ACR Methodology for $\text{N}_2\text{O}$ Emission Reductions through Changes in Fertilizer Management

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Chicago, Illinois
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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\textsubscript{2}O from fertilizer application, and indirect N\textsubscript{2}O from leaching and ammonia volatilization, modeled for baseline and project
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

<table>
<thead>
<tr>
<th>Sources</th>
<th>Gas</th>
<th>Included / Excluded</th>
<th>Justification / Explanation of choice</th>
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<td>N₂O</td>
<td>Included</td>
<td>Non-CO₂ gas emitted from fertilizer application</td>
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<td>Emissions resulting from Fossil Fuel Combustion</td>
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<td></td>
<td>N₂O</td>
<td>Included</td>
<td>Gas emitted from fossil fuel combustion</td>
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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.

- Demonstrate additionality of project scenario via ACR three-prong test and add’l tool
<table>
<thead>
<tr>
<th>Input Category</th>
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<th>Input</th>
<th>Units</th>
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</table>
Model calibration

• Crucial step as soil conditions, moisture and cropping affect C and N biogeochemistry and thus N$_2$O 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)
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

\[
GHG_{BSL,N2O,E,j,i} = N_{DIRECT,j,i} + N_{VOLAT,j,i} \cdot EF_4 + N_{LEACH,j,i} \cdot EF_5 \cdot \frac{44}{28} \cdot GWP_{N2O}
\]

\[
GHG_{P,N2O,E,j,i} = N_{DIRECT,j,i} + N_{VOLAT,j,i} \cdot EF_4 + N_{LEACH,j,i} \cdot EF_5 \cdot \frac{44}{28} \cdot GWP_{N2O}
\]

- 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 \( \text{(SAR-100)} \)
Calculating net emission reductions

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

\[
GHG_{BSL\_N2O,E} = \sum_{i=1}^{t^*} \left( \sum_{i=1}^{M} GHG_{BSL,N2O,E,i} \times A_i \right)
\]

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

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

\[
GHG_{P\_N2O,E} = \sum_{i=1}^{t^*} \left( \sum_{i=1}^{M} GHG_{P,N2O,E,i} \times A_i \right)
\]

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

\[
ER_{ALM-ACR} = PE - BE
\]

\[
ERTs = ER_{ALM-ACR,t2} - ER_{ALM-ACR,t1}
\]

(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 $\text{ER}_{\text{ALM-ACR(ERROR)}} \leq 10\%$ of $\text{ER}_{\text{ALM-ACR}} \rightarrow$ no uncertainty deduction
- If $\text{ER}_{\text{ALM-ACR(ERROR)}} > 10\%$ of $\text{ER}_{\text{ALM-ACR}} \rightarrow$

\[ = \text{ER}_{\text{ALM-ACR}} - (\text{ER}_{\text{ALM-ACR}} \times \text{ER}_{\text{ALM-ACR ERROR}} - 10\% \]
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

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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 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⁻¹ yr⁻¹
County-level emissions from anhydrous ammonia (tCO$_2$e/acre-yr)