Soil Carbon Sequestration and Land Use Change Associated with Biofuels Production

Steffen Mueller and Jennifer Dunn

THE UNIVERSITY OF ILLINOIS AT CHICAGO

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CRC Workshop on Life Cycle Analysis of Transportation Fuels

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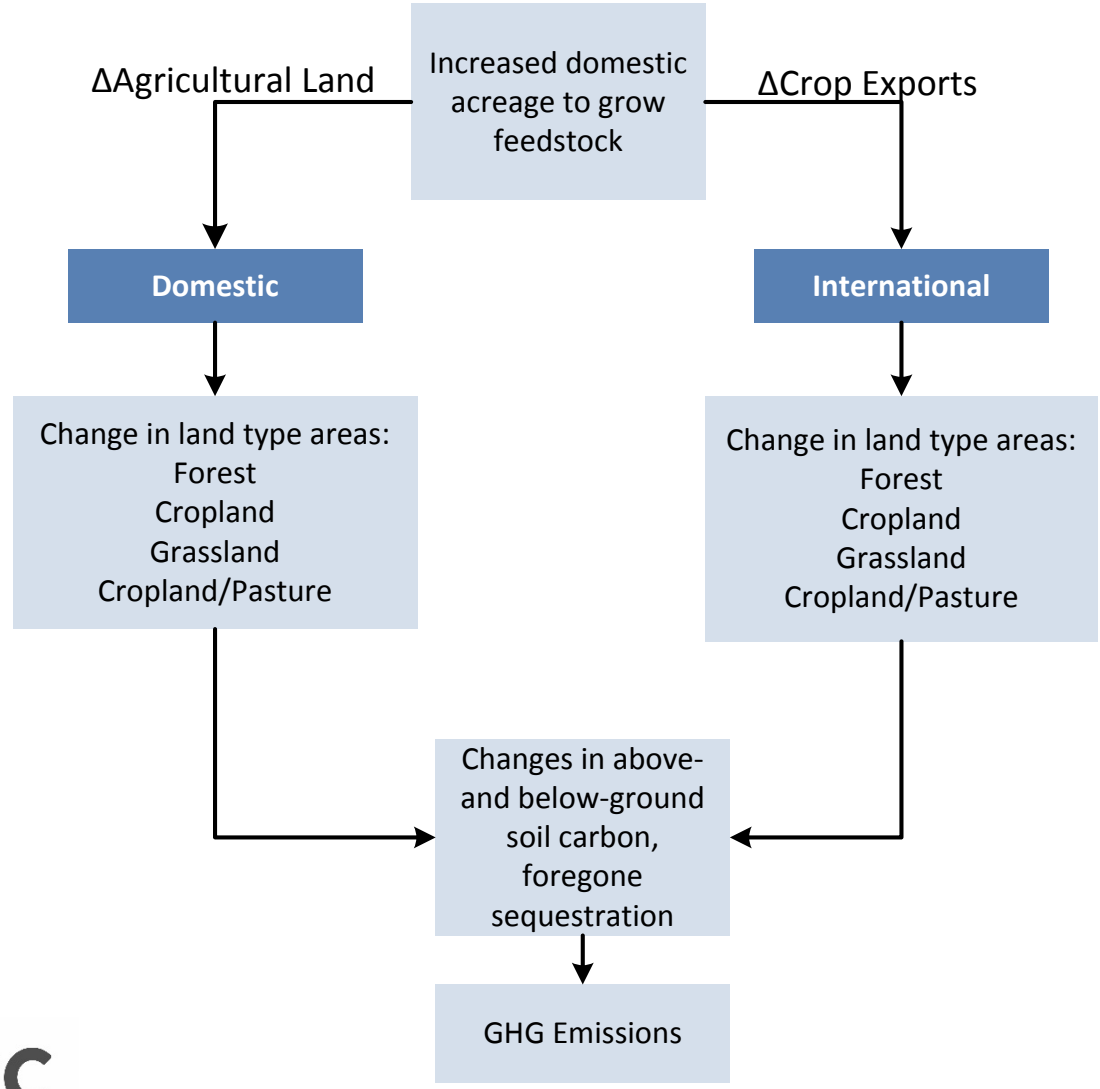
Land Use GHG Emissions Overview



Where Do We See Advances in LUC Emissions Assessments

- Advances in assessments of land area changes
  - Updated CGE models and elasticities (not discussed here)
  - Understanding the accuracy of available remote sensing data tools
  - Emerging software tools
- Advances in understanding of carbon stocks – New CCLUB
  - Carbon data with high spatial resolution
  - Parameterization which allows exploration of the impact of management practices, soil depth, yield increases, manure & cover crops
  - Understanding marginal lands and cropland pasture lands
  - Baseline Considerations

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Understanding the Accuracy of Available Remote Sensing Data Tools

- Domestic expansion and reversion of agriculture can be assessed using a combination of different tools including Cropland Data Layers (CDL/NLCD) and National Agricultural Imaging Program (NAIP) visible imagery
- CDL/NLCD:
  - Negative: Accuracy varies widely by state and is generally lowest for states with less existing production agriculture i.e., in states with greatest expansion likelihood
  - Positive: Accuracy is being disclosed. Capability to discern crop types.
- NAIP Imagery
  - Negative: Sometimes training and experience required to interpret imagery (discern flooding, native lands vs. managed lands)
  - Positive: Dated, historic imagery. Provides visible confirmation at 1-2 m resolution

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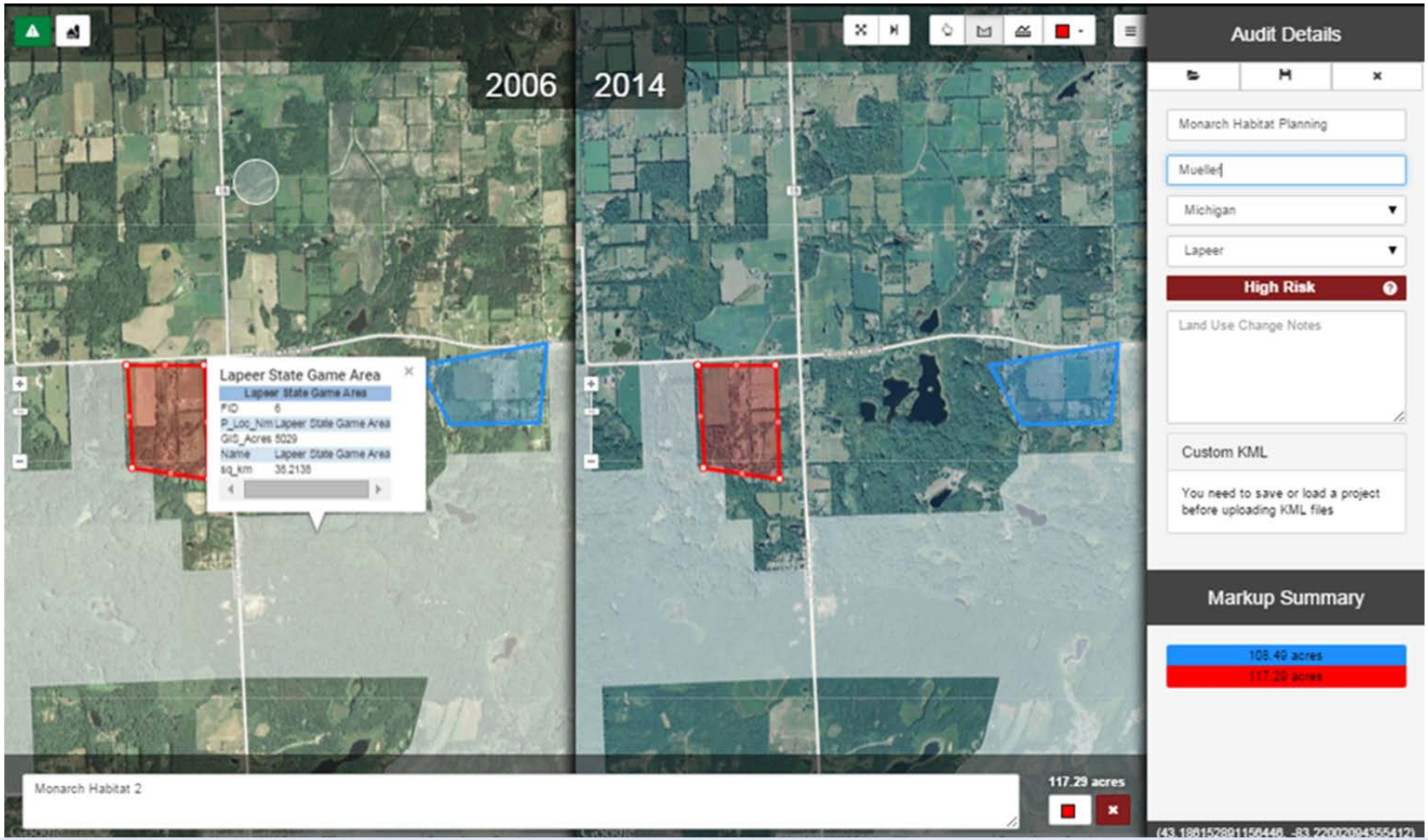
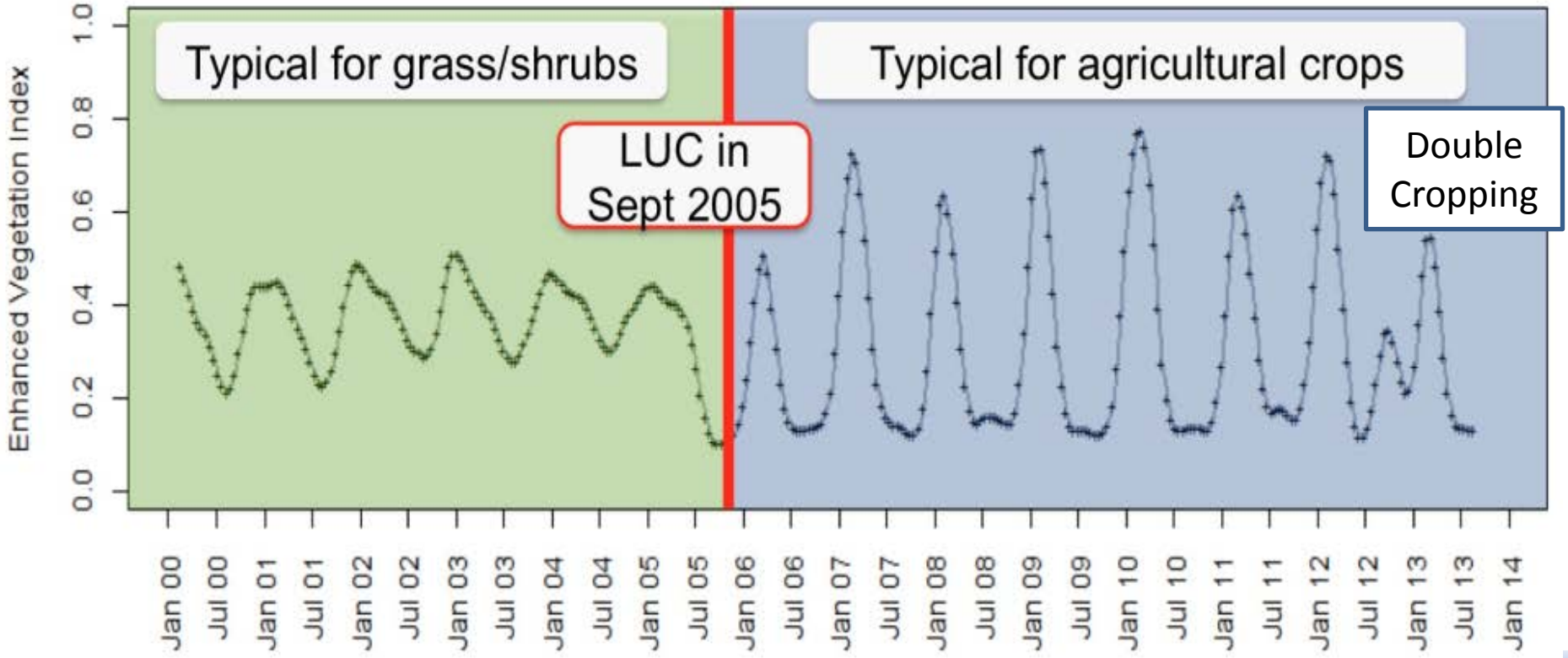
New Software: Genscape/GRAS Tool for Domestic LUC Analysis

- Use of NAIP Imagery (1-2 m resolution)
- Side by side viewer of pre 2008 and current image for direct comparison
- Overlay protected areas, carbon masks, LUC risk masks

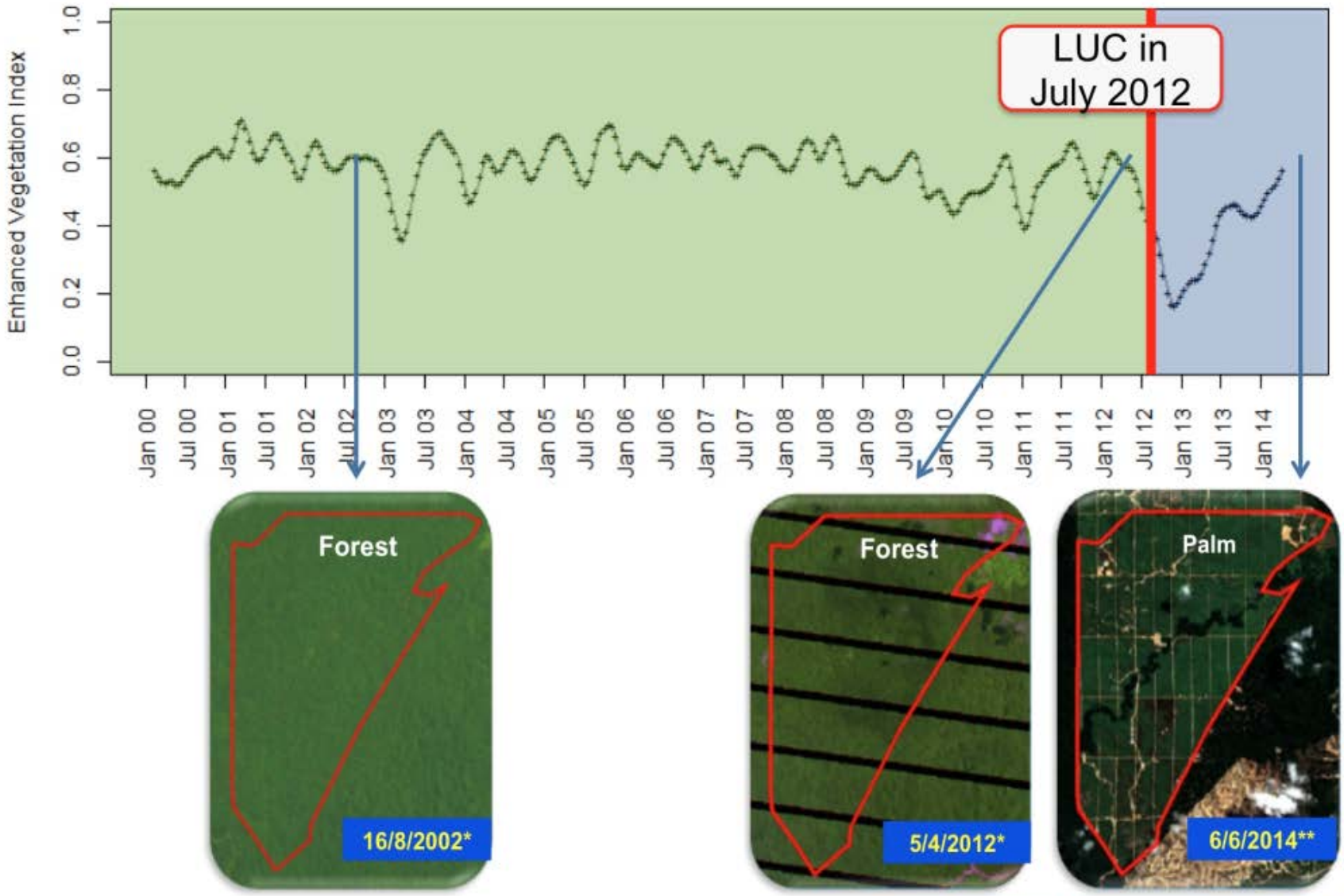


New Software: GRAS Tool for Global LUC Analysis

- Use of MODIS Enhanced Vegetation Index (300 Images) going back to 2000.
- Differentiate among the types of green cover, see the history of the land, assess double cropping and detect LUC.
- Grassland has EVI value of 0.3-0.4. The same would apply for perennial trees such as rain forests but on a higher EVI value of about 0.6. Conversion would appear as a clear change in those with a drop of EVI to a value below 0.2. Arable land used for crops appears as regular large waves.



New Software: GRAS Tool for Global LUC Analysis



* Landsat 7 pan sharped, false color image (resolution :15 m)
** Landsat 8 pan sharped, true color image (resolution :15 m)

Advances in Understanding of Carbon Stocks – New CCLUB

- Multiple Feedstocks: corn, corn stover, miscanthus, switchgrass, poplar, willow
- Use of CENTURY based soil organic carbon model
- Many parameterization options allows user to explore sensitivity to various input variables
  - Yield/No-yield scenarios for corn, different tillage systems, multiple GTAP land area scenarios
- Introduction of expanded land management change scenarios for stover ethanol
  - 30% and 60% removal rates
  - Carbon adjustments from cover cropping and manure application
  - Display of national, AEZ and county-level soil carbon changes
  - Use of different LCA allocation methods (marginal vs. energy vs. mass allocation)

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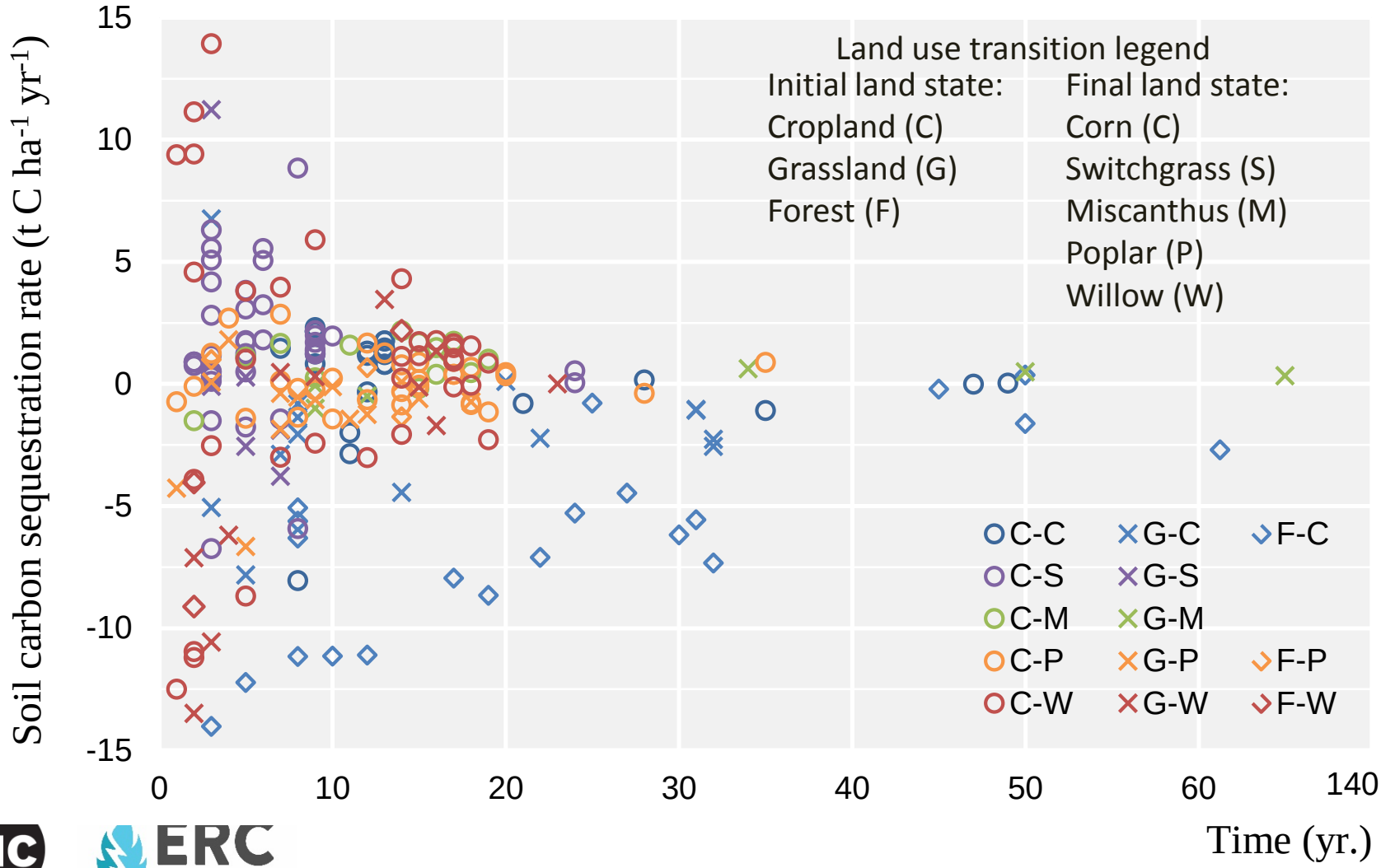
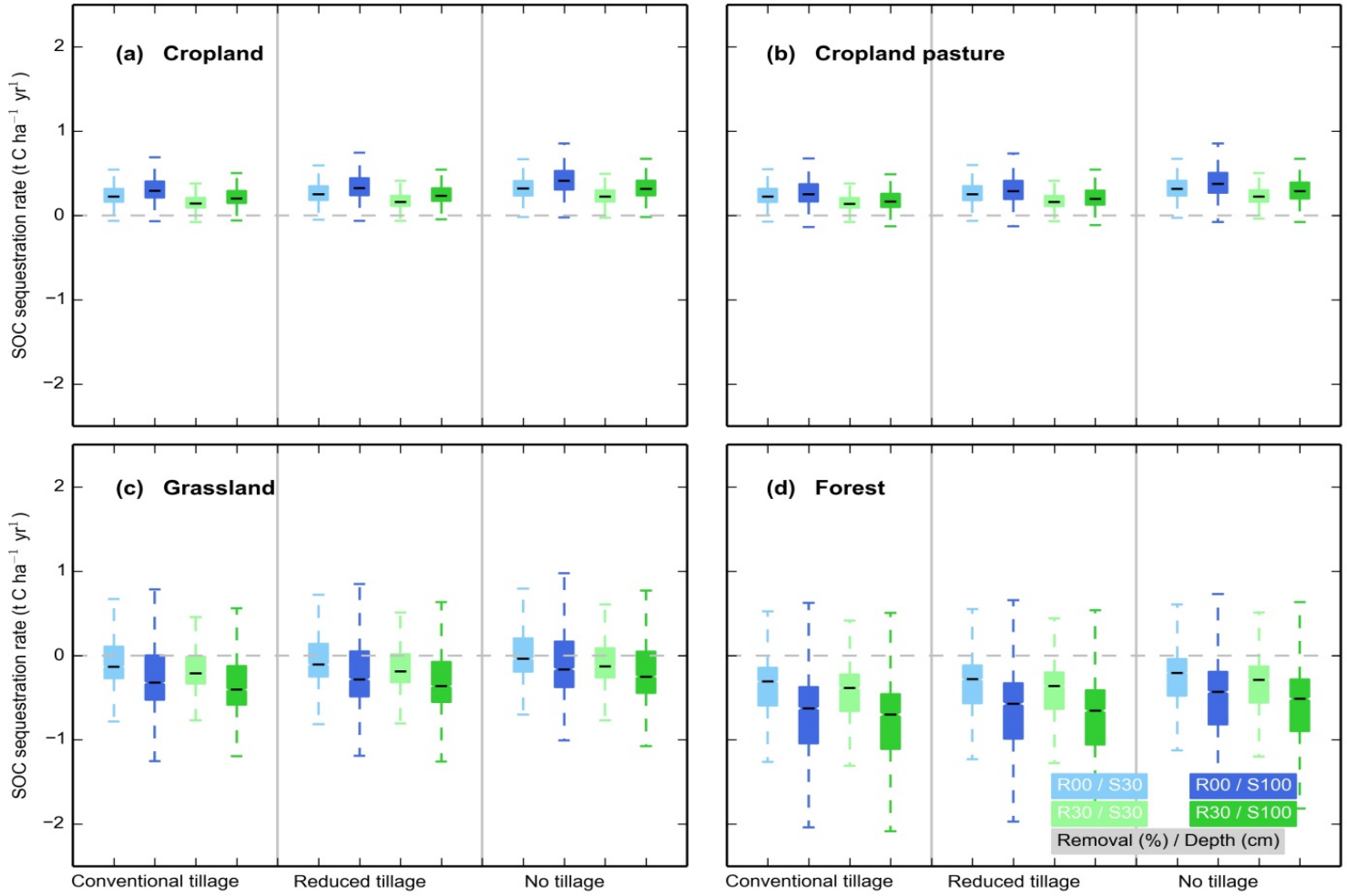
Meta Analysis of Soil Carbon Studies



Qin et al., *GCB Bioenergy*, 2015

CCLUB: Carbon Data with High Spatial Resolution & Variation

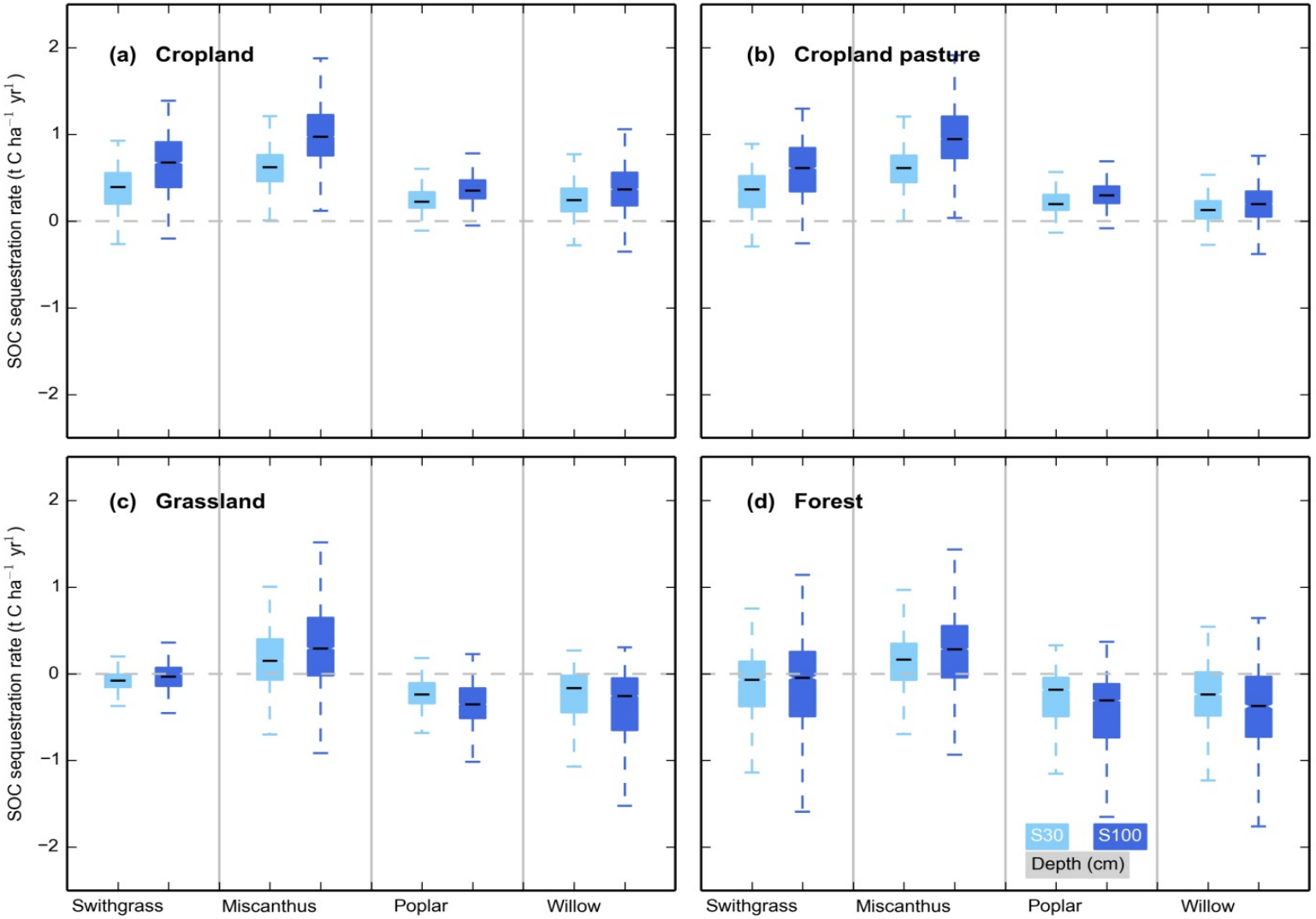
Conversion of cropland to corn with stover removal shows mostly increasing SOC; conversion of grassland or forest shows largely decreasing SOC



Qin et al., *GCB Bioenergy*, under review

CCLUB: Carbon Data with High Spatial Resolution & Variation

Conversion to energy grasses tends to increase or maintain SOC; conversion to short rotation woody crop production can cause it to decline



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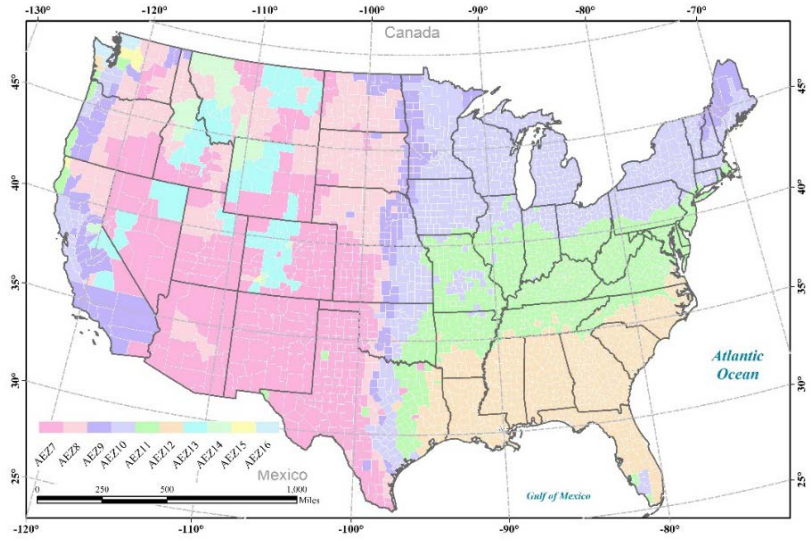
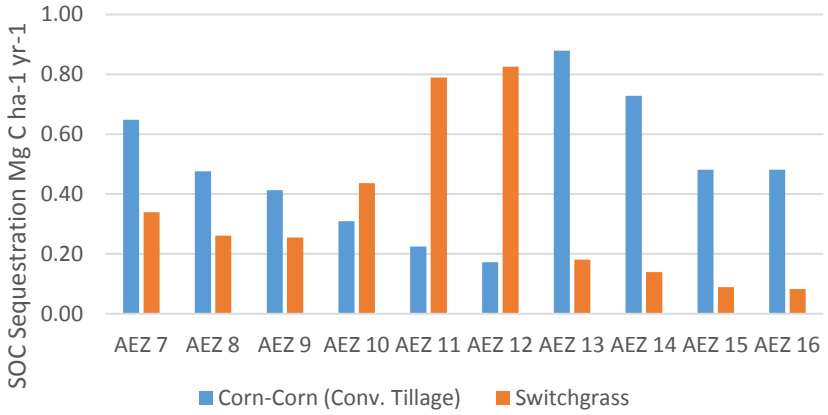
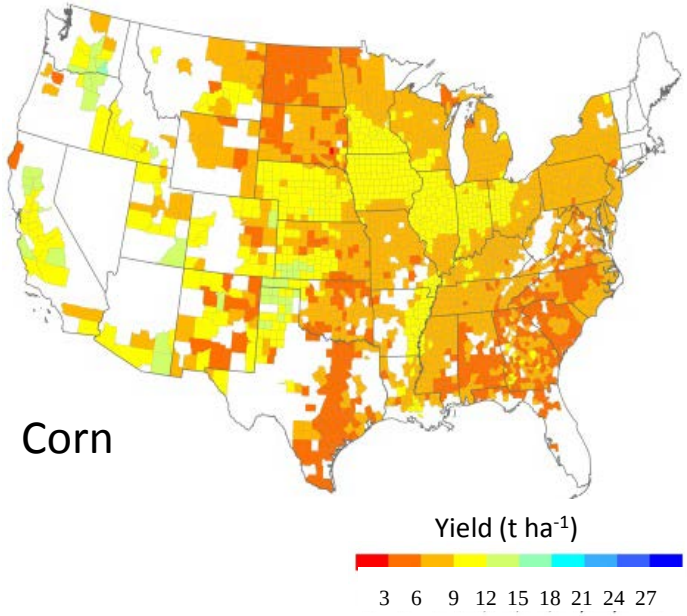
Carbon Data with High Spatial Resolution & Variation

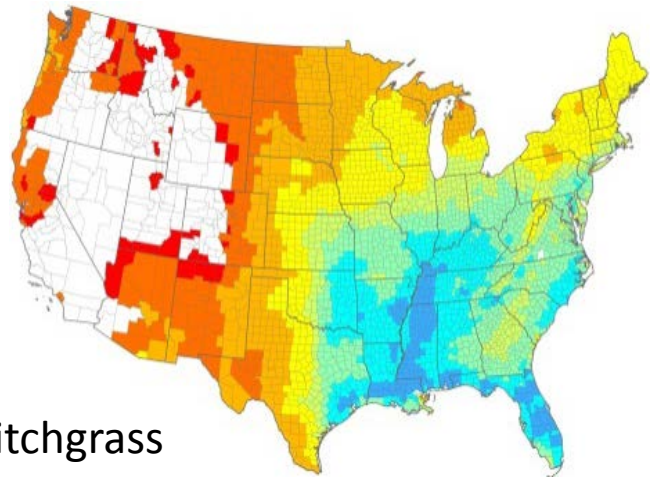


Cropland Pasture Transitions





Corn



Switchgrass

Understanding Cropland Pasture Lands and Marginal Lands

- Frequent change in Definition Over Years:
  - In 1944: “Cropland used solely for pasture that had been plowed within the preceding seven years”
  - Today: “This category includes land used only for pasture or grazing that could have been used for crops without additional improvement”
- In general CP land toggles between cropland and pasture but at what point is CP land still considered CP as opposed to cropland
- Currently CP land seems to be declining and toggling towards cropland
  - Absent good data we assume that those lands end in cropland that have been toggling more frequently between the two states i.e. the likely more productive CP acres
  - CP to Cropland carbon content more characteristic of cropland

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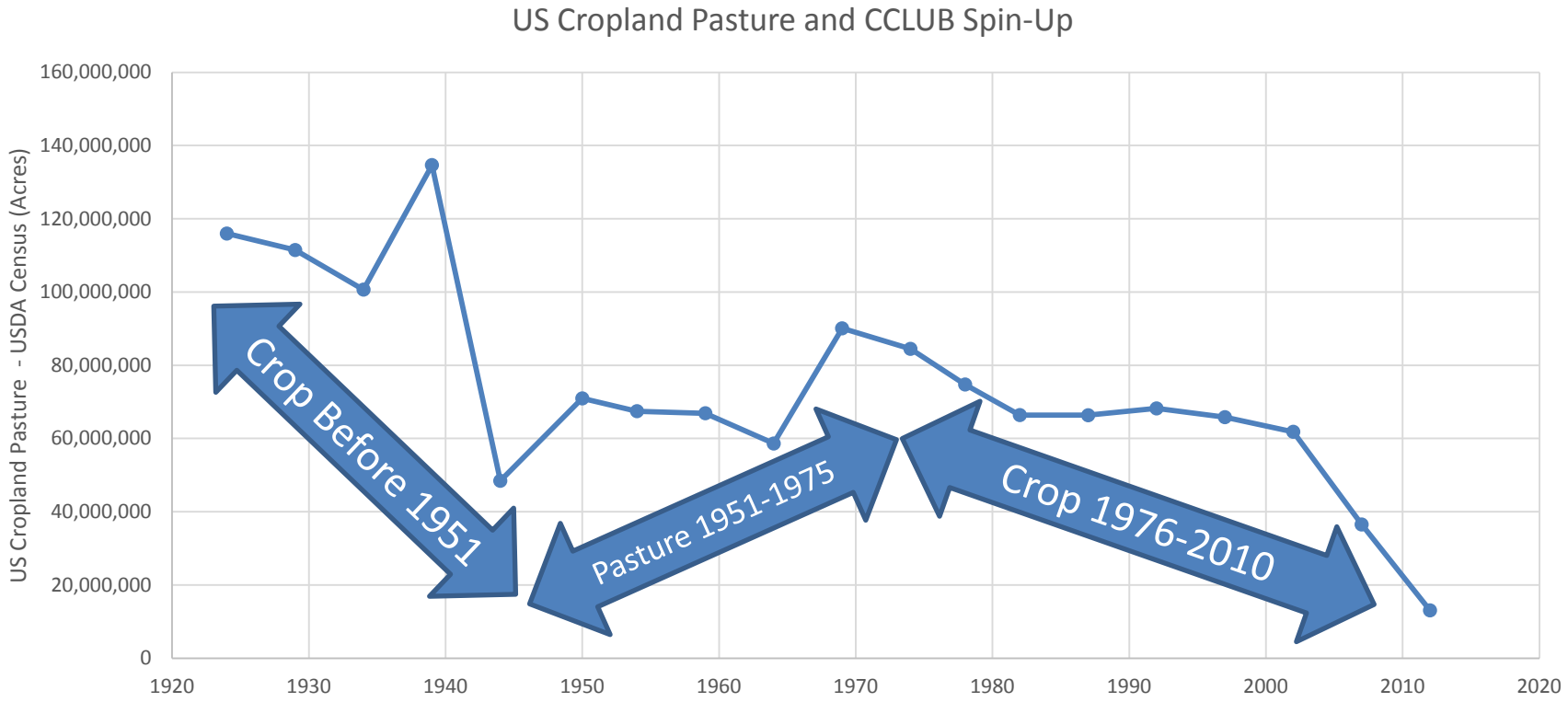
Cropland Pasture

CCLUB requires land use history. Difficult for CP lands. Our assumptions are:

- Periods of CP Increase - Carbon content more characteristic of Pastureland
- Periods of CP Decrease - Carbon content more characteristic of Cropland



Altering final land use of cropland-pastureland before conversion to switchgrass has little effect

County	Final land use	SOC Change (t C/ha/yr)	GHG emissions (g CO_2/MJ)
Alllamakee, IA	Pasture	-0.01	0.4
	Crop	-0.04	1.6
Butler, KS	Pasture	0.06	-1.7
	Crop	0.02	-0.6
Vernon, MO	Pasture	0.06	-1.6
	Crop	0.04	-1.1

- Directionality of SOC results does not change
- Influence on GHG results are fairly minor
- Switchgrass ethanol life-cycle GHG emissions without LUC are about 20 g CO_2e/MJ

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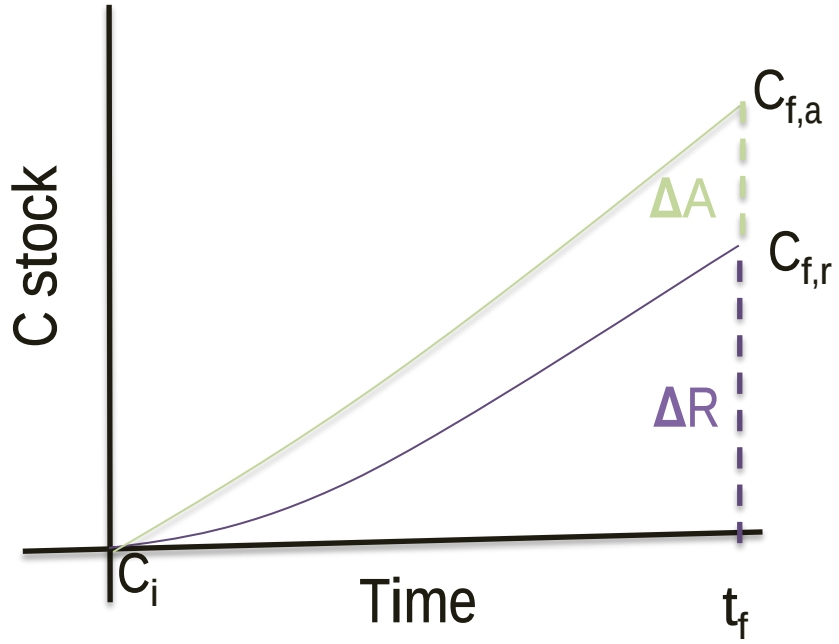
Choice of baseline in LUC GHG emissions modeling



Reference Baseline (ΔR):

Difference between final and initial states

Anticipated Baseline (ΔA):

Difference between final states under existing and anticipated baselines. For example, how much carbon would the land have accumulated without switching its land use.

Baseline in CCLUB

- Reference Baseline is used for modeling.
- However, the land management practices used for stover removal is based on anticipated baseline

Land Management Change National-Level Results Stover and Grain Ethanol Combined Production

	LMC with LUC (g CO_2eq MJ^{-1})				LMC without LUC (g CO_2eq MJ^{-1})		
	Baseline	Cover crop	Manure		Baseline	Cover crop	Manure
Combined Gallon							
	50	48	47		**44**	42	42
Marginal Allocation							
Grain Ethanol	55	55	55		47	47	47
Stover Ethanol	30	17	12		31	18	12
Energy Allocation							
Grain Ethanol	**52**	50	50		**44**	41	42
Stover Ethanol	50	49	46		51	50	47

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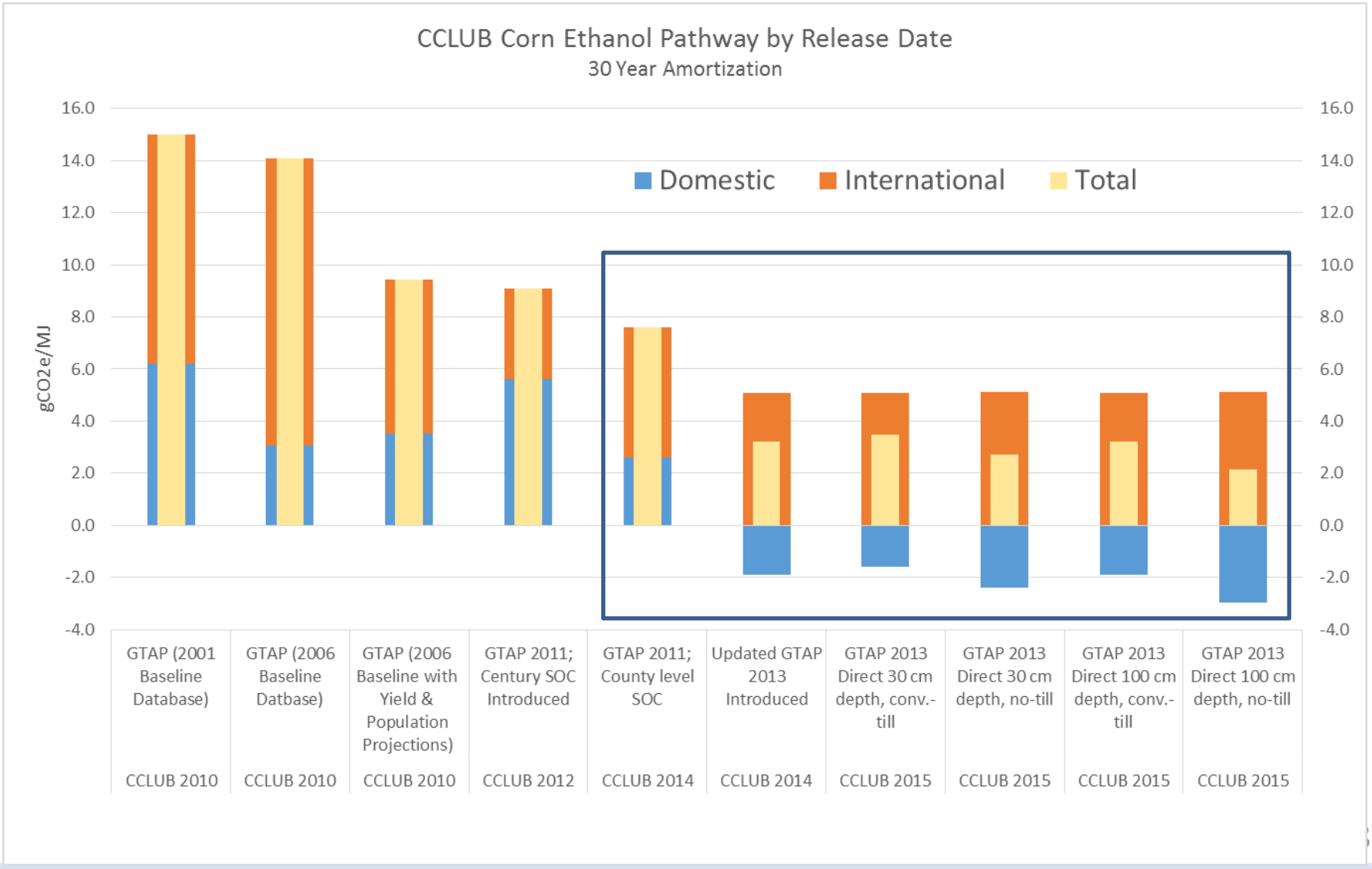
CCLUB Corn Ethanol LUC Emissions



Conclusions

- New software tools are emerging that can help identify land use history of a parcel
  - Confirm or refute land use change
  - Global coverage
- Our understanding of carbon stocks is evolving
  - Soil carbon can be positively or negatively influenced by bioenergy feedstock production
  - Soil carbon modeling is an important tool that enables identification of SOC change hot spots and a consistent basis for development of spatially-specific SOC emission factors.
  - Further work necessary to understand marginal and CP lands
  - Baseline considerations are important

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