

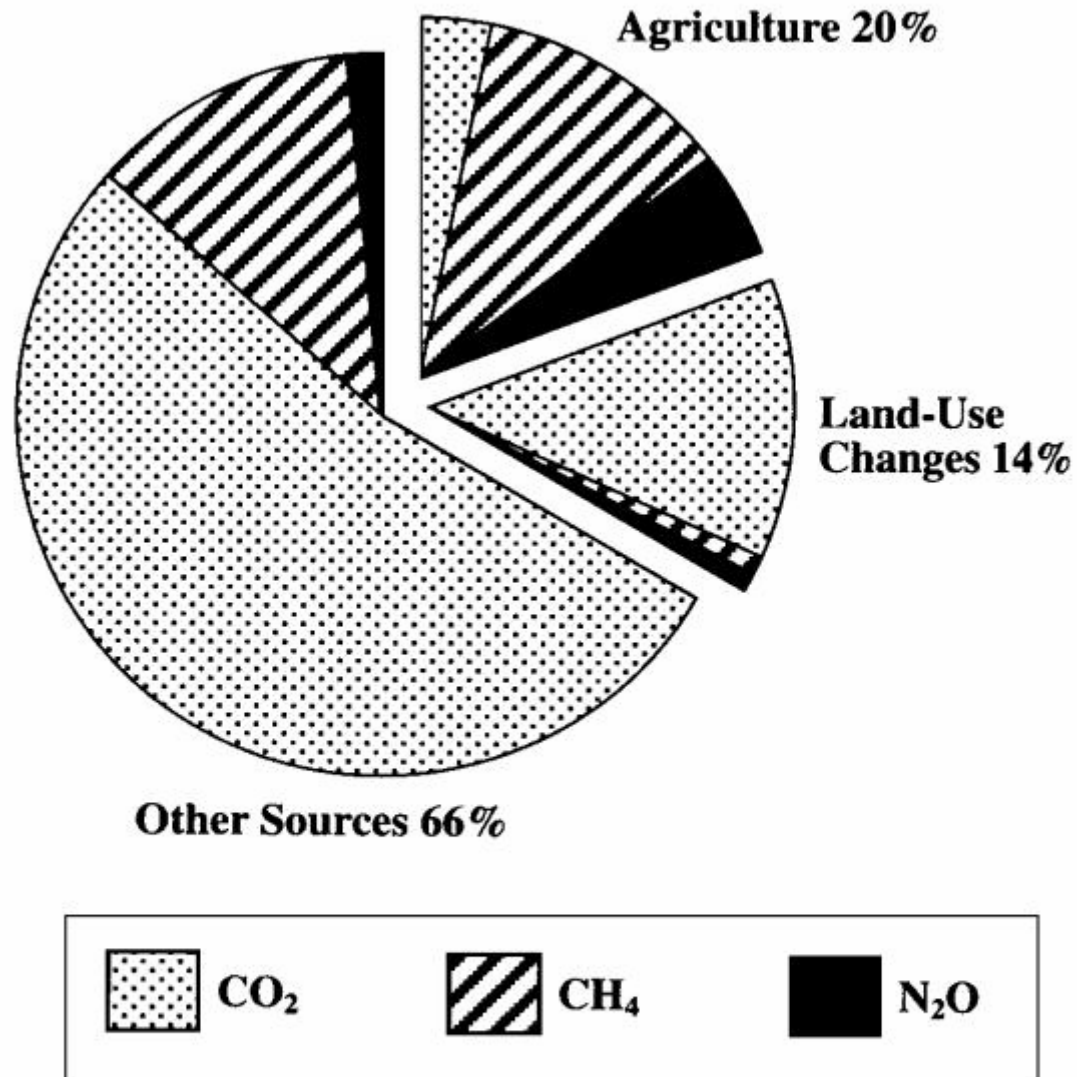


**Inventorying Agricultural Soil  
Greenhouse Gas Emissions:  
Methods Used by Annex 1 Countries**

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Colorado State University  
USA**

# Outline

- Introduction- Importance of agricultural soil emissions (Global and Annex1)
- Methods used by Annex1 countries in inventorying agricultural soil emissions:
  - IPCC default
  - CORINAIR
  - Case studies from Annex1 countries
- Conclusion



Contribution of agricultural sector GHG emissions to global total radiative forcing (IPCC, 1995)



**Enteric fermentation**



**Manure management**



**Rice cultivation**

**Source/sink categories under the agricultural sector**



**Agricultural soils**



**Prescribed burning of savannas**

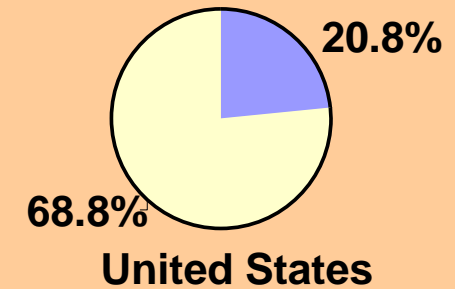
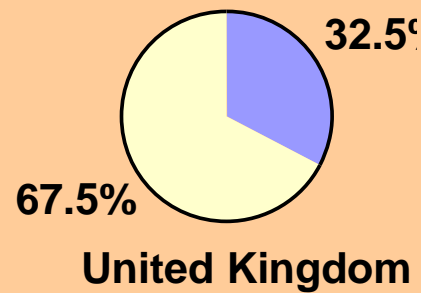
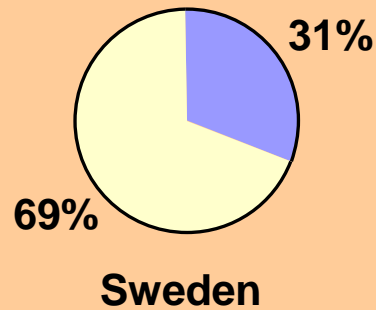
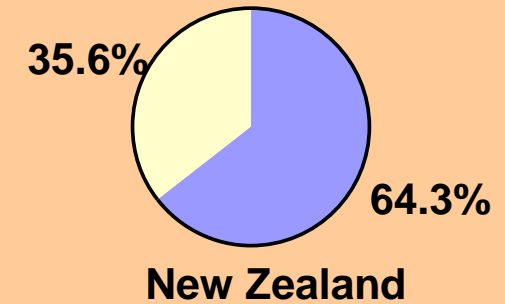
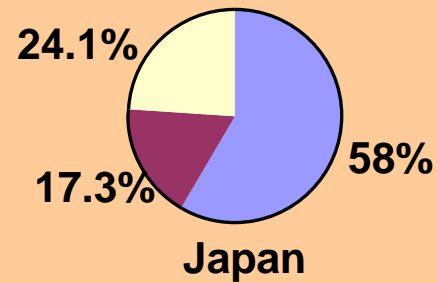
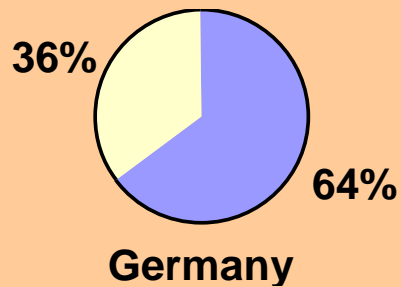
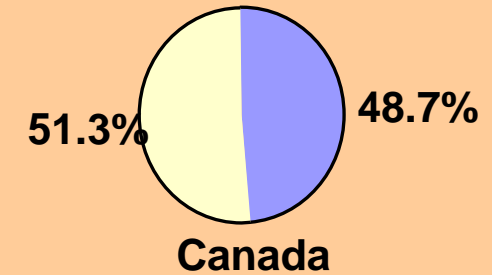
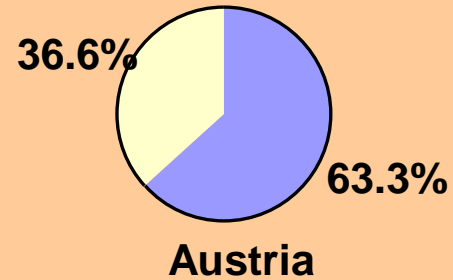
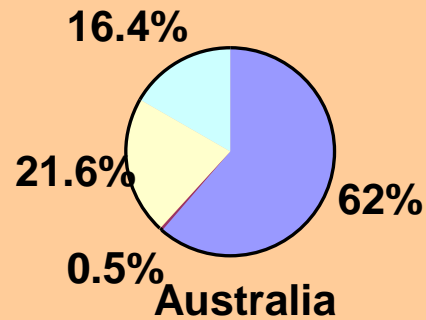


**Burning of agricultural residues**

# Importance of estimating agricultural soil emissions

- Agricultural soil emissions- close to 50% of the total Annex1 agricultural sector emissions
- Potential soil C sequestration by 2010, due to land use and management improvements (IPCC, 2000)
  - annual croplands - 125 Tg
  - all agricultural land - 800 Tg

## Relative contribution of Agricultural soils to global warming potential of the total agricultural sector



■ livestock 
 ■ rice cultivation 
 ■ ag soils 
 ■ field burning of savannas/ residues

**Methods used for inventorying  
agricultural soil emissions by  
Annex1 countries**

## IPCC inventory methodology

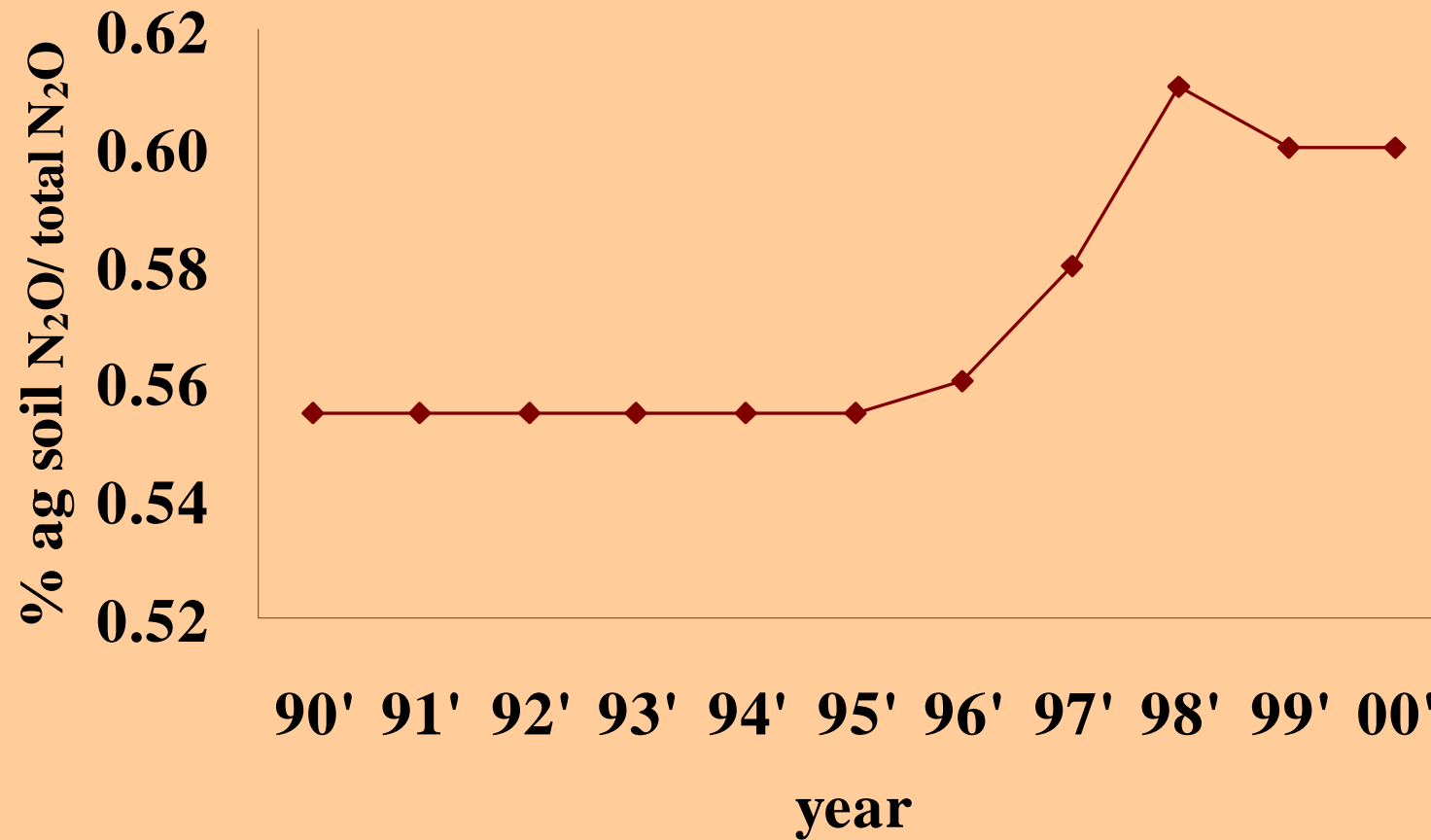
- **Tier 1-** simple equations and default emission factors
- **Tier 2-** default equations with country-specific parameters that better account for climate, soil, management and other local conditions
- **Tier 3-** country-specific methods that may include more complex models and inventory systems

## IPCC inventory methodology contd..

### **Estimation of N<sub>2</sub>O emissions from agricultural soils**

- 1) direct N<sub>2</sub>O emissions from agricultural soils
- 2) direct soil emissions of N<sub>2</sub>O from animal production (livestock grazing)
- 3) indirect emissions of N<sub>2</sub>O from N used in agriculture (losses from N volatilization and leaching)

## Agricultural soil emissions as a percentage of total N<sub>2</sub>O emissions by Annex 1 countries



## IPCC inventory methodology contd..

### **Estimation of emissions/ removals of CO<sub>2</sub> from agricultural soils:**

- 1) Changes in C stored in mineral soils due to changes in land-use practices
- 2) Cultivated organic soils
- 3) Liming of agricultural soils

## IPCC inventory methodology contd..

### Estimation of changes in mineral soil C stocks

$$\Delta SC = [(SC_t - SC_{(t-D)}) * A] / D$$

$$SC_i = SC_R * F_{LU} * F_{MG} * F_I$$

$\Delta SC$  = annual SOC stock change

$SC_t$  = SOC stock at time  $t$

$SC_{(t-D)}$  = SOC stock at time  $t-20$  years

$SC_R$  = reference carbon stock

$F_{LU}, F_{MG}, F_I$  = stock change factors for LU and management

$D$  = Duration (default is 20 years).

# Evaluation of IPCC default methodology for agricultural soil emission estimation

- Universal, and allows comparability between countries
- Likely statistical bias in data used to estimate emission factors for N<sub>2</sub>O & CO<sub>2</sub>. Most studies done in temperate countries
- Method for N<sub>2</sub>O does not reflect variation among different crops, soils and climates that can influence N<sub>2</sub>O production
- Estimation of mineral soil C changes takes into account the spatial variability associated with soil type, climate and management regime.
- Relatively high uncertainty in global default stock change and emission factors

## **CORINAIR (CORe INventory of AIR emissions in Europe) methodology- European Union**

- Improved methods for N<sub>2</sub>O based on multivariate regression analyses using climate, weather and soil conditions.
- No alternative methodology suggested for estimating CO<sub>2</sub>. But higher emission factors compared to IPCC have been suggested for CO<sub>2</sub> from cultivated organic soils
- Can be transformed to IPCC format based on the information in the Annex 2 of the Volume 1 of revised IPCC guidelines

**Country specific methods developed by certain  
Annex1 countries**

# Australia



- 21% forests and about 2/3 agricultural land.  
Main LU changes- forests to agriculture, forest plantations
- Increased agricultural soil emissions since 1990, due to increase in crop area, N fertilizer use, and no. of livestock.

## N<sub>2</sub>O emissions from agricultural soils

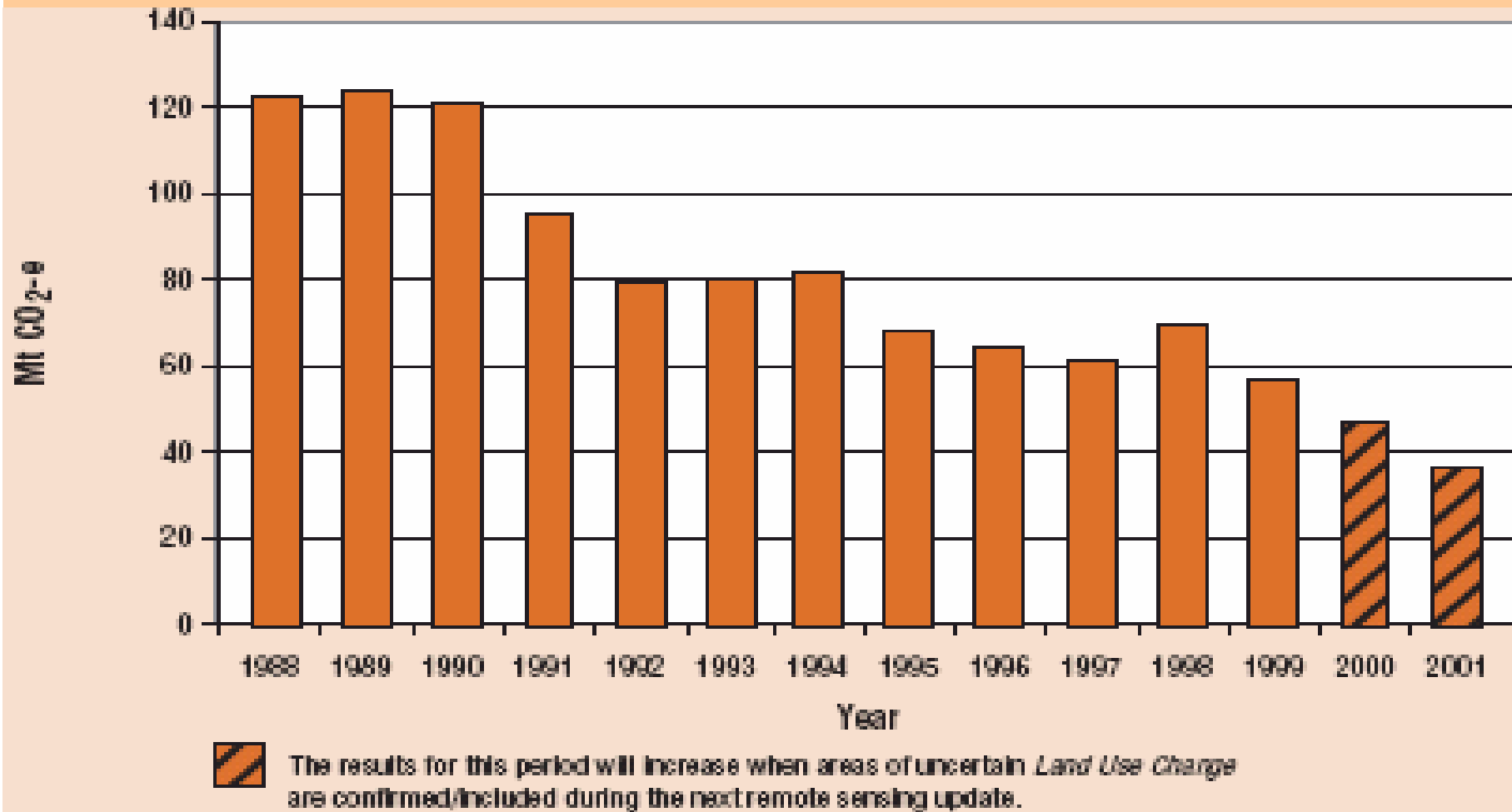
- Agricultural soil N<sub>2</sub>O is about 82% of the national total
- Mostly country specific methods and emission factors.  
Emission factors derived from national studies
- Soil disturbance as a country-specific category, to account for the enhanced N<sub>2</sub>O emission due to farming activity

## Australia contd..

### **National Carbon Accounting System (NCAS)**

- A model-based accounting system, based on resource inventories, field studies, remote sensing and modeling
- Full C Accounting Model (FullCAM) for estimating land use change emissions associated with biomass and soil C pools
- Five component models: 3PG (forest growth), CAMFor (forest systems), CAMAg (agricultural systems), GENDEC (microbial decomposition), Roth-C (ag soil C)
- Fine temporal and spatial resolution, and an integrated approach to yield more robust C estimates

## Results from NCAS



Source: Australian Greenhouse Office

## Austria



- 41% agricultural land, and 46% forests (reforestation and afforestation; forest sink about 10% the national total net emission)
- About 47% of national N<sub>2</sub>O emissions are from agricultural soils.

### Austrian Carbon Balance Model (ACBM)

- Model covers five national subsystems including agriculture; Includes intersystem C flows
- Agricultural soil C estimated using a 3-pool model.
- Net emissions from agricultural soil using the ACBM was 13% lower than estimates made using the IPCC default.

# Canada

- 42% forests, 7% agriculture (2/3 crops and improved pasture)

## National C and Greenhouse gas emission Accounting and Verification System for agriculture (NCGAVS)

- Estimates soil C change and direct N<sub>2</sub>O emissions from land use change, crop- and grazing- land management, etc.
- Model-based system using integrated databases of information on climate, land use change and management
- Basic geographic units are SLC polygons; topographic effects addressed.
- CENTURY based estimates showed an overall CO<sub>2</sub> loss of 7.08 Mt. in 1990, and a net sink of 0.5 Mt in 2002

## Germany



- About 31% forests, and 54% of agricultural land
- Two dynamic models are used for estimating N<sub>2</sub>O :
  - Denitrification and Decomposition (DNDC) model (for agricultural soils)
  - Photosynthesis and Evapotranspiration- Nitrification- Denitrification and Decomposition (PnET-N-DNDC) model (for forest soils)
- Models integrate complex interactions among primary drivers, soil environmental factors and biogeochemical reactions.
- Input parameters- daily climate data, soil and vegetation properties, land management practices.
- Better estimates from multi-year simulations at regional scale
- Consistent with IPCC default (ag soil estimates only 10% higher compared to IPCC)

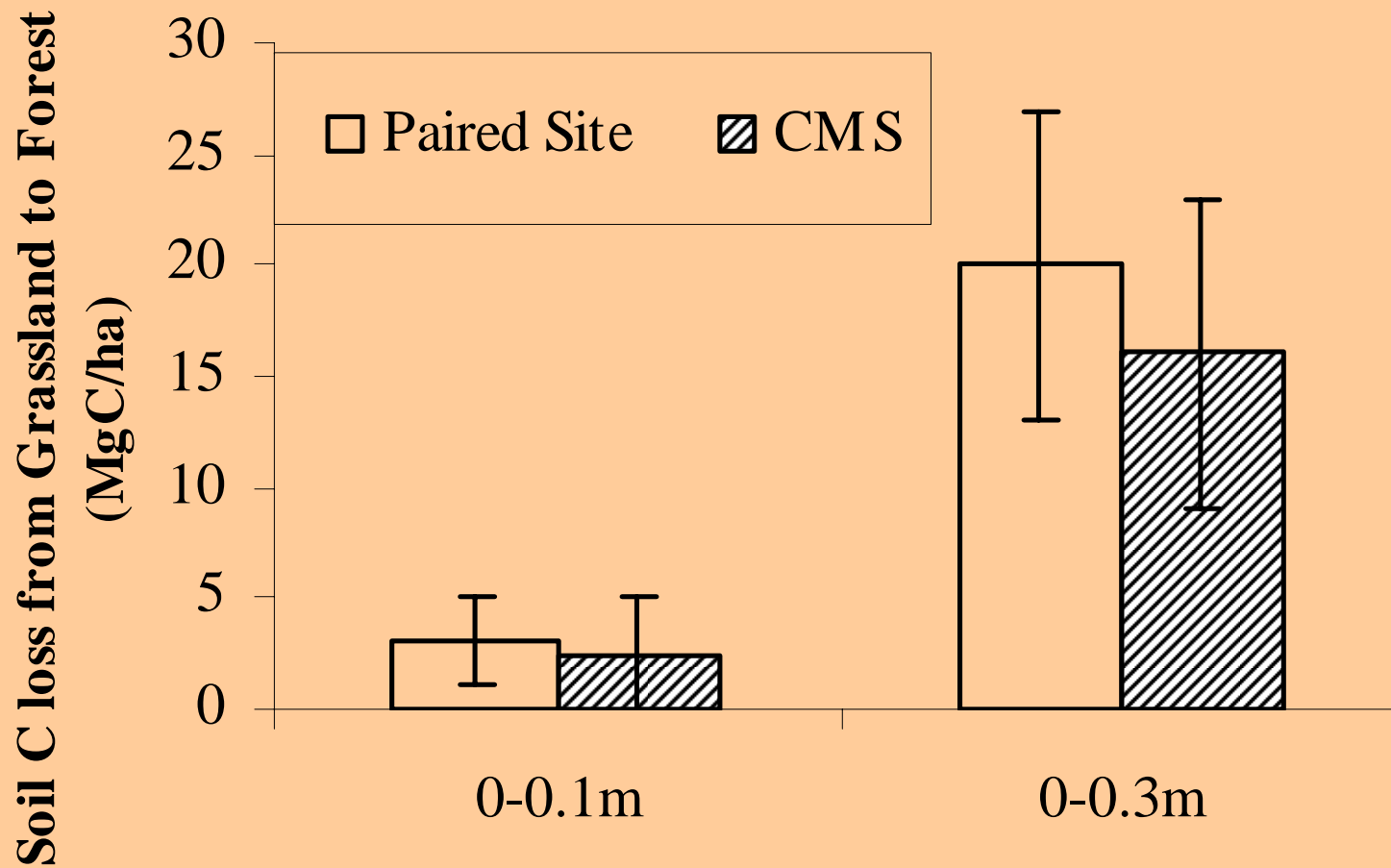
## New Zealand



- About 50% pastoral farming and 30% forests;  
Main recent land use change- pasture to exotic forests

## Carbon Monitoring System (CMS)

- To estimate C stock changes due to land cover changes; a model similar in concept to the IPCC Tier 1 approach
- Soil C estimated for land cover/use categories in 18 different soil-climate classes
- More detailed breakdown of climate zones, and inclusion of an erosivity index compared to IPCC method
- Good results at local site scale, but sometimes overestimation at regional scale, due to variation in local factors such as stoniness and slope
- Major data gaps need to be filled before efficient operation



## Soil C changes- Observed vs estimated (CMS)

(Source: Tate et al.)

## Sweden



More than 2/3 forests, and 8% land in agriculture

## Introductory Carbon Balance Model (ICBM)

- a two-pool model calibrated using long-term field data, incorporated into a regional framework to estimate changes in soil C
- Conceptually simple; can be run and optimized in a conventional spreadsheet program
- Input data from agricultural statistics, daily weather data, soil type, crop type, etc.
- This model approach is still in the testing phase, and only the emissions from organic soils are reported in the NIR.

## United Kingdom



11% forests; 17% crops, 4% set aside, 50% grazing and other

- Soil C changes estimated using a land use change matrix linked to a dynamic model of C gain or loss.

**Basic equation used:**

$$C_t = C_f - (C_f - C_0) e^{-kt}$$

( $C_t$ - C stock at time t (tons/ ha);  $C_0$ - initial C stock;

$C_f$ - C density after change to new land use;

k- specific rate of C change ( $\text{yr}^{-1}$ )

- Changes in soil C stocks calculated for combinations of land use category/ soil type for each country

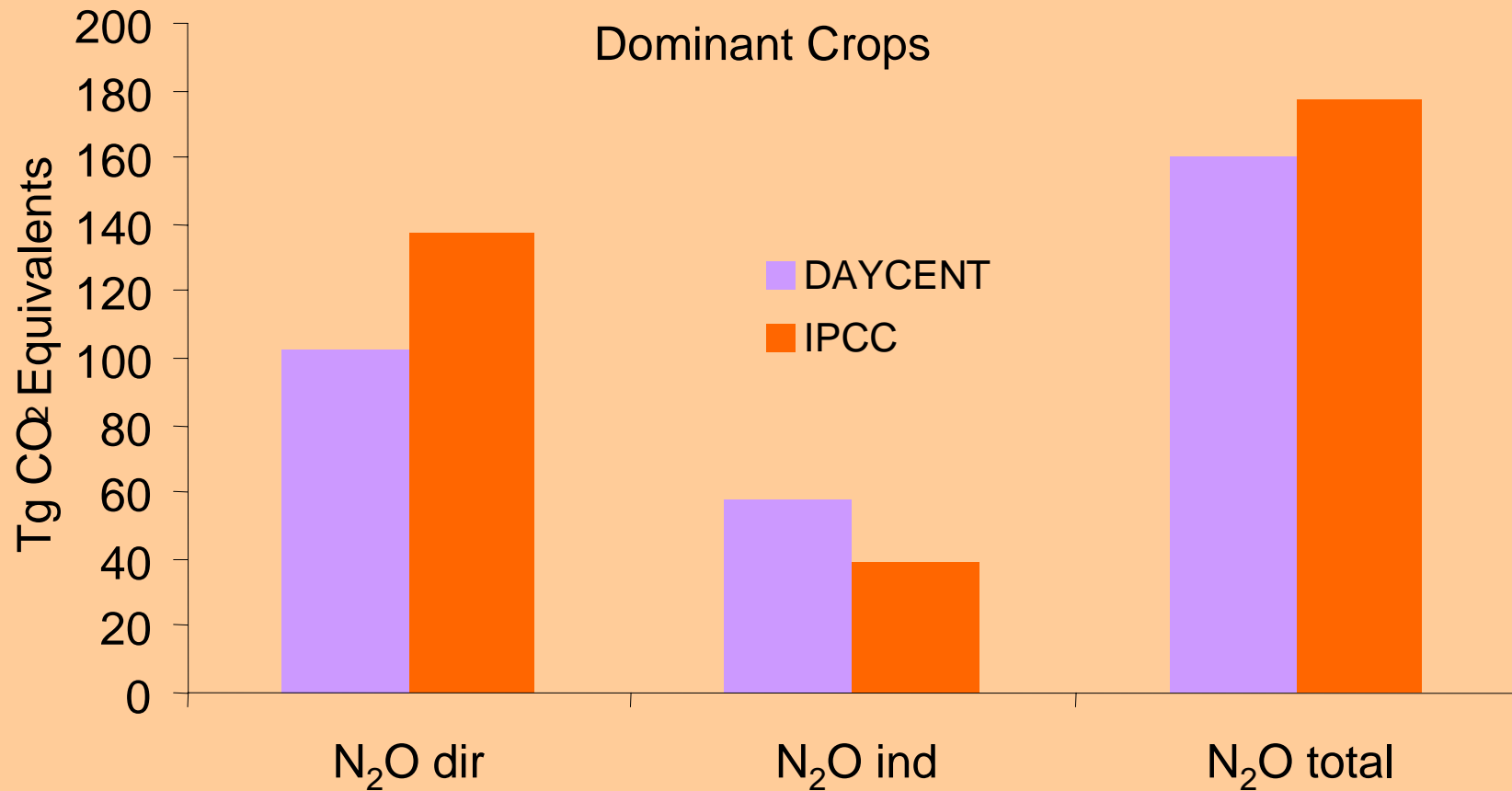
## United States



24% forests, 19% crops, 6% intensive pasture, 21% rangeland

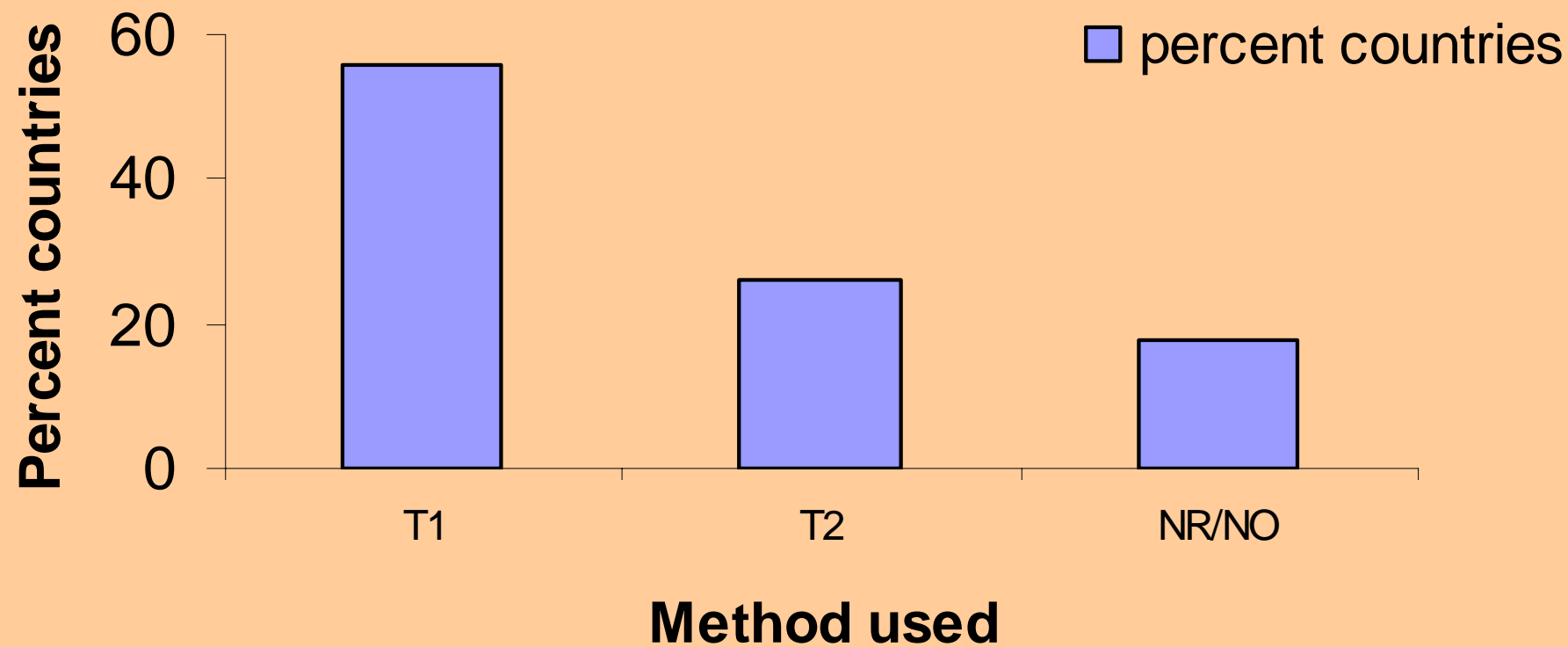
- IPCC Tier2 with US-specific reference C stocks and stock change factors (+11 Tg for mineral soils; -9 Tg for org. soils)
- Dynamic approach using CENTURY model (+23 Tg for mineral soils)
- Data- National Resources Inventory (NRI) data on land use, crop type, irrigation, pasture management, soil type, and other databases on tillage, fertilizer use, manuring, etc.
- For N<sub>2</sub>O, simulation-based approach using DAYCENT model
- DAYCENT estimates are about 10% lower than those with IPCC default method

# National N<sub>2</sub>O – DAYCENT vs. IPCC Methodology

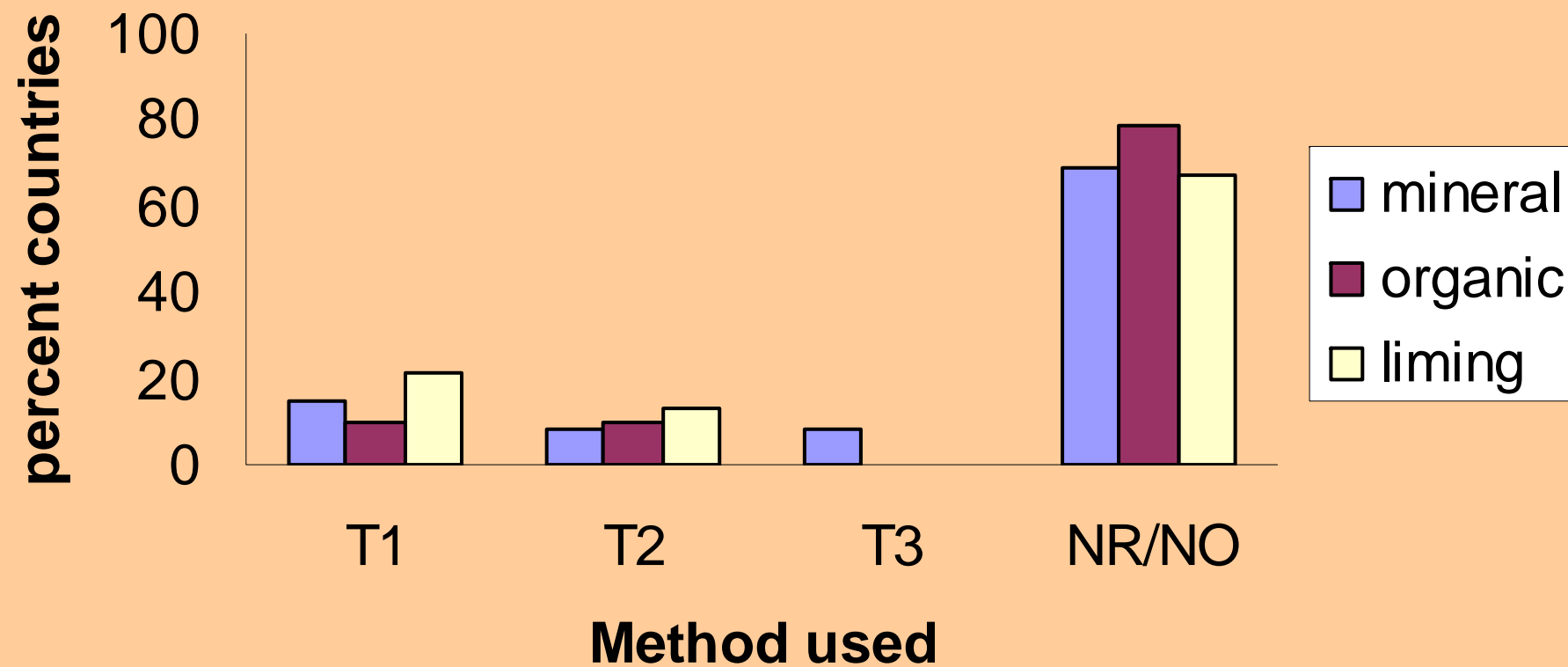


(S. Del Grosso, personal communication, 2005)

## Percentage of countries estimating N2O emissions



## Percentage of countries estimating CO2 emissions



## Conclusions

- Currently, less comprehensive reporting of GHG emissions/removals for soils than for many other sectors.
- IPCC default methodology still mostly being used.
- Country-specific methods, usually process-based models with detailed activity data, are being developed in several Annex1 countries.
- Continued development/implementation of Tier3 methods should increase accuracy of soil GHG estimates, provided that countries are diligent with documentation, transparency and uncertainty assessment.

# Acknowledgements

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