



ACR Protocol: N₂O Emission Reductions through Changes in Fertilizer Management

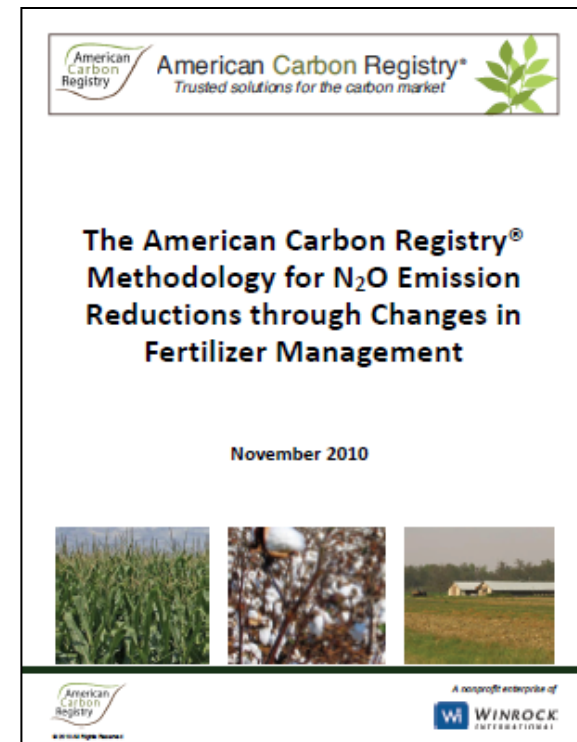
**C-AGG Meeting
Sacramento, California
March 29, 2011**





At a glance

- Applicable to any modified fertilizer practice
 - Change fertilizer type, timing, placement, rate, use of timed-release fertilizers, nitrification inhibitors, other advanced technologies
- Uses peer-reviewed, highly parameterized DNDC model
- No geographic or crop constraints
- Calculates direct N₂O emissions from fertilizer, and indirect N₂O from leaching and ammonia volatilization, for baseline and project





Objectives

- **Scientific rigor for compliance-grade offsets**
 - “Tier 3” model, calibrated and validated for project, to capture all the site-specific and seasonal factors affecting N₂O emissions
- **Flexibility for farmers**
 - They choose practices; even implement multiple changes
 - Focus on what enhances farmer competitiveness and (incidentally) reduces GHG emissions
- **Cost-effective, practical to apply and scalable**
- **“Stackable” with water and air quality benefits**



Development process

- Development funded by Packard Foundation
- Two years in development:
 - Simplified methodology with 9 input factors, tested through field trials 2009 in CA (lettuce), IA (corn), AR (cotton)
 - Spatial analysis of N₂O from fertilizer across 31 states (wheat, corn, cotton)
- ACR approval process:
 - Public comments and responses by authors
 - Stakeholder consultation via C/T/M-AGG
 - Scientific peer review by 4 leading nutrient management experts; responses by authors



Project boundary

- **Physical:** all participating fields
 - Aggregation likely
- **Temporal:** one year or longer
- **GHG boundary:**

Sources	Gas	Included / Excluded	Justification / Explanation of choice
Direct and Indirect Nitrous Oxide Emissions Resulting from Fertilizer Application	CO ₂	Excluded	Not applicable
	CH ₄	Excluded	Not applicable
	N ₂ O	Included	GHG emitted from fertilizer application
Emissions resulting from Fossil Fuel Combustion	CO ₂	Included	GHG emitted from fossil fuel combustion
	CH ₄	Included	GHG emitted from fossil fuel combustion
	N ₂ O	Included	GHG emitted from fossil fuel combustion
Emissions from fertilizer production	CO ₂	Included	GHG emitted from production of urea and synthetic fertilizer



Baseline scenario and additionality

- Preliminary screen based on Start Date
- Identify all realistic and credible land use scenarios on project lands in absence of project
 - Continuation of pre-project fertilizer management
 - Project activity without registration as ACR activity
- Demonstrate additionality of project scenario via ACR three-prong test
- For both baseline and additionality, must present objective evidence suitable to verifier



DNDC model calibration

- Plant growth impacts soil water, C and N regimes, which determine biogeochemical reactions affecting N₂O emissions
- Calibration parameters:
 - 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 (°C)
 - Water demand (g water/g dry matter)
 - N fixation index (1 for non-legume crops)
- Default values provided in DNDC crop library



Existing DNDC field trials

- Used worldwide for 17 years; 140 peer-reviewed publications
- UC Davis: tomatoes, rice, lettuce, corn, wheat
- Cal State Fresno: corn, cotton
- UC Santa Cruz: broccoli, strawberries
- ARB Research Division: DNDC for N₂O emissions from agriculture statewide, with calibration on: vegetable crops (700,000 acres), fruits and nuts (1.5m acres), field and seed crops (3.2m acres)
- EDF/CA Rice Commission: rice
- North America outside CA: alfalfa, barley, corn, beans, potato, oats, rice, rye soybean, spring & winter wheat

Key formulas

$$GHG_{BSL_N_2O,E,j,i} = \left(NL_{DIRECT,j,i} + \left(NL_{VOLAT,j,i} * EF_4 \right) + \left(NL_{LEACH,j,i} * EF_5 \right) \right) * \frac{44}{28} * GWP_{N_2O}$$

$$BE = GHG_{BSL_N_2O,E} + GHG_{BSL_FF,E} + GHG_{BSL,F,E}$$

$$GHG_{BSL_N_2O,E} = \sum_{t=1}^{t^*} \left(\sum_{i=1}^M \left(GHG_{BSL,N_2O,E,i} * A_i \right) \right)$$

$$GHG_{BSL_FF,E} = \sum_a \left(Fuel_{a,t} \times EF_a \right)$$

$$GHG_{BSL,F,E} = \sum_{t=1}^t \left(\sum_{i=1}^M \left(A_i * AR_{i,f} * EF_{CO_2f} \right) \right)$$

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

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

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

- No leakage deduction since no shifting of fertilizer use nor yield decrease >5%
- Uncertainty deduction if total uncertainty exceeds 10% of the mean at 90% confidence
- No buffer deduction since reductions irreversible



Aggregator perspective (1)

- Building on existing base of farmers in Midwest and Great Lakes states; testing willingness to move to performance-based, project-specific protocols like ACR
- Aggregation will be key to keeping transaction costs down
- Protocol complexity is not a concern; rather the ability to tell farmers *ex ante* how many credits will accrue to each practice change – i.e. what are the revenues per acre?
 - Need more real-world data and economic analysis to assist farmer decisions
- Farmers may not wait another year
 - Time is now to capture their interest, get capital flowing, create 2011 vintage reductions



Aggregator perspective (2)

- Actively developing projects and recruiting farmers using the protocol
- Greatest strengths of protocol are:
 - *Flexibility* in allowing farmers to choose practices, including implementing multiple practice changes
 - Other protocols choose more prescriptive approach, or limit eligibility to rate reductions; approaches are complementary and will appeal to different landowners
 - *Environmental rigor* using DNDC
 - *Flexibility* in application to any crop – useful for CA
- Uncertainty on CA regulatory approvals raises challenges for investment decisions and off-take agreements



Further information

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Winrock International - American Carbon Registry

- First U.S. private voluntary GHG registry, founded 1996 by Environmental Resources Trust
 - 30 million tons issued to date
- 15 years experience in protocol development, offset issuance, serialization and online transaction reporting
- In-house expertise in forest carbon, REDD+, agriculture and rangelands, international renewable energy, cookstoves, CCS
- Parent non-profit has offices in ~70 countries





Winrock International Institute for Agricultural Development

*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





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	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			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			

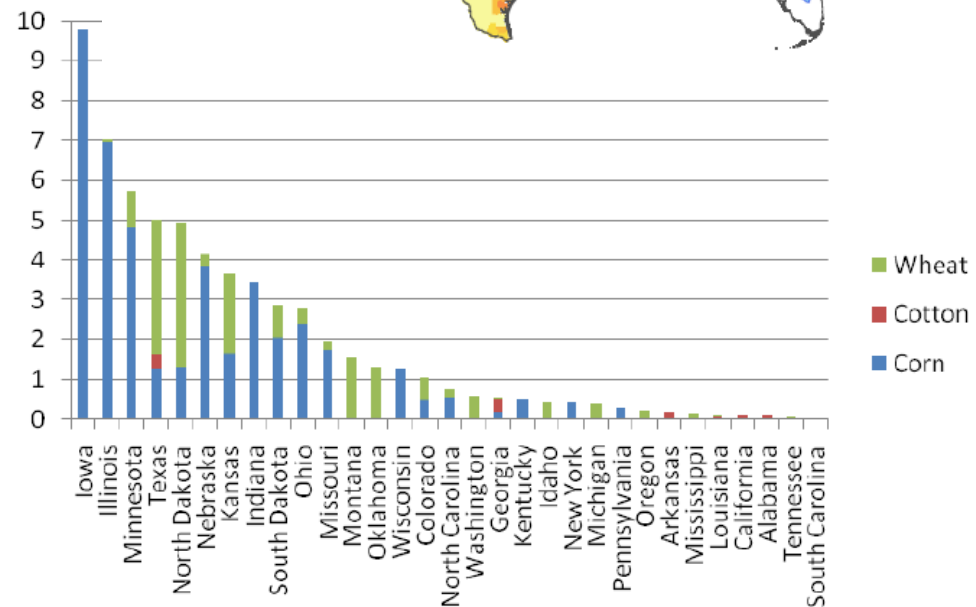
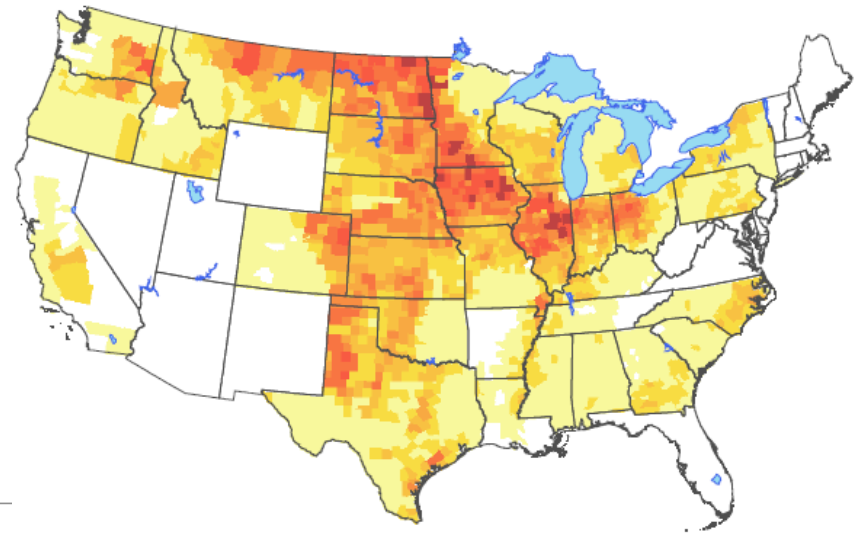


First interim product: development of a simplified methodology, with field testing

- Simplified methodology based on Bouwman *et al* 2002
 - Improve on simple IPCC defaults
 - Methodology required site-specific info on fertilizer type, crop type, soil texture, soil carbon concentration, soil drainage, pH, climate, etc.
 - 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 N₂O 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 N₂O emissions
- 61m tonnes CO₂e emissions
 - 70% corn, 25% wheat, 5% cotton
- 0.12 - 1.45 tCO₂e ac⁻¹yr⁻¹



County-level emissions from anhydrous ammonia (tCO₂e/acre-yr)

