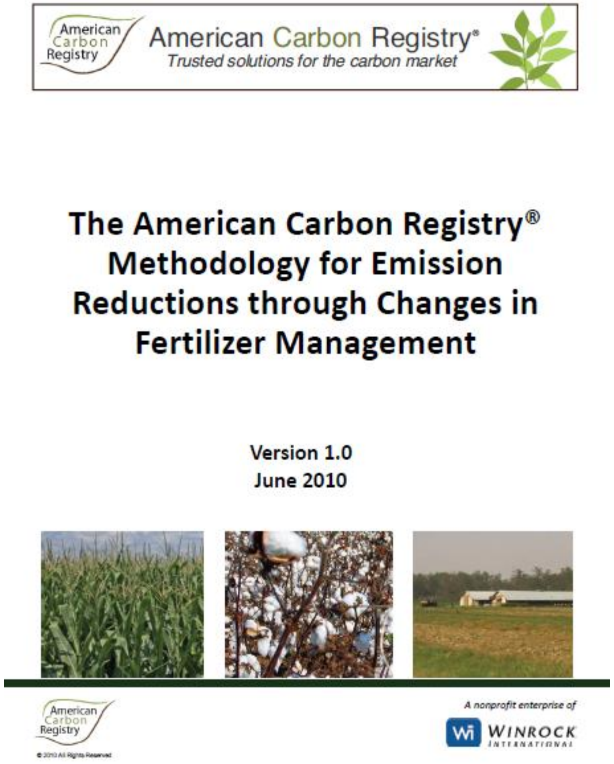
ACR Methodology for N_2O Emission Reductions through Changes in Fertilizer Management

X-AGG Joint Meeting
Chicago, Illinois
October 4-5, 2010

Methodology at a glance

- Applicable to ALM project activities that involve a change in fertilizer management
  - Fertilizer rate, type, placement, timing, timed-release fertilizers, nitrification inhibitors, etc.
- Peer-reviewed, highly parameterized model
- Direct N_2O from fertilizer application, and indirect N_2O from leaching and ammonia volatilization, modeled for baseline and project



American Carbon Registry®
Trusted solutions for the carbon market

The American Carbon Registry® Methodology for Emission Reductions through Changes in Fertilizer Management

Version 1.0
June 2010

A nonprofit enterprise of
WINROCK INTERNATIONAL

Methodology objectives

- Rigorous, scalable and cost-effective approach for accounting emission reductions from a broad range of practices
  - Practical for project proponents and farmers
  - Rigorous quantification (Tier 3)
  - Balance precision and cost
- Broad range of eligible practice changes
- Aggregation for cost-effectiveness and risk diversification

Development process

- Packard Foundation support
- Developed by Winrock International and Applied Geosolutions LLC
- Several interim products and analyses led to current approach
- Current status:
  - Background work 2009-2010
  - Methodology posted for public comment July-Aug 2010
  - Initial peer review complete
  - Anticipated release Oct/Nov 2010

Applicability conditions

- Management in both baseline and project cases involves use of fertilizer
- Records of yields and fertilizer application from at least 5 previous years
- Project must incorporate a minimum of 10 separate fields
- No significant decrease in yields as a result of project implementation
- Fertilizer use must not be increased in owned or managed lands that are not part of the project
- No drainage or flooding of wetlands

Project boundary

- Physical: all land areas uniquely identified
  - Aggregation likely (multi-farm level) though not required
  - Land and offsets title documented
- GHG boundary
  - No carbon pools (*de minimis* relative to primary impacts)

Sources	Gas	Included / Excluded	Justification / Explanation of choice
Direct and Indirect Emissions Resulting from Fertilizer Application	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable
	N_2O	Included	Non-CO_2 gas emitted from fertilizer application
Emissions resulting from Fossil Fuel Combustion	CO_2	Included	Gas emitted from fossil fuel combustion
	CH_4	Included	Gas emitted from fossil fuel combustion
	N_2O	Included	Gas emitted from fossil fuel combustion

Baseline scenario and additionality

- Realistic and credible land use scenarios in absence of project activity evaluated using common practice, barriers, and investment analysis
  - Continuation of the pre-project fertilizer management (historical baseline)
  - Fertilizer management as modeled under the project but in the absence of registration as an ALM ACR project activity
  - Etc.
- Demonstate additionality of project scenario via ACR three-prong test and add’l tool

DNDC model inputs

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	***CI***	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			X	
	C4	Daily meteorology	multiple	M		X	X	
Soils	***S1***	Land-use type	type	M	X			
	S2	Clay content	0-1	M		X	X	
	S3	Bulk density	g/cm^3	M		X	X	
	S4	Soil pH	value	M		X	X	
	S5	SOC at surface soil	kg C/kg	M		X	X	
	S6	Soil texture	type	M		X	X	
	S7	Slope	%	M		X		
	S8	Depth of water retention layer	cm	M		X	X	
	S9	High groundwater table	cm	M		X	X	
	S10	Field capacity	0-1	M		X		X
	S11	Wilting point	0-1	M		X		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	X	
	CR5	C/N ratio of the leaf + stem tissue	ratio	M		X	X	
	CR6	C/N ratio of the root tissue	ratio	M		X	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			
	I3	Irrigation type	3 types‡	M	X			
	I4	Irrigation application rate	mm	M	X			

Model calibration

- Crucial step as soil conditions, moisture and cropping affect C and N biogeochemistry and thus N_2O emissions
- Calibration parameters (default values available):
  - Maximum crop biomass (kg C/ha)
  - Biomass fractions (grain, leaves + stems, roots)
  - Biomass C/N ratio (grain, leaves + stems, roots)
  - Total N demand to reach maximum production (kg N/ha)
  - Thermal degree days
  - Water demand (g water / g dry matter)
  - N fixation index (1 for non-legume crops)

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Modeling baseline and project scenarios

- Uncertainty ranges for soil input parameters defined via measurements or soil survey data
- Run DNDC in Monte Carlo mode
- Model output (for each stratum and Monte Carlo run, baseline and project):
  - Direct annual N_2O emissions ($NL_{DIRECT,j,i,}$) in kg N_2O-N.ha^{-1}
  - Annual nitrate leaching loss ($NL_{LEACH,j,i}$) in kg NO_3^--N.ha^{-1}
  - Annual ammonia volatilization and nitric oxide emissions ($NL_{VOLAT,j,i}$) in kg NH_3-N.ha^{-1} + NO_x-N.ha^{-1}

Modeling baseline and project scenarios

$$GHG_{BSL,N2O,E,j,i} = \left(NL_{DIRECT,j,i} + \left(NL_{VOLAT,j,i} * EF_4\right) + \left(NL_{LEACH,j,i} * EF_5\right)\right) * \frac{44}{28} * GWP_{N2O}$$

$$GHG_{P,N2O,E,j,i} = \left(NL_{DIRECT,j,i} + \left(NL_{VOLAT,j,i} * EF_4\right) + \left(NL_{LEACH,j,i} * EF_5\right)\right) * \frac{44}{28} * GWP_{N2O}$$

- Baseline and project emissions in each stratum, summed across *N* Monte Carlo runs
- Emission factors for volatilization and leaching are based on IPCC defaults
- GWP of 310 (SAR-100)

Calculating net emission reductions

$$BE = GHG_{BSL\_N2O,E} + GHG_{BSL\_FF,E}$$

$$PE = GHG_{P\_N2O,E} + GHG_{P\_FF,E}$$

$$GHG_{BSL\_N20,E} = \sum_{t=1}^{t^*}\left(\sum_{i=1}^{M}\left(GHG_{BSL,N2O,E,i} * A_i\right)\right)$$

$$GHG_{P\_N20,E} = \sum_{t=1}^{t^*}\left(\sum_{i=1}^{M}\left(GHG_{P,N2O,E,i} * A_i\right)\right)$$

$$GHG_{BSL\_FF,E} = \sum_{a}(Fuel_{a,t} \times EF_a)$$

$$GHG_{P\_FF,E} = \sum_{a}(Fuel_{a,t} \times EF_a)$$

$$ER_{ALM-ACR} = PE - BE$$

$$ERTs = ER_{ALM-ACR,t2} - ER_{ALM-ACR,t1}$$

(uncertainty deduction
but no leakage or risk
buffer deductions)

Uncertainty

- Defined as 90% confidence interval as % of the mean
- Derived from 4,096 Monte Carlo runs
  - For baseline and project scenarios, by stratum
  - Total uncertainty: propagating errors across strata and between baseline and project emissions
- If $ER_{ALM\text{-}ACR\_ERROR}$ ≤10% of $ER_{ALM\text{-}ACR}$ → no uncertainty deduction
- If $ER_{ALM\text{-}ACR\_ERROR}$ >10% of $ER_{ALM\text{-}ACR}$ →

$$= ER_{ALM-ACR} - \left(ER_{ALM-ACR} * \left(ER_{ALM-ACR\_ERROR} - 10\%\right)\right)$$

Project monitoring

- Geographic position of project boundaries over time
- Adherence to fertilizer management plan, data collection and management
- Area of strata
- Climate input parameters
- Cropping (type, planting date, harvest, C/N ratios)
- Tillage events
- Fertilizer applications: number, date, application (surface, depth), type (7), rate (kg N/ha), use of timed-release and nitrification inhibitors
- Organic amendments
- Irrigation events
- Fossil fuel use

Peer review comments

- Exclusion of soil C changes as *de minimis*
- Quantifying GHG emissions on yield-scaled basis?
- All models imperfect for complex biogeochemical systems
- Model complexity, input requirements, expertise needed
  - Simplified approach with larger discounts…?
  - Has to be “easy” for the farmer, not necessarily the proponent or verifier
- Monitoring of leakage
- Buffer for violations (not reversals)
- Embodied upstream emissions from fertilizer manufacturing
- Model structural uncertainty

Further information

Nicholas Martin

Chief Technical Officer, American Carbon Registry

nmartin@winrock.org
www.americancarbonregistry.org

(703) 842-9500

American Carbon Registry

- First U.S. private voluntary GHG registry
  - Founded 1996 by Environmental Defense Fund and Environmental Resources Trust
  - 30 million tons issued
- Pioneered system of transparent on-line reporting and serialization of verified project-based offsets – now the industry standard
- Joined Winrock International in 2007
  - Founded 1984 as a “public benefit corporation” under Arkansas state law

Offset types

- Forest carbon (AR, IFM, REDD)
- Agricultural and rangeland activities
- Livestock manure management
- Landfill gas
- CCS / enhanced oil recovery
- Fuel switching
- Industrial gas substitution
- Truck stop idling
- Fugitive methane in oil & gas production, processing, transmission

Winrock International

Nonprofit that works in the U.S. and around the world to empower the disadvantaged, increase economic opportunity, and sustain natural resources

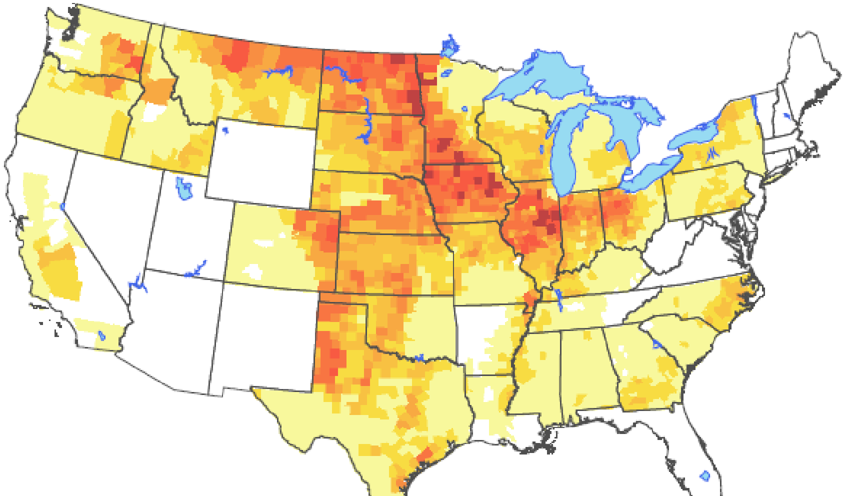
- Build expertise, train leaders
- Apply sound science and economics
- Mobilize markets
- Promote innovation
- Help the disadvantaged

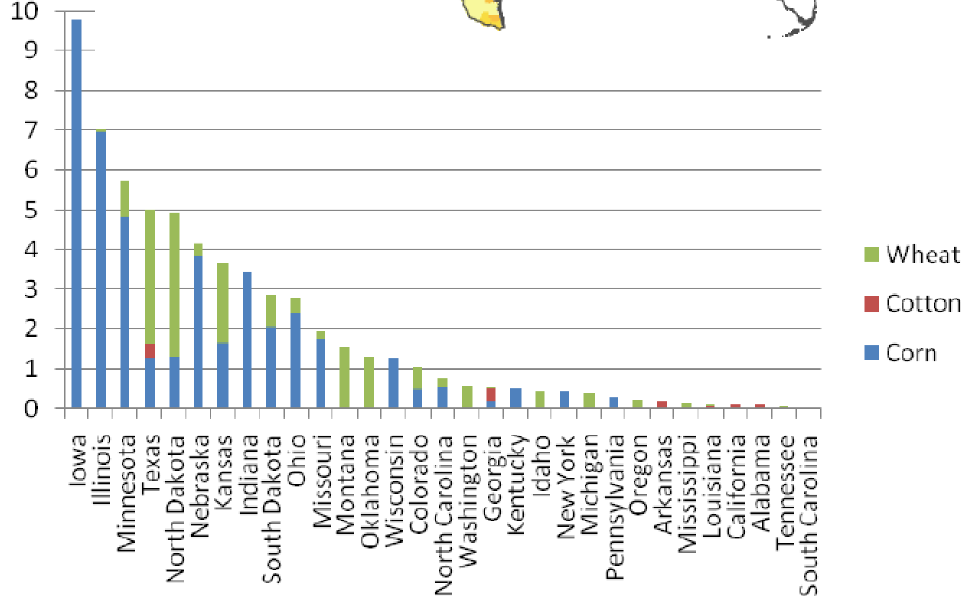
First interim product: development of a simplified methodology, with field testing

- Simplified methodology based on Bouwman *et al* 2002
  - Improve on simple IPCC defaults
  - Methodology required site-specific info on fertilizer type, soil carbon concentration, drainage, pH, soil texture, crop type
  - Test sites in AR (cotton), IA (corn), CA (lettuce) in 2009 season
  - Field data compared to DNDC modeling results
- Results:
  - Improvement on IPCC, far more specific to site
  - Insufficient for seasonal variations
  - In some cases methodology and model results diverge
  - Simplified methodology is powerful for broad regional analyses, but insufficient for rigorous project-level accounting

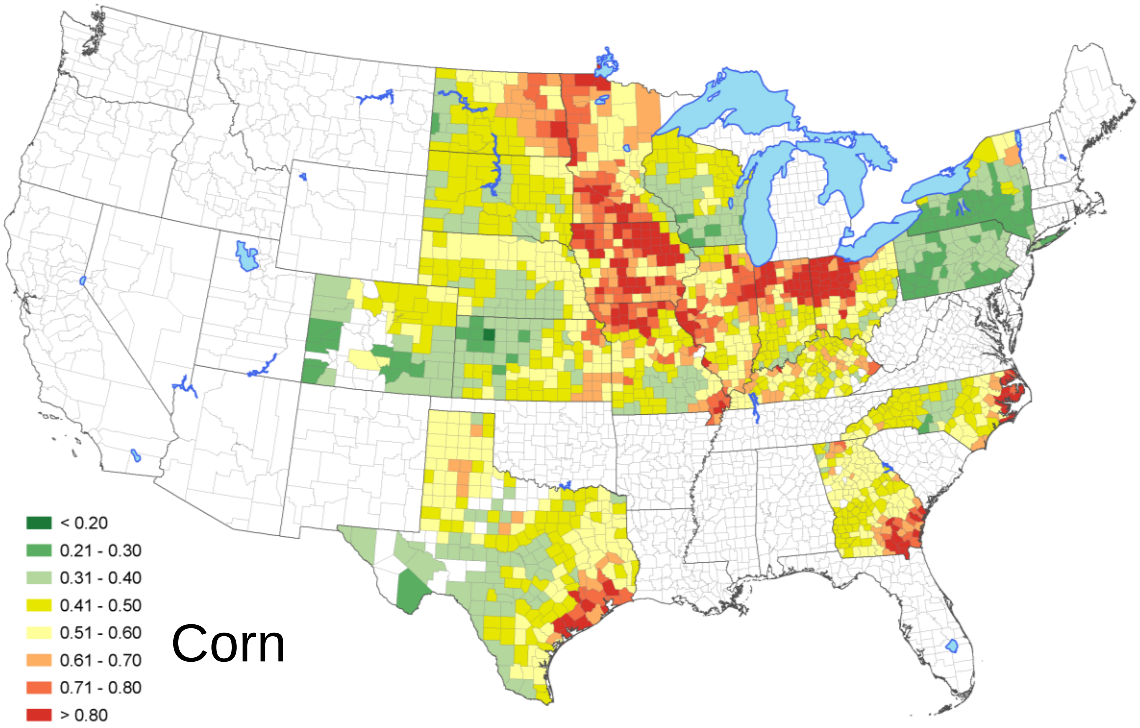
Second interim product: spatial analysis of N_2O emissions in 31 U.S. states

- Analysis of 129m acres wheat, corn and cotton in 31 states
  - 6.2m tonnes of nitrogen applied
  - 3 fertilizer types
- Modified Bouwman model:
  - Fertilizer quantity, type, soil texture and drainage, pH soil carbon concentration used to predict N_2O emissions
- 61m tonnes CO_2e emissions
  - 70% corn, 25% wheat, 5% cotton
- 0.12 - 1.45 $tCO_2e\ ac^{-1}yr^{-1}$

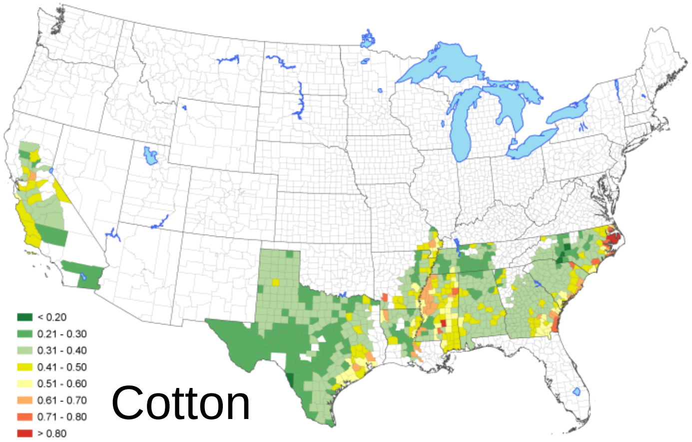




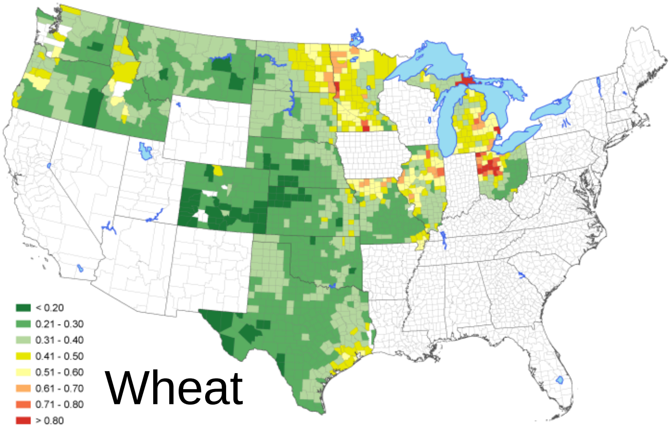
County-level emissions from anhydrous ammonia (tCO_2e/acre-yr)



Corn



Cotton



Wheat