# Lifecycle Greenhouse Gas Emissions from Agricultural Sector and Land Use Change Impacts

## Steps in Lifecycle Analysis

Step 1 — Determine Agricultural Sector and Land Use Change Impacts

Step 2 — **Determine GHGs from Agricultural Sector and Land Use Change Impacts**

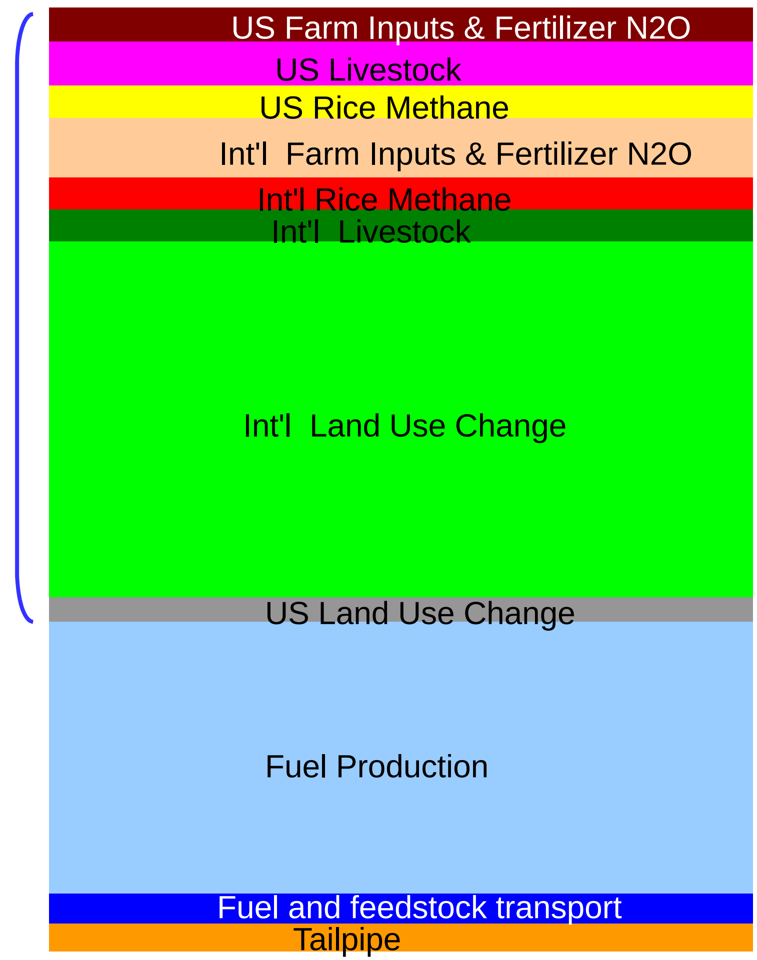
**GHG Emissions Factors**

Step 3 — Determine GHGs from Processing

Step 4 — Determine GHGs from Fuel and Feedstock Transport

Step 5 — Compare Emissions to Petroleum Baseline

## Lifecycle GHG Emissions



# Overview

- Methods and data sources used to determine emissions factors for:
  - Domestic Agricultural GHG Emissions
  - Domestic Land Use Change GHG Emissions
  - International Agricultural GHG Emissions
  - International Land Use Change GHG Emissions

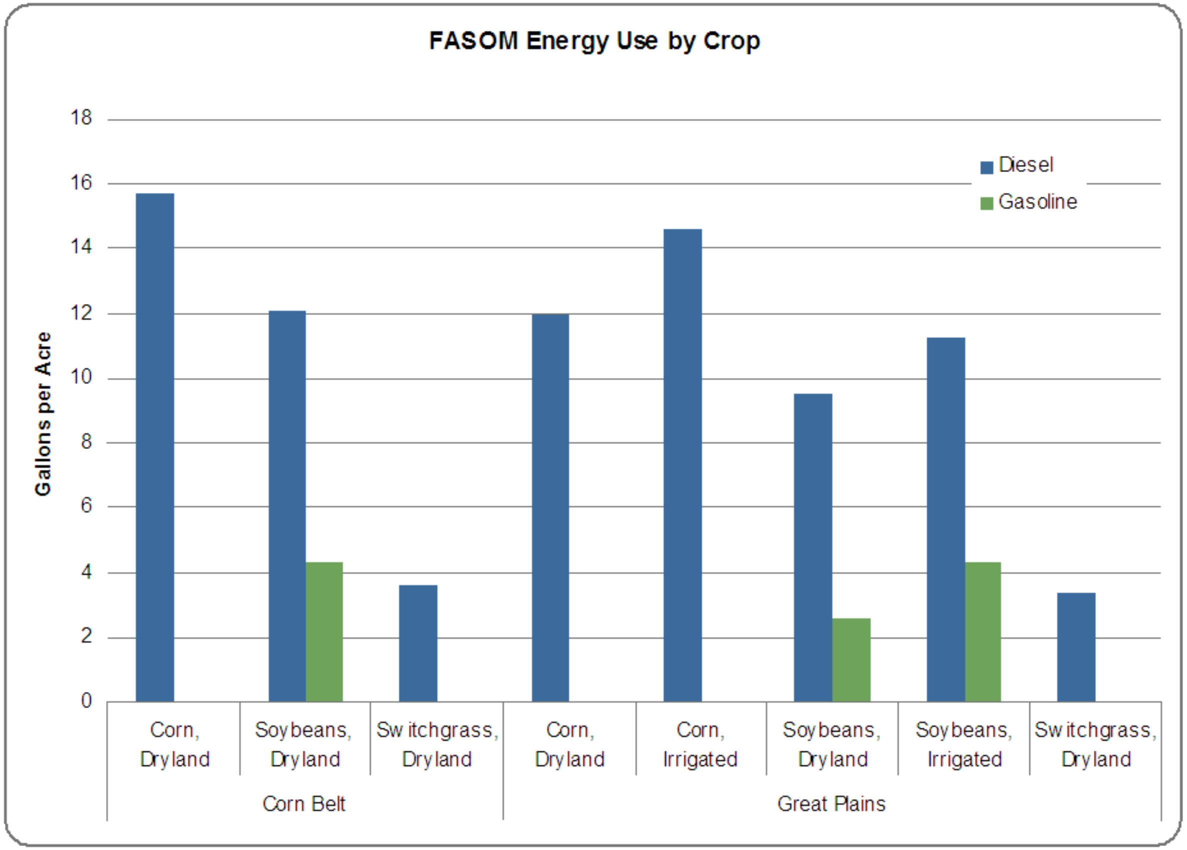
# Domestic Agricultural Lifecycle GHG Emissions

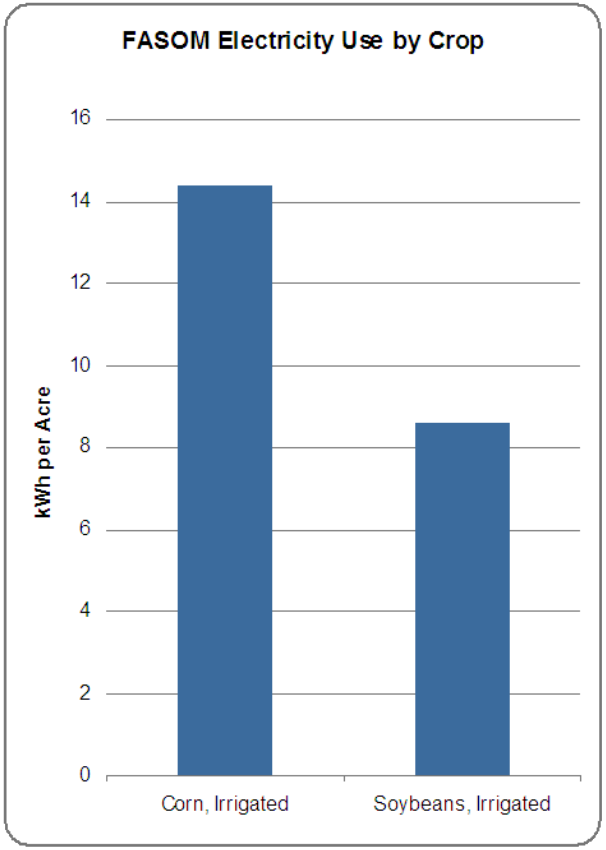
- Lifecycle analysis accounts for all domestic sources of agricultural GHG emissions resulting from biofuel feedstock production
  - Farm energy use (e.g., diesel, gasoline, electricity)
    - On farm combustion and upstream energy production
  - Farm inputs (e.g., fertilizer, pesticides)
    - Upstream input production, and
    - Downstream indirect emissions
  - Livestock emissions
    - Enteric fermentation
    - Manure management
  - Other activities including methane from rice production and residue burning

- FASOM includes emissions factors for on-farm energy use.
- Upstream GHG emissions calculated with GREET.

- IPCC tier 3 approach to account for livestock and fertilizer N2O emissions.
- N2O emissions in FASOM are being updated with inputs from the Century Model.

## U.S. Energy Use by Crop in the Corn Belt Region and Great Plains




- Shifts in crop production can change the overall level of agricultural energy use and thus GHG emissions.

# Domestic Land Use Change GHG Emissions

- FASOM utilizes soil C data from the Century model which simulates sequestration dynamics based on weather, soil physical properties and land management.
- FASOM tracks agricultural practices that influence terrestrial C stocks per acre in cropland and pasture, including tillage and irrigation.
  - FASOM includes reduced tillage and no-till practices that reduce soil oxidation and thereby increase C sequestration.
- After a change in tillage or land management FASOM accounts for soil C changes and a new soil carbon equilibrium is reached in 15-25 years.

# International Agricultural GHG Emissions

- Lifecycle analysis accounts for GHG emissions from international crop production.
  - Average farm energy use by crop and country estimated with FAO and IEA data.
    - Upstream energy production GHGs calculated with GREET
  - Average farm inputs by crop and country from FAO data.
    - Upstream input production GHGs calculated with GREET
    - $N_2O$ emissions calculated with Tier 1 IPCC guidance
  - Average livestock emissions by region from IPCC guidance.
    - Enteric fermentation
    - Manure management
  - Other activities including methane from rice production and residue burning determine with IPCC guidelines.

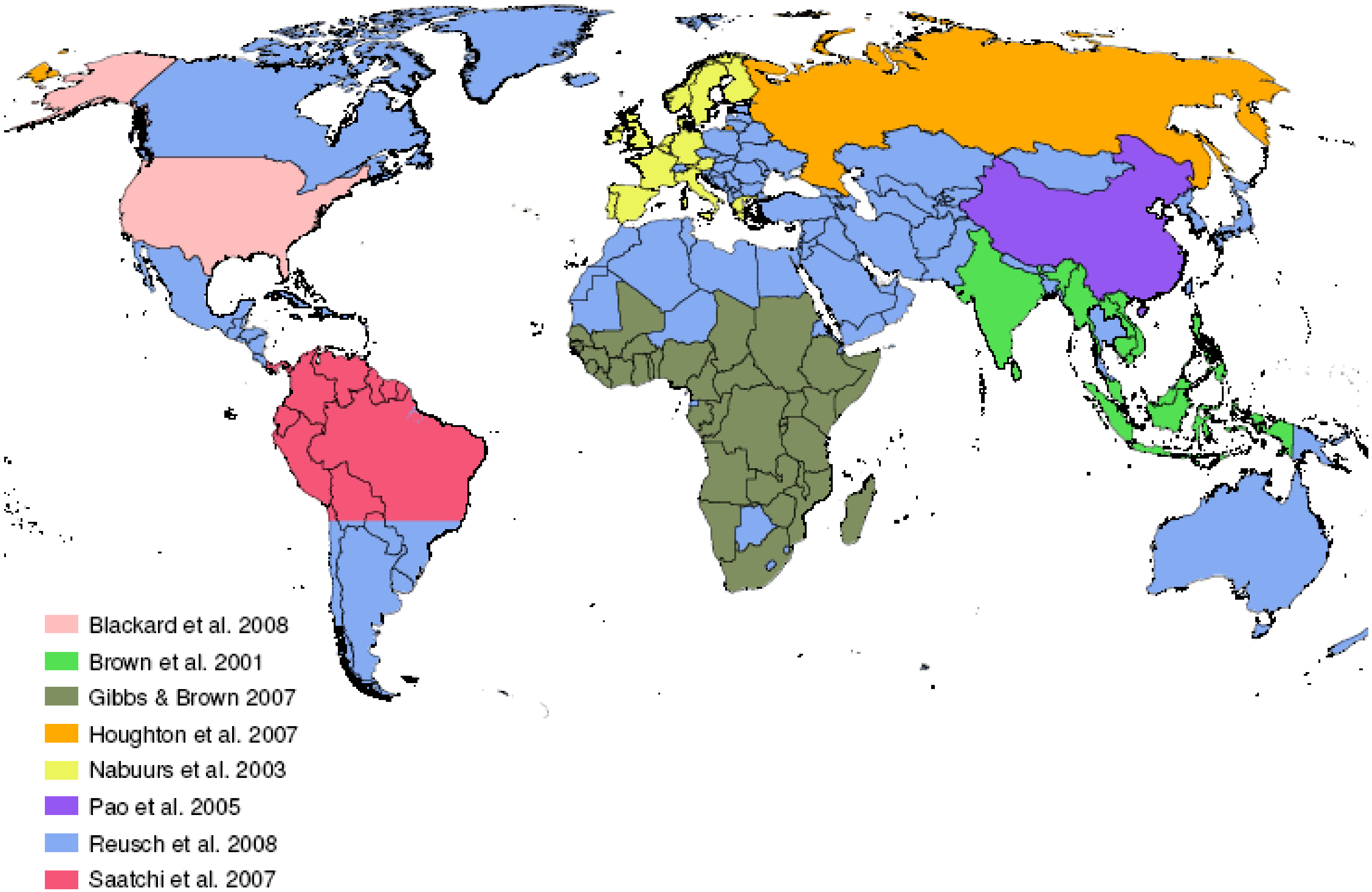
# International Land Use Change GHG Emissions

- Land conversion emissions factors estimated by Winrock International Inc., following IPCC's 2006 Agriculture, Forest and Other Land Use (AFOLU) guidelines, and data from the scientific literature.
  - Winrock staff contribute to the IPCC land use change good practice guidance and are widely recognized as the leaders in this field.

- Land conversion emission factors ($tCO_2$ $ha^{-1}$) = SUM of:
  - Change in aboveground and belowground biomass carbon stocks
  - Change in soil carbon stocks
  - Lost forest sequestration (if applicable)
  - Non-$CO_2$ emissions from clearing with fire (if applicable)

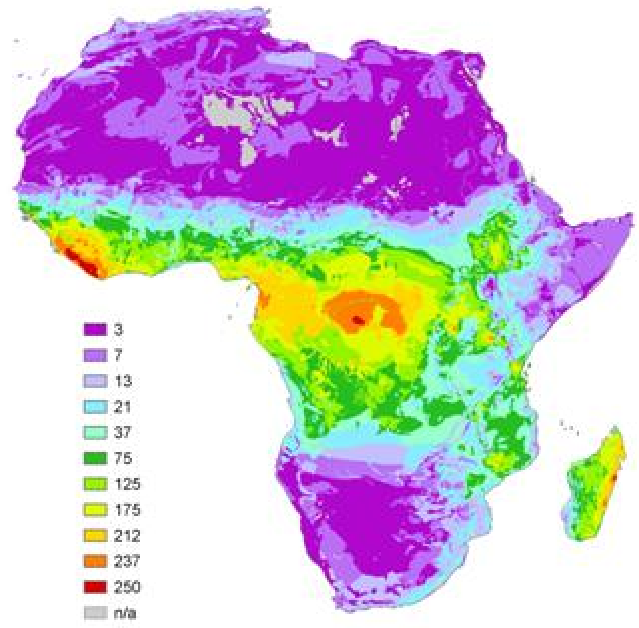
# Data Sources for Forest C Stocks

- Winrock uses the best available empirical data for each region.



# International Biomass Carbon Stocks

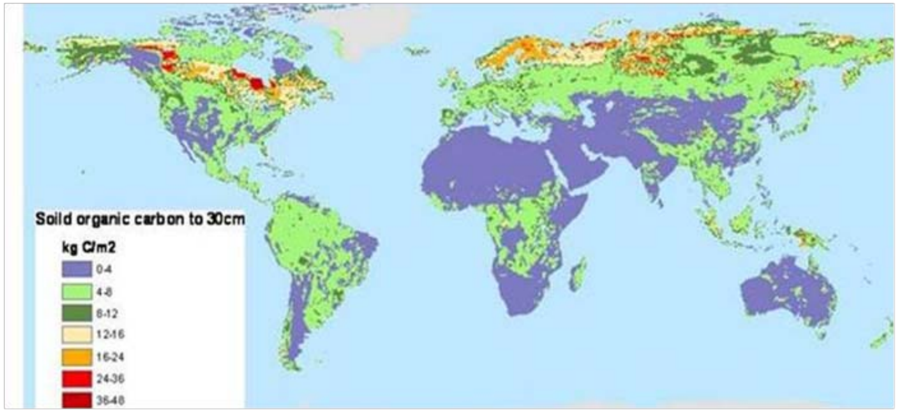
- **Forest C stocks**: from best available continental- and global-scale data products and studies.
  - Does not include litter or dead wood.
- **Grassland C stocks**: IPCC Tier 1 defaults except for Brazil
- **Shrubland, Savanna C stocks**:
  - Empirical data for Brazil
  - Ratio of 1 : 1.8 : 3.4 for grassland, savanna and shrubland, respectively for other countries
- **Cropland C stocks**: IPCC Tier 1 default (5 t C $ha^{-1}$)
- **Belowground biomass** based on aboveground estimates using root biomass equation from Cairns et al. (1997)




**Africa Forest C Stock Map (Gibbs and Brown 2007)**

# International Soil Carbon Stocks

- Reference level soil C stock in top 30 cm derived from FAO Soil Map of the World.
  - This data layer was chosen because tilling for cropland conversion typically affects only the upper layers of the soil profile.
- Account for soil C emissions for conversion to annual cropland only.
- IPCC methodology and default factors applied for calculating soil C stock changes:
  - Land use factor
  - Management factor
  - Input factor
- Change in soil C occurs over a default 20-year timeframe



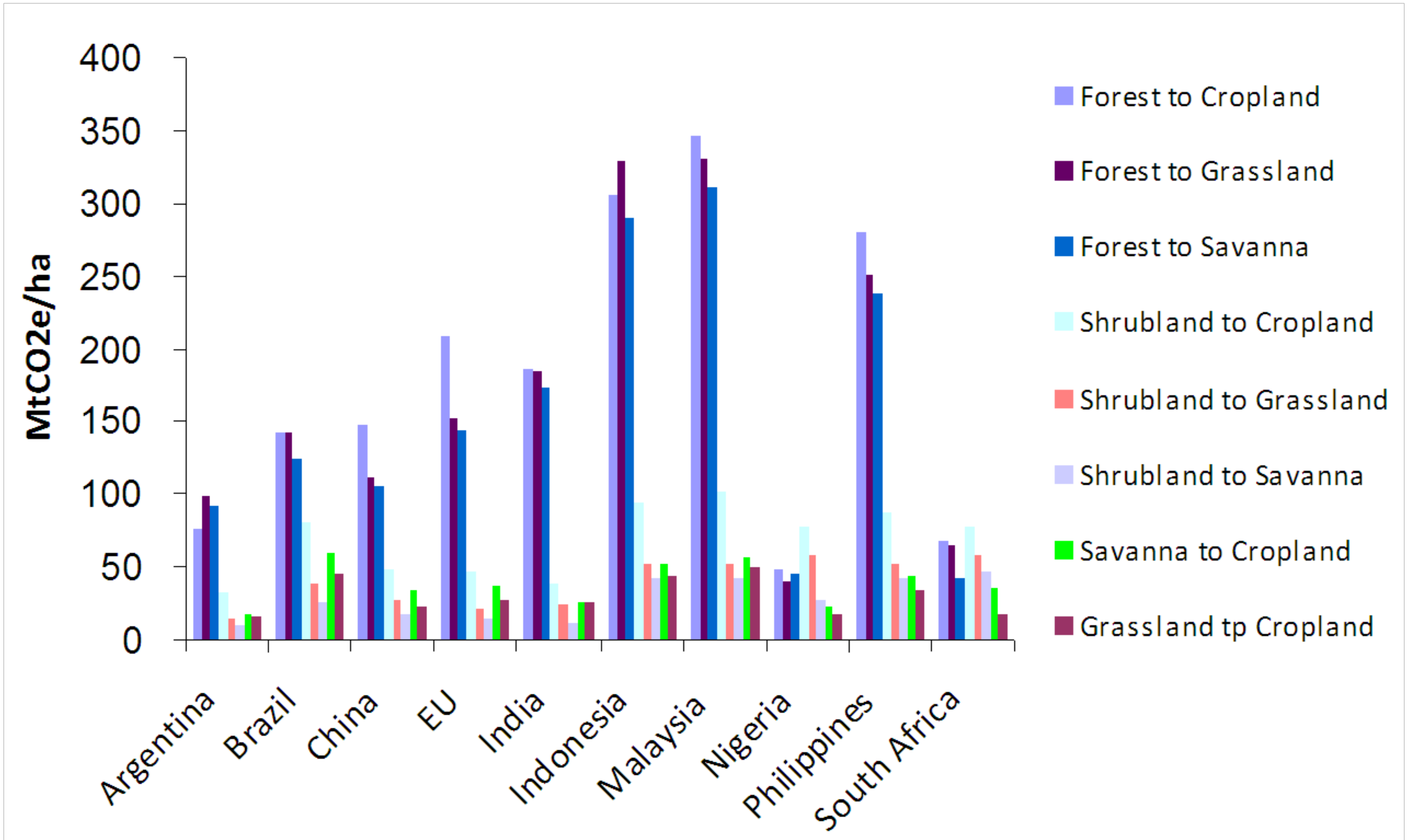

FAO/UNESCO Soil Map of the World

# Other Factors that Affect Land Conversion GHG Emissions

- Following IPCC guidelines, other factors are considered that affect land use change GHG emissions:

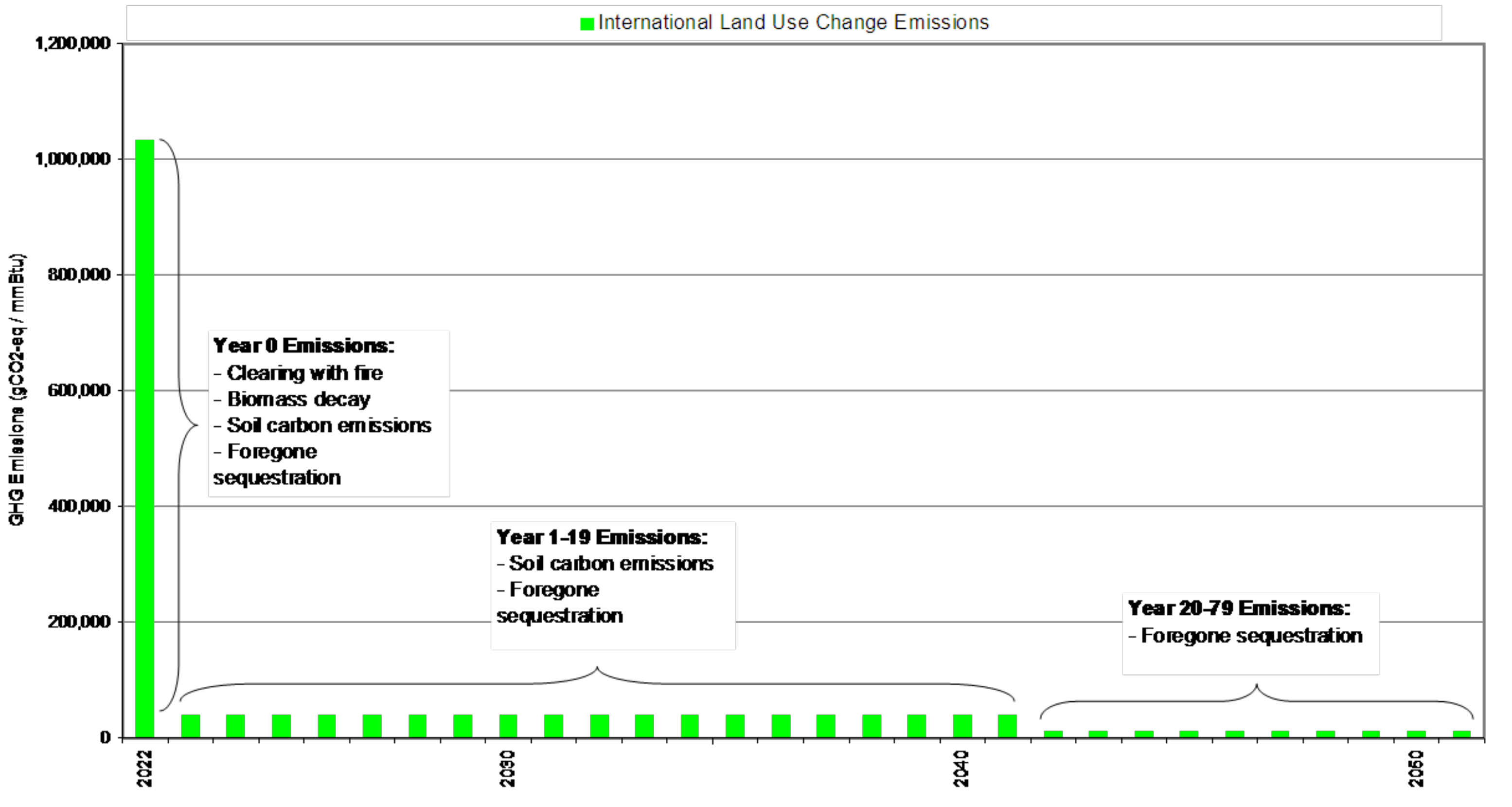
- **Lost Forest Sequestration**
  - Trees that would have continued to grow are cut down and no longer act as carbon sinks → "lost" sequestration.
  - Average annual biomass accumulation rates based on IPCC default tables (2006 AFOLU Table 4.9) for annual growth of natural forests greater than 20 years old. IPCC factors are area-weighted by FAO ecological zone.
  - Assumed that lost forest sequestration ends after 80 years.
- **Clearing with Fire**
  - Non-$CO_2$ emissions estimated based on IPCC methodology and default parameters in Table 2.5 and Equation 2.27 of the IPCC AFOLU.
  - Winrock determined which countries use fire to clear land for agriculture.
    - Clearing with fire occurs mostly along the tropical belt.
  - Fire is used only for conversion to cropland.
- **Harvested Wood Products**
  - Harvested wood products (HWPs), including long-term storage and retirement, were not considered in the proposed rule analysis.
  - Ongoing work considers the impact of HWP in more detail, including consideration of how deforestation impacts timber markets.

# 30-Year Land Conversion GHG Emissions Factors by Country



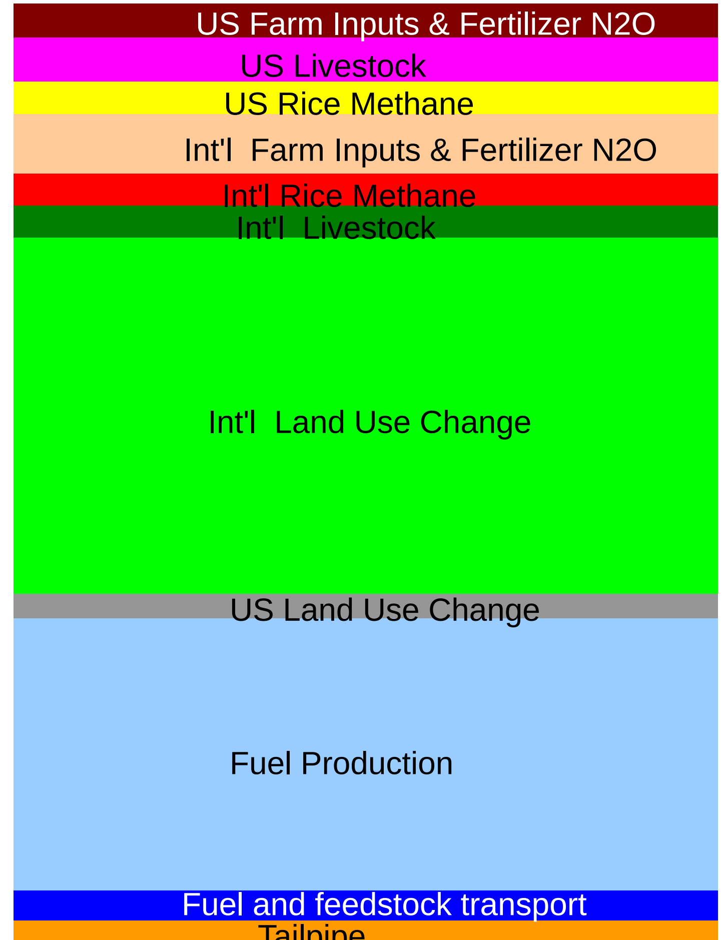
# Timing of Land Use Change GHG Emissions

**Land Use Change Emissions Over Time in the Corn Ethanol Scenario**



| Steps in Lifecycle Analysis | | Time | Topic |
|---|---|---|---|
| Step 1 | Determine Agricultural Sector Impacts and Land Use Change | Day 1<br>1:30 – 5:00 | Agricultural Sector Modeling<br>Amount of Land Use Change |
| Step 2 | Determine GHGs from Agricultural Sector Impacts and Land Use Change | **Day 2**<br>**8:30 – 11:30** | Types of Land Use Change<br>LUC GHG emissions<br>**Timing & Discount Rate** |
| Step 3 | Determine GHGs from Processing | Day 2<br>11:30 -- 12:30 | Biofuel Processing |
| Step 4 | Determine GHGs from Fuel and Feedstock Transport | Day 2<br>11:30 – 12:30 | Petroleum Baseline |
| Step 5 | Compare Emissions to Petroleum Baseline | Day 2<br>11:30 – 12:30 | Petroleum Baseline |

Lifecycle GHG Emissions

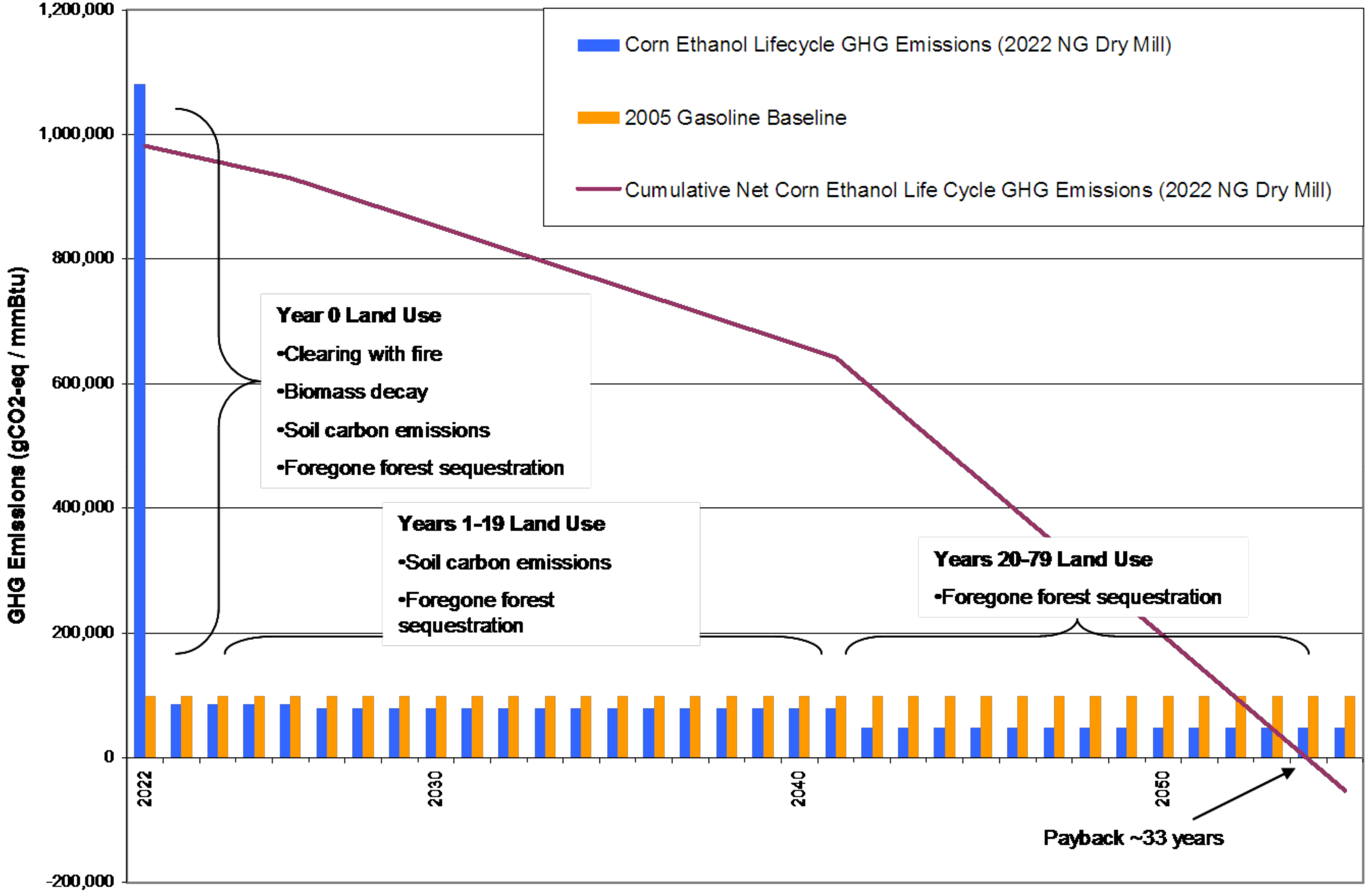


# Time Period and Discount Rate

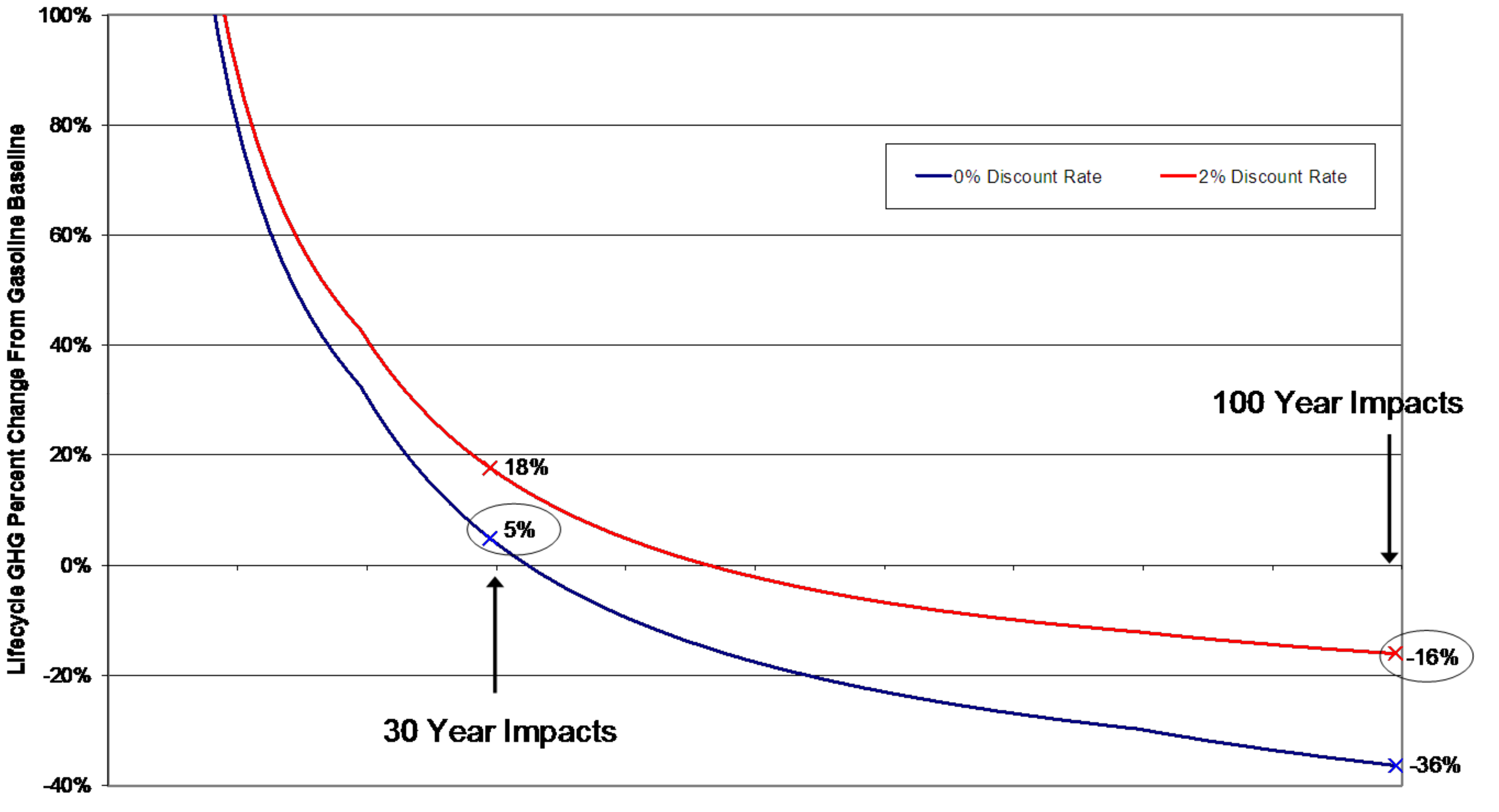
# Accounting for the time dimension of land conversion GHG releases

- Land use change results in stream of emissions that are changing over time
- There are GHG benefits of use of biofuels over time replacing petroleum fuels
- We need to define a life cycle GHG value that is applicable to all gallons across time
- Method of dealing with the timing of land use change emissions has significant impact on results
- Results presented based on a net present value of emissions and benefits
- Test sensitivity of results based on key factors:
  - Length of renewable fuels program
  - Time horizon of emissions
  - Discount rate or amortization

# Payback Period For Corn Ethanol



# Impacts of Time Period and Discount Rate on Corn Ethanol Results



# Choice of Time Period

- A NPV approach would normally consider impacts and benefits indefinitely
  - At higher discount rates length of time is seldom an issue (future values discounted to zero)
  - But at low discount rates even emissions after 100 years have some value
- Issue:
  - If not an infinite timeframe, over what time period should we evaluate the impacts?
- 100 years
  - The emission impacts of the initial land-use change will have an impact (i.e., foregone sequestration) for 80 -100 years
    - A 100 year horizon captures changes in the time profile of terrestrial carbon fluxes on managed and unmanaged lands (economic rotation periods are less and annual biomass growth is minimal respectively)
  - The Global Warming Potentials (GWPs) used to weight emissions are based on impacts over 100 years
- 30 years
  - It is hard to predict that far out into the future what types of fuels will be used (e.g., unlikely corn ethanol will be used for 100 years).
  - Some would argue that getting GHG emission reductions in next 30 years or less is critical and if fuels do not have benefits in that time frame then should not be used. In this sense it is more conservative.

# Time Period Considerations

- May want to consider separate time periods
  - Program time frame, how long biofuels will be in place
  - Impact time period, determining the GHG impact that occurs even after program is over
- Land reversion
  - There are a number of reasons why land converted to cropland as a result of biofuel production could revert back to its prior use or change to a different use
    - Continuing crop yield improvements
    - Biofuel production ends
    - Changes in population or food demand

# Discounting of Emissions

- Reasons to discount:
  - Discounting is consistent with peoples' preference for valuing the importance of near term impacts more than impacts at a future date.
  - There is greater uncertainty with future emission impacts and discounting is a way of valuing more certain near term impacts greater than uncertain future impacts.
- Reasons not to discount:
  - Valuing future and near terms emissions the same is more equitable for future generations.
  - Discounting is an economic consideration and should not be applied to emissions (can discount the value of emissions impacts but not emissions themselves).

# If Discounting, Rationale for 2% Discount Rate

- Discount rates of 3% or lower are consistent with:
  - How households decide whether to trade off consumption today versus tomorrow
  - Intergenerational considerations
  - Long-run uncertainty in economic growth and interest rates
  - The risk of high impact climate damages that could reduce economic growth

- We use a 2% discount rate because:
  - 2% falls within the range of EPA and OMB recommended rates of 0.5 - 3% for intergenerational discounting
  - 2% has been used in the economics literature to quantify the intergenerational impacts of climate change policies

# Next Steps

- Evaluating alternatives for final rule
  - Different project period and impact period
  - Land reversion
  - Other methods (e.g., fuel warming potential)
- Conducting peer review on this specific topic
- Comments through public comment period