



Technical Working Group on Agricultural Greenhouse Gases (T-AGG)

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March 29&30, 2011 C-AGG Meeting, Sacramento CA



Possibilities...

- ...private or voluntary GHG market
- ...incentive program to mitigate GHGs
- ...corporate-driven supply chain requirements
- ...low carbon biofuels
- ...cap & trade legislation w voluntary offsets

- All require technical and background scientific information to ensure environmental progress is achieved and farmers are fairly compensated
- Previously only limited number of agricultural activities under discussion



T-AGG Process

- Collaborative and transparent
- Advisory board and Science advisors
 - researchers, government agencies, agriculture & agri-business, NGOs
 - Many years of experience in carbon & other GHGs
- Broader network
 - Email list and website
 - Information gathering meetings, Protocols -Nov '09, Experts -Apr '10, X-AGG Oct '10.
 - Frequent interaction with researchers, protocol developers, model developers, policy makers and others working in this space
 - Open review process and outreach meetings
 - Active collaboration with C-AGG/M-AGG

Contributors and Reviewers

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- Tim Parkin
- Katie Bickel Goldman
- Andrea Martin
- Sasha Kravchenko
- Wilfred (Mac) Post
- Mark Liebig
- Henry Janzen
- Plus numerous scientists who participated in expert survey

Supported by The David and Lucile Packard Foundation

Physical Potential

- Net GHG/ha, total ha available, and over what time frame
- Significant upstream or downstream GHG impacts (lifecycle analysis)

Scientific Certainty

- **Is information sufficient by practice and geography?**
- **Does directional certainty exist for net GHGs?**

Economic Potential

- Costs for management shifts (opportunity costs, break even price, yield impacts...)

Possible Barriers

- Economic – capital costs
- Technical – monitoring, adoption, or production barriers
- Social – negative community or farmer impacts, resistance to change
- Negative ecological impact

Implementation & Accounting

- **Quantification - Are there good methods for measuring or modeling GHG outcomes on a project scale?**
- Monitoring and verification
- Additionality – Is there sufficient information for standardized approaches?
- Baseline – Are there viable approaches for setting baseline? Sufficient data?
- Leakage risk – Is there leakage risk (life cycle analysis)? Can it be accounted for? **Output based approaches?**
- Reversal risk – Is there risk? Can it be estimated? Is it too high?

Significant Co-benefits?

May consider activity with lower GHG potential if it provides other social, economic or environmental co-benefits

Mitigation Activities Considered

Cropland Management.	Grazing Land Management	Land Use Change
Conservation till and no-till	Improved grazing land management	Cropland → grazing land
Fallow management	Change species composition	Cropland → natural landscape
Diversify and/or intensify cropping systems	Irrigation management	Convert pasture to natural (cease grazing)
Change crop type (annual or perennial)	Rotational grazing	Restore wetlands
Short rotation woody crops	Fire management	Restore other degraded lands
Application of organic soil amendments (incl. biochar)	Fertilization	
Irrigation management		
Improve fertilizer NUE and reduce N rate		
Rice water management and cultivars		
Reduce chemical inputs		
Improve organic soil management		
Agroforestry		
Herbaceous buffers		
Improve manure management		
Drain agricultural land in humid areas		

T-AGG Reports

- **Assessing Greenhouse Gas Mitigation Opportunities and Implementation Strategies** for Agricultural Land Management in the United States: *Side-by-side assessment of biophysical and economic agricultural GHG mitigation potential; barriers and co-effects, quantification approaches, and feasibility of implementation for the US*
 - Greenhouse Gas Mitigation Potential of Agricultural Land Management in the United States: A **Synthesis of the Literature** (2nd Edition, March 2011)
 - T-AGG **Survey of Experts**: Scientific Certainty Associated with GHG Mitigation Potential of Agricultural Land Management Practices
 - Using Biogeochemical **Process Models** to Quantify Greenhouse Gas Mitigation from Agricultural Management Projects
 - An **Output-based Intensity Approach** for Crediting Greenhouse Gas Mitigation in Agriculture: Explanation and Policy Implications (published in new Journal - GHG Measurement and Management)
- *3 Chapters in upcoming book "Climate Change Mitigation and Agriculture" Edited by Eva Wollenberg, Marja-Liisa Tapio-Bistrom, Maryanne Grieg-Gran and Alison Nihart (online in May, print in October)*

T-AGG Work Underway

- Endnote Library
- Mitigation Potential Database
- Outreach to policy makers and others
- Outreach and education to agriculture community through NRCS, SWCD and extension (brief, power point, webinars)
- Summary of meta-analyses underway by two research teams on tillage and depth and exploring our own analyses on saturation of carbon storage and tillage intensity
- Considering review of mitigation potential and project level quantification approaches for livestock (beef and dairy focus)
- Developing international project with CCAFS and FAO – special issue and international workshop on quantification of GHG from agricultural mitigation at national and project levels.

Literature Review

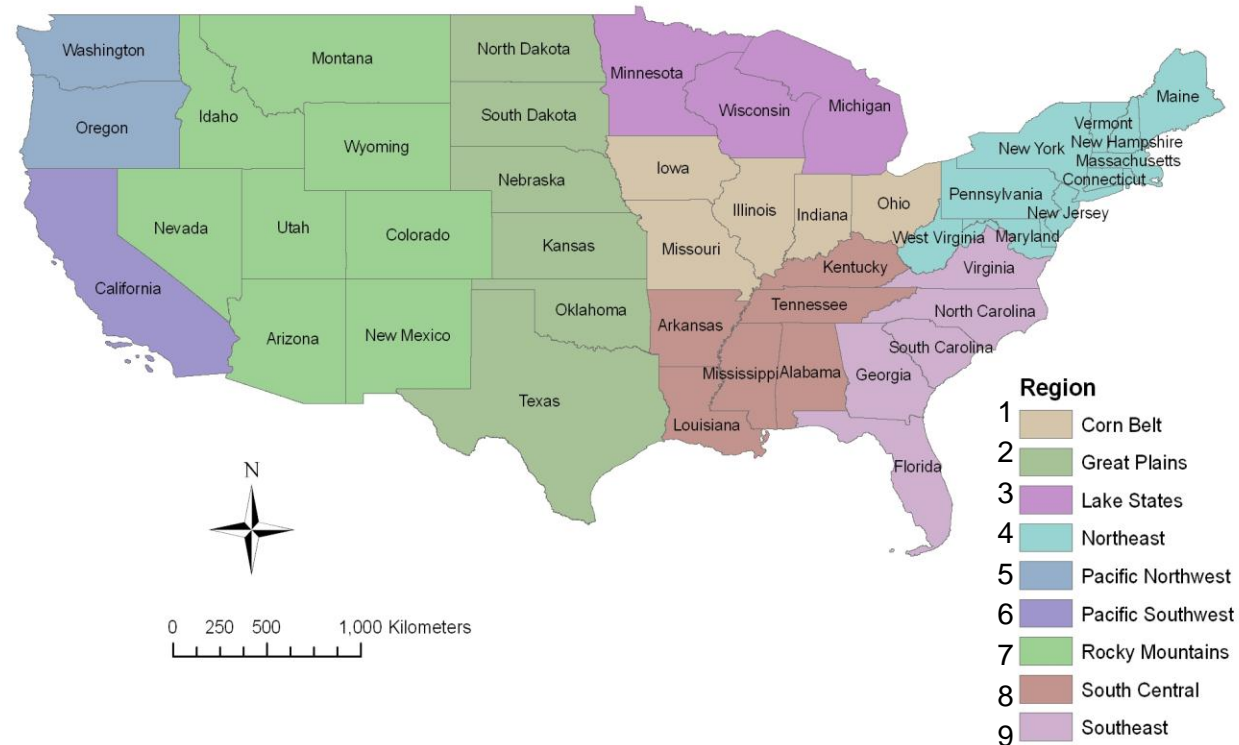


- Over 800 papers (mostly peer reviewed)
- Soil carbon, N₂O and CH₄
- Upstream and process emissions
- Showing range of values

U.S. Agricultural Regions

Research Coverage

- What type of data?
- How much data?
- Where is it from?



Research Coverage

Mitigation Practice	Number of Comparisons (field/expert/ model)	Regional Representation
No-till	526/1/1	All U.S. regions, best data for Southeast, Great Plains, Corn Belt
Winter cover crops	76/4/1	Everything except PNW*, Rocky MTS, South Central* - sufficient growing season and water
Reduce N fertilizer rate	24/3/2	Corn Belt, Lake States, Rocky Mountains, Great Plains (missing eastern US)
Improved grazing management on rangeland	17/2/0	Great Plains, Rocky Mountains (right coverage)

Biophysical GHG Mitigation Potential of Selected Activities for the U.S.

Activity	Soil Carbon	Land Emissions (N ₂ O and CH ₄)	Process/Upstream Emissions	Net Impact	Max Area
	(t CO ₂ e ha ⁻¹ yr ⁻¹)				(Mha)
Conventional to no-till *	1.08	-0.18	0.12	1.01	72
Conventional to conservation till *	0.91	0.07	0.08	1.06	72
Eliminate summer fallow*	0.48	-0.03	-0.12	0.32	20
Use winter cover crops*	0.84	0.20	0.56	1.50	74
Reduce N fertilizer application rates	0.00	0.38	0.07	0.45	106
Use nitrification inhibitors	0.00	1.01	No data	1.01	92
Rice water management	0.00	1.56	0.00	1.56	1.3
Improved grazing management, rangeland*	0.93	0.28	No data	1.22	166

**Carbon sequestration may saturate over time*

Scientific Certainty: Expert Consultation

- Meta-analyses not always possible
- How confident are experts in the potential GHG mitigation of select land management practices?
- Used a survey of experts to measure (1) confidence in potentials and (2) level of evidence in existing research
- 4 topic areas (average 10 experts each session)
 - Cropland soil carbon
 - N₂O emissions reductions
 - CH₄ and other GHGs
 - Grazing land management

Voting Choices for Each Activity

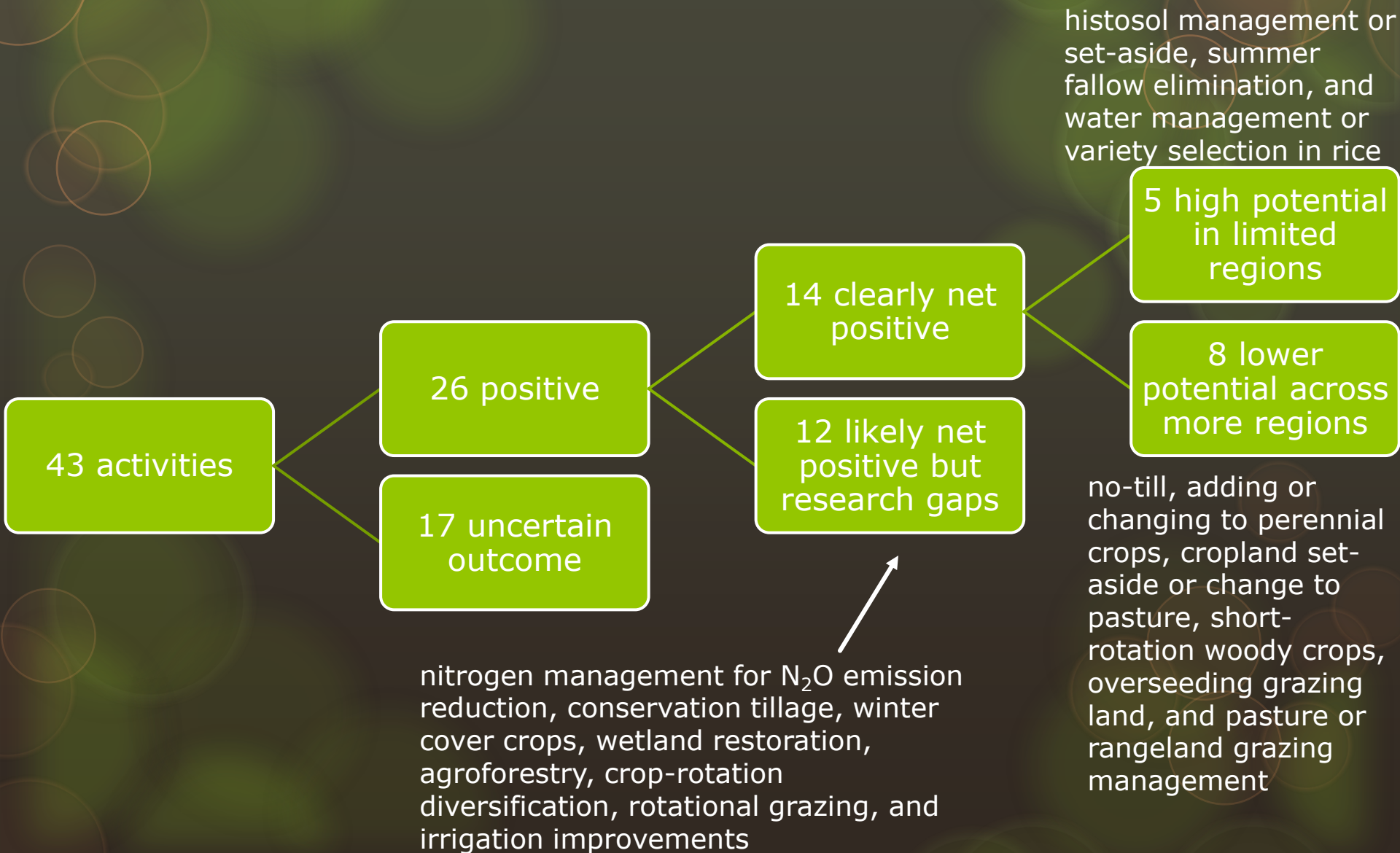
Level	Confidence	Evidence
High	confident that the value is within the range given (i.e., ± 20% of the estimate)	sufficient evidence in all applicable regions
Med	quite sure that the direction of the effect is correct (i.e., whether it increases or decreases emissions), but uncertain of the magnitude, pending further studies	some regions or situations have sufficient evidence, but more is needed in others
Low	this is an educated, qualitative guess, based on scattered and incomplete data, but it seems reasonable (no directional certainty)	evidence is scattered and incomplete
None	no confidence in the value	not aware of any trustworthy evidence
Unknown	unable to state an opinion	unable to state an opinion

Selected Results from Survey

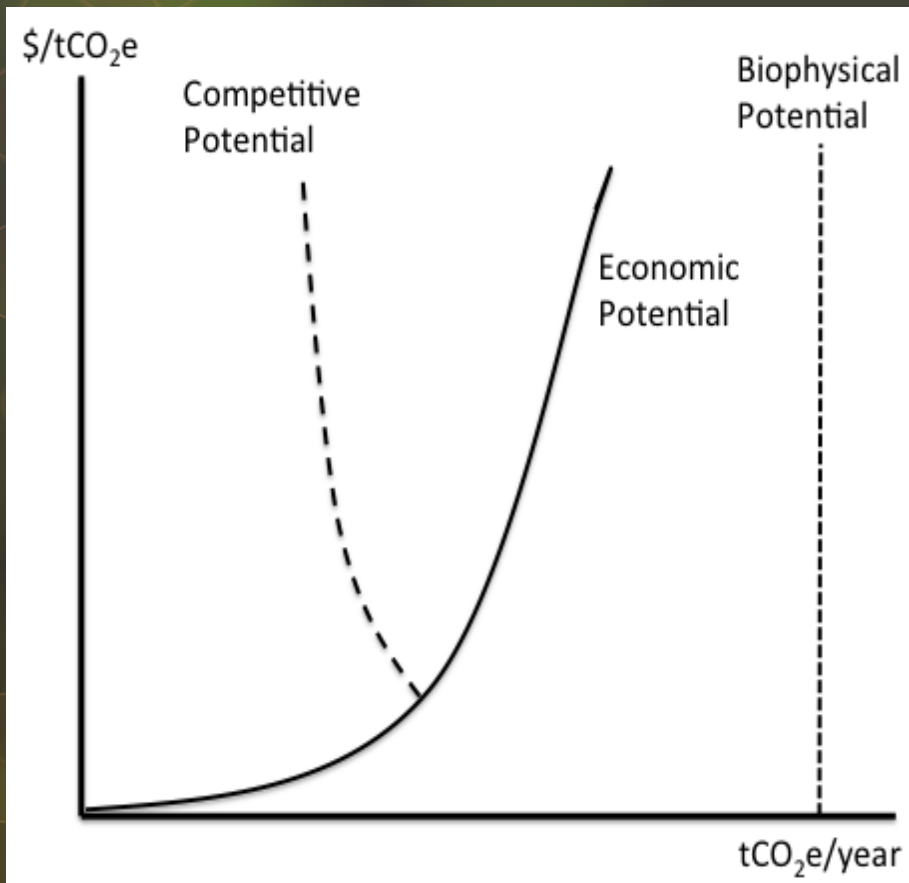
Activity	Confidence	Evidence	Major Issue
Conventional to conservation tillage	Low	Low	Definitions for baseline and treatment often unclear
Conventional to no-till	Med	Med	
Use winter cover crops	Low	Low	Lack of data; impact on main crop (and GHG implications) is unclear
Reduce N fertilizer application rates	Low	Low	Emissions vary by soil texture, irrigation status, etc.; need to address yield impact
Use nitrification inhibitors	Low	Low	Lack of data; varies by fertilizer source
Rice water management (mid-season drainage)	Med	Med	Multiple drainage events may enhance potential
Improved grazing management, rangeland	Med	Med	BMPs are critical in drought years
Manage species composition on grazing land	Med	Low	Variable results by species, region (rainfall etc.)

Summary of Biophysical Potential

Lit review, research coverage, expert assessment



Economic Potential



*Adapted from Murray et al. (2005)
and McCarl and Schneider (2001)*

- Biophysical Potential represents the maximum obtainable mitigation from the terrestrial
- Economic Potential follows an upward-sloping supply schedule, as one would expect (indicating higher levels of abatement for greater CO_2 price incentives).
- Competitive Potential exhibits a “backward-bending” shape—the implication here is that at some CO_2 price threshold, other abatement options are more attractive at higher prices (due to higher GHG returns).
- (Smith et al. 2007) global mitigation potential at $\$20/tCO_2$ ~30% of biophysical potential; at $\$100$ ~75%

Reviewed Studies of Economic Potential


- 17 papers reviewed (EP and CP)
- Activities examined: no-till, conservation till, reduced fallow, conversion to permanent grass, decreased N use, and afforestation.
- Show a range of mitigation potentials achieved at various costs depending on practice assessed and method used.
- Studies have weak (or no) coverage of transaction costs and non-market adoption barriers which can be significant

Quantification of net GHG changes

Complexity	Quantification approach	Aggregation Level/Uncertainty	Notes
pTier 1	IPCC Tier 1 default factors	Typically large spatial units; National scale; annual resolution	Suitable for rough overviews and where limited data is available
pTier 2	Hybrid of process-model; empirical data; regional emission factors	Finer spatial and temporal resolution than above; can be monthly time step; application will depend on available information	Can be suitable for project-based accounting and inventory roll-ups to national scale;
pTier 3	Process-based models	Site-scale with high temporal resolution;	Suitable for small-scale applications where local variability can be managed; complexity, cost and time spent applying the model may be beyond the average project developers expertise.; flexible (multiple practices)
	Sampling and Measurement	Site scale uncertainty can be high if not applied correctly	Level of errors may become overwhelming in sites/projects with high variability; can be most costly to implement; flexible (multiple practices); particularly difficult for N ₂ O and CH ₄

Field Sampling vs Modeling

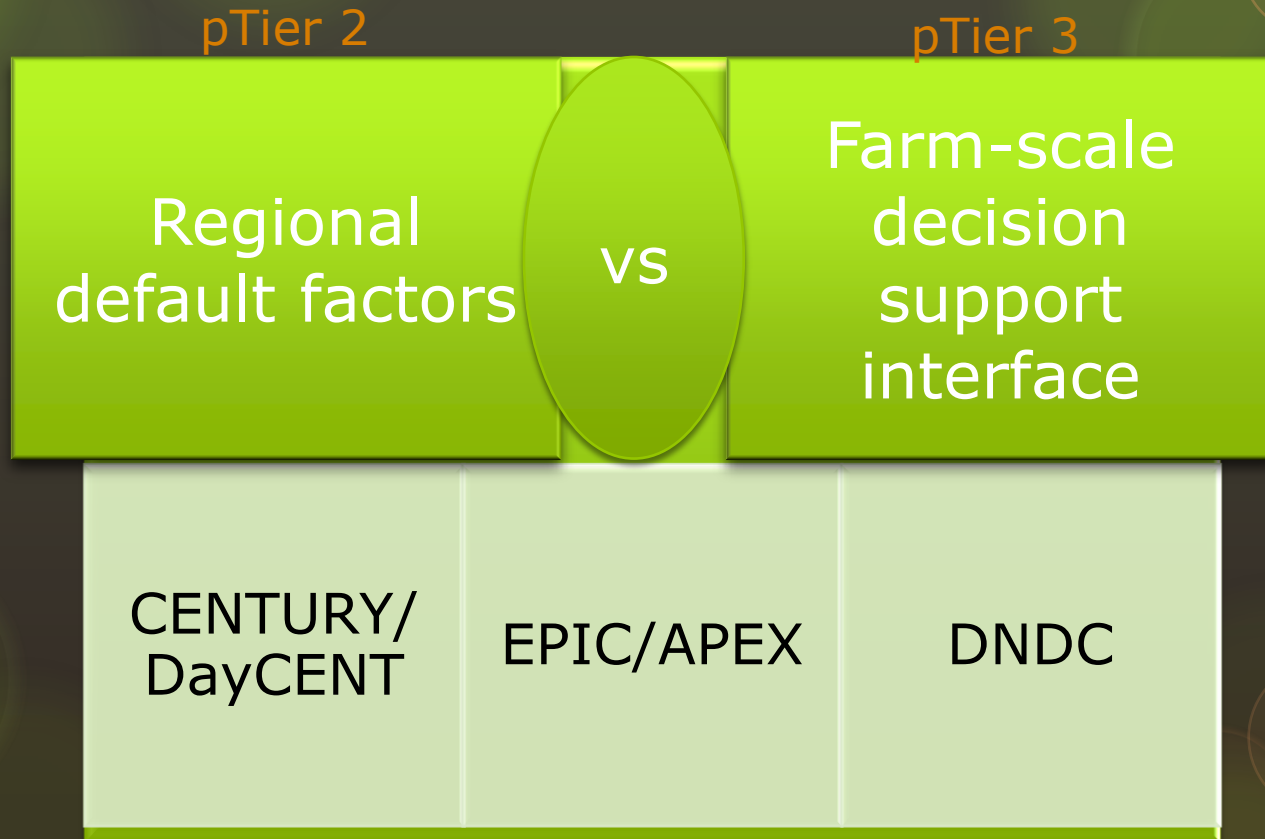
- *Field sampling can be complex and expensive to implement. Thus for large scale programs in US experts suggest modeling with field sampling (at reference sites) to calibrate and verify models*
- *Modeling approaches are practice based*
 - They assess performance/outcome and can allow significant flexibility in combinations of practices and crops and innovation within known and researched areas.
 - *Expansion of known options*
- *Field sampling approaches are outcome based*
 - Unlimited flexibility which would allow for truly original approaches
 - *Exploration of unknown options*



SOC only
\$850.00 (10 samples)
\$3,400.00 (40 samples)
\$34,000.00 (400 samples)

Costs taken from Paragon Report
<http://www.carbonoffsetsolutions.ca>

Applying models



Quantification methods differ by activities

Management Type	Field Based (Carbon only)	Model Based (Carbon, N ₂ O, and CH ₄)		
		Tier 1*	Tier 2	Tier 3
Land Use Change	Yes-d		Yes	Yes
Managing soil carbon on crop land	Yes-d		Yes	Yes
Managing N use for N ₂ O reduction		Yes	Yes**	Yes**
Managing CH ₄ through crop management		Yes	Yes	Maybe
Managing rangeland C by amendment	Yes-d		Maybe***	Maybe***
Managing rangeland C by animal management	Yes-d		Maybe***	Maybe***

Yes-d – depends because high SOC and spatial variability makes field sampling difficult and expensive especially if the annual changes in soil carbon are small relative to this background carbon.

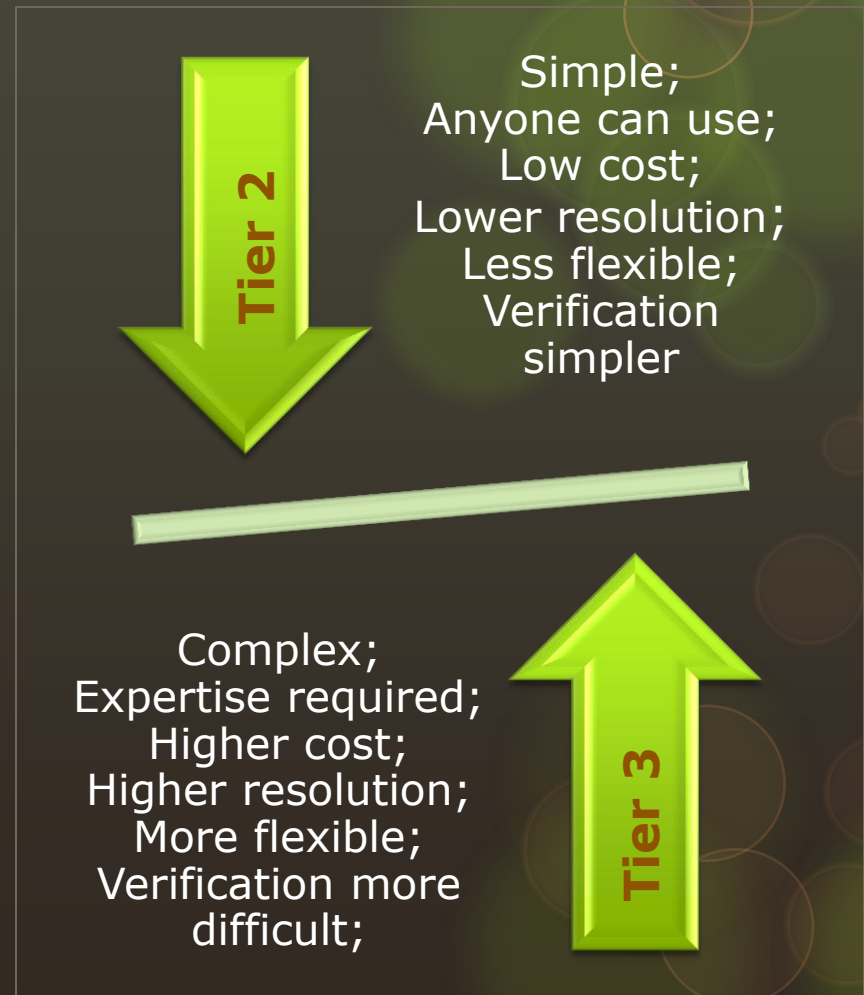
** Only use Tier 1 if no other more accurate method available. Tier 1 likely will not provide sufficient certainty for many protocols or programs in the US.*

*** Likely will need to use tier 1 for offsite N₂O (from leached and volatilized N sources); and may require several measured field data inputs.*

****Process-based models that integrate pasture/range productivity and soil carbon dynamics with livestock-based emissions of nitrous oxide and methane are still under development.*

Take home on Quantification

- Models with field calibration/verification
- Want a standardized, repeatable process without bias
- Need standard process for assessing uncertainty
- Models may not have needed data for all cropping systems and practices
- Important choice regarding scale of use



Verification

- Alignment of definitions
 - Models (and decision support interface for tier 3)
 - Methods/Protocols
 - Verification criteria
- Possible to verify
 - Visual inspection (machinery)
 - Simple sampling (depth of organic matter)
 - Records (receipts)
 - Remote sensing

Definitions of tillage systems in the Parkland and Dry Prairie protocol areas

Example from Canada - Alberta program

Tillage System	Cropped Land Period ²	Fallow Period ³
No Till	Up to two passes with low-disturbance openers (up to 38% each) ^{4, 5} or one pass with a slightly higher disturbance opener (up to 46%) to apply seed, fertilizer or manure ⁵ , discretionary tillage of up to 10% ⁶ , no cultivation allowed. Manure applications are either injection or broadcast within these disturbance criteria – no incorporation.	No cultivations
Reduced Till	Soil disturbance to apply seed, fertilizer, or manure exceeds no till definition and/or one cultivation in fall or spring	One to two cultivations
Full Till	More than one cultivation between harvest and subsequent seeding if no fallow in that period, or, more than three cultivations between harvest to subsequent seeding if fallow.	More than two cultivations

Notes:

² Cropped land period applies to the management cycle that terminates at harvest, (e.g. harvest to harvest defines the cropped land period). This includes land preparation for seeding which may occur in the previous fall.

³ Fallow period extends from harvest for one full year to the next harvest, typically in the fall.

⁴ Percentage values associated with openers are based on maximum opener width (e.g. 5 inch openers actually measure 5.5 inches) divided by the spacing between shanks of the implement.

⁵ Additional operations with harrows, packers, or similar non-soil disturbing implements are accepted (e.g., rodweeders are not acceptable).

⁶ Discretionary tillage of up to 10% means that up to 10% of the surface area of a single agricultural field may be cultivated to address specific management issues. These areas are determined on an annual basis, meaning that specific areas may change from year to year. Discretionary tillage of greater than 10% of field area must be disclosed and that field is not eligible to generate offsets. This must be disclosed in project documentation.

Example of verification actions

Tillage Practice and number of passes

- GPS output from specific farm equipment; or
- Satellite data interpretation (with ground truthing); or
- Aerial Photo interpretation (at specific times of year, if available, this can provide strong evidence of recent practices); and/or
- Physical inspection of field;
- Physical inspection of seeding/tillage equipment claimed as low till (openers divided by shank spacing); and
- Review of farm records by professional Agrologist in addition to a physical inspection of tillage equipment with accompanying statement of review

Additionality/Baseline

Standardized approaches are based upon regional or sector trends

Data sources for developing performance standards and baselines for U.S. agricultural mitigation practices

Activity	Data Requirement	Data Available	Data source(s)	Caveats
Conventional to no-till	Adoption rates for No Till	Yes	ARMS, CTIC	Cannot distinguish between permanent and rotational no till. ARMS is state-level only
Use winter cover crops	Cover crops used (species, acreage) at local or region scale	Yes	USDA-NASS Ag. Census	1) Only reports acreage and production totals 2) not consistently mapped with primary production systems
Include perennial crops in rotation	BAU perennial crop acreage and yield	No		
Short rotation woody crops (SRWCs)	BAU SRWC acreage and yield	No		
Reduce N fertilizer rates	Application by crop and spatial scale	Yes	ARMS NUGIS Ag Census + Other sources	1) ARMS is only available at the state level 2) Other data sources are not crop-specific 3) NuGIS infers application rates for different crops, and cannot isolate variation in N use across different management regimes
Change fertilizer N source to slow release	Baseline use of slow release technology	No		
Rice water management (mid-season drainage)	Baseline use of mid-season drainage	Not national		1) No national data 2) Local data available from observed rice systems in California—might not apply to rice systems in the southern US
Convert cropland to pasture	Observed crop to pasture transitions	Yes	NRI Ag. Census (USDA-MLU)	1) MLU only reports land use totals 2) NRI distinction between cropland, non-cultivated cropland, and intensively managed pasture only vaguely defined
Improved grazing land management, rangeland	Grazing land use data, stocking rates	Yes	NRI USDA-MLU Ag. Census USDA-NASS	1)only sticking rates

Leakage

- Current approach for voluntary markets and CDM is leakage belts and discounting
- Alternative approach is OBO which incorporates leakage into crediting
- For both need to make leakage adjustments

	Leakage Estimation Approach	
	Comprehensive Modeling	Formulaic Approach
What different approaches produce	Develop estimates across full range of relevant agricultural practices (look up table)	Develop individual estimates for individual or multiple practices based on available data.
Model or data needs	FASOMGHG, POLYSIS, or FAPRI	Data on how management change affects productivity, elasticity of supply and demand, relative GHG emissions for in program and outside program actions, importance in global supply

Reversals

- Loss of sequestered carbon (not N_2O, CH_4); Tillage & above ground carbon loss
- Assuming historical climate and disturbance, reversals may be a limited issue for agriculture
- Long-term trends in climate, may also impact emissions and carbon storage (+/-).

	Reversal Event	GHG Impact
Intentional	Shift back to conventional tillage	Soil carbon release
	Removal of tree crop, wind break, or other shrub crop	Removal of above ground carbon
Undefined	Tillage due to superweeds	Significant soil carbon release
Unintentional	Fire	For tree and shrub crops, loss of above ground carbon.

Output Based metrics

- Usually use area metrics CO₂e per acre
- Output metrics based on productivity and efficiency
 - CO₂e per ton of crop produced (yield)
- Positives
 - Encourages increasing efficiency, aligning with food security
 - Expand ag practices that would count for mitigation programs
 - Internalize yield impacts on the broader system (good and bad leakage)
- Concerns
 - Yield volatility adds uncertainty and complexity
 - Intensity approach, allows overall emissions to continue to increase
 - Discomfort paying for it if farmers would do it anyway because it increases yield or reduces costs

Summary

- Positive net mitigation potential from a wide range of practices
- Still a number of critical research gaps for a number of high potential activities (research underway)
- Mitigation potential will be constrained by land use competition, opportunity costs, transaction costs, and adoption barriers
- For a large scale program, modeling may be the best quantification approach
- Models can be applied at either regional or farm level scales given current modeling and data capabilities; depends on management activity.
- Some significant data gaps for standardized additionality and baseline approaches.





Technical Working Group on
Agricultural Greenhouse Gases (T-AGG)

Thank you

Website with reports and email list
<http://www.nicholasinstitute.duke.edu/t-agg>





Table 2. List of DNDC inputs with units and data source. Where two data sources are indicated, the choice rests with the Project Proponent.

Input Category	Code	Input	Units	Mandatory / Optional	Data Source			
					Project records	Measured	Look-up	Default
Location	L1	GPS location of stratum	decimal °	M		X		
Climate	C1	Atmospheric background NH ₃ concentration	µg N/m ³	M				X
	C2	Atmospheric background CO ₂ concentration	ppm	M				X
	C3	N concentration in rainfall	mg N/l or ppm	M				
	C4	Daily meteorology	multiple	M		X	X	X
Soils	S1	Land-use type	type	M	X			
	S2	Clay content	0-1	M		X	X	X
	S3	Bulk density	g/cm ³	M		X	X	X
	S4	Soil pH	value	M		X	X	X
	S5	SOC at surface soil	kg C/kg	M		X	X	X
	S6	Soil texture	type	M		X	X	X
	S7	Slope	%	M		X		
	S8	Depth of water retention layer	cm	M		X	X	X
	S9	High groundwater table	cm	M		X	X	X
	S10	Field capacity	0-1	M		X		
	S11	Wilting point	0-1	M		X		
Cropping system	CR1	Crop type	type	M	X			
	CR2	Planting date	date	M	X			
	CR3	Harvest date	date	M	X			
	CR4	C/N ratio of the grain	ratio	M			X	
	CR5	C/N ratio of the leaf + stem tissue	ratio	M			X	
	CR6	C/N ratio of the root tissue	ratio	M			X	
	CR7	Fraction of leaves and stem left in field after harvest	0-1	M			X	
	CR8	Maximum yield	kg dry matter/ha	M	X			
Tillage system	T1	Number of tillage events	number	M	X			
	T2	Date of tillage events	date	M	X			
	T3	Depth of tillage events	6 depths†	M	X			
N Fertilizer	F1	Number of fertilizer applications	number	M	X			
	F2	Date of each fertilizer application	date	M	X			
	F3	Application method	surface / injection	M	X			
	F4	Type of fertilizer	type	M	X			
	F5	Fertilizer application rate	kg N/ha	M	X			
	F6	Time-release fertilizer	# days for full release	M	X			
	F7	Nitrification inhibitors		M	X			
Organic Fertilizer	O1	Number of organic applications per year	number	M	X			
	O2	Date of application	date	M	X			
	O3	Type of organic amendment	type	M	X			
	O4	Application rate	kg C/ha	M	X			
	O5	Amendment C/N ratio	ratio	M				X
Irrigation System	I1	Number of irrigation events	number	M	X			
	I2	Date of irrigation	date	M	X			