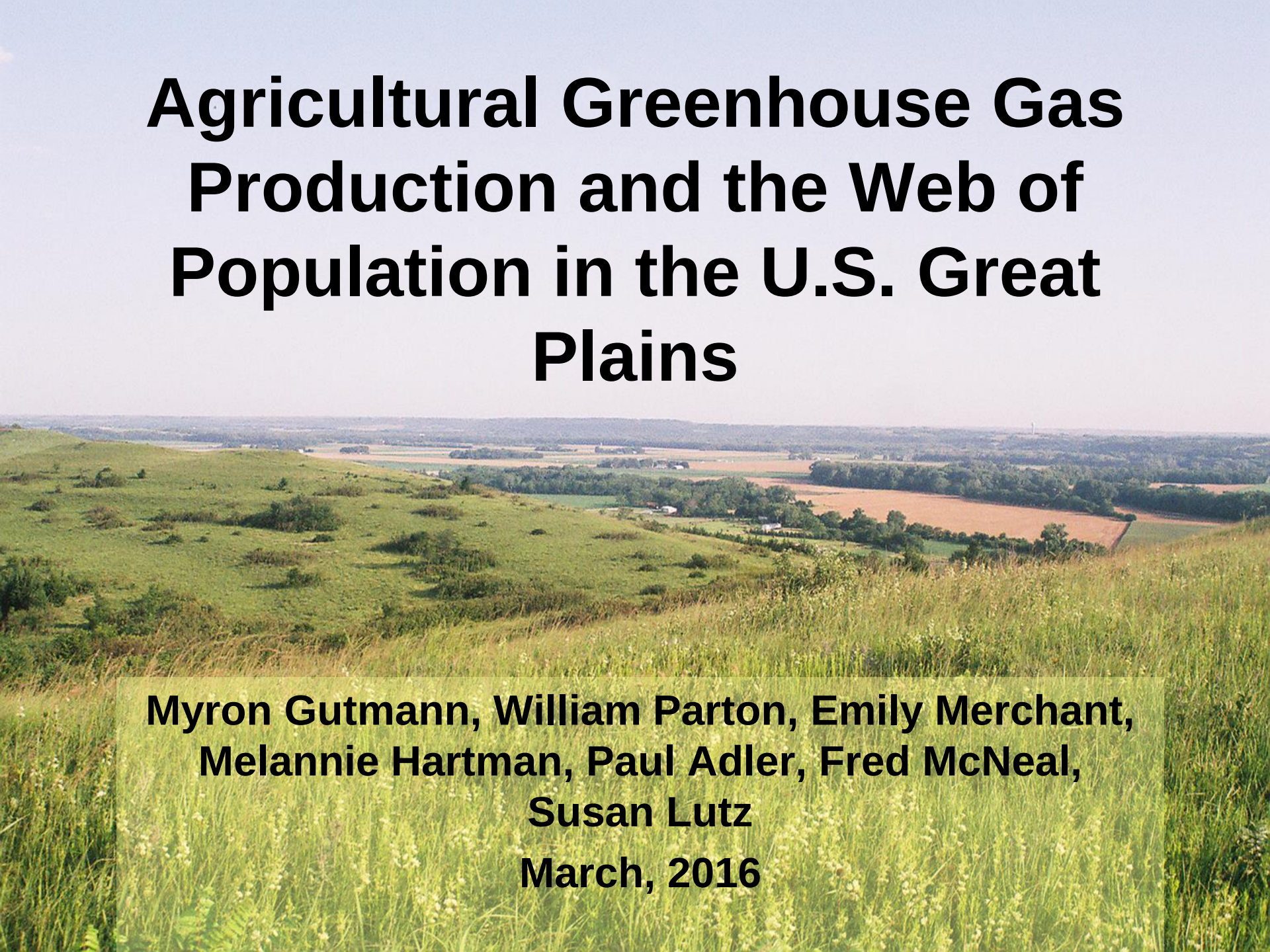
Agricultural Greenhouse Gas Production and the Web of Population in the U.S. Great Plains



Myron Gutmann, William Parton, Emily Merchant, Melannie Hartman, Paul Adler, Fred McNeal, Susan Lutz

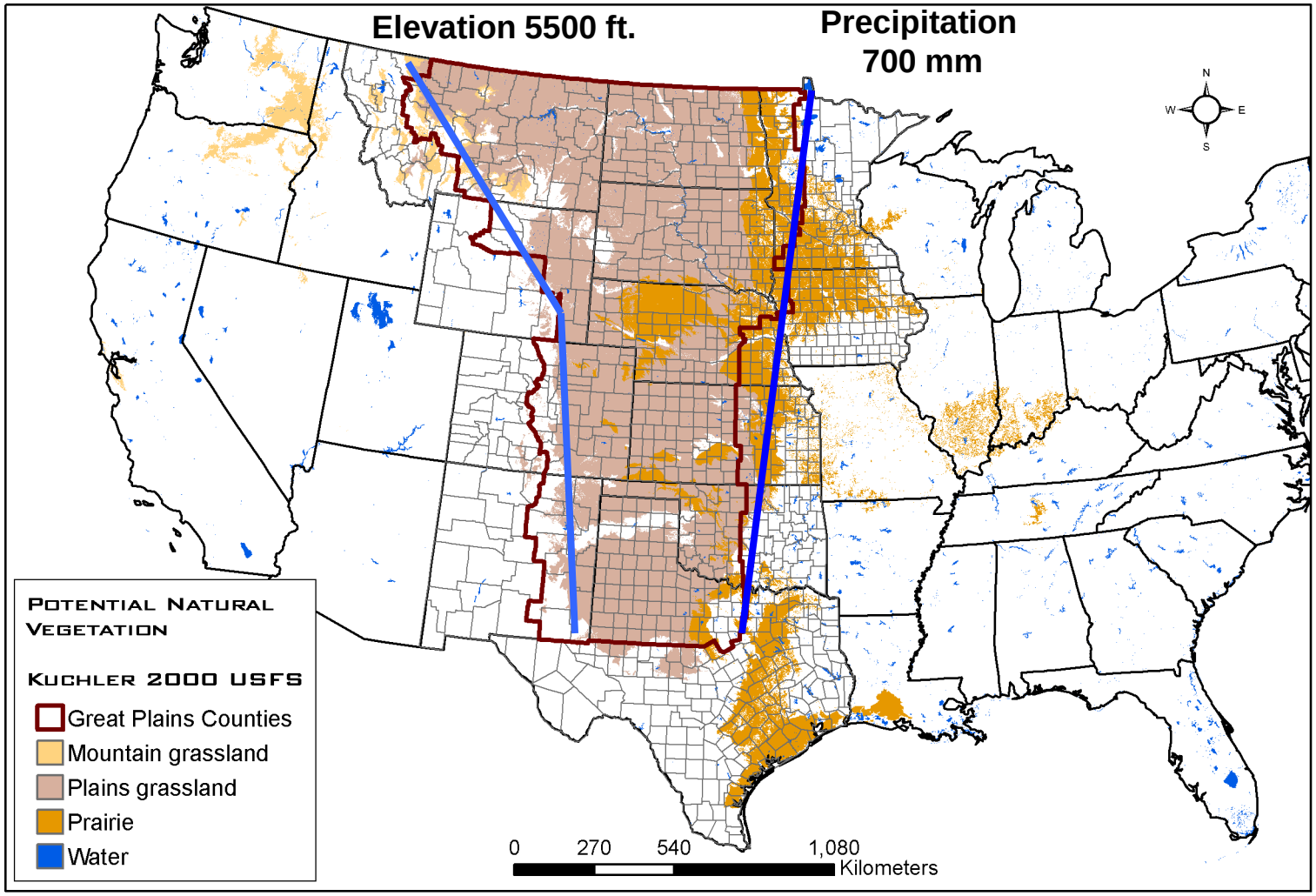
March, 2016

Why Study the Great Plains?

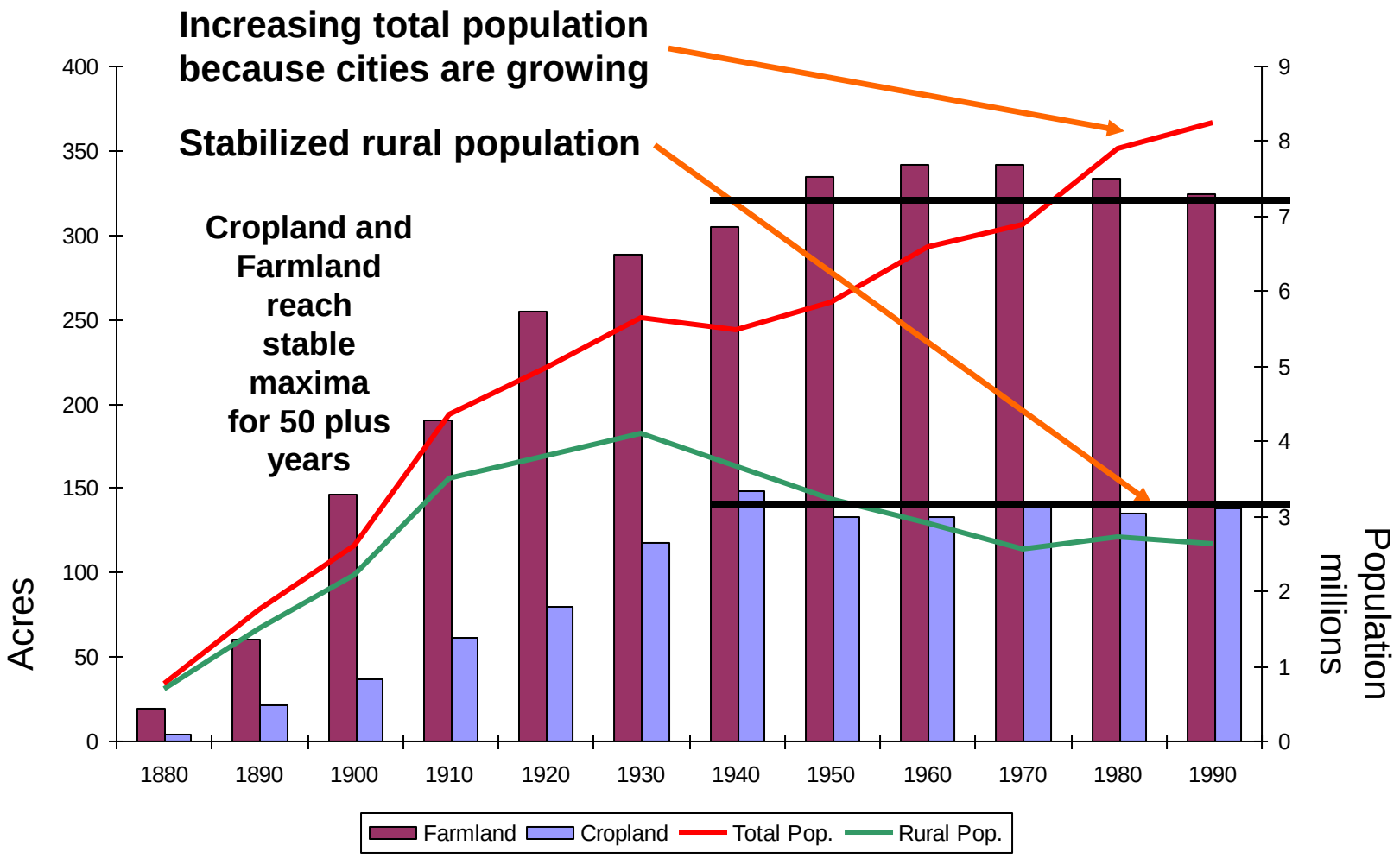
- Big region, still mostly rural, some cities
- Sensitive to environmental change, but temperate grasslands may be adding carbon
- Good data since 1860s, at individual & county levels, plus environmental data since 1930s
- Literature: long cycles of human response to environment (settlement), environmental response to human population (dust bowl) & large-scale linkage-telecoupling (globalization)
- Research supported by Grants R01 HD33554 and R01 HD044889 from the National Institute of Child Health and Human Development

Macro and Micro Land Use Patterns

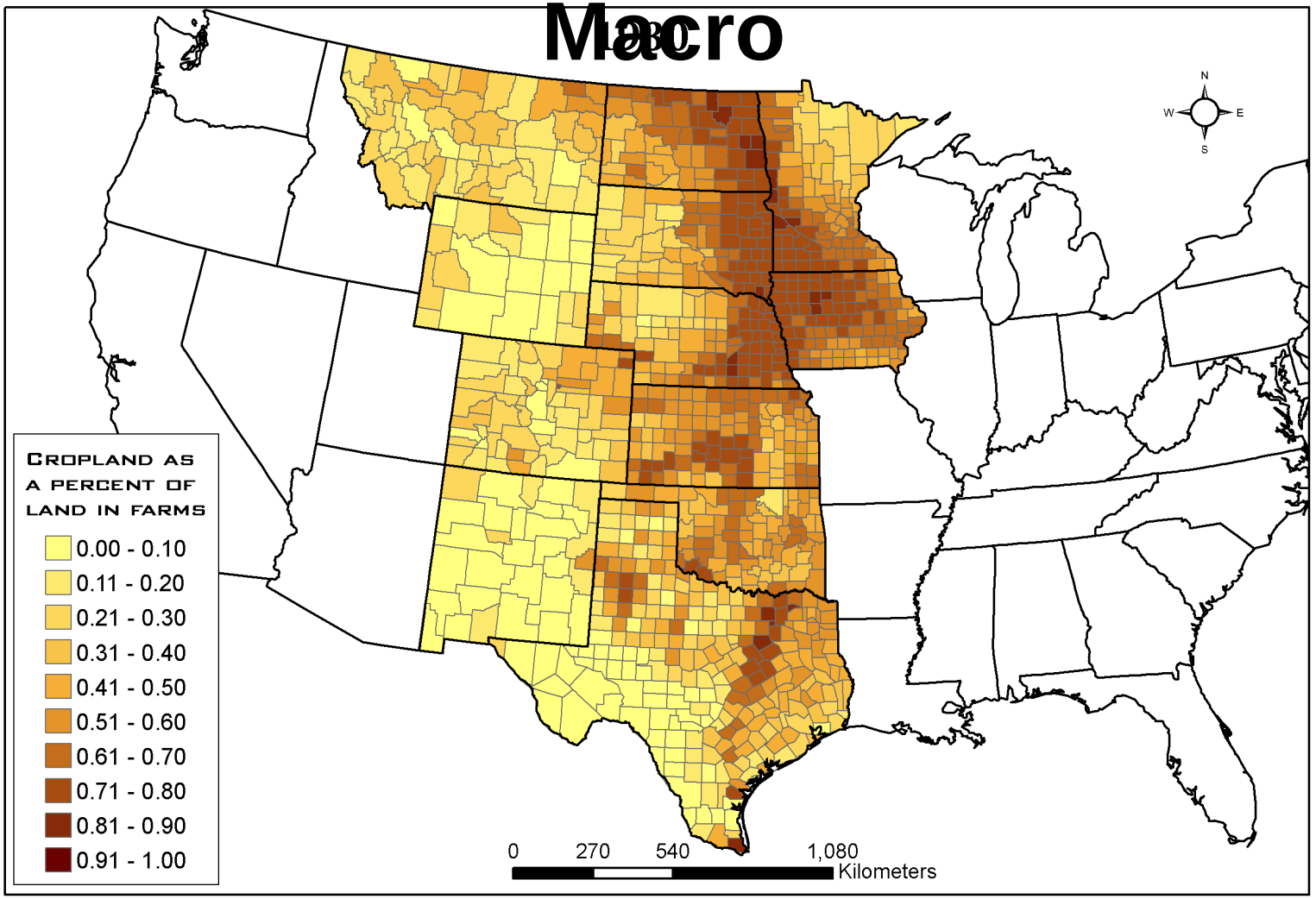
Study Area


Elevation 5500 ft.
Precipitation
700 mm
N
W
E
S
Potential Natural Vegetation
Kuchler 2000 USFS
Great Plains Counties
Mountain grassland
Plains grassland
Prairie
Water
0
270
540
1,080
Kilometers

Long Term Macro Patterns

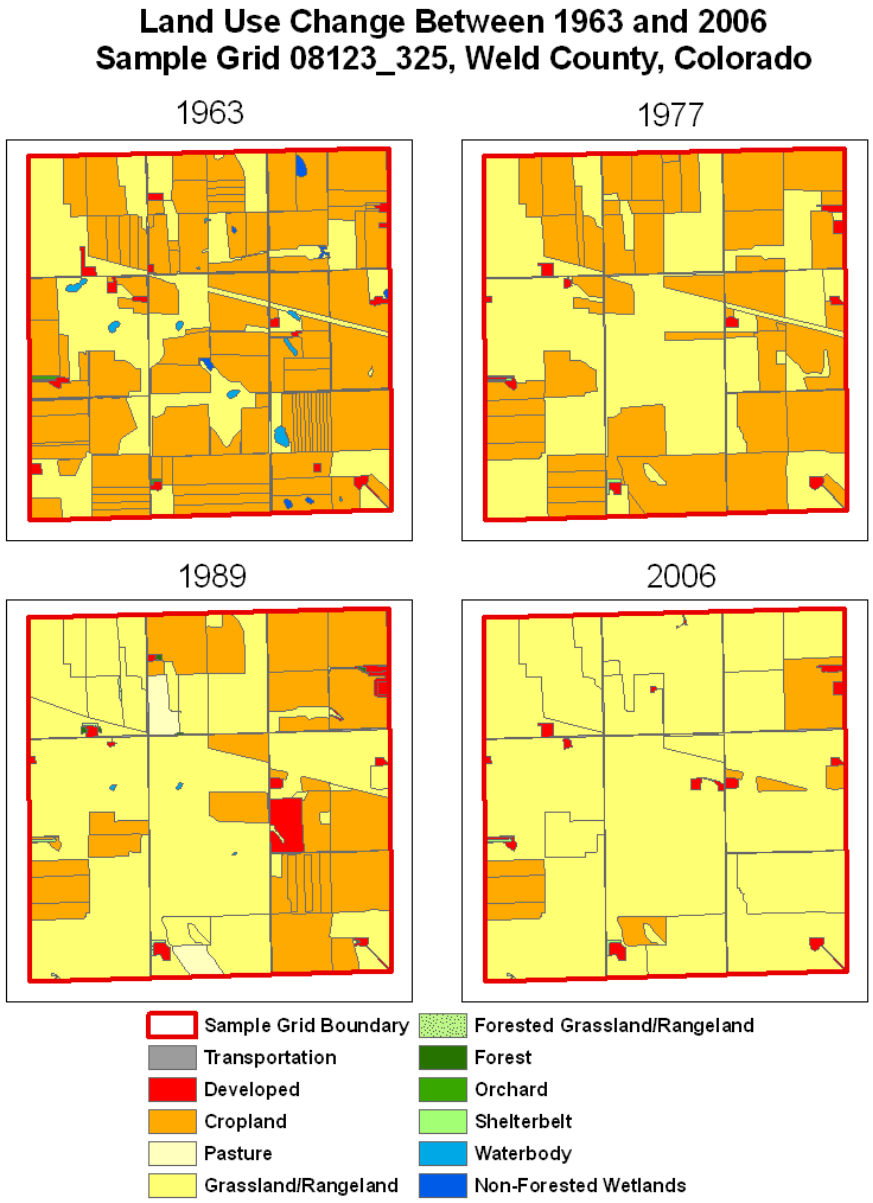


But Not Without Change: Macro



Source: Great Plains County-Level Database @ ICPSR

… and Micro



Source: Great Plains Project Interpreted Aerial Photograph Database

Measuring the Environmental Impact

Question: how to estimate environmental impact of land use change?

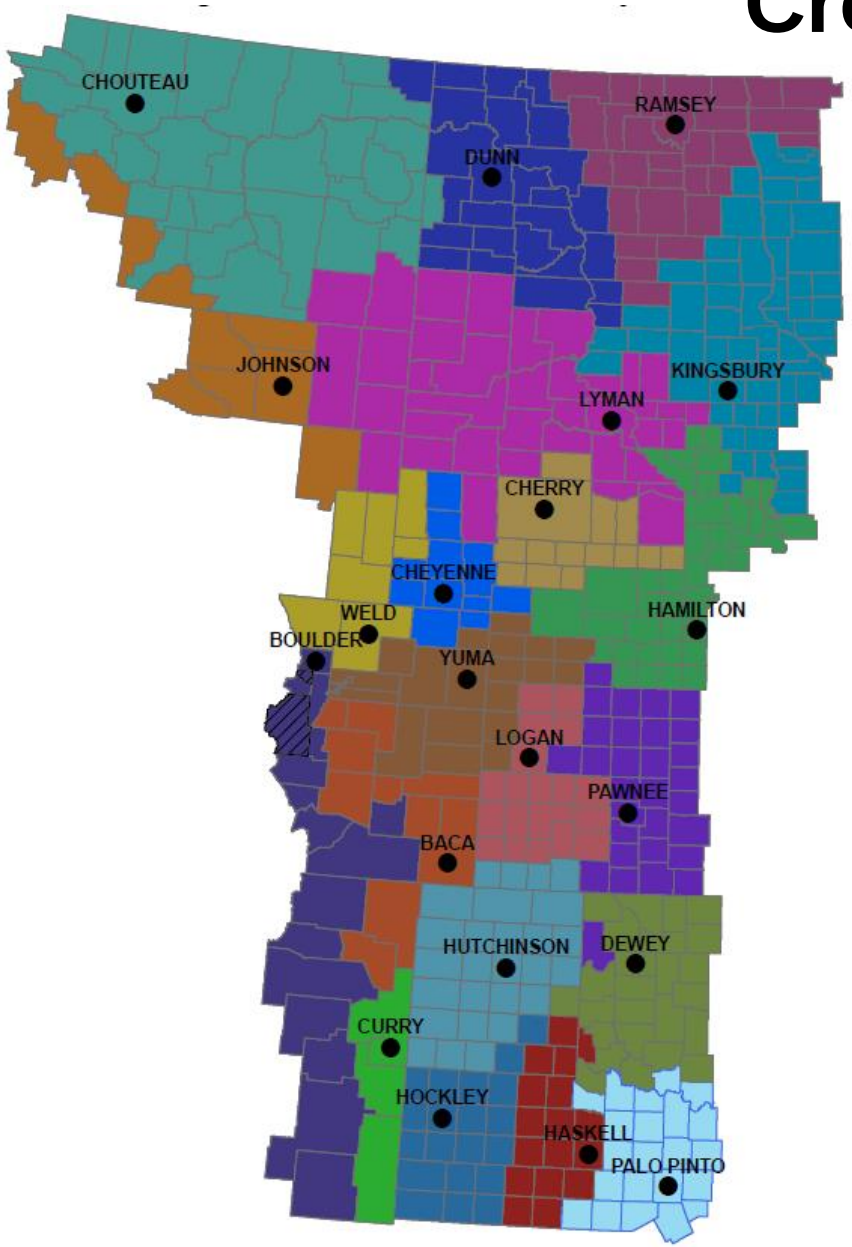
- **One Approach: Biogeochemical Simulation, plus other estimates**
- **Known historical farm practices**
- **Historical county-level land use and yield data (from agricultural census)**
- **Historical weather data for counties**
- **Validated yields**
- **Estimates of Soil Carbon & Nitrogen**

Biogeochemical Modeling: How Has Great Plains Agriculture Affected the Environment?

- Cropping transfers carbon and nitrogen between the soil and the atmosphere.
- Livestock production generates methane.
- Equipment used in cropping requires energy and emits carbon dioxide.
- Land coming out of agriculture can go into highly managed lawns.

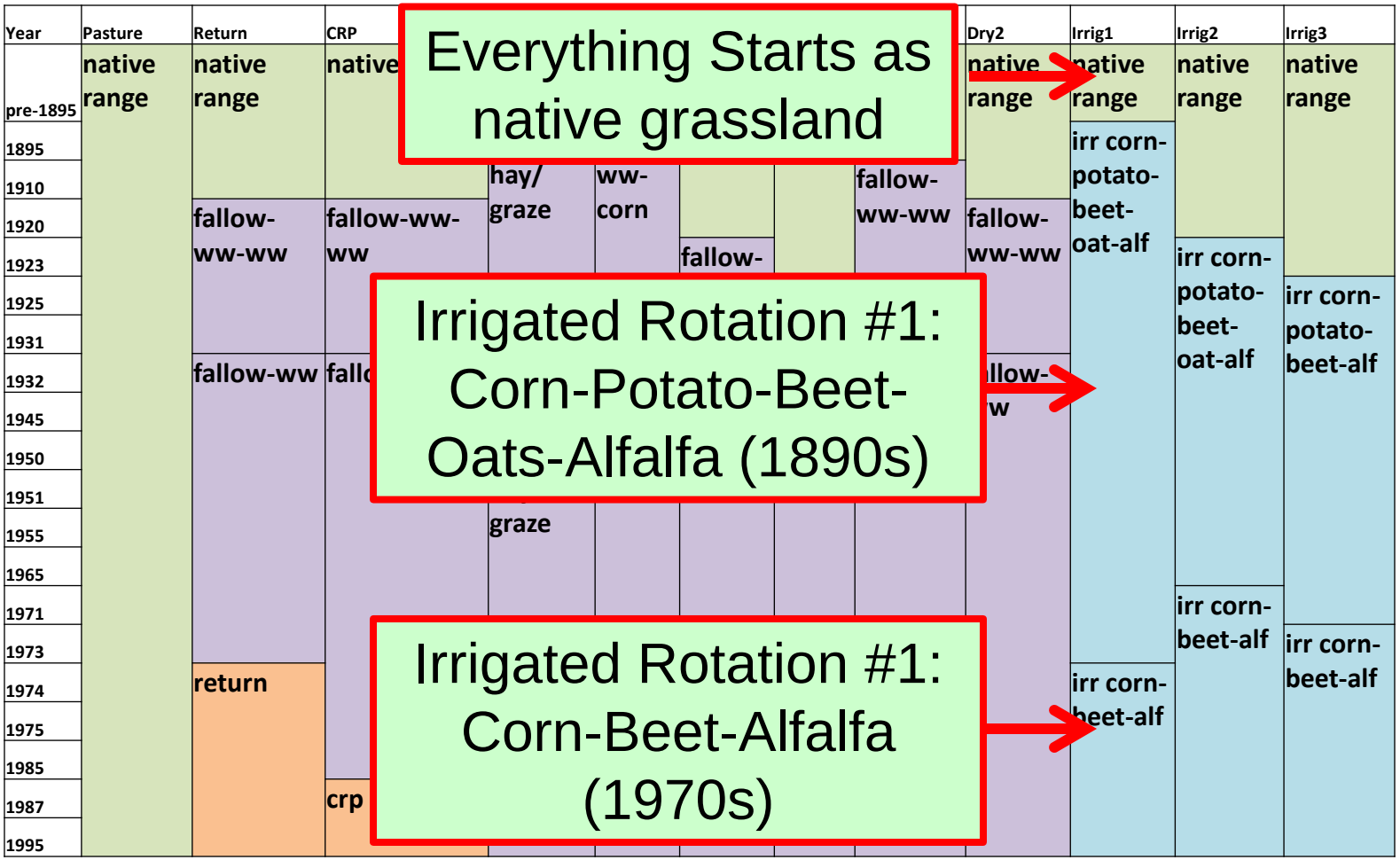
We quantify greenhouse gas (GHG) fluxes from these activities over 150 years

Estimating GHG from Great Plains Cropping

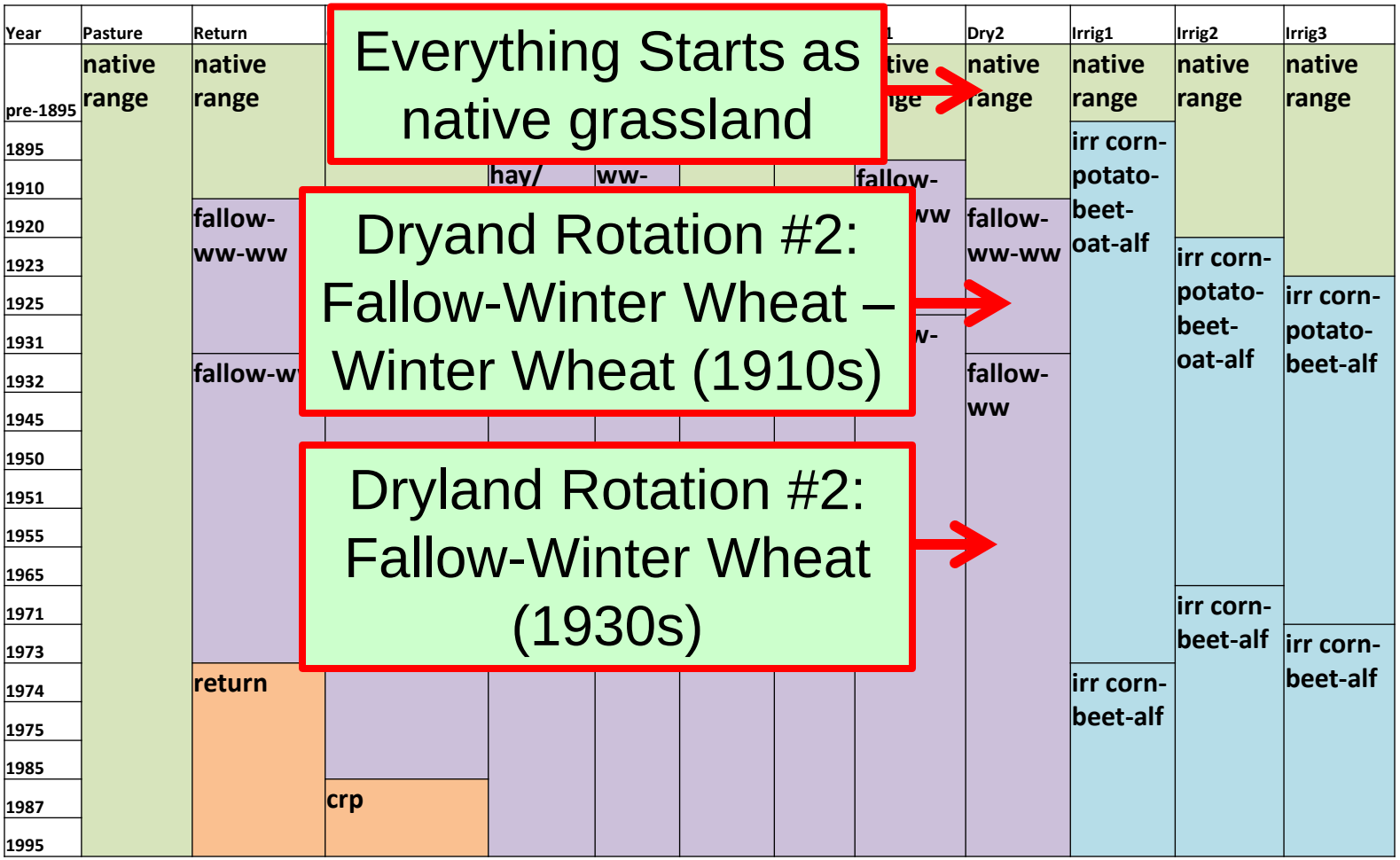


- Parameterized the DAYCENT model using detailed agricultural histories for 21 reference counties.
- Assigned each county to one of the 21 reference counties on the basis of climate and agricultural history.
- Ran the model using the specifications for the reference counties and data specific to each of the 476 GP counties.

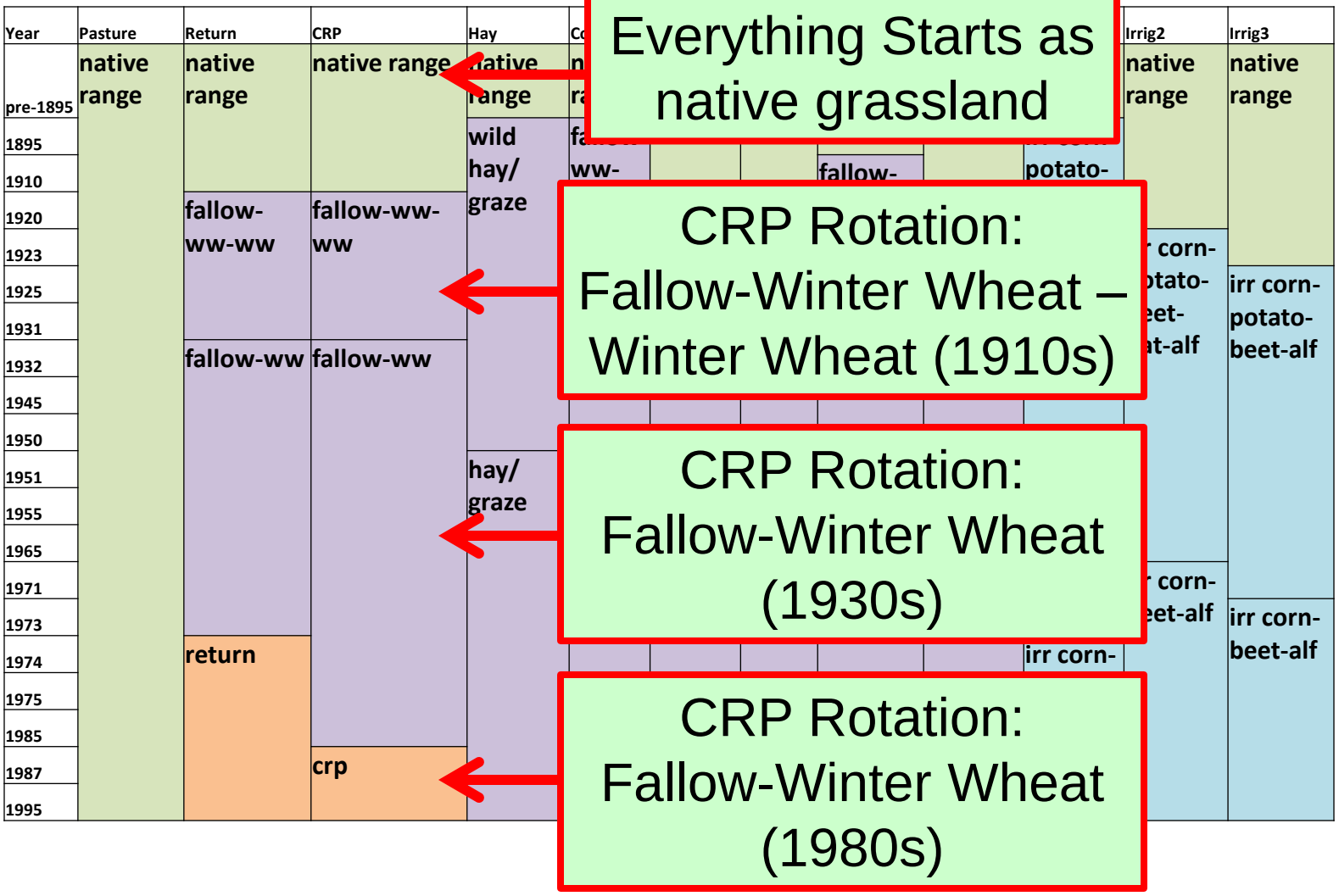
Weld, CO Schedule Files



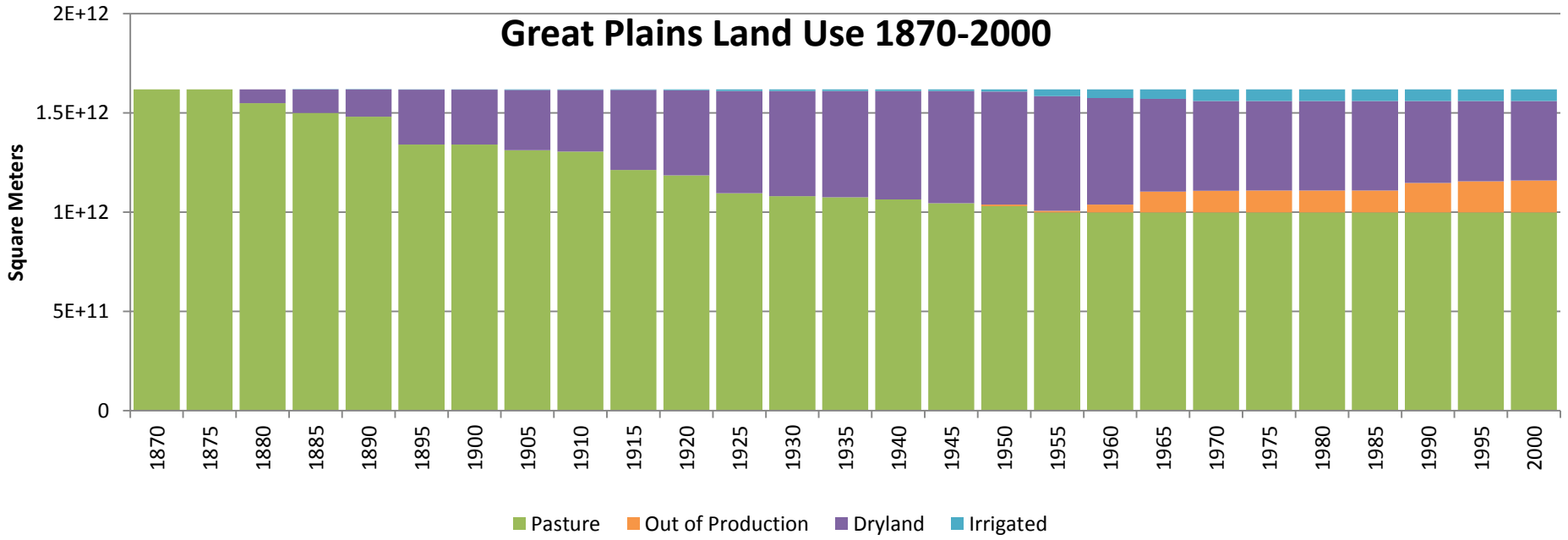
Weld, CO Schedule Files

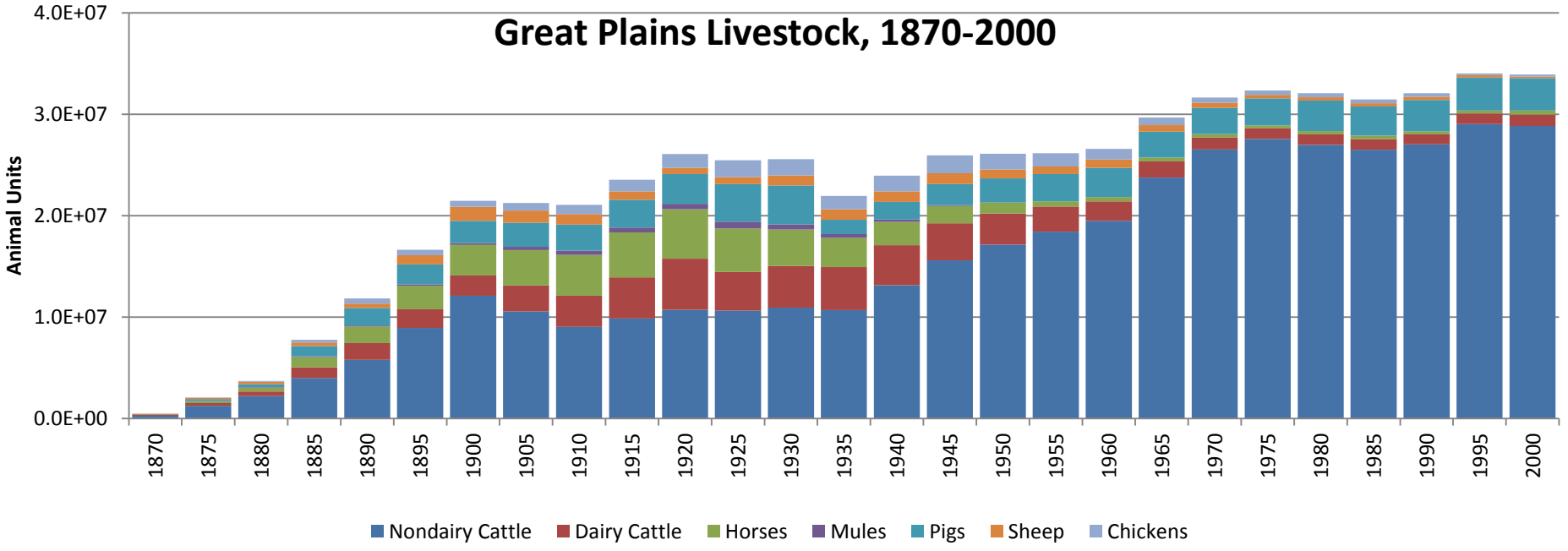


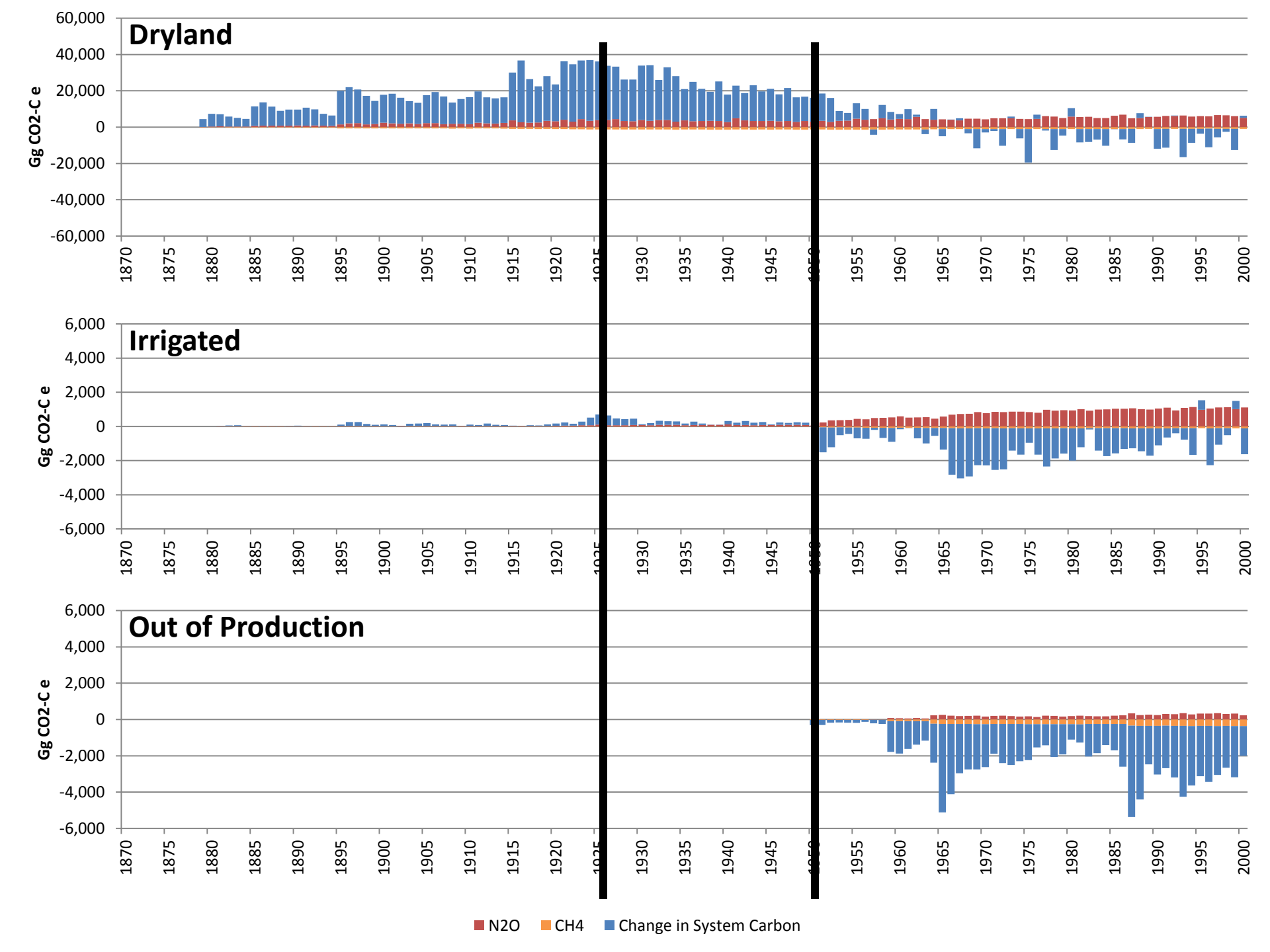
Weld, CO Schedule Files



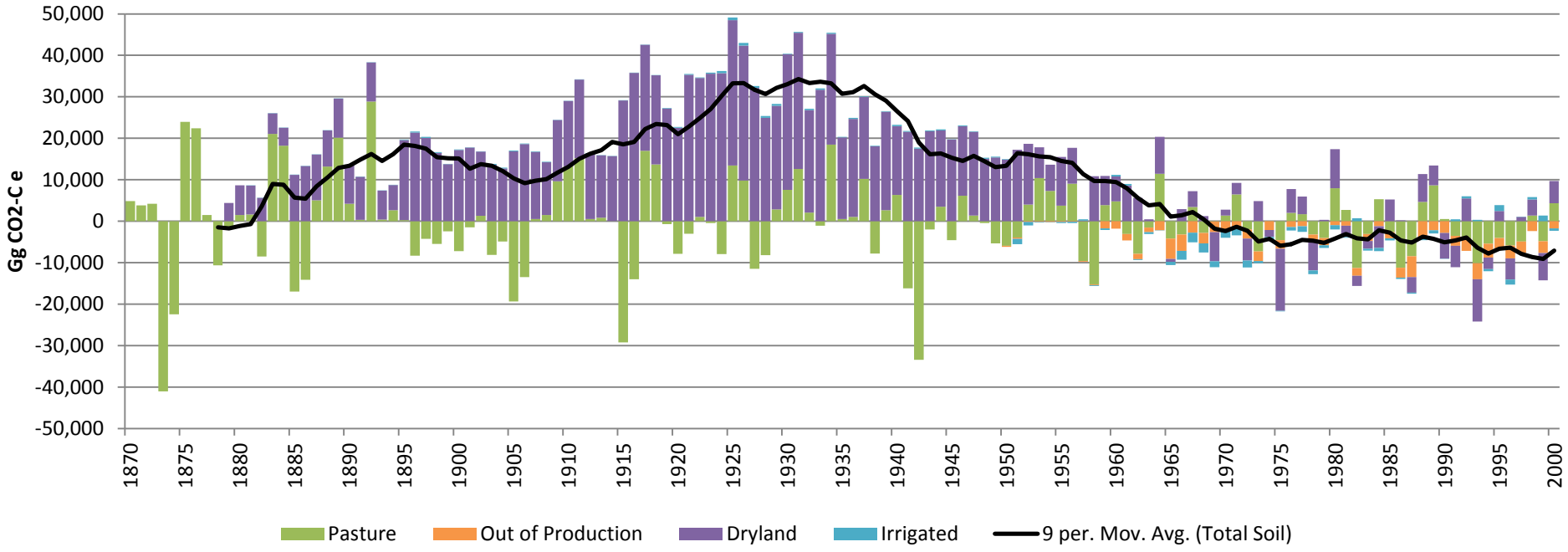
… and then a lot of computing happens…


Great Plains Land Use 1870-2000
Square Meters
2E+12
1.5E+12
1E+12
5E+11
0
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Pasture
Out of Production
Dryland
Irrigated

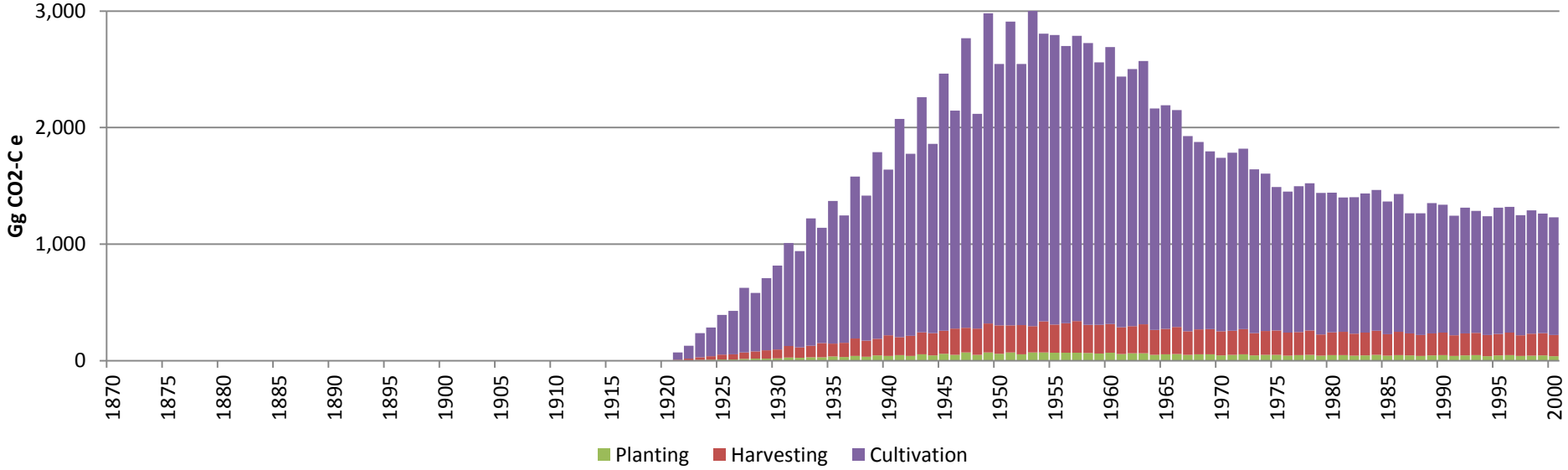

Great Plains Livestock, 1870-2000
Animal Units
4.0E+07
3.0E+07
2.0E+07
1.0E+07
0.0E+00
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Nondairy Cattle
Dairy Cattle
Horses
Mules
Pigs
Sheep
Chickens


Dryland
Irrigated
Out of Production
Gg CO2-C e
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
6,000
4,000
2,000
-2,000
-4,000
-6,000
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
N2O
CH4
Change in System Carbon

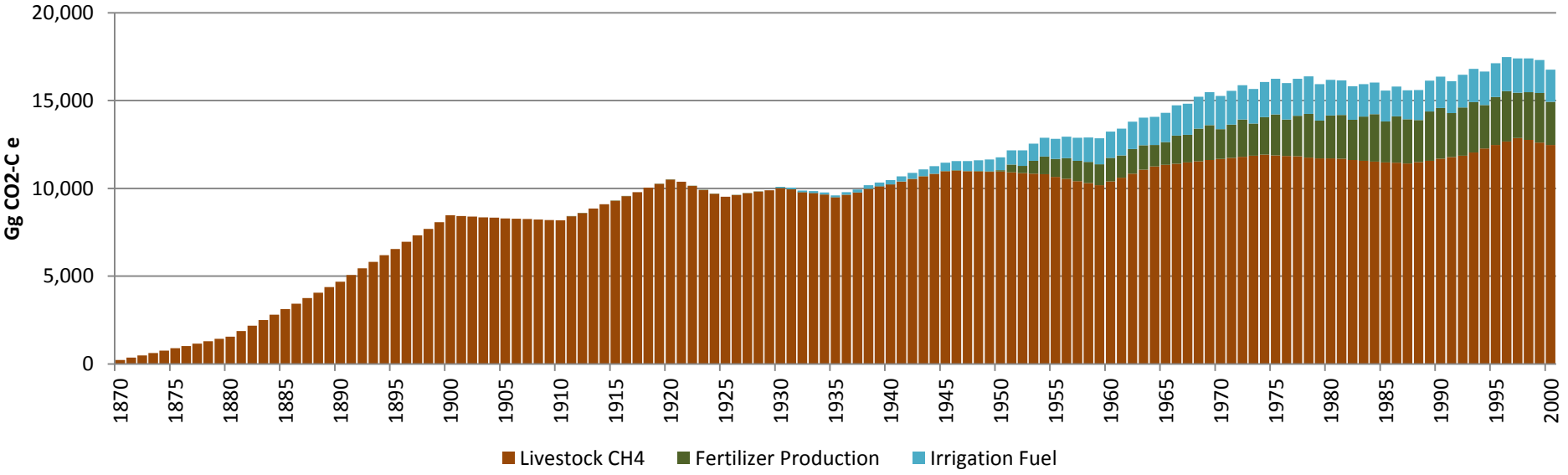
Greenhouse Gas Flux From Land Management, US Great Plains 1870-2000



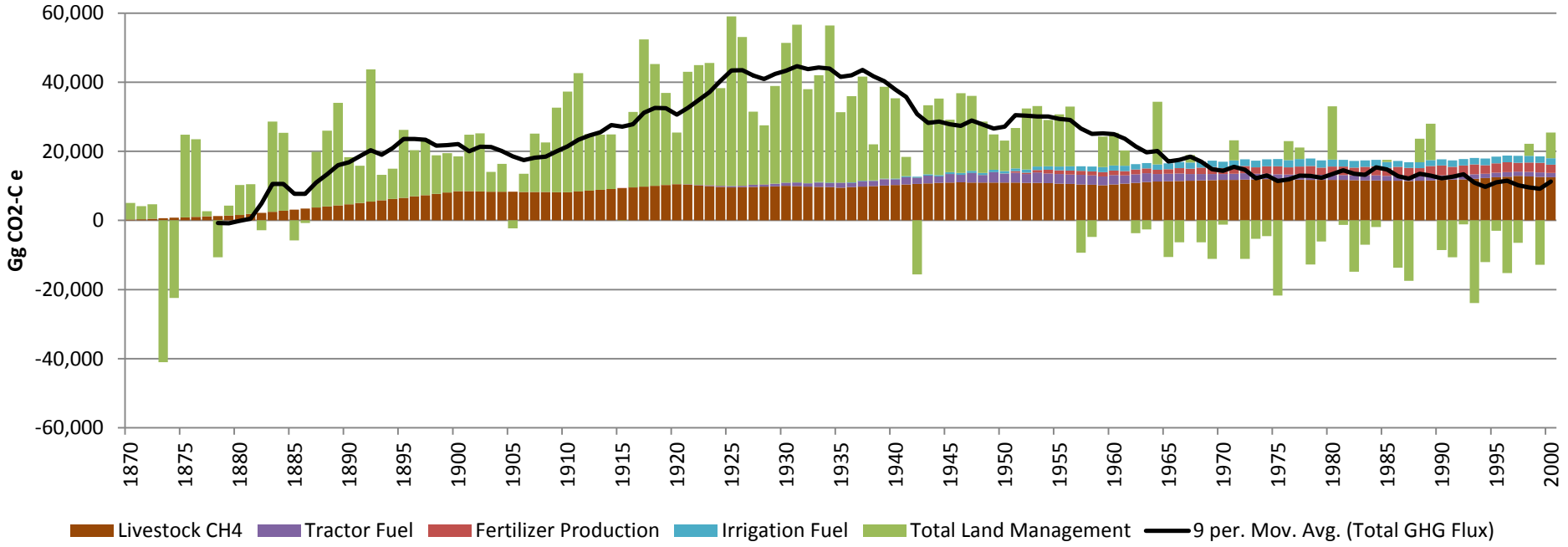
Tractor Fuel for Great Plains Cropping, 1870-2000



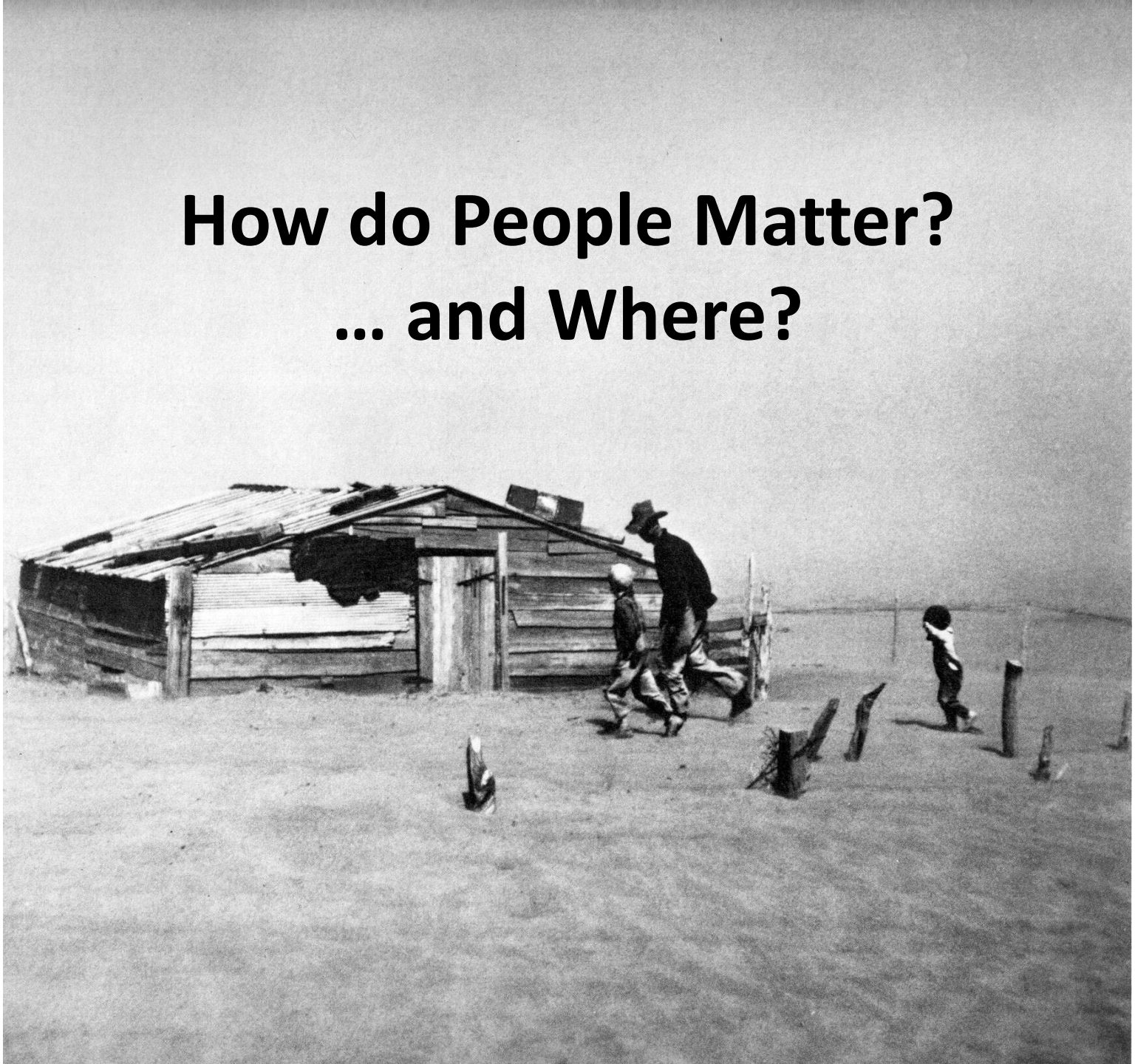
Livestock, Irrigation Pumping, and Fertilizer Production



All Greenhouse Gas Fluxes from Great Plains Agriculture, 1870-2000

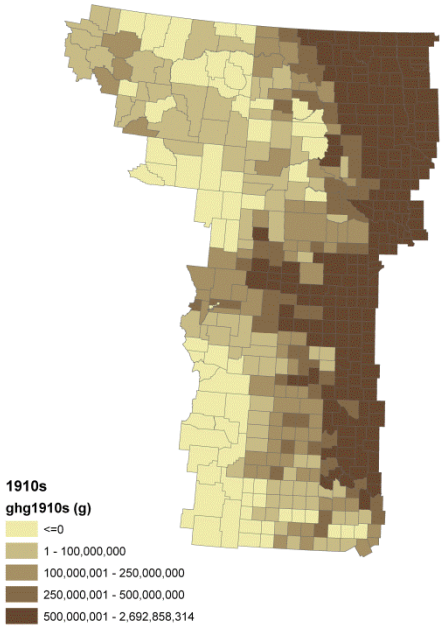


How do People Matter?
… and Where?

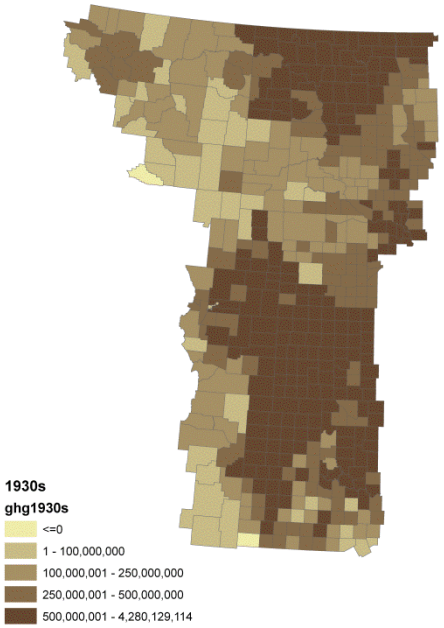


Decadal Net Greenhouse Gas Production from Land Use, 1910s – 1990s

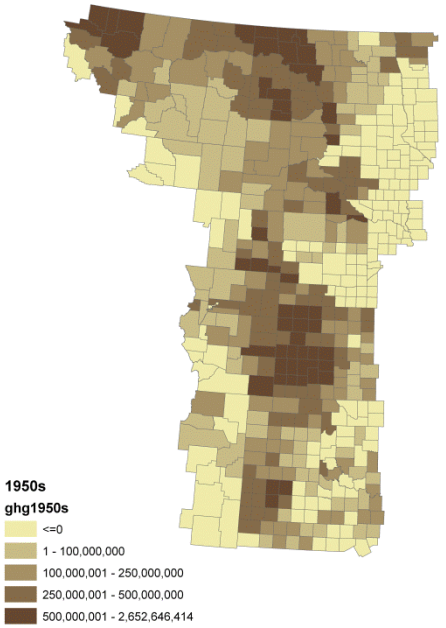
1910s



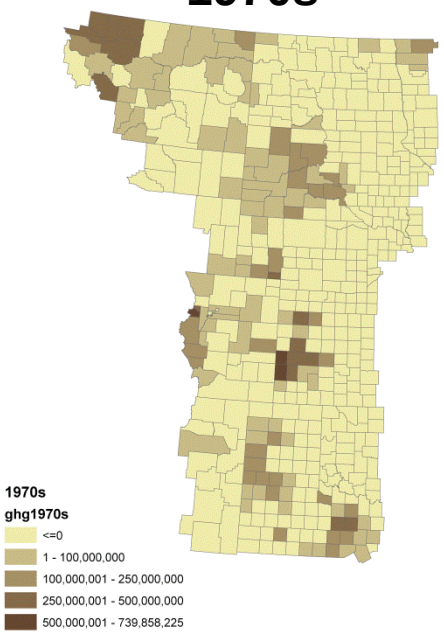
1930s



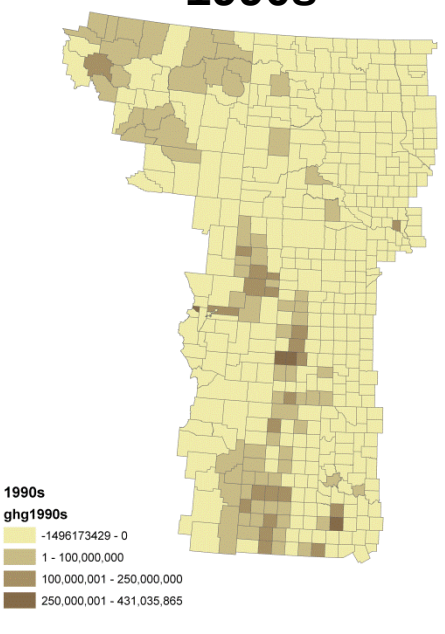
1950s



1970s

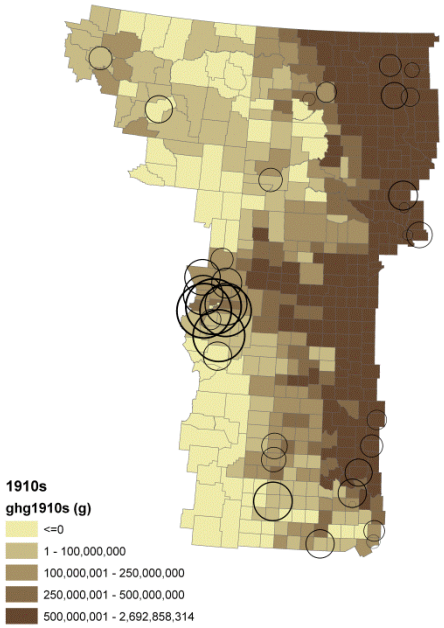


1990s

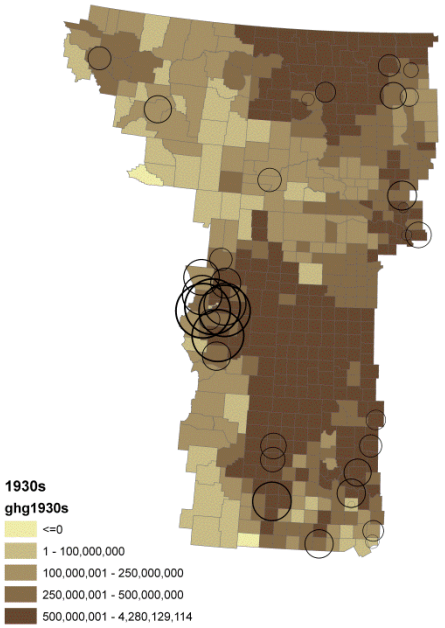


Decadal Net Greenhouse Gas Production from Land Use, 1910s – 1990s With Metro Areas as Circles

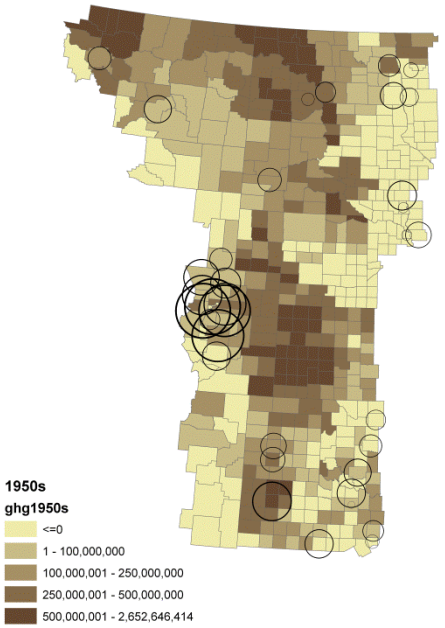
1910s



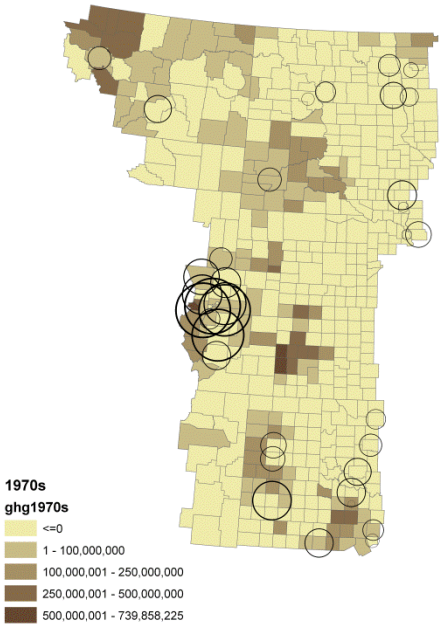
1930s



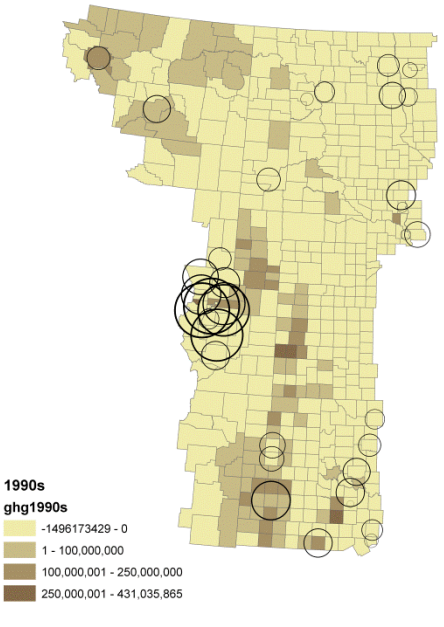
1950s



1970s



1990s



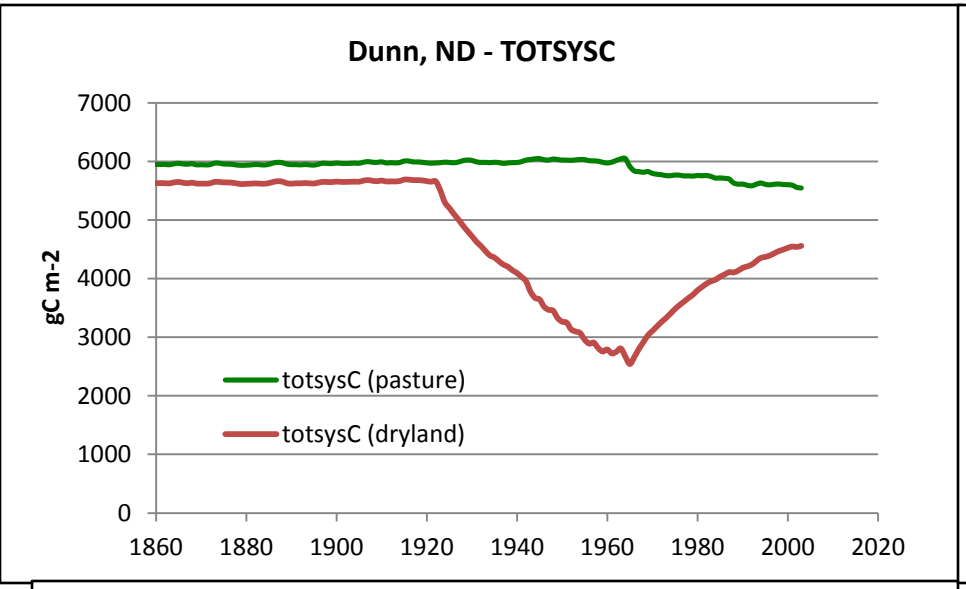
First Conclusions

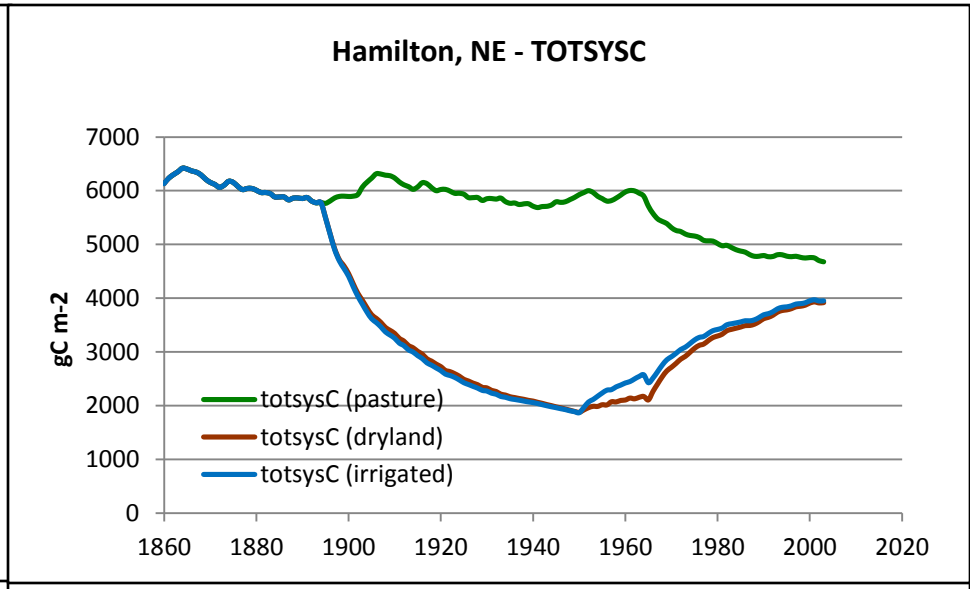
- People drive land use change, and through that early GHG production, but the "population" signal isn't strong
- Local consumption also isn't a strong signal, meaning that local/regional populations aren't significant after the period of plowout
- What this needs is a study with longer reach – to consumers elsewhere – which we're hoping to begin soon.

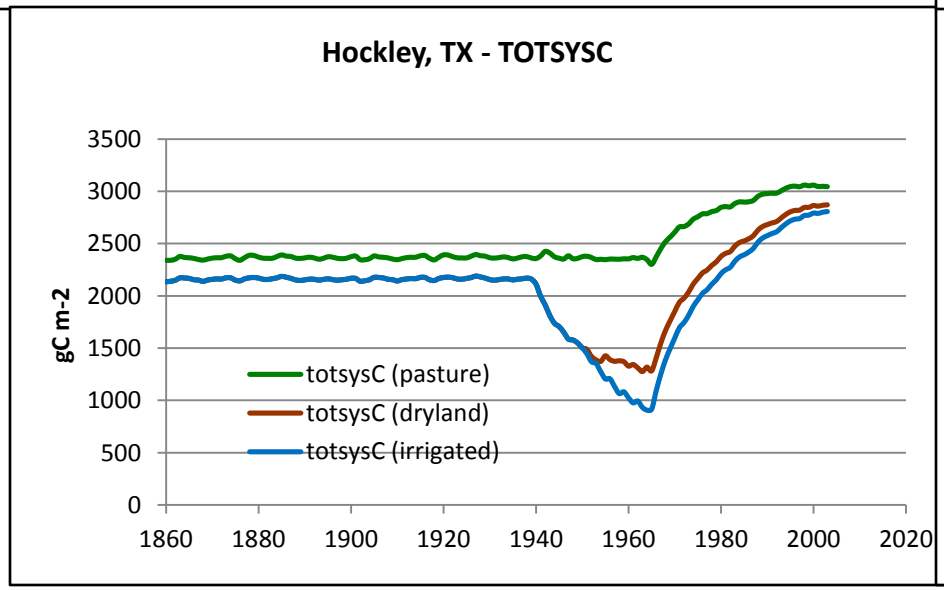
Adding People to the Mix: Lawns

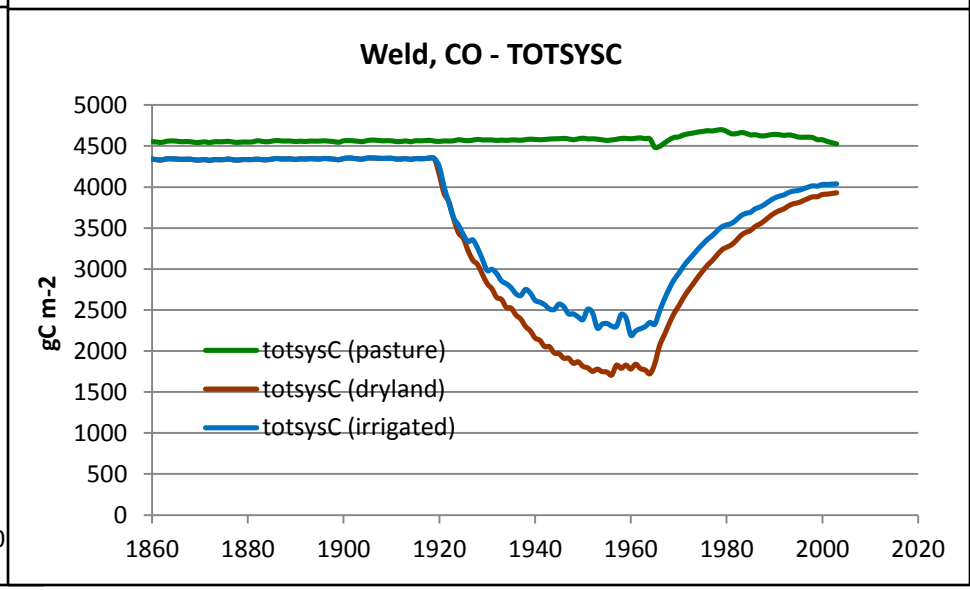
- Lawn Schedules are just another crop
- No lawns before 1945
- Lawn conversion allowable every ten years: 1945-1955-1965-1975-1985-1995

Total System C (on one square meter)

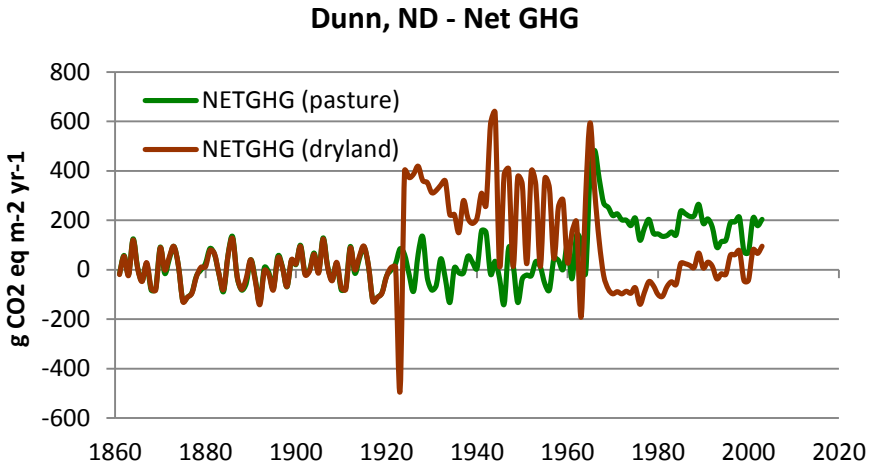


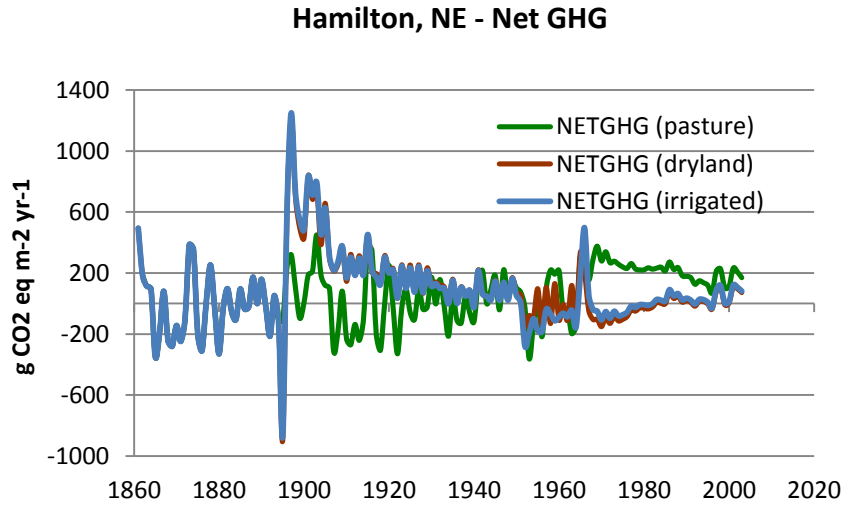


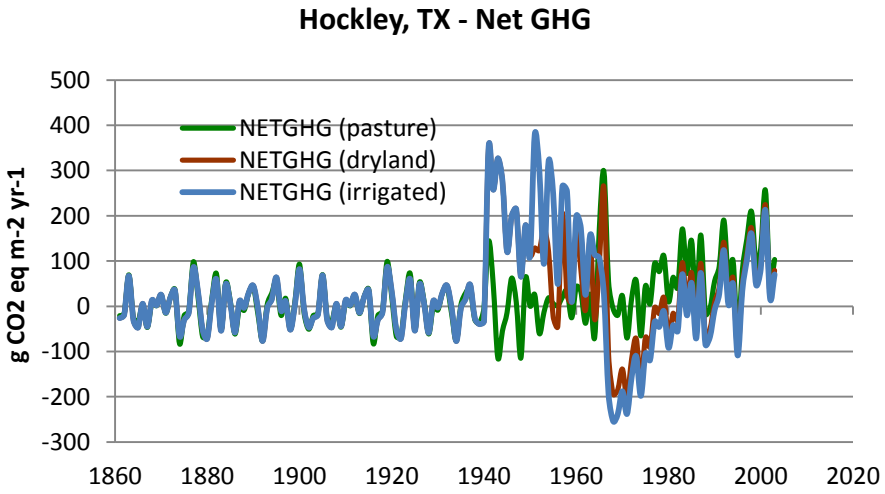


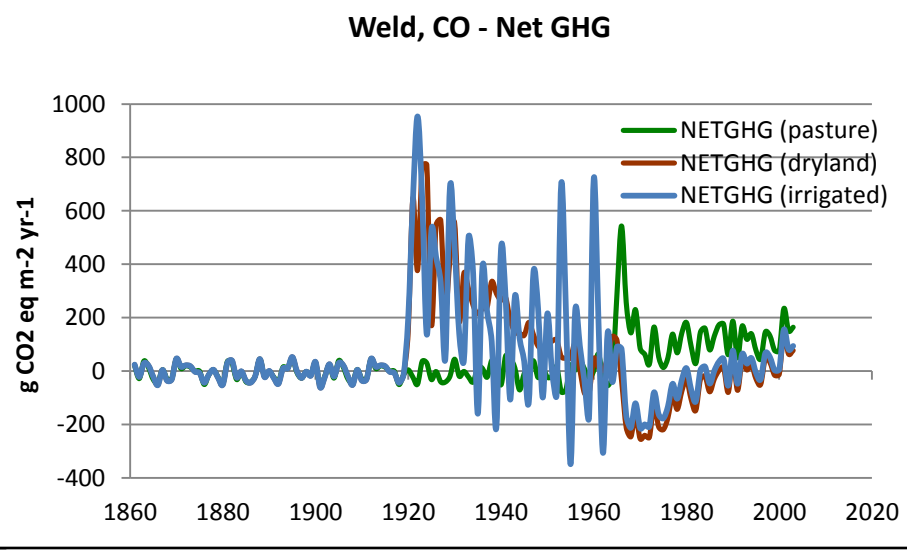


Net GHG emissions (on one square meter)





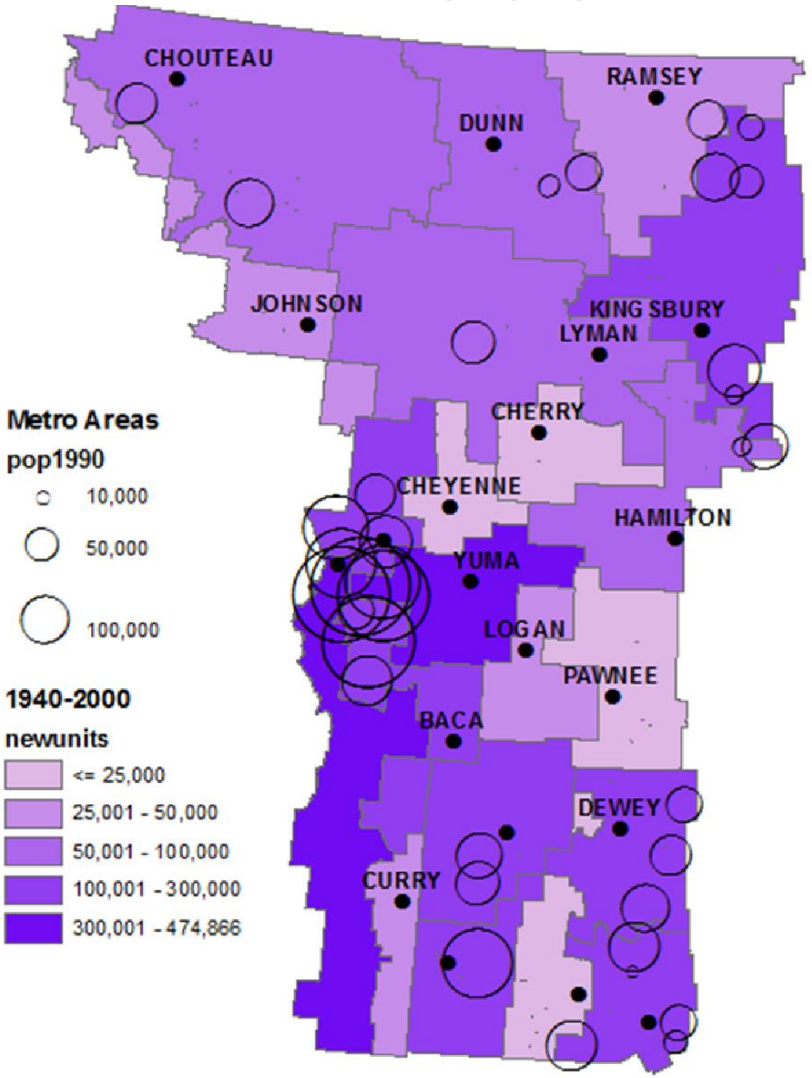




Adding People to the Mix: Lawns

- Lawn Schedules are just another crop
- No lawns before 1945
- Lawn conversion allowable every ten years: 1945-1955-1965-1975-1985-1995
- Land converted to lawns scaled to change in housing units (based on ca. 2006 observed lawns & known # of housing units)

New Housing Units, 1940-2000



From Lawn Models to Total GHG with Lawns

- Land devoted to lawn can come from pasture, dry cropping, or irrigated cropping
- All land comes from pasture or return (even though there's no return for irrigated)
- Where should lawns come from?
  - All Pasture, Dryland, or Irrigated (via return)?
  - Mixtures: Pasture/Dryland and various Pasture-Dryland-Irrigated mixes (via return)?

Minimal vs. Maximal Impact

- **Maximal Impact**: all land converted from pasture
- **Minimal Impact**: all land converted from dry cropland
- Exceptions ("**Mixed Scenarios**"): In 77 counties, too little land in the return schedule for maximum, so land converted directly from dryland (2) and pasture (75)

Impact of Transition to Lawns, by Decade

Decade	Reference	Lawns Maximal Impact	Lawns Minimal Impact	Lawns % Difference Maximum	Lawns % Difference Minimum
1940-49	140,451	140,643	140,209	0.14%	-0.17%
1950-59	96,352	96,678	96,059	0.34%	-0.30%
1960-69	-6,632	-6,125	-6,259	7.64%	5.62%
1970-79	-48,113	-47,343	-47,811	1.60%	0.63%
1980-89	-22,572	-21,034	-22,098	6.81%	2.10%
1990-99	-90,014	-88,247	-89,469	1.96%	0.61%

Impact of Transition to Lawns, Cumulative

Decade	Cumulative Reference	Cumulative Lawns Maximal Impact	Cumulative Lawns Minimal Impact	Cumulative Lawns % Difference Maximum	Cumulative Lawns % Difference Minimum
1940-49	140,451	140,643	140,209	0.14%	-0.17%
1950-59	236,803	237,321	236,267	0.22%	-0.23%
1960-69	230,171	231,196	230,008	0.45%	-0.07%
1970-79	182,058	183,853	182,197	0.99%	0.08%
1980-89	159,487	162,819	160,099	2.09%	0.38%
1990-99	69,473	74,572	70,630	7.34%	1.67%

And More Conclusions

- At the regional and decadal scale, population
  - Is linked to land use change
  - Is not well tied to environmental outcomes
- Lawn analysis shows:
  - Not much impact regionally
  - Potential for strong impact at the local level
- Productive direction, but much more to do, especially coupling to national & global production & consumption networks

The end

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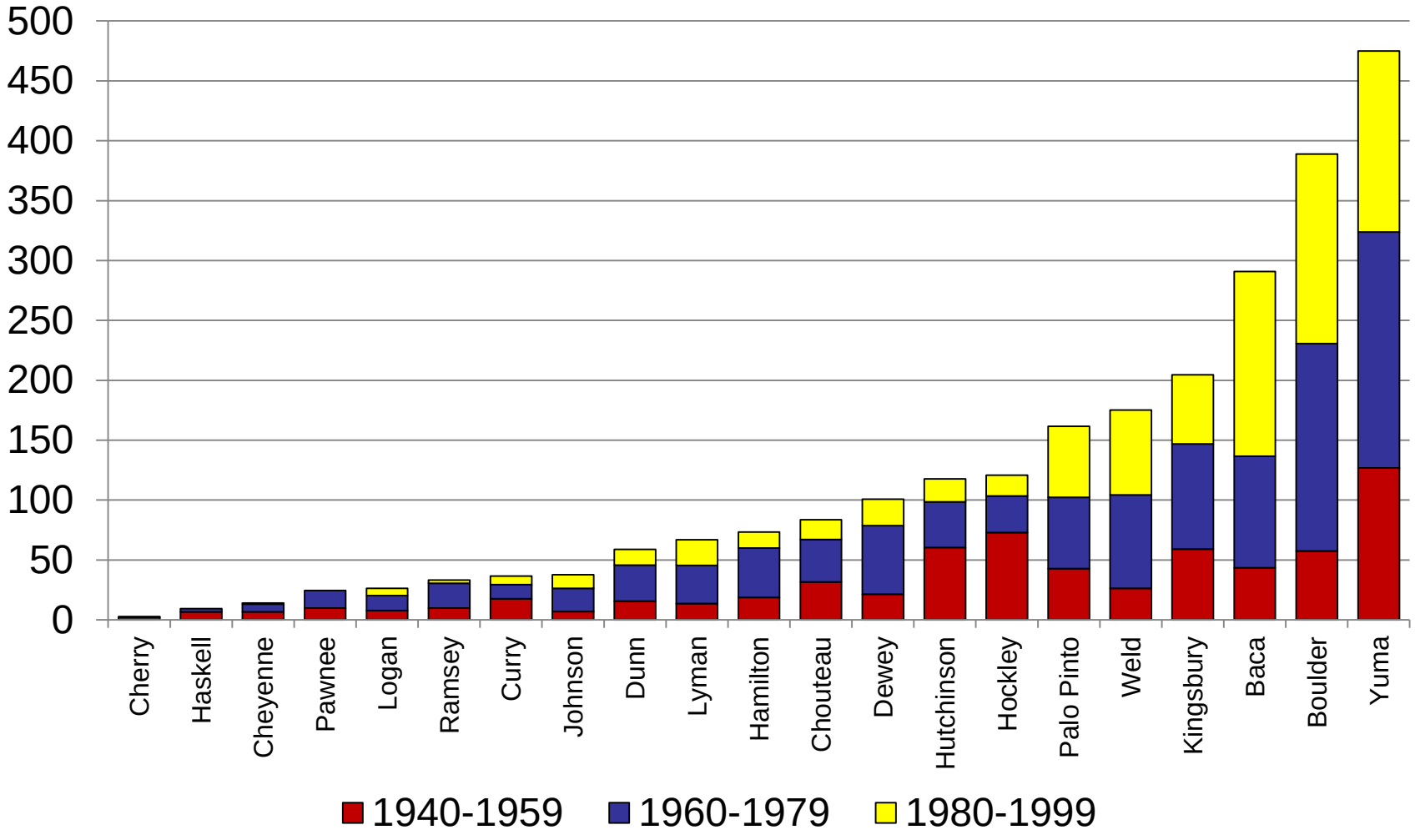
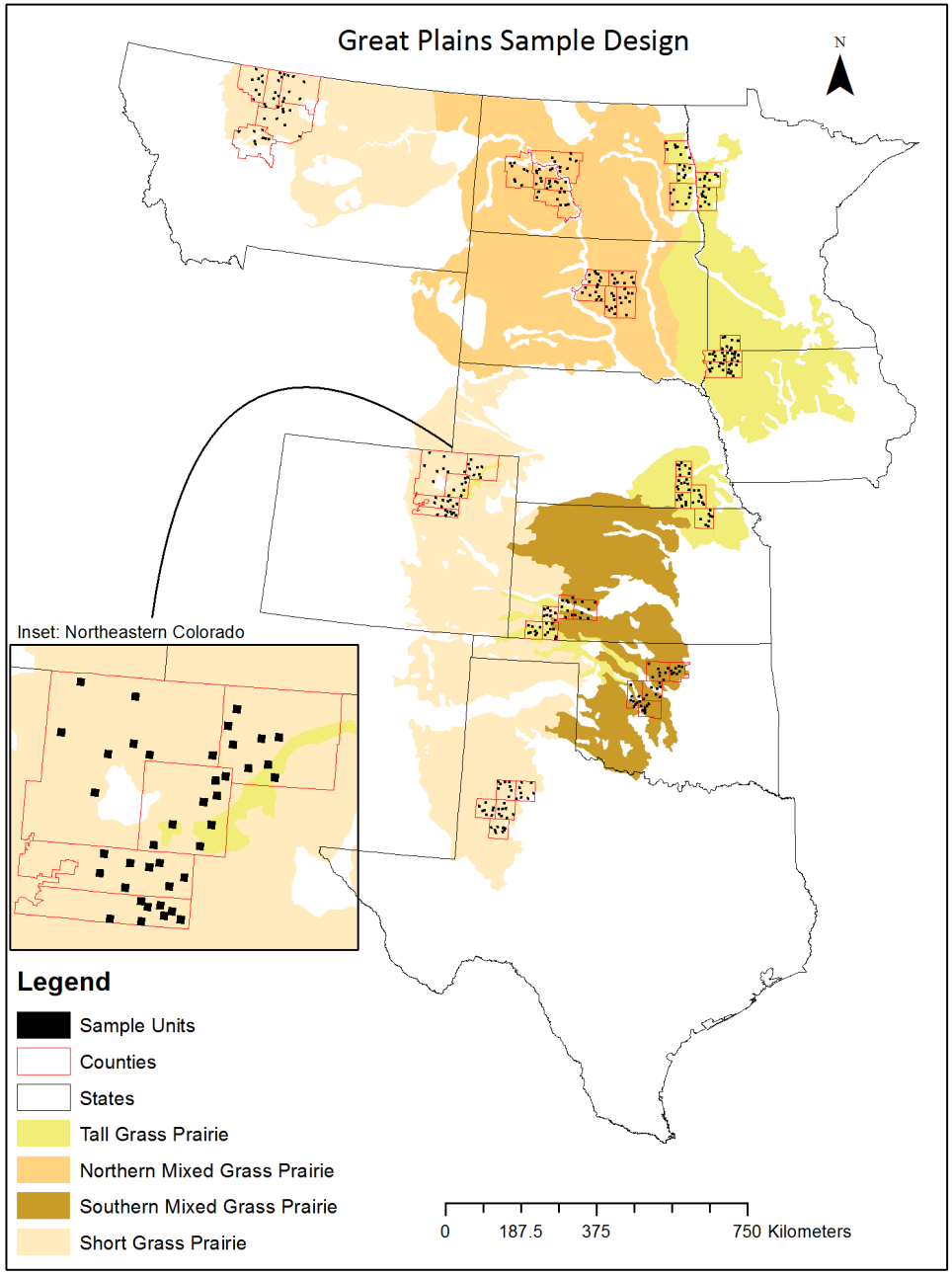
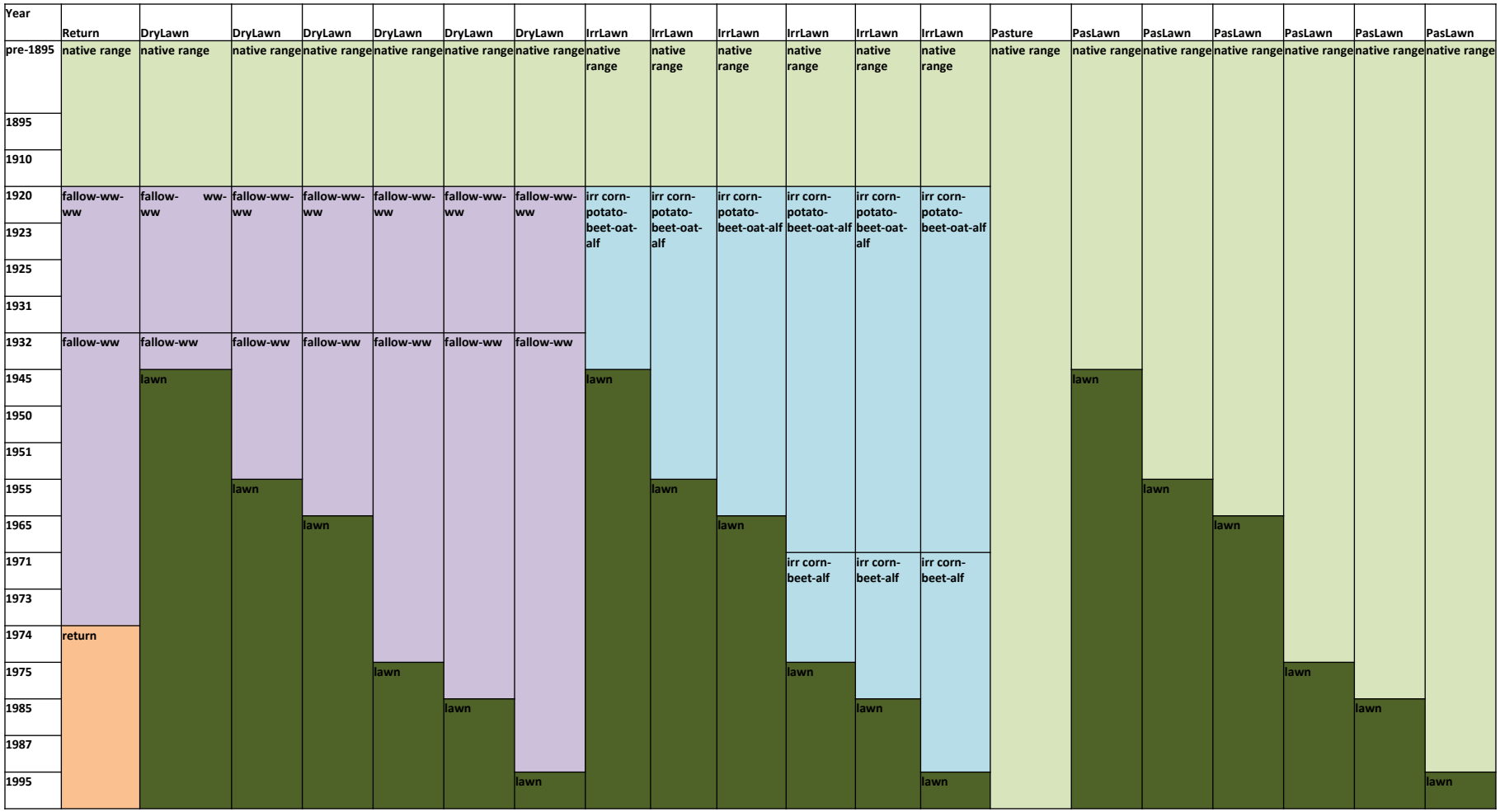
Extra Slides

Number of New Housing Units, by 20-year Period (thousands)



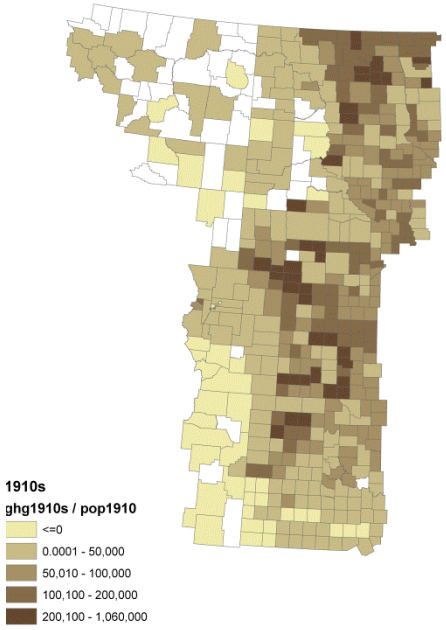

Great Plains Sample Design
N
Inset: Northeastern Colorado
Legend
Sample Units
Counties
States
Tall Grass Prairie
Northern Mixed Grass Prairie
Southern Mixed Grass Prairie
Short Grass Prairie
0
187.5
375
750 Kilometers

Weld, CO Lawn Schedules

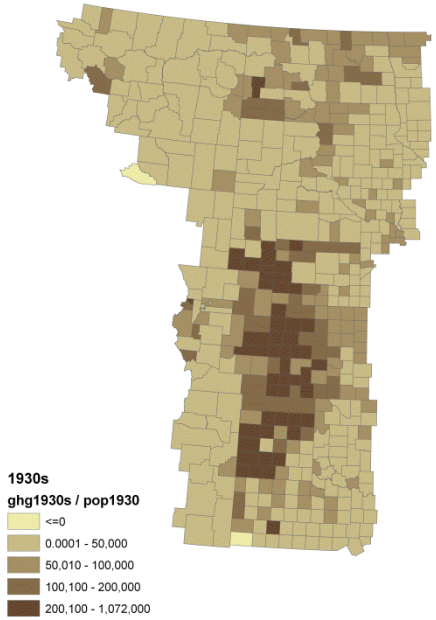


Per Capita
Decadal Net Greenhouse Gas Production from Land Use, Per Square Mile 1910s – 1990s

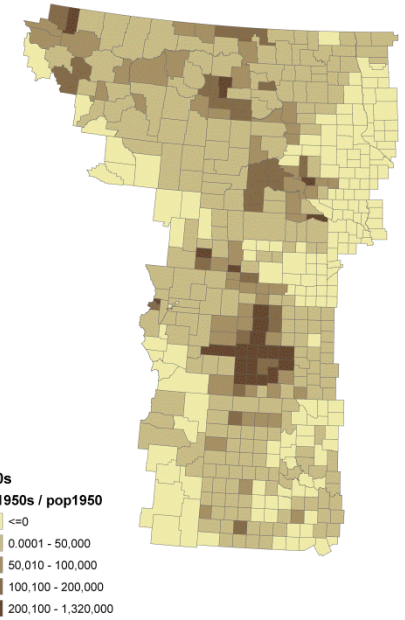
1910s



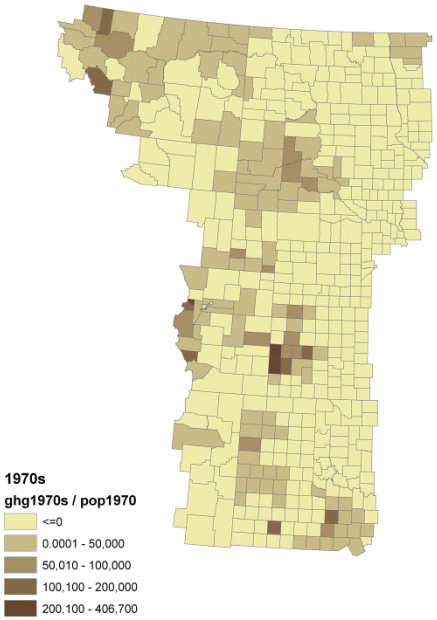
1930s



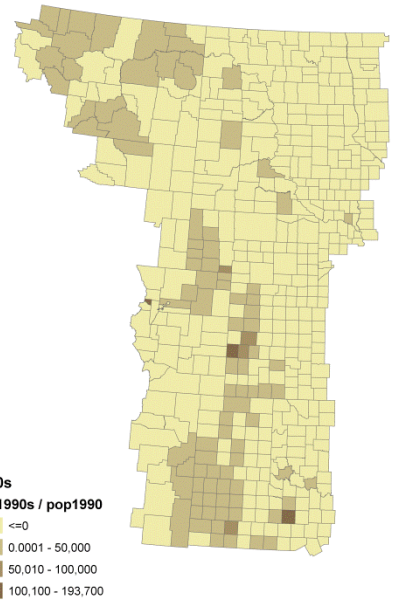
1950s



1970s



1990s



Percent Change in Greenhouse Gas Emissions - Adding Lawns*

	1 Acre Per Housing Unit	2 Acres Per Housing Unit
All Pasture	**0.9**	**1.8**
All Dryland	**0.1**	**0.4**
All Irrigated	**0.0**	**0.3**
Half Pasture- Half Dryland	**0.5**	**0.9**
Half Pasture- 25% Dryland 25% Irrigated	**0.5**	**0.9**
25% Pasture 50% Dryland 25% Irrigated	**0.3**	**0.6**

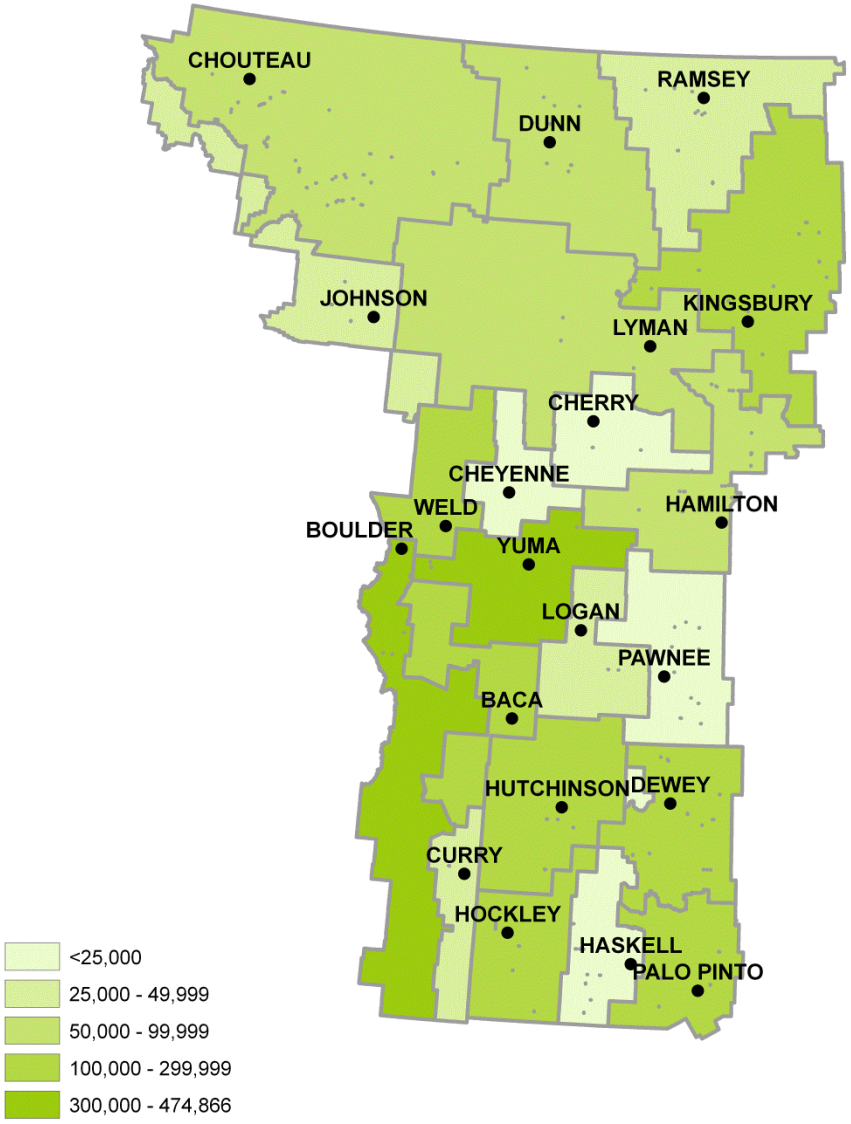
*Change in Net GHG compared with Production from Crops and Pasture, 1940-2003

Lawns – Selected Clusters One Acre Per Housing Unit*

	All Pasture	All Irrigated	Mixed Sources**
Weld	**3.8**	**0.0**	**0.3**
Yuma	**2.7**	**-1.0**	**0.1**
Logan	**0.2**	**0.2**	**0.2**
Chouteau	**0.7**	**0.1**	**0.3**
Curry	**1.0**	**-1.1**	**-0.6**
Lyman	**0.1**	**0.1**	**0.1**
Palo Pinto	**7.1**	**1.7**	**3.1**
Hutchinson	**0.2**	**-0.3**	**-0.2**
Boulder	**111.8**	**8.5**	**35.0**
Baca	**12.6**	**-0.9**	**3.0**

*Change in Net GHG compared with Production from Crops and Pasture
** 25% Pasture, 50% Dryland Cropping, 25% Irrigated Cropping

Change in Housing Units 1940-2003



Lawn Impact – Baca Cluster – One Acre Per Housing Unit*

	West	East	Total
All Pasture	**12.6**	**0.1**	**6.1**
All Dryland	**0.1**	**0.0**	**1.0**
All Irrigated	**-0.1**	**0.0**	**-6.4**
Half Pasture-Half Dryland	**6.3**	**0.1**	**3.5**
Half Pasture- 25% Dryland 25% Irrigated	**6.1**	**0.1**	**1.7**
25% Pasture 50% Dryland 25% Irrigated	**3.0**	**0.1**	**.04**

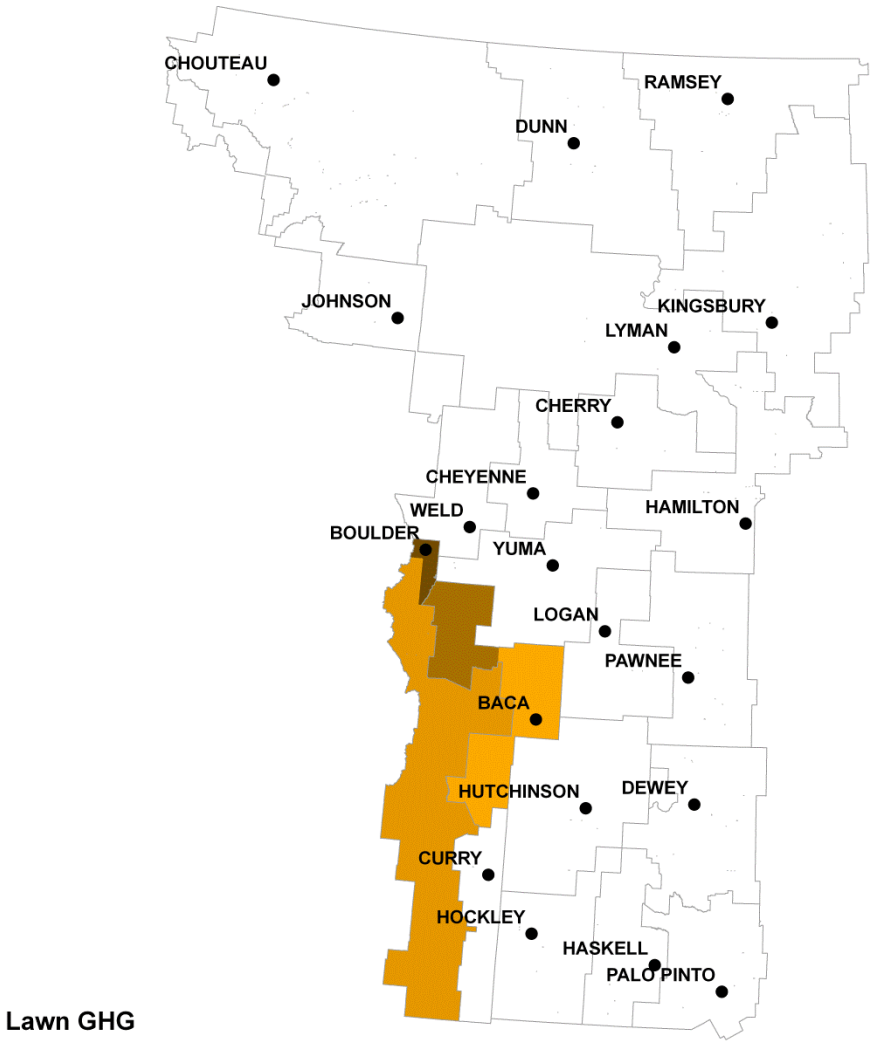
*Change in Net GHG compared with Production from Crops and Pasture

Lawn Impact – Boulder Cluster – One Acre Per Housing Unit*

	North	South	Total
All Pasture	**149.2**	**5.6**	**111.8**
All Dryland	**105.4**	**-1.5**	**9.8**
All Irrigated	**99.2**	**-2.2**	**8.5**
Half Pasture-Half Dryland	**100.2**	**2.0**	**60.8**
Half Pasture-25% Dryland 25% Irrigated	**98.6**	**1.9**	**60.5**
25% Pasture 50% Dryland 25% Irrigated	**101.3**	**0.1**	**35.0**

*Change in Net GHG compared with Production from Crops and Pasture

Change in Cumulative GHG 1940-2003
1 acre lawn per housing unit



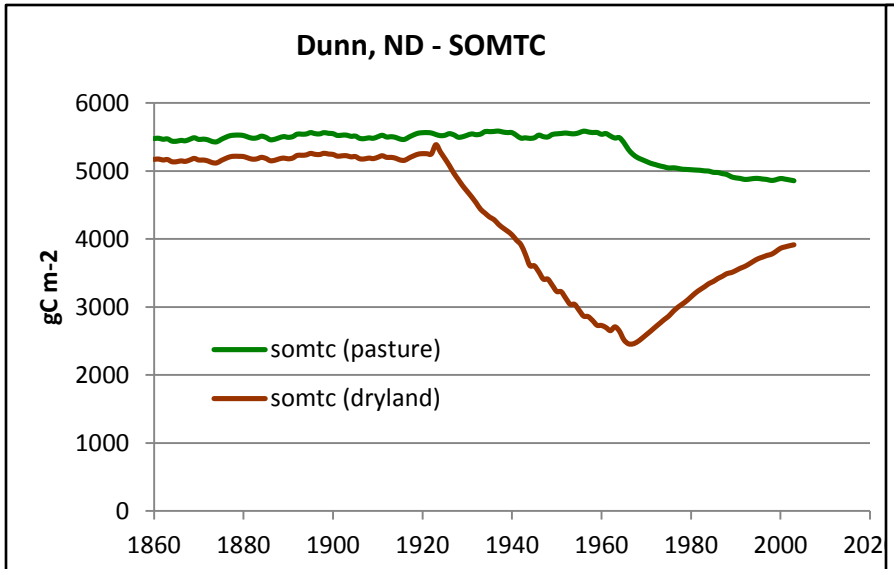
Great Plains Lawns Results from Four Counties

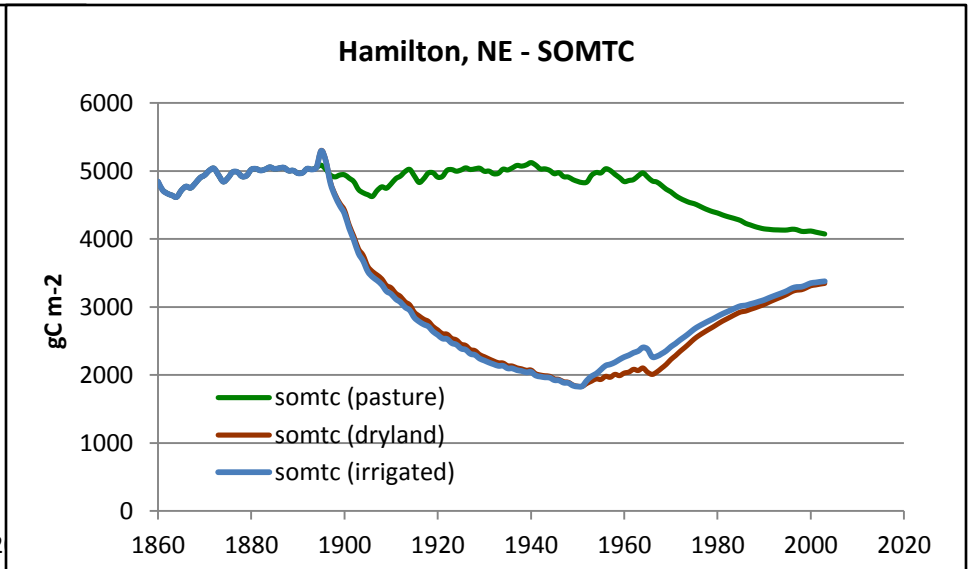
Pasture to Lawn 1965
Dryland Crops to Lawn 1965
Irrigated Crops to Lawn 1965

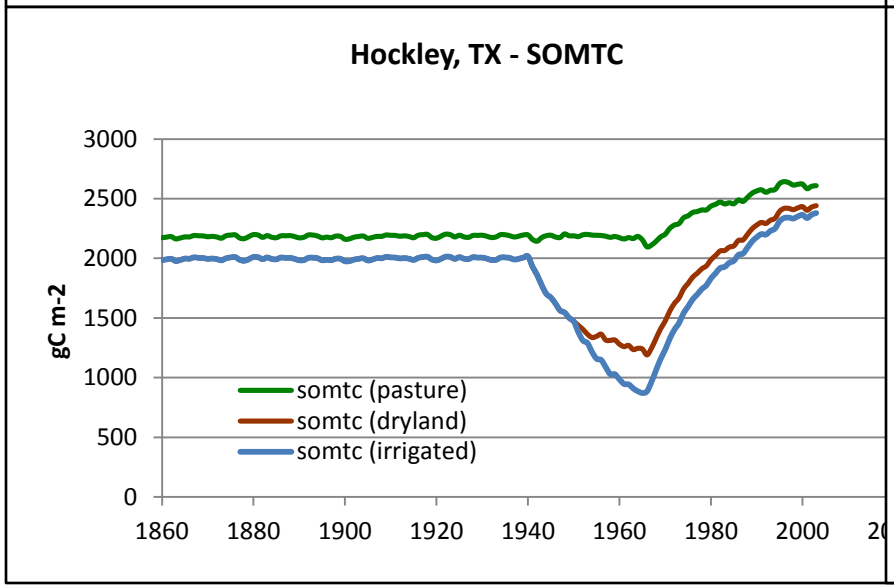
Dunn, ND
Hamilton, NE
Hockley, TX
Weld, CO

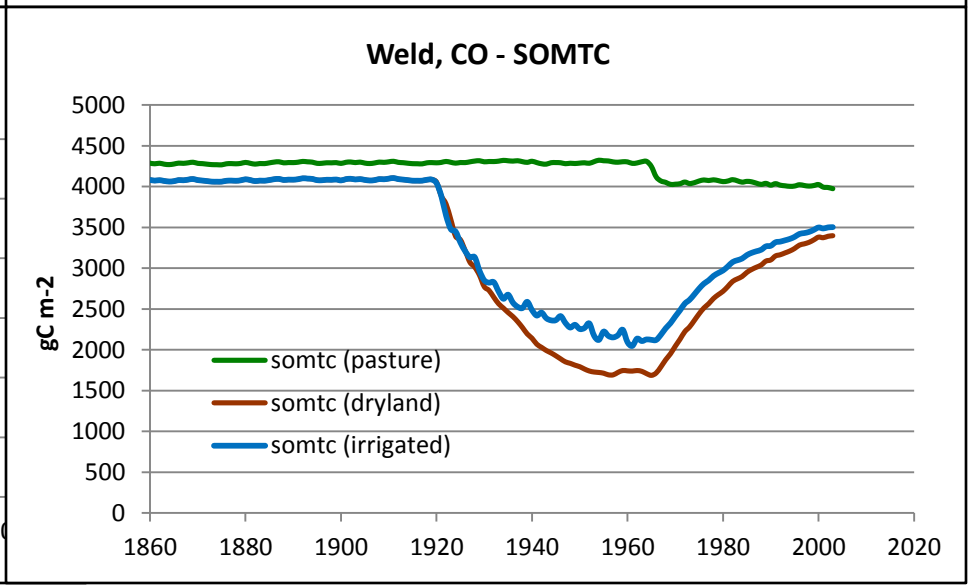
Prepared by: Melannie Hartman
April 22, 2014

Total Soil Organic Matter C

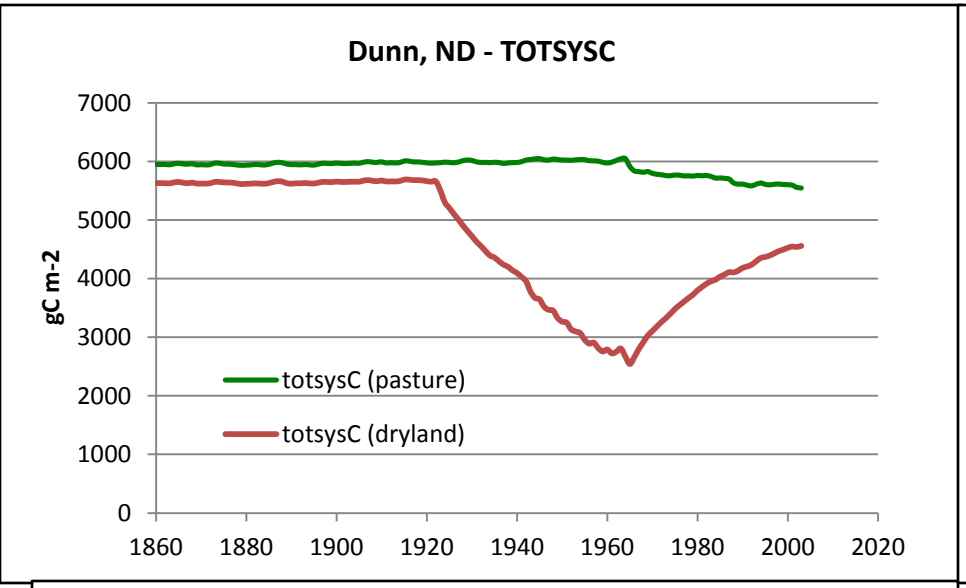


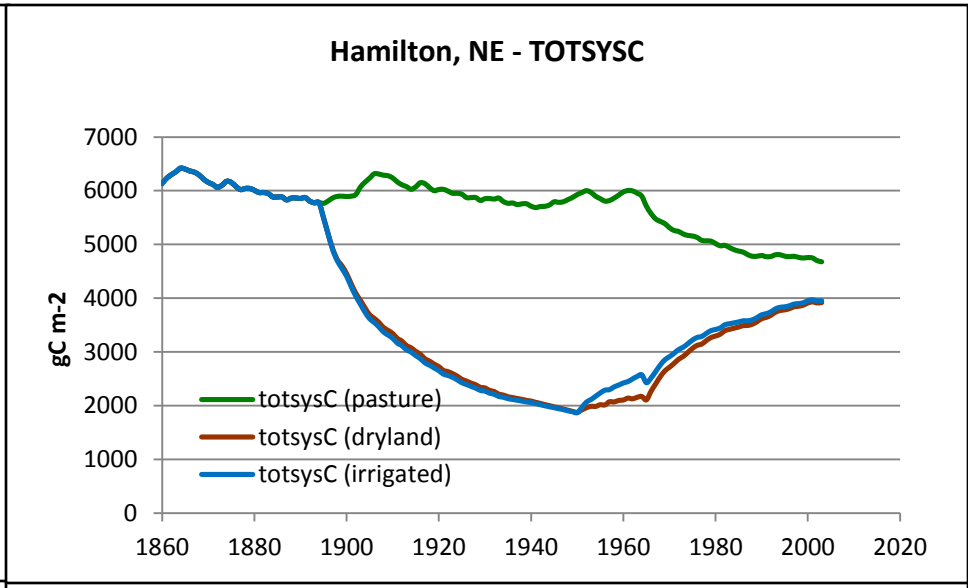


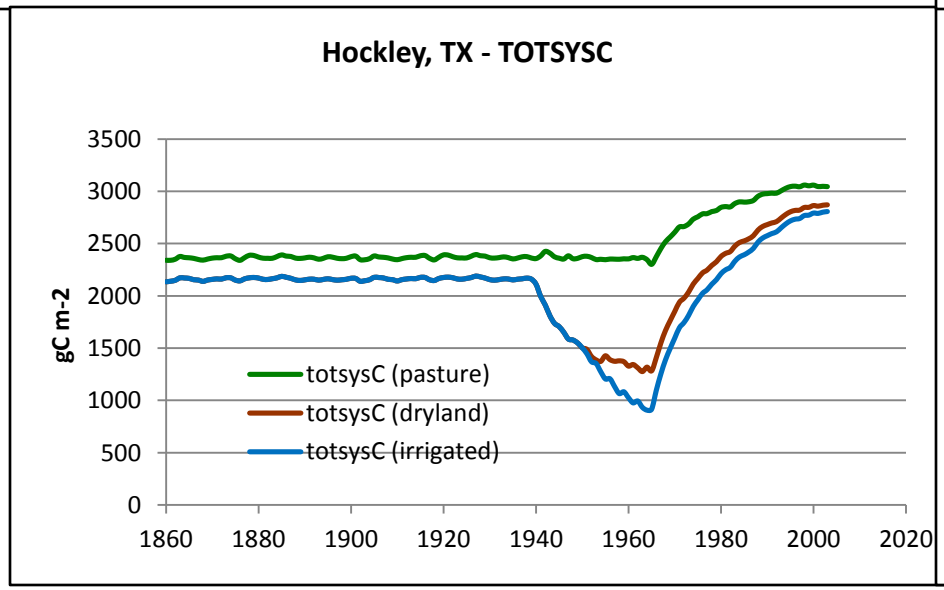


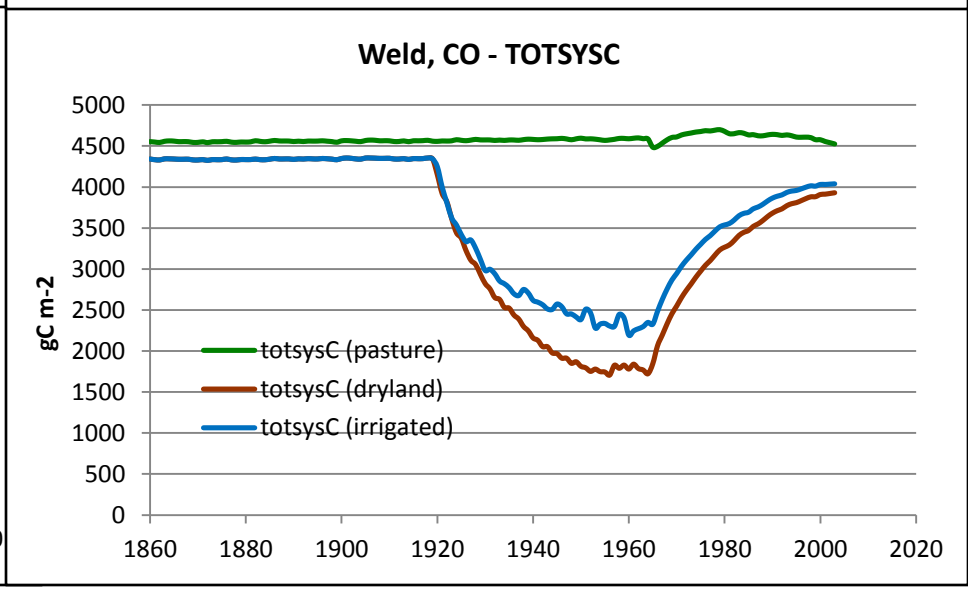


Total System C

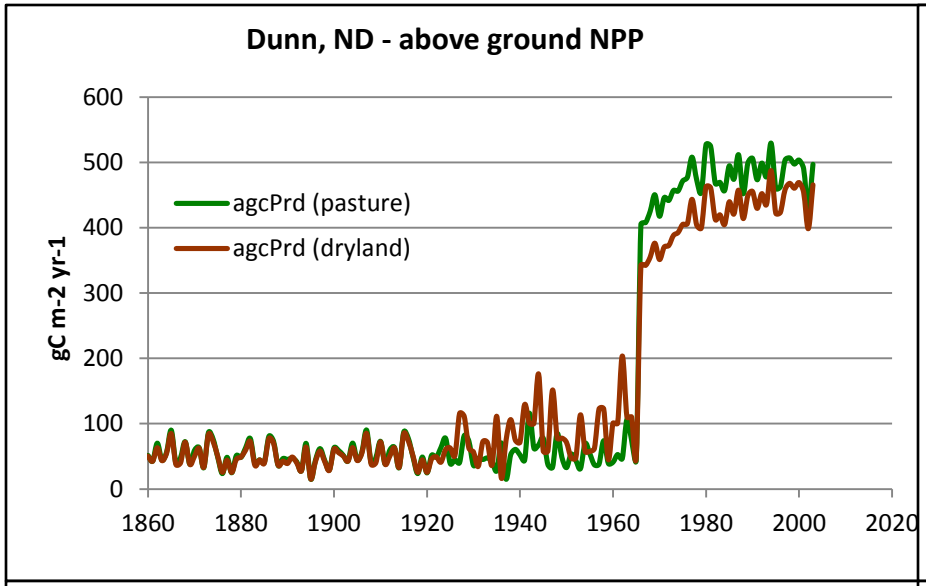


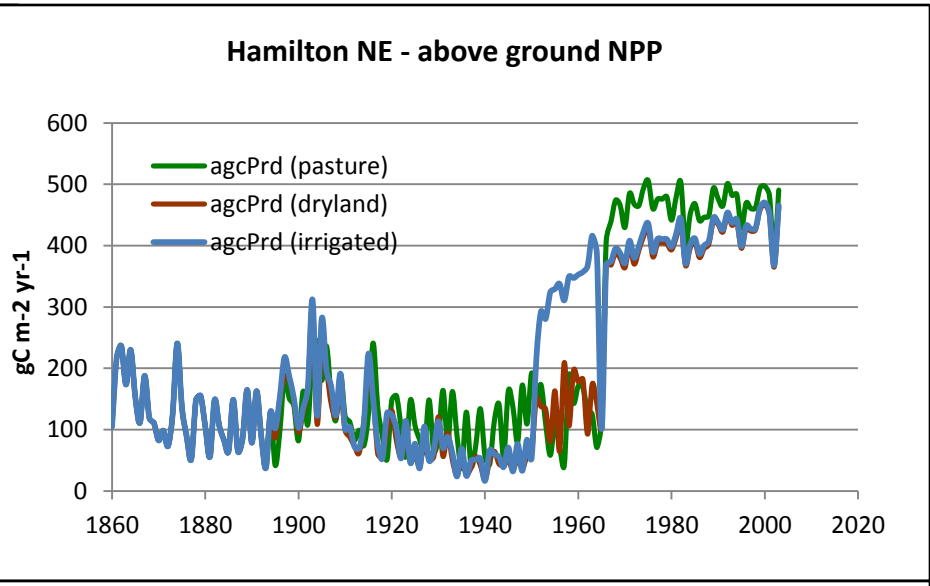


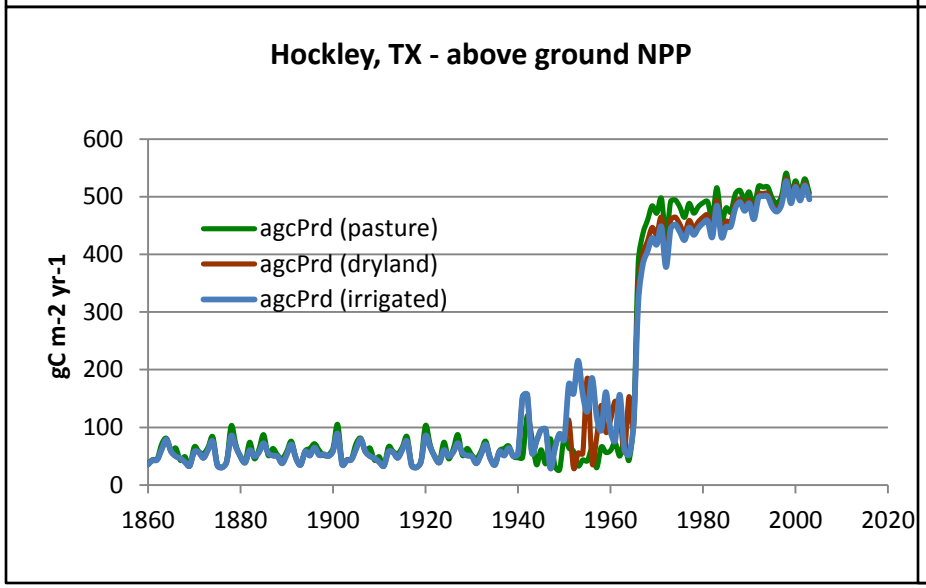


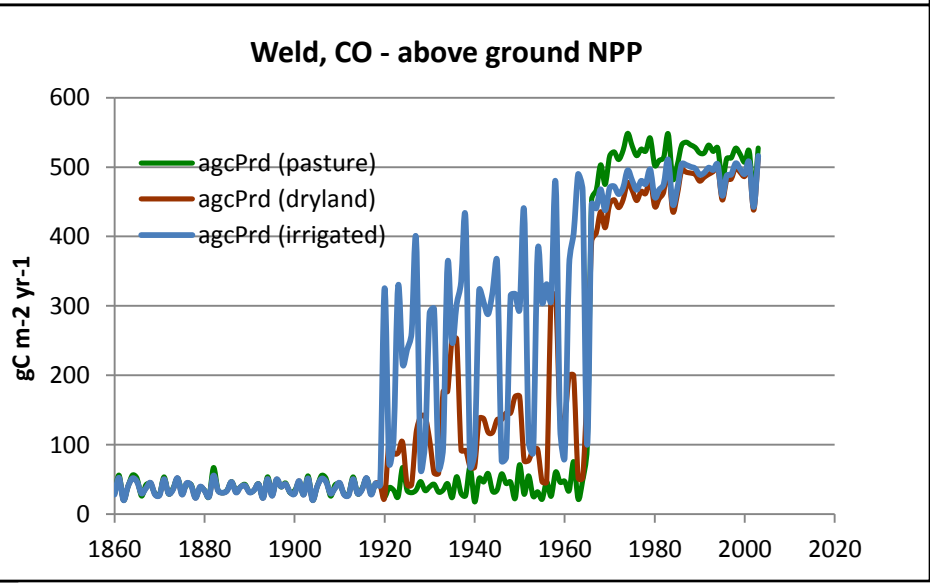


Above Ground Production

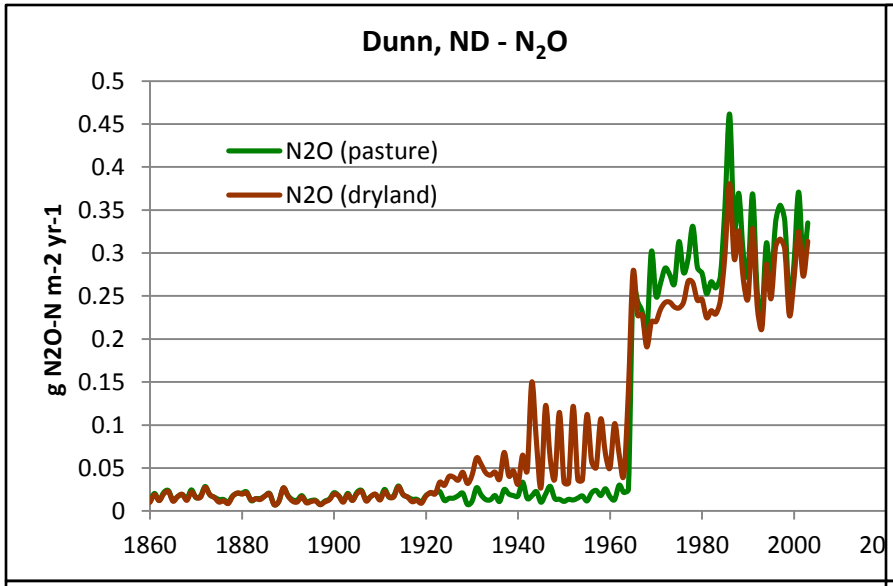


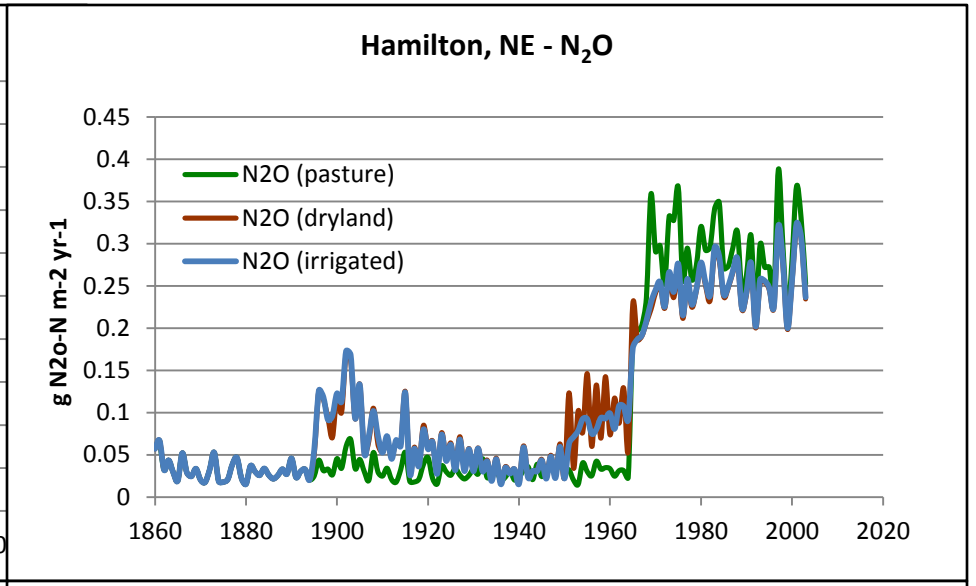


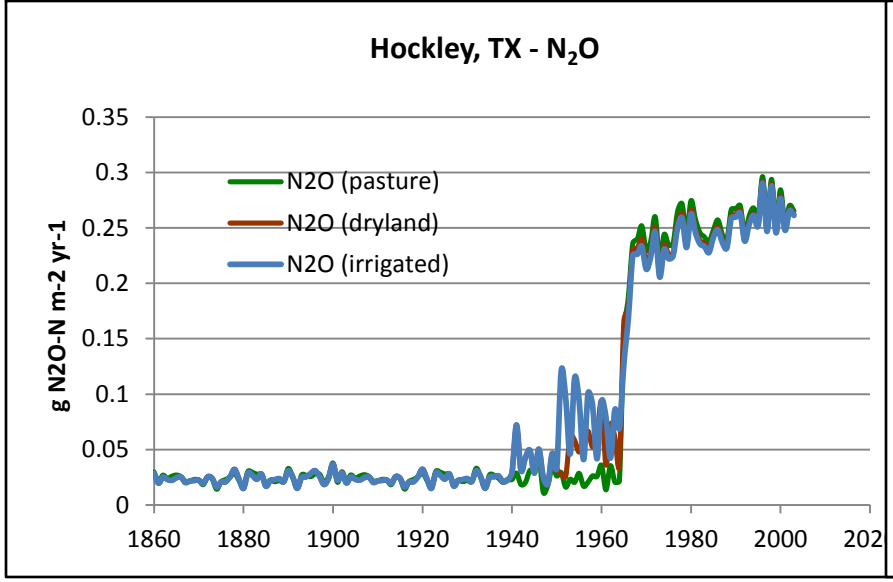


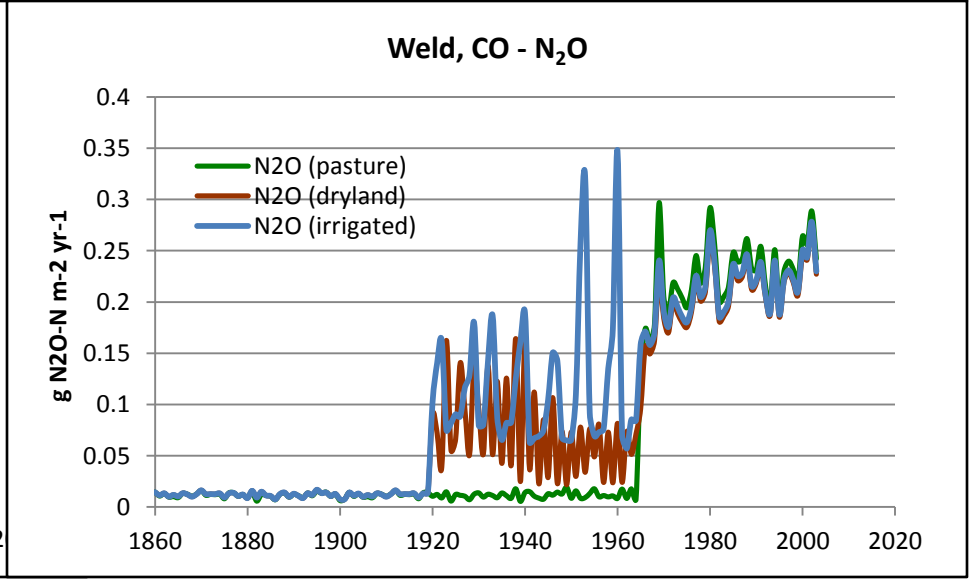


Soil N_2O emissions

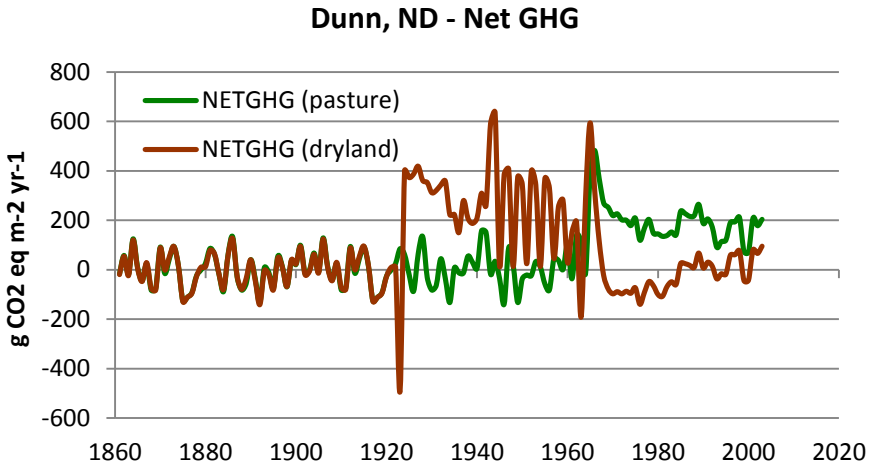


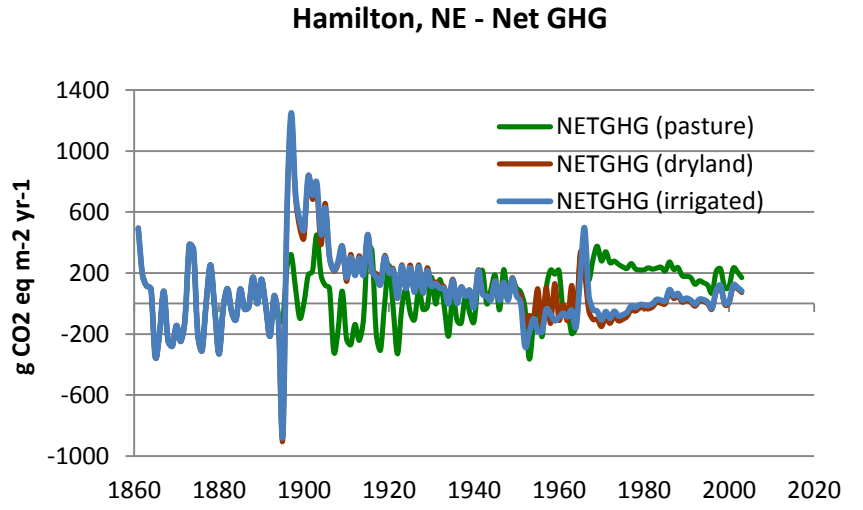


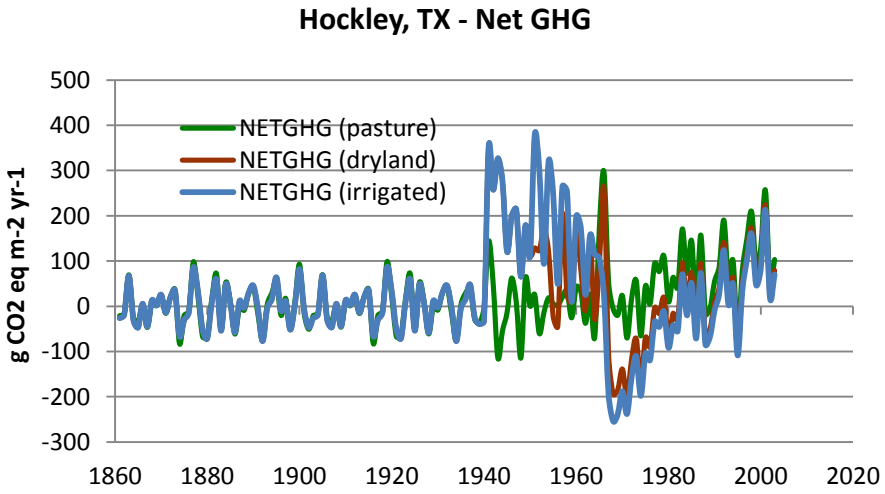


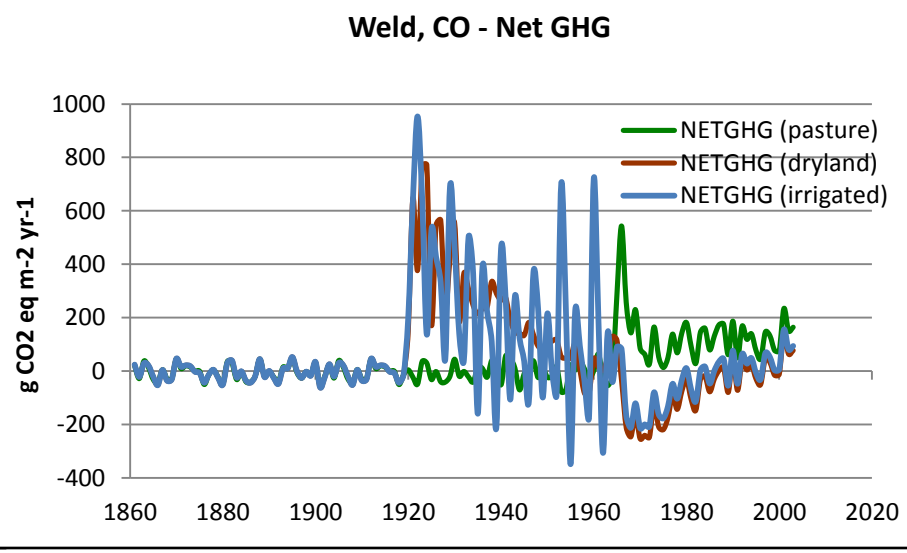


Net GHG emissions

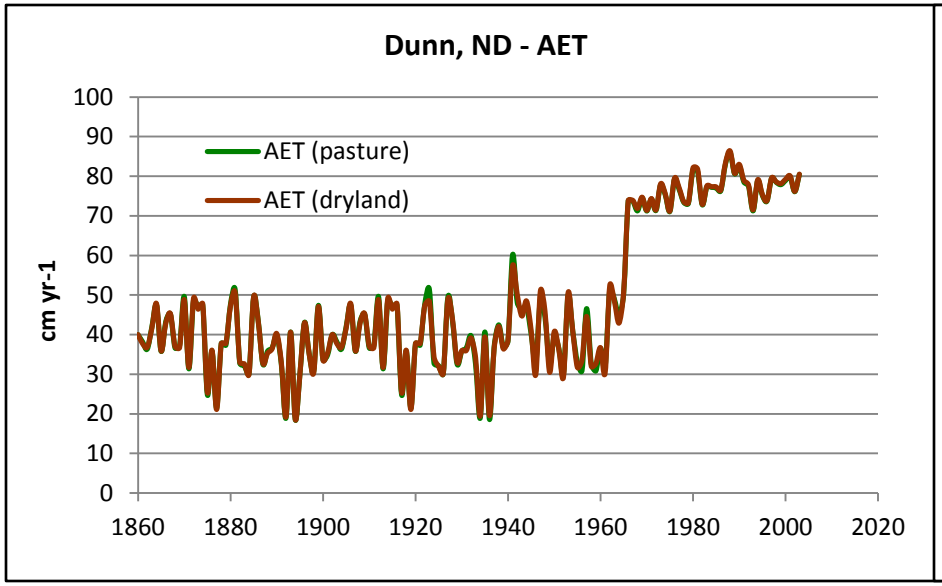


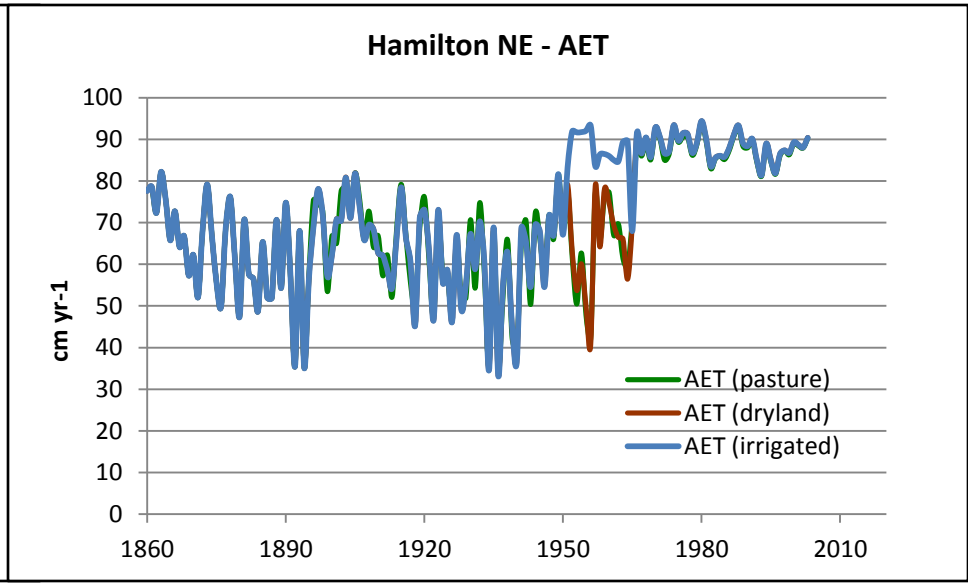


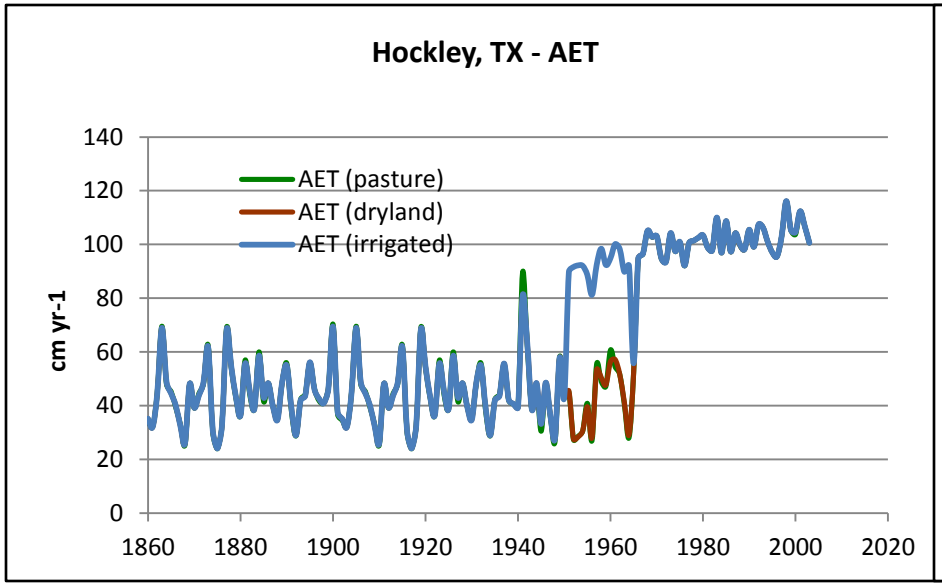


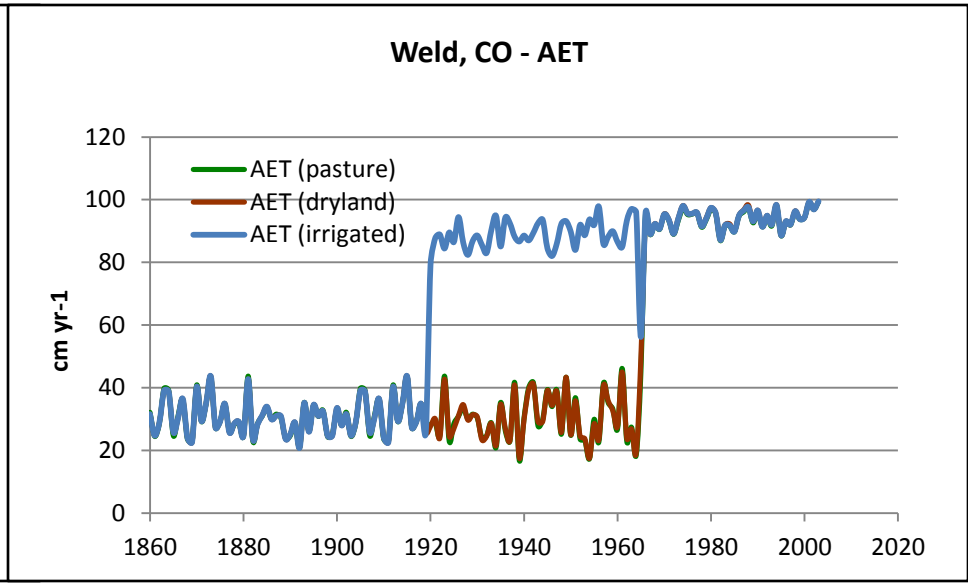


Actual Evapotranspiration









How to Study the Plains?

Population and Environment: County-Scale Integration & Analysis of Demographic, Economic, & Agricultural Data

Farmer Interviews

Satellite Image Analysis

Aerial Photo Interpretation

Biogeochemical Modeling

Greenhouse Gas Estimates

Agent-Based Models

Big Synthesis: What Have We Learned About People and Environment in the Great Plains?