Lydia Olander and Alison Eagle
Nicholas Institute, Duke University
Oct 4, 2010 – X-AGG Meeting, Chicago IL

"Agricultural land management practices in the United States have the technical potential to contribute about 230 Mt CO_2e/yr of GHG mitigation by 2030 "

-Smith et al., 2008

WHAT IF.....?

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

- All require technical and background scientific information to ensure environmental progress is achieved and farmers are fairly compensated
- Information needs are context-specific

T-AGG PURPOSE AND PROCESS

Lay the scientific and analytical foundation necessary for building a suite of methodologies for high-quality greenhouse gas (GHG) mitigation for the agricultural sector.

- Side-by-side assessment of biophysical and economic agricultural GHG mitigation potential; barriers and co-effects and feasibility of implementation for the US
- Review of scientific complexities planned (C, N2O)
- Producing **technical reports** with executive summaries for stakeholders and decision makers
- Outreach and engagement

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
  - Frequent interaction with protocol developers, model developers, policy makers and others working in this space
  - Open review process and outreach meetings
  - C-AGG/M-AGG

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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 – Sufficient methods and data?

- Measurement, monitoring and verification – Are there good methods for measuring or modeling GHG outcomes on a project scale? and for verifying projects?
- Additionality – Can it be assessed sufficiently?
- Baseline – Are there viable approaches for setting baseline? Sufficient data?
- Leakage risk – Is there leakage risk (life cycle analysis)? Can it be accounted for?
- 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

Greenhouse Gas Mitigation Potential of Agricultural Land management in the United States: A Synthesis of the Literature

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		

METHODS: LITERATURE

- Over 800 papers (mostly peer reviewed)
- Soil carbon, N_2O and CH_4
- Upstream and process emissions
- Showing range of values
- Scaled up to national rate using weighted averages



QUANTIFYING FUEL AND OTHER ENERGY GHGS

- Measuring the CHANGE in fuel and/or fertilizer N

Fertilizer N and fuel-related GHG emissions, t CO_2e ha^{-1} yr^{-1}

Examples	Fuel	N Fert.	Total
National Average – all crops	0.36	0.41	0.77
Grain corn, 250 kg N ha^{-1}	0.59–0.71[1]	0.94	1.59
Alfalfa hay, 20 kg N ha^{-1}	0.18–0.27	0.07	0.30
[1]No-till can reduce fuel emissions by 0.07–0.18 t CO_2e ha^{-1} yr^{-1}			

- Other inputs: minimal upstream GHG impact
- Irrigation energy costs: ~0–1.85 t CO_2e ha^{-1} yr^{-1}

BIOPHYSICAL GHG MITIGATION POTENTIAL

	Soil C	N_2O& CH_4 Emissions	Upstream & Process	Net Impact	Maximum Area
	---- t CO_2e/ha/yr ------				Mha
No-till*	1.09 (-0.26–2.60)	-0.18 (-0.91–0.72)	0.14 (0.07–0.18)	1.04	72
Reduce N fertilizer	0.00	0.40 (0.14–1.32)	0.06 (0.04–0.08)	0.46	124

**Carbon sequestration may saturate over time*

BIOPHYSICAL GHG MITIGATION POTENTIAL

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Winter cover crops	0.83 (0.37–3.24)	0.25 (0.00–1.05)	0.61 (0.41–0.81)	1.69	74

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Winter cover crops	0.83 (0.37–3.24)	0.25 (0.00–1.05)	0.61 (0.41–0.81)	1.69	74
Diversify annual crop rotations	0.58 (-2.50–3.01)	0.07 (-0.04–0.65)	0.00	0.65	100

BIOPHYSICAL GHG MITIGATION POTENTIAL

	Soil C	N_2O& CH_4 Emissions	Upstream & Process	Net Impact	Maximum Area
	---- t CO_2e/ha/yr ------				Mha
No-till	1.09 (-0.26–2.60)	-0.18 (-0.91–0.72)	0.14 (0.07–0.18)	1.04	71.9
Reduce N fertilizer	0.00	0.40 (0.14–1.32)	0.06 (0.04–0.08)	0.46	124.0
Winter cover crops	0.83 (0.37–3.24)	0.25 (0.00–1.05)	0.61 (0.41–0.81)	1.69	73.9
Diversify annual crop rotations	0.58 (-2.50–3.01)	0.07 (-0.04–0.65)	0.00	0.65	100
Improved rangeland management	1.01 (-0.10–4.99)	0.28 (0.27–0.31)	No data	1.30	166

METHODS: DATA AVAILABILITY AND GAPS

- Quantify valid comparisons in research
- Highlights where research is missing

Mitigation Practice	Number of Comparisons	Regional Representation
No-till	477	All U.S. regions, best data for Southeast, Great Plains, Corn Belt
Winter cover crops	67	Only regions with sufficient growing season
Reduce N fertilizer rate	29	Corn Belt, Lake States, Rocky Mountains, Great Plains – much other data that is not side-by-side comparisons
Change N source to slow release	11	Lake States, Rocky Mountains – no data for other regions

SURVEY OF SCIENTIFIC CERTAINTY

- Begin with literature review
  - Average biophysical potential, # of studies, # of field & lab comparisons, regional coverage
- Use survey of experts (Nov/Dec 2010) to determine level of certainty with existing data
  - Areas of expertise/focus (soil C, N_2O, grazing land, CH_4/multiple)
  - Obtain certainty measures for (1) direction of impact, (2) level of impact, (3) regional or soil or climate caveats
  - Assess agreement among experts

With support from the Natural Resources Defense Council

Assessing Greenhouse Gas Mitigation Opportunities and Implementation Options for Agricultural Land management in the United States

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MODELING FOR ECONOMIC RESPONSE

- Land use competition & implementation costs – not all activities can achieve full biophysical potential
- Optimization model - FASOMGHG
- Full GHG accounting – assumes that all sources and sinks are counted in the market
- Other factors (social, environmental, capital cost barriers) considered qualitatively

EXAMPLE OF ECON RESULTS

Currently being updated

	Carbon price			
	$5/t CO_2e	$15/t CO_2e	$30/t CO_2e	$50/t CO_2e
Reduced Agricultural Fossil Fuel Use	0.39	2.15	5.37	9.34
Changing Tillage Practices (2x)	**1.97**	8.67	18.12	**26.68**
Pasture N_2O Management*	0.49	0.87	0.94	0.93
Reduced N Use	0.20	0.33	4.75	**10.48**
Irrigation Management	0.08	0.29	0.49	0.79
Reduced Chemical Use	0.03	0.25	0.61	1.14
Manure Management	**1.10**	3.15	5.08	6.61
Improved Enteric Fermentation	**7.28**	19.66	30.71	**35.93**
Decreased CH4 from Rice Cultivation*	0.31	1.17	2.07	3.35
Total Mitigation	*12.13*	*37.74*	*70.56*	*99.25*

Net GHG Mitigation by Management type and Carbon price (Mt CO_2e) – totals indicate emission reductions or increased carbon sequestration per year for the US

Forest management, bioenergy and afforestation can generate anywhere from 210 (at $5) to 550 MtCO2e (at $50)

CO-EFFECTS EXAMPLES

- Environmental Co-effects of Agricultural GHG mitigation projects are primarily positive
  - Positive impacts expected
    - Better N fertilizer management -> reduced N loading -> improved water quality, reduce dead zones, reduce costs for farmers
    - No-till, buffers, cover crops ->Improved species habitat; soil stability, moisture conservation, and water filtration
  - Negative impacts expected
    - No till -> sometimes increases herbicide loading -> reduce water quality, development of glyphosate resistant weeds


KEY POINTS ABOUT GHG QUANTIFICATION

- Practice based is performance based
- Methods do account for multiple practices in combination
- Use modeling with field sampling to calibrate and verify
  - Field sampling probably not cost effective

QUANTIFICATION OF NET GHG CHANGES

Complexity	Quantification approach	Aggregation Level/Uncertainty	Notes
Tier 1	IPCC Tier 1 default factors	Typically large spatial units; National scale; annual resolution	Suitable for rough overviews and where limited data is available
Tier 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;
Tier 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_2O and CH_4

FIELD SAMPLING: TIER 3 QUANTIFICATION

High soil variability, small changes, large background SOC; multiple samplings over time; expensive; N2O,CH4 not viable

Detecting change in GHG easier than totals; stratification and repeat samplings significantly reduce sample numbers; integrates multiple practices

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

Best option - combining modeling with measurement at reference sites and/or on projects.

MODELS: TIER 1 QUANTIFICATION

- N_2O emissions from leaching and run-off are dependent on fertilizer application rates (synthetic and organic), soil organic matter content, grazing levels and crop residues
- The fraction of N leached ($Frac_{Leach-(H)}$) from agricultural fields is highly variable. The default value here is 0.3 with an uncertainty range of 0.1 to 0.8. .

EQUATION 11.10

N_2O FROM N LEACHING/RUNOFF FROM MANAGED SOILS IN REGIONS WHERE LEACHING/RUNOFF OCCURS (TIER 1)

$$N_2O_{(L)}-N = \left(F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}\right) \bullet Frac_{LEACH-(H)} \bullet EF_5$$

Tier 1 equations or defaults are often used in combination with Tier 2 and a little with Tier 3 methods, to fill in gaps.

MODELS: TIER 2 QUANTIFICATION

- Hybrid; mid level resolution
- Empirical Extrapolations, like Tier 1, but with more local/regional data
- Use process models at regional scales to generate regional estimates and factors
- Requires project inputs for management but not for site characteristics where national or regional data are used (soils properties, climate and crop data)
- May not integrate multiple practices easily

MODELS: TIER 3 QUANTIFICATION

- Using BGC process model at project scale
- Easily integrates multiple practices
- Requires some field data (slope, field capacity, C and N content of crop) as well as management data
- Rest of site/soil data can come from databases like NRCS SSURGO soil survey data or local weather stations
- Need some expertise to run the models in their full forms; very specific guidance or simplified interfaces that standardize application may be required for widespread use

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	Data Source: Measured	Data Source: Look-up	Data Source: 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		
	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			

Viability of methods for quantifying GHG Change using field measurement and modeling

	Field Based (Carbon only)	Model Based (Carbon, N20, and CH4)		
Management Type		**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 N20 reduction		Yes	Yes**	Yes**
Managing CH4 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 N20 (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.*

PROCESS MODELS

Current Practices → New Practices → GHG Change

Land use history

Site data (soils, climate..)

BGC Models

Century/Daycent; DNDC; RothC; EPIC/APEX

- Based on empirical research
- Biogeochemical processes

User interface or guidance

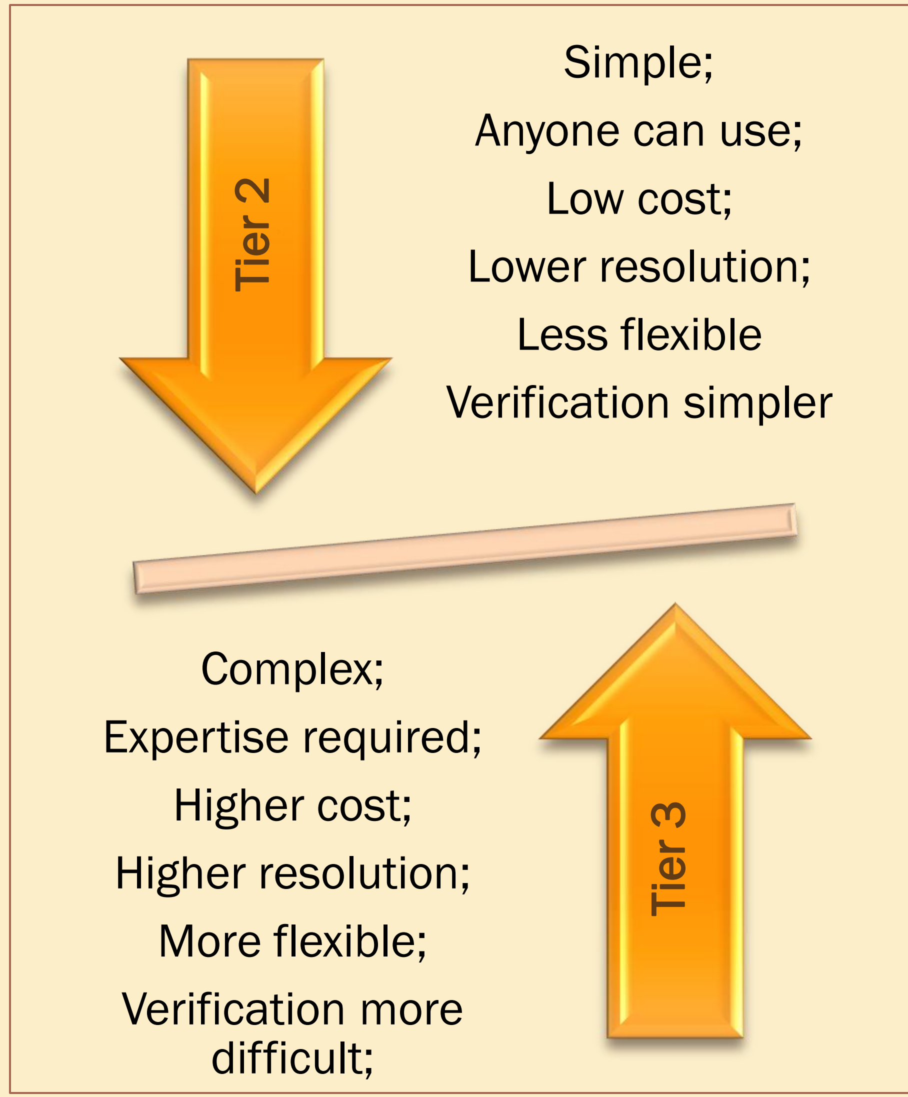
- Scale of use
- Specified inputs
- Specified uncertainty procedure

Baseline GHG and GHG change

- Regional or project baseline
- Net GHG changes
- Combine multiple practices

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



ADDITIONALITY/BASELINE

- Various additionality tests (legal req., date)
- Performance Standard for additionality are based upon regional or sector trends
- Used for in out threshold or for setting regional crediting level
- Alternative is project level approach (CDM)

	Regional/Sectoral	Farm level	
Management Type	**Databases**	**T**	**SR**
Land Use Change	NLCD (parcel level); NRI (county-level); ERS (State, regional level)		Y
Managing soil carbon on crop land	ARMS (state level, by crop, tillage type, self reported); State extension reports (state level, needs to be assessed); National Ag Statistics NASS (county level; crop mix)		Y
Managing N20 by amount and type of fertilizer	ARMS (state level, by crop, nutrient timing placement, amount, type, self reported); State extension reports (state level, needs to be assessed);	Y	Y
Managing N20 by application approach	Same as above		Y
Managing CH4 through crop management	Irrigation data?		Y
Managing rangeland C by amendment	State extension reports (state level, need to be assessed)	Y	Y
Management rangeland C by animal management	ERS data to estimate rangeland acreage (state-level) with NAS data on animal production to estimate stocking rates		Y

MONITORING AND VERIFICATION

	Visual		Farm Records	
Management Type	**Site Visit**	**Remote**	**T**	**SR**
Land Use Change	Y	Y		SR
Managing soil carbon on crop land	Y	maybe		SR
Managing N20 by amount and type of fertilizer			Y	SR
Managing N20 by application approach				SR
Managing CH4 through crop management				SR
Managing rangeland C by amendment			Y	SR
Management rangeland C by animal management	maybe	maybe		SR

- **Reversals of C sequestration and accounting for such events;**
- **Maintenance of intended management practices;**
- **Quantification procedures and calculations are correct;**
- **Data integrity and consistency with the project plans and quantification protocols;** and
- Expected outcomes of projects/program are being achieved.

LEAKAGE

- Number of policy options that should be considered (particularly for a government program)
- Current approach for voluntary markets and CDM is leakage belts and discounting
- Alternative approach is OBO which incorporates leakage into crediting

	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
- Likely to be a small issue for agriculture
- Tillage & above ground carbon loss
- Intentional estimate financial risks
- Unintentional estimate fire risk

	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 CO_2e per acre
- Output metrics based on productivity and efficiency
  - CO_2e 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

NEXT STEPS

- Obtain feedback on draft reports
- Draft new papers on complexities and latest science on C and N_2O
- Engage in meetings and briefings to share our reports and get feedback
- Initiating international project to test the waters
- Considering new project in livestock management

Thank you

Website with reports and email list

http://www.nicholasinstitute.duke.edu/t-agg

REGIONAL VARIATION: FOR C AND N2O

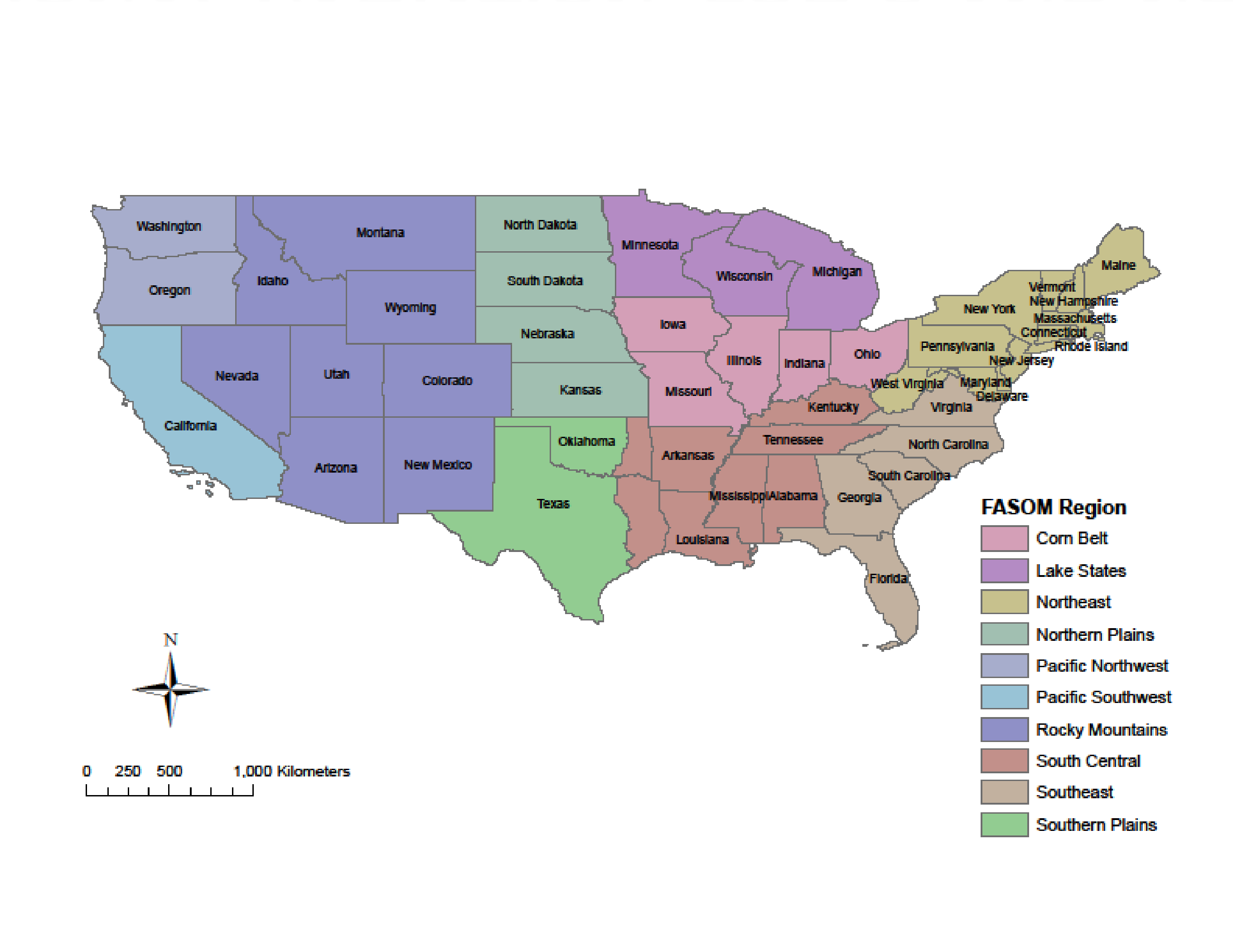


Figure 2. Representative map of FASOMGHG regions and sub-regions