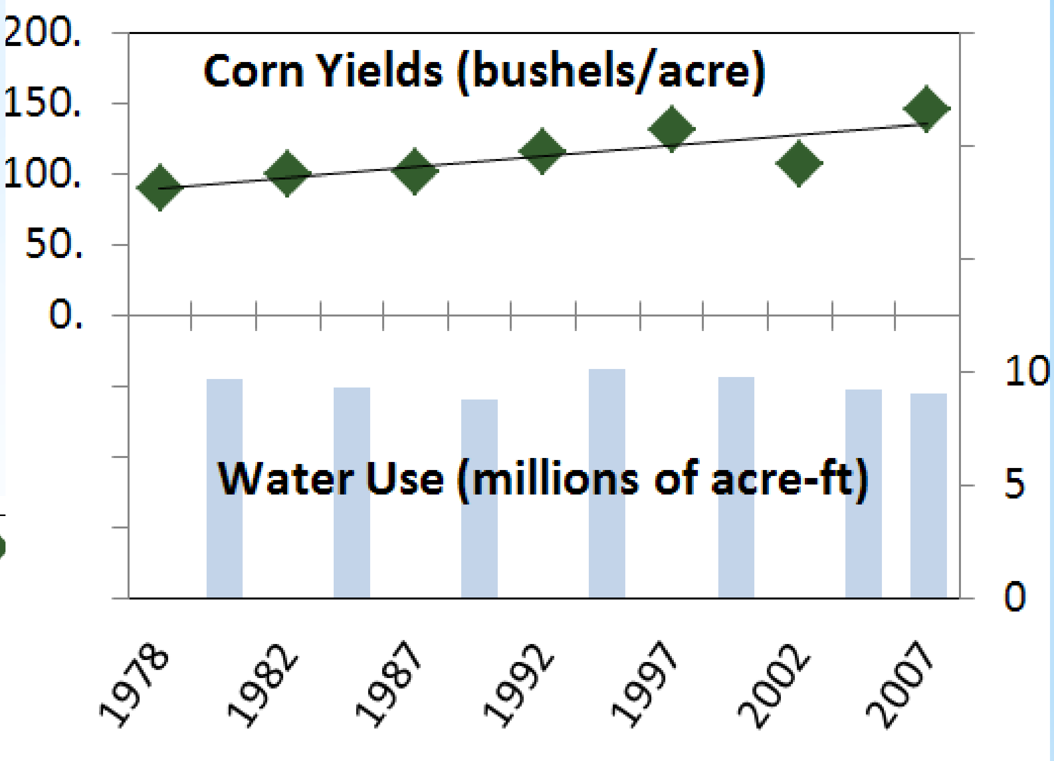
Wheat
↓
Fallow
↓
Rye

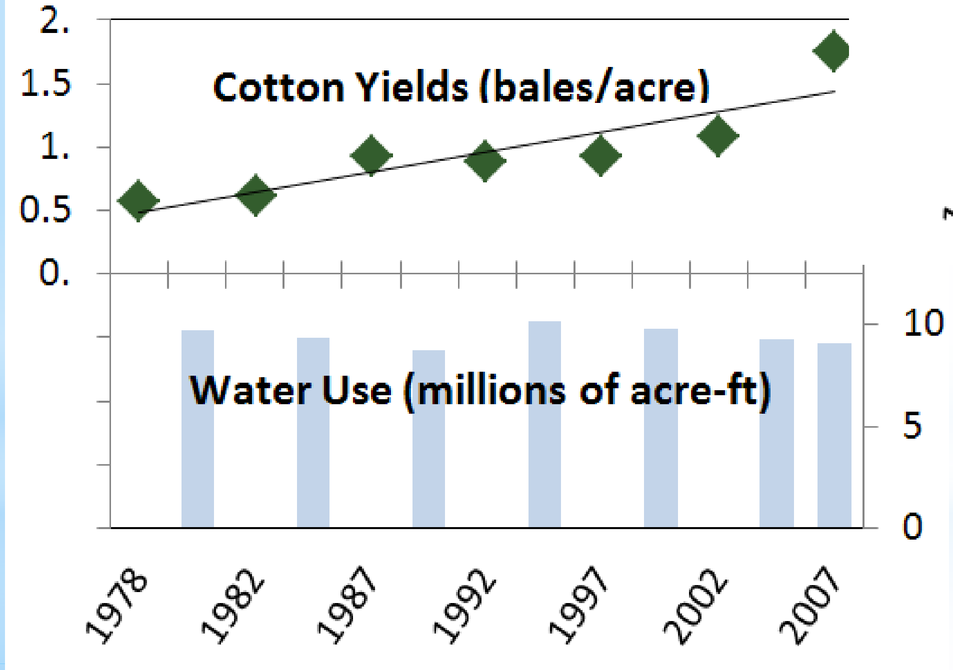
Old world bluestem

25% less irrigation

40% less nitrogen

Crop breeding for water use efficiency





TAMU-TWRI, 2012

Very little effort in WUE of forages!

Irrigation water use by sorghum and corn silages 4-yr avg.

Bean and McCullem Texas A&M AgriLife-Amarillo

Silage crop	Silage yield	Irrigation applied	Water footprint
	tons/acre	in./yr	ac-in/ton
Sorghum	22.4	14.9	0.67
Corn	22.5	22.9	1.00

Result: forage sorghum can produce as much silage as corn at 2/3 the amount of irrigation.

The rub: forage sorghum produces less milk than corn silage. BMR trait can partially negate that deficit.

Comments about Water Use Efficiency vs. Water Footprint

WUE = is yield/water input [or /water used]
ROI or 'Bang for the Buck'

WF = is 1/WUE water use/yield
Impact of using a nonrenewable resource for producing a low-value product because the economy depends on stretching the water supply.

Point: WUE of rain < that from irrigation.

Virtual Water in Agricultural Production

Virtual water is that used in production and processing of a commodity. Part of life cycle analyses.

Refers to amount "transferred" among regions in food/feed to water deficit areas.

Ag production responsible for 90% of global demand for freshwater, mainly for irrigation.

Increasing competitive demands for water.

Beef production is criticized for high resource input and negative environmental impact per unit of output.

Q: How much water is used in beef production?

Q: How can we reduce water footprint in beef?

Partitioning of Virtual Water in Life Cycle Analyses

Green water: precipitation and stored in soil

Blue water: developed, stored, transported e.g. diverted surface or groundwater for irrigation, drinking, cleaning

Gray water: amount needed to dilute polluted water to allowable levels.

Virtual Water in Ag Products Workshop. 2016.
UNL Center for Water Resources – Dr. C. Ray
UNL Water for Food Institute – Dr. M. Mekonnen

Beckett & Oltjen. 1993. Estimation of the water requirement for beef production in the U.S. JAS 71:818-826.

Boneless meat. Blue water only.

3.7 m^3 / kg of boneless meat. (440 gal / lb)

Recommendation:

Improving efficiency in irrigation use on stocker pasture would reduce overall water requirement.

Based irrigation requirement on California practices.

We are interested in stocker at low irrigation.

Literature values of WF for beef (m^3/kg)

1. **Boneless meat (U.S.): 3.7**
   Beckett & Oltjen. 1993. JAS
2. **Global average of liveweight: 15.4**
   MeKonnen & Hoekstra. 2012. Ecosystems
3. **Pasture-fed beef (U.S.) liveweight: 19.6**
   Ibid.
4. **Western feedlot (U.S.) liveweight: 3.9**
   Ibid.
5. **Southern Plains carcass weight: 2.5**
   Rotz et al. 2015. JAS

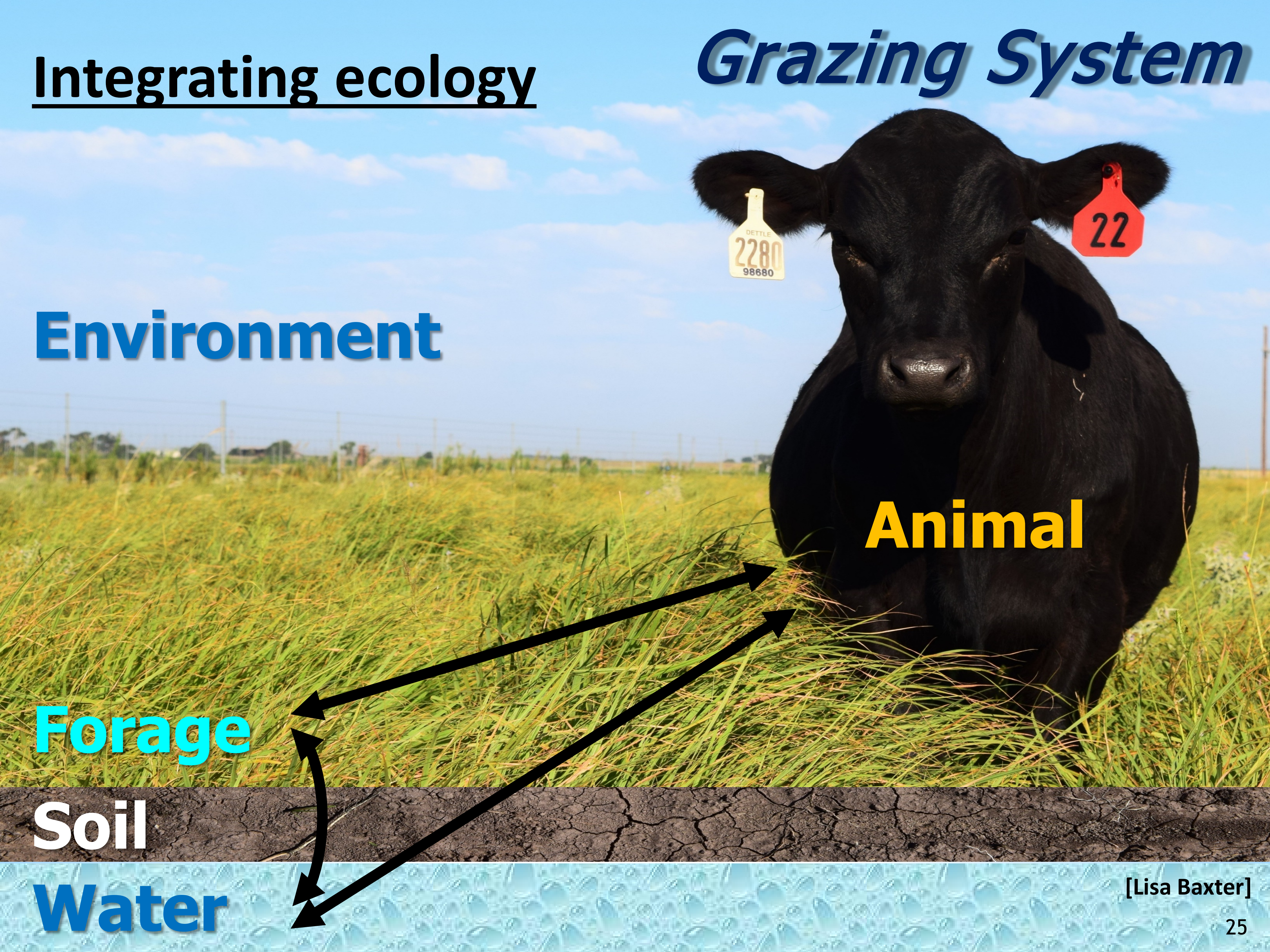
Results vary with animal mass unit, type of water, and estimates of irrigation.

Beef Production Chain

Cow-calf → **Stocker** → **Fattening**

Cow-calf	Stocker	Fattening
graze extensive grassland, crop residue	graze improved forages	high-grain feedlot diets

Is it possible to strategically integrate high-quality legumes *without* increasing the water footprint?


Integrating ecology
Grazing System
Environment
Animal
Forage
Soil
Water
[Lisa Baxter]

Species comparison for water footprint

m^3 transpired / kg biomass yield

Forage species	Water footprint
	m^3 transpired/kg biomass
Bermudagrass	.265
Corn	.370
Wheat	.500
Alfalfa	.770

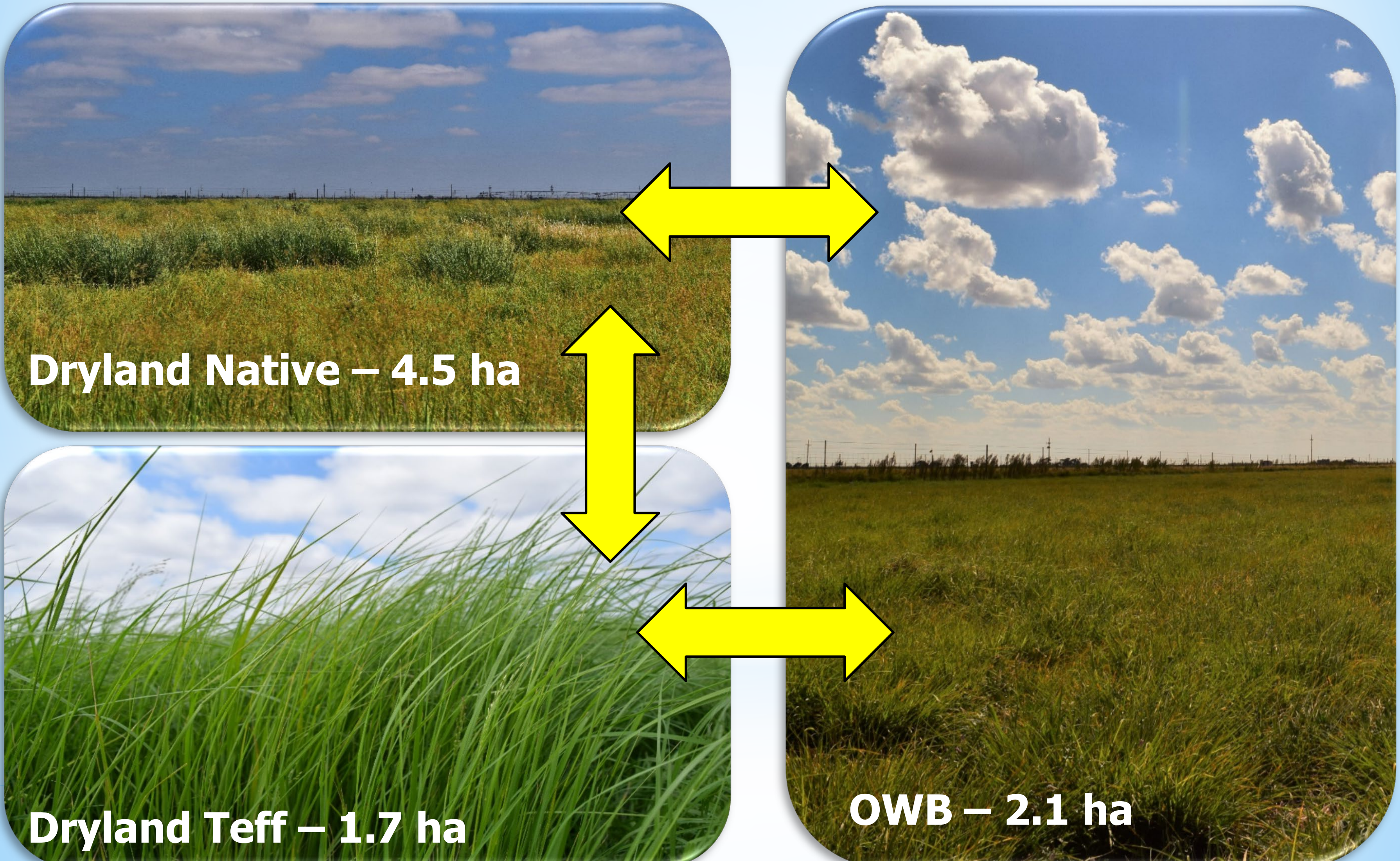
Beef Stocker Treatments

Forage system	N fertilizer	Avg irrigation
	kg/ha	mm/yr
Grass only	67	207
Grass-alfalfa	0	223

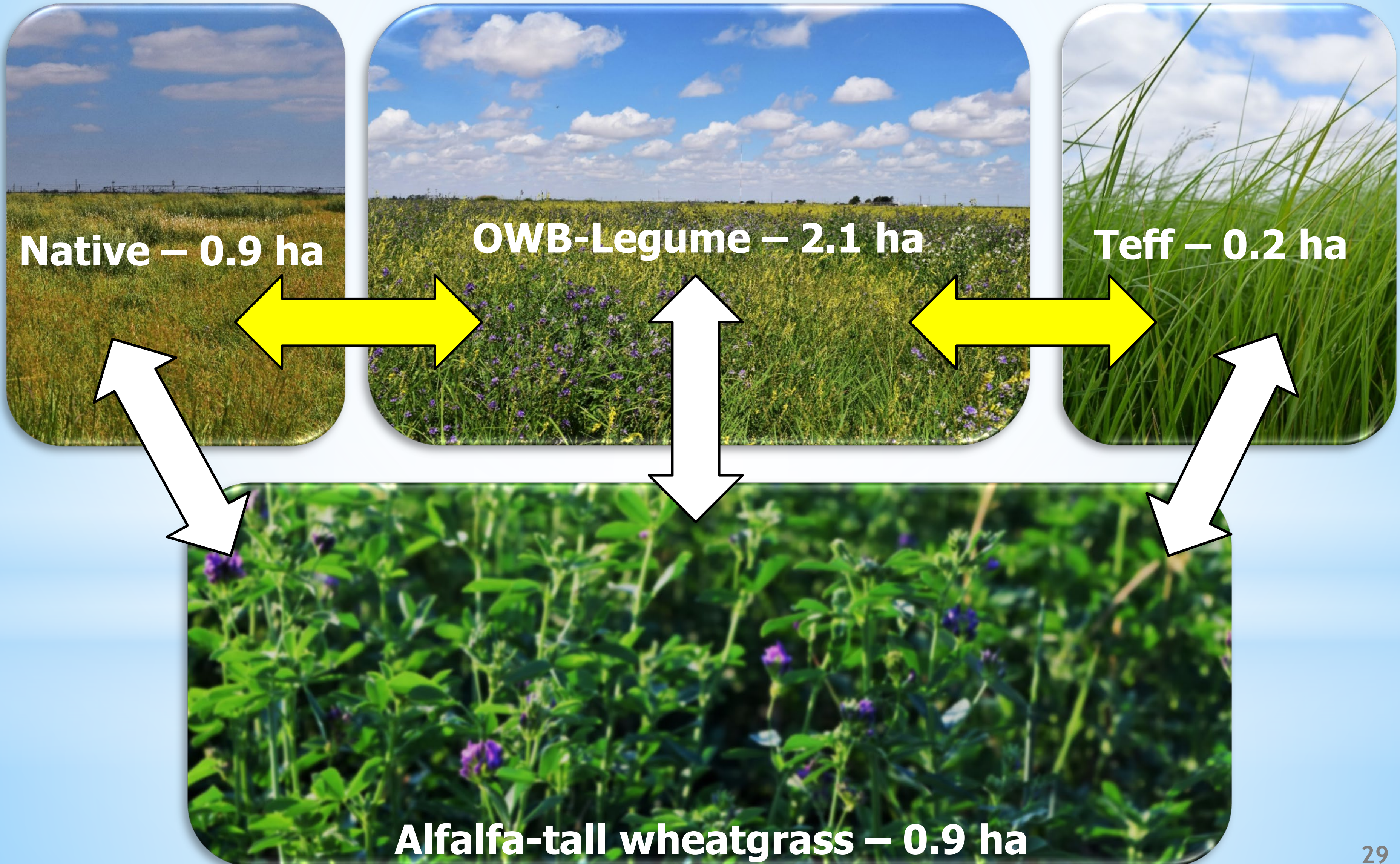
Angus steers grazed from early June to early October. Forage allowance was not restricted.

Lisa Baxter, PhD student
Crop Sci. (2017) 57:2294,2303

Grass-only grazing rotation
(12 head on 8.3 ha)



GL grazing rotation (8 head on 4.1 ha)



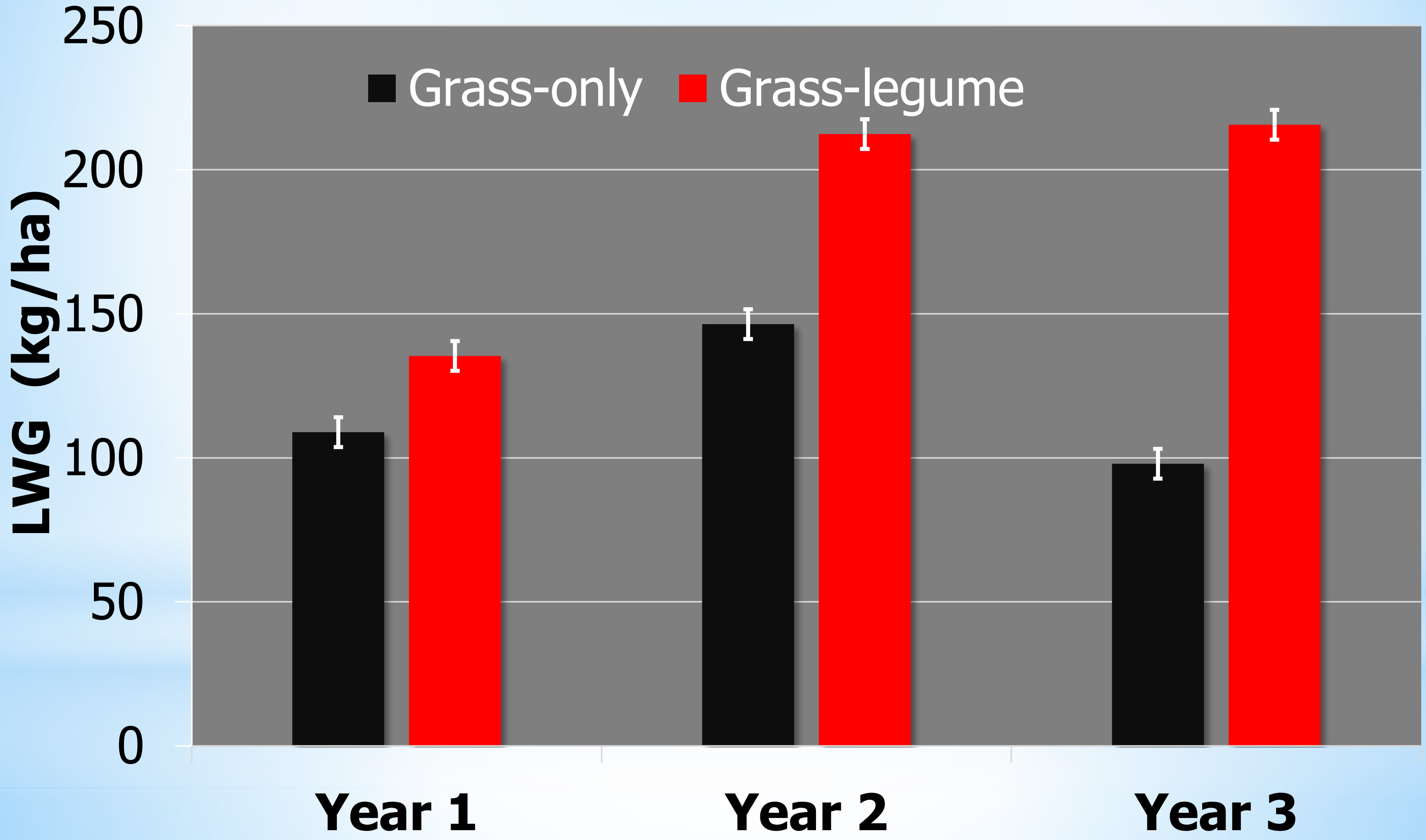
[Lisa Baxter]

Water Footprint Calculations

- Water footprint = **m^3** water delivery / **kg** LWG
  - (Effective rainfall + corrected irrigation) / *observed* LWG
  - (Corrected irrigation + drinking water) / *observed* LWG
  - (Effective rainfall + *total* irrigation) / *total* LWG

  Included gain predicted from feeding back the harvested hay.
  - (*Total* irrigation + drinking water) / *total* LWG

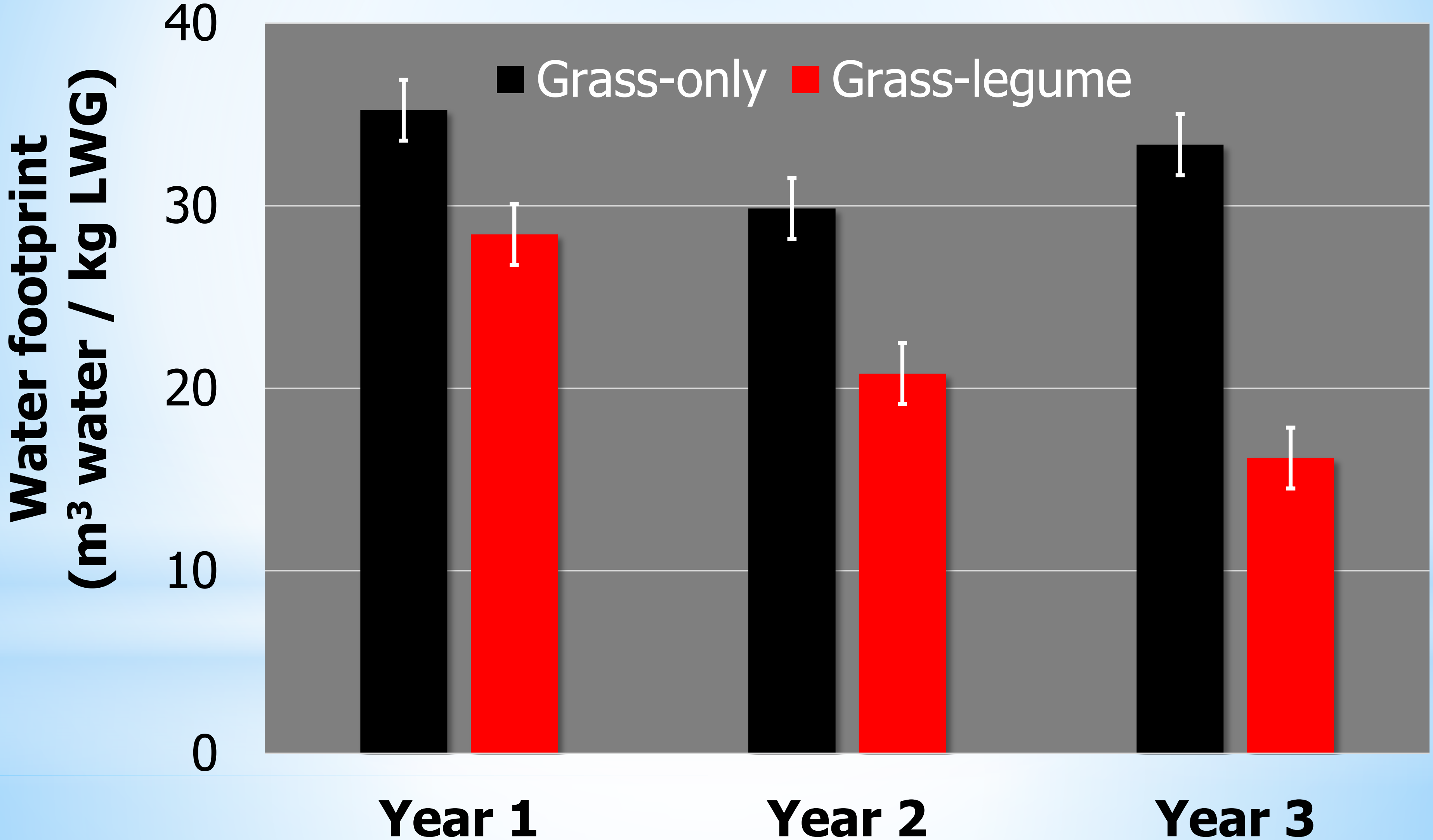
Comparison of Observed LWG per ha



Bars represent SE mean.

n = 3; $P < 0.001$

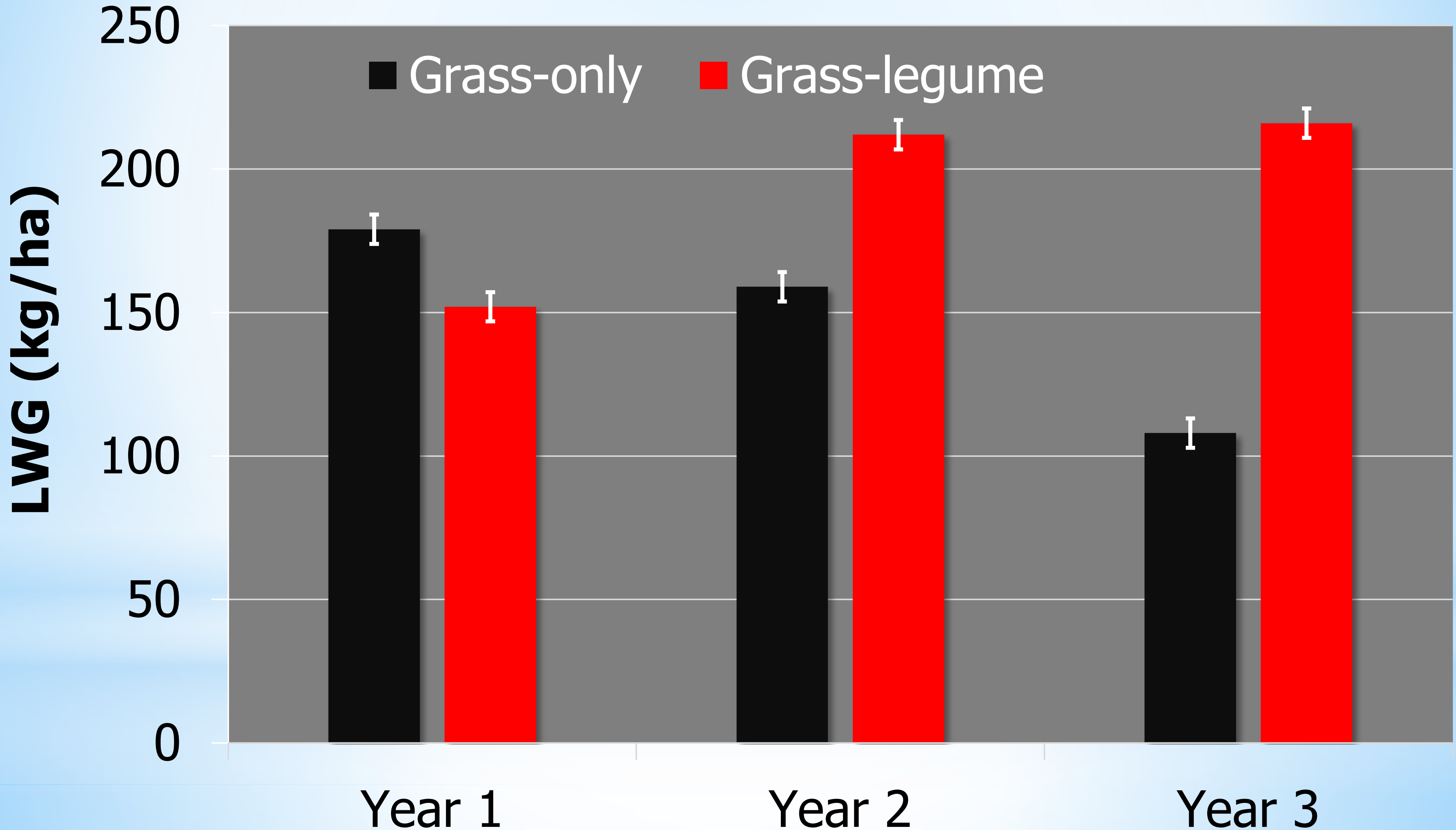
Water Footprint for Observed LWG



Bars represent SE mean.

n = 3; $P < 0.001$

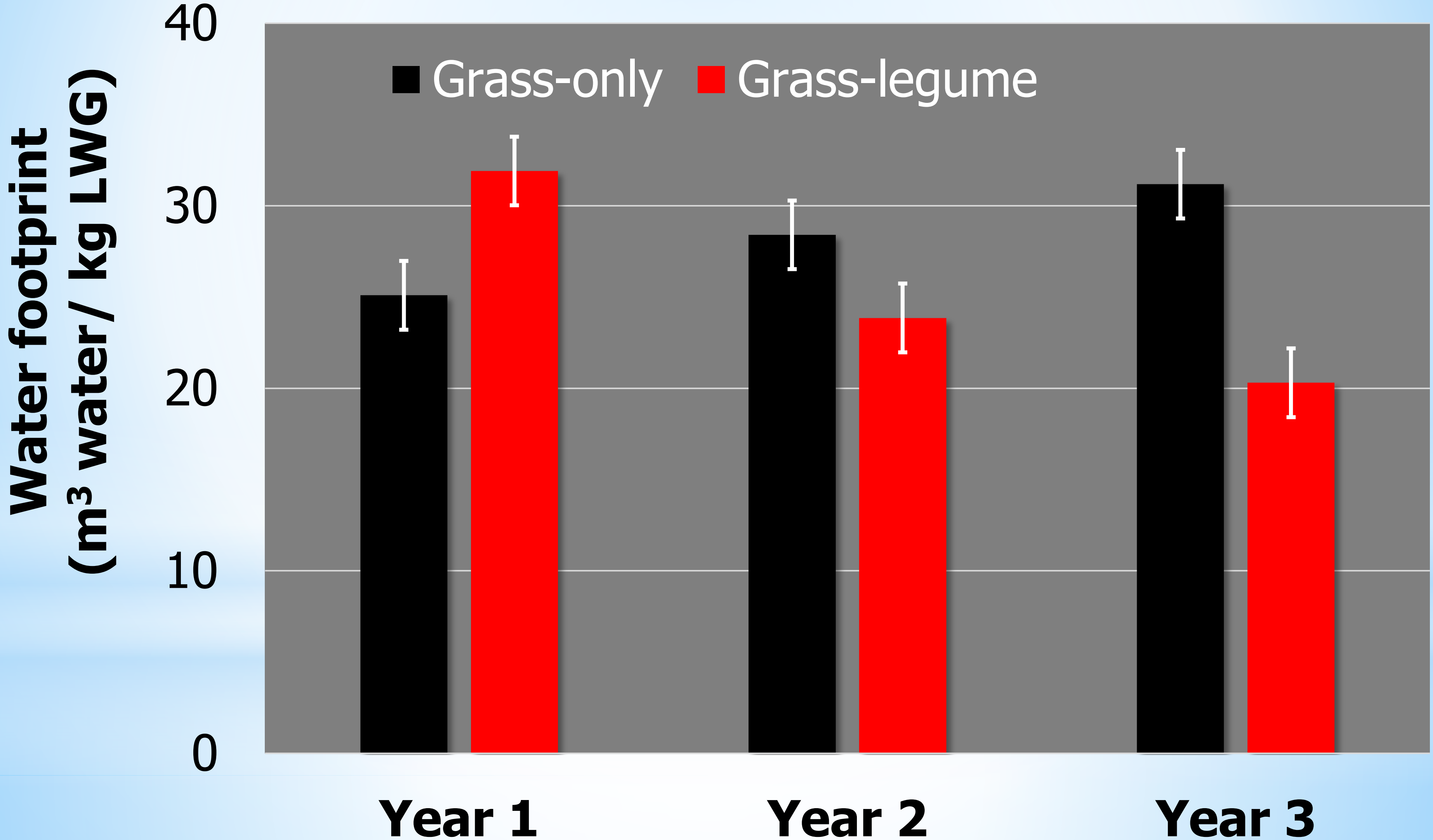
Comparison of Total LWG per ha



Bars represent SE mean.

n = 3; $P < 0.001$

Water Footprint for Total LWG



Bars represent SE mean.

n = 3; P < 0.02

Water footprints in m³/kg beef gain

	Water inputs	Grass-only	Grass + legume	Δ %
Observed	Effective rain + irrig + drinking	33	22	-34 %
	Irrigation + drinking	3.3	2.4	-27 %
Total: with hay	Effective rain + irrig + drinking			
	Irrigation + drinking			

Water footprints in m^3/kg beef gain

	Water inputs	Grass-only	Grass + legume	Δ %
Observed	Effective rain + irrig + drinking	33	22	-34 %
	Irrigation + drinking	3.3	2.4	-27 %
Total: with hay	Effective rain + irrig + drinking	28	25	-11%
	Irrigation + drinking	3.7	6.9	+89%

Why? Legume presence required slightly more irrigation, but it increased animal gain 60% over grass alone. Twice the protein content, more digestible energy.

Alfalfa uses more water per kg of forage, but leverages two major attributes:

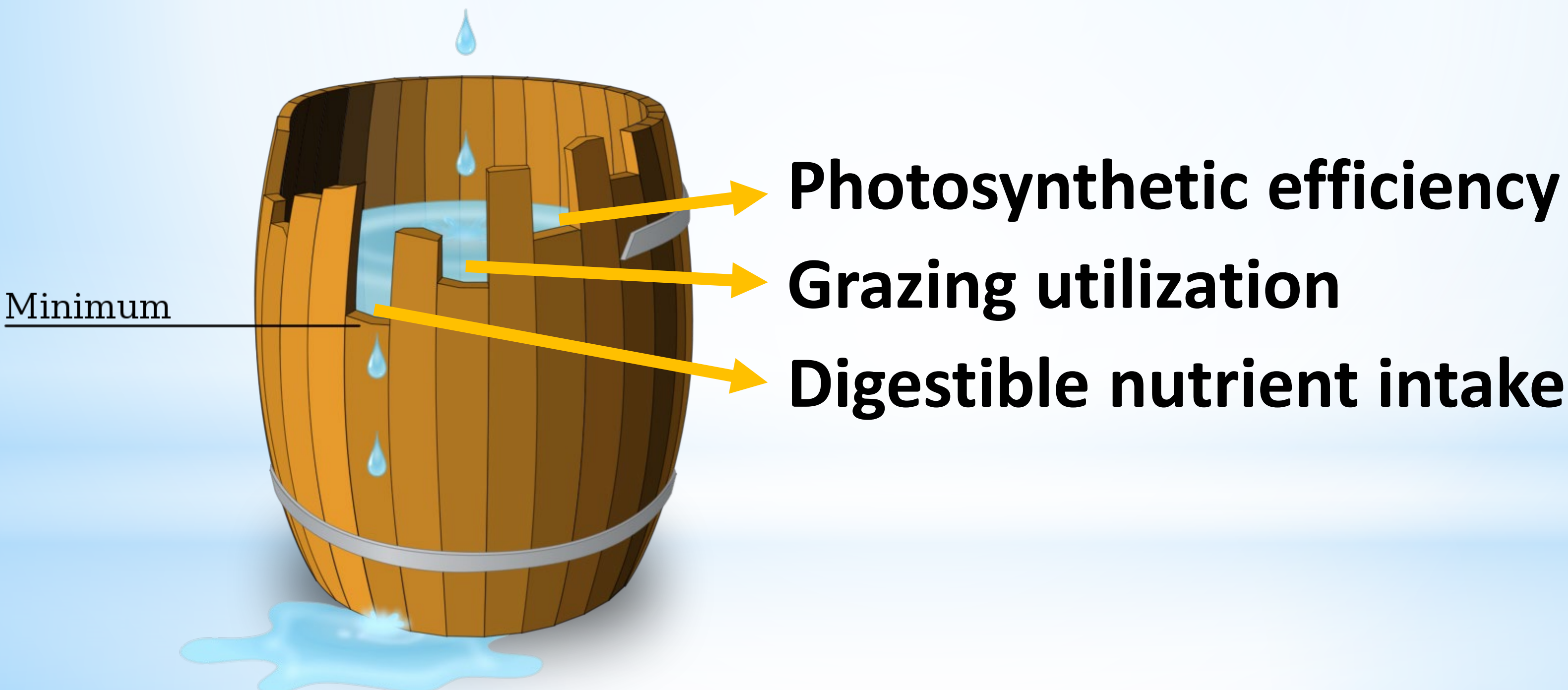
1. Greater nutritive value in grass-legume

Forage system	CP	IVTOMD	ADG
	%	%	kg
Grass only	7.0	55	0.79
Grass-alfalfa	14.4	64	0.94

2. Fixes N via symbiosis, so C and GHG footprints are also lower.

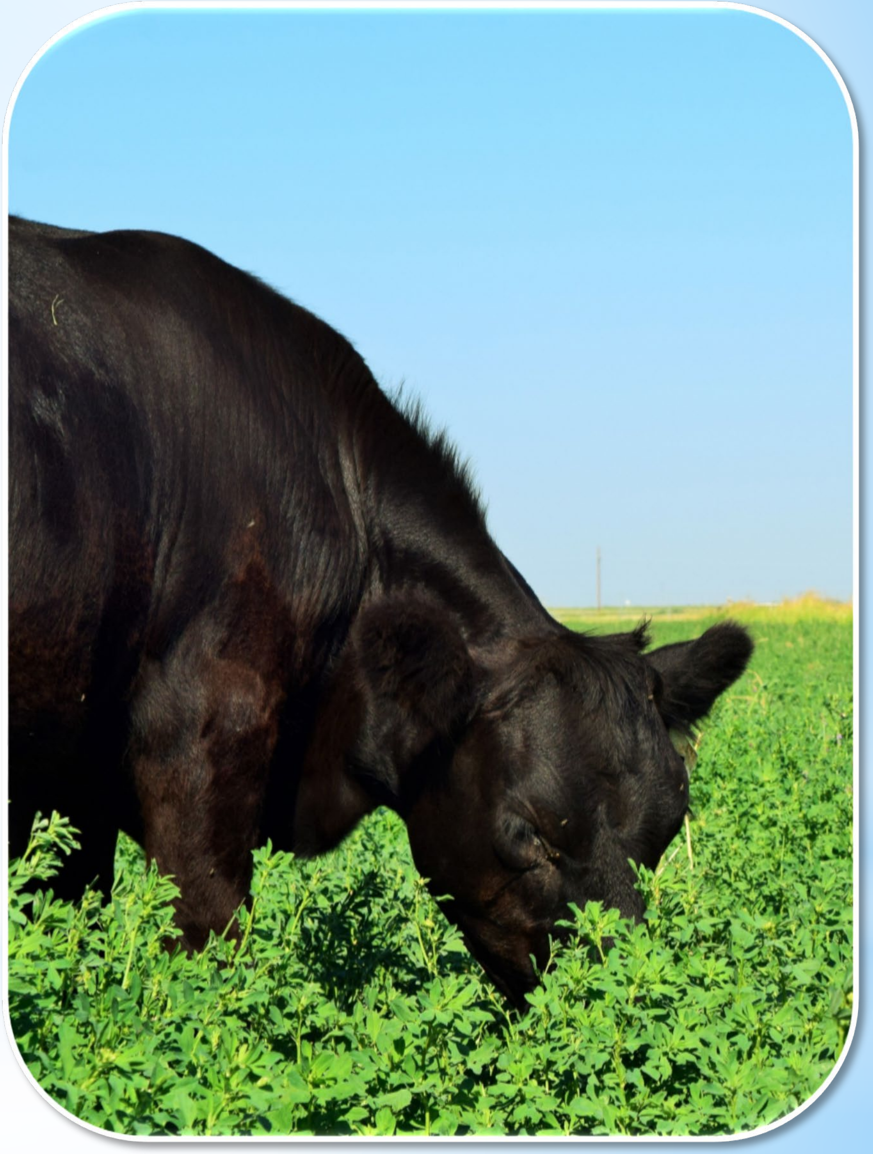
Efficiency of resource use: Law of the Minimum

- Deficit of most limiting factor restricts yield.
- Limiting resource renders inefficient all other inputs.
- Upon relief, the next most-limiting factor restricts yield until genetic potential is reached.



Liebig's barrel

- **Inclusion of legumes increased beef stocker gain per animal-day and per ha**
- **Grass-Legume system received slightly more water**



[Lisa Baxter]

CONCLUSIONS AND VISION

1. **Legumes reduced water footprint of green (rain) and blue (irrigation + drinking) water,**
   …but not for blue water alone when credit for surplus hay was converted to LWG.
2. **The grass-legume system reduced the limiting factor of nutritive quality deficiency, making more efficient the water use.**
3. **Alfalfa can play a role in low-input-irrigated stocker pastures in the Ogallala Aquifer region.**
4. **Combination of efficient water management, forage selection, and high forage quality can reduce overall water footprint of beef production in the High Plains.**

Graduate Student Research

Digital image analysis of OWB canopy

Simulating OWB growth with ALMANAC model

Pollinator communities and soil ecology in OWB

Alfalfa effect on enteric methane emissions

Alfalfa effect on native grass water relations

Acknowledgements

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TEXAS TECH UNIVERSITY College of Agricultural Sciences & Natural Resources

Contributors

Lisa Baxter	Madhav Dhakal
Vivien Allen	Rick Kellison
Phil Brown	Paul Green
Krishna Bhandari	Victoria Xiong

OgallalaWater.org

QUESTIONS ?