Biogeochemical Process-Based Modeling of Nutrients and Greenhouse Gas Emissions from California Dairies

(A on-going project supported by California Energy Commission PIER and USDA NRI programs)

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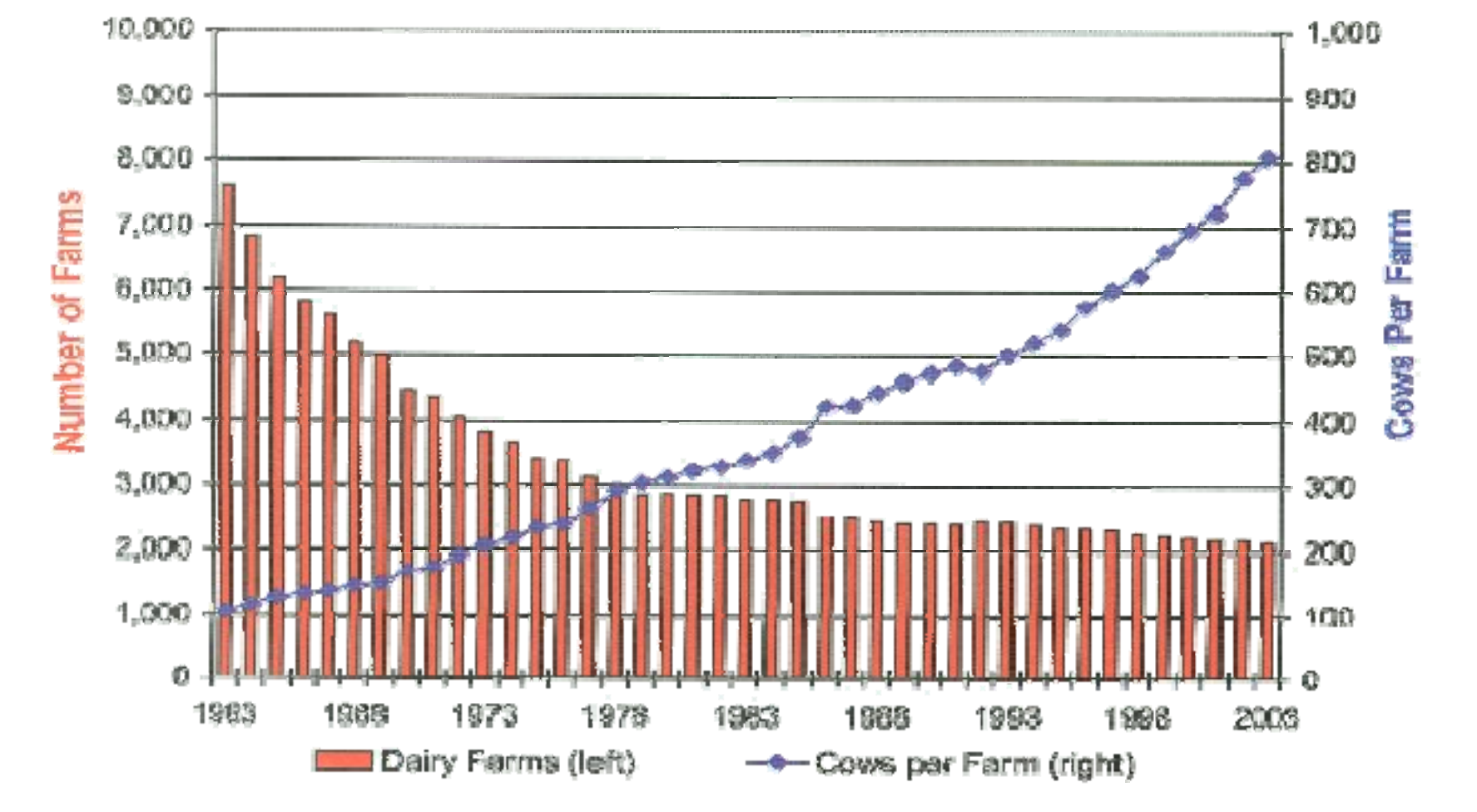
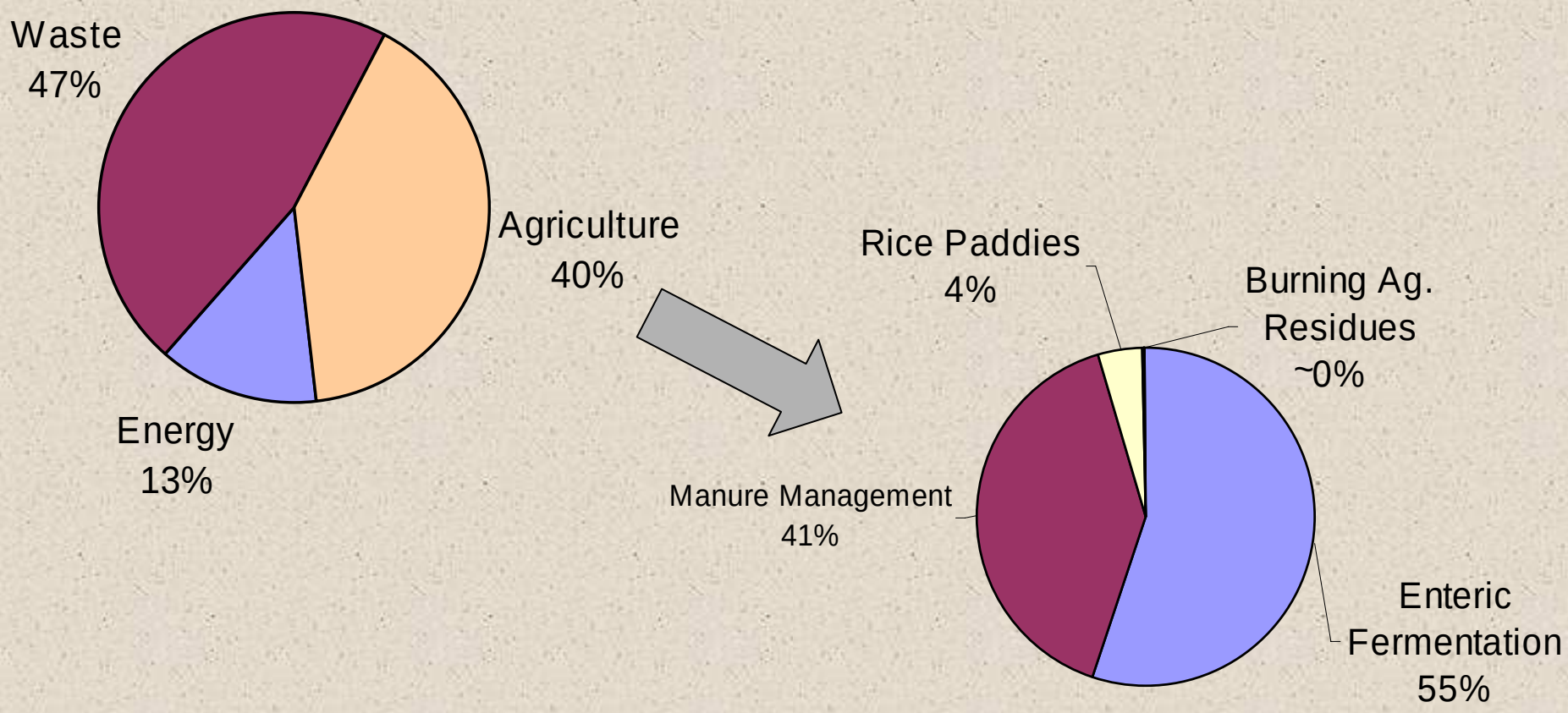
California Dairy Industry



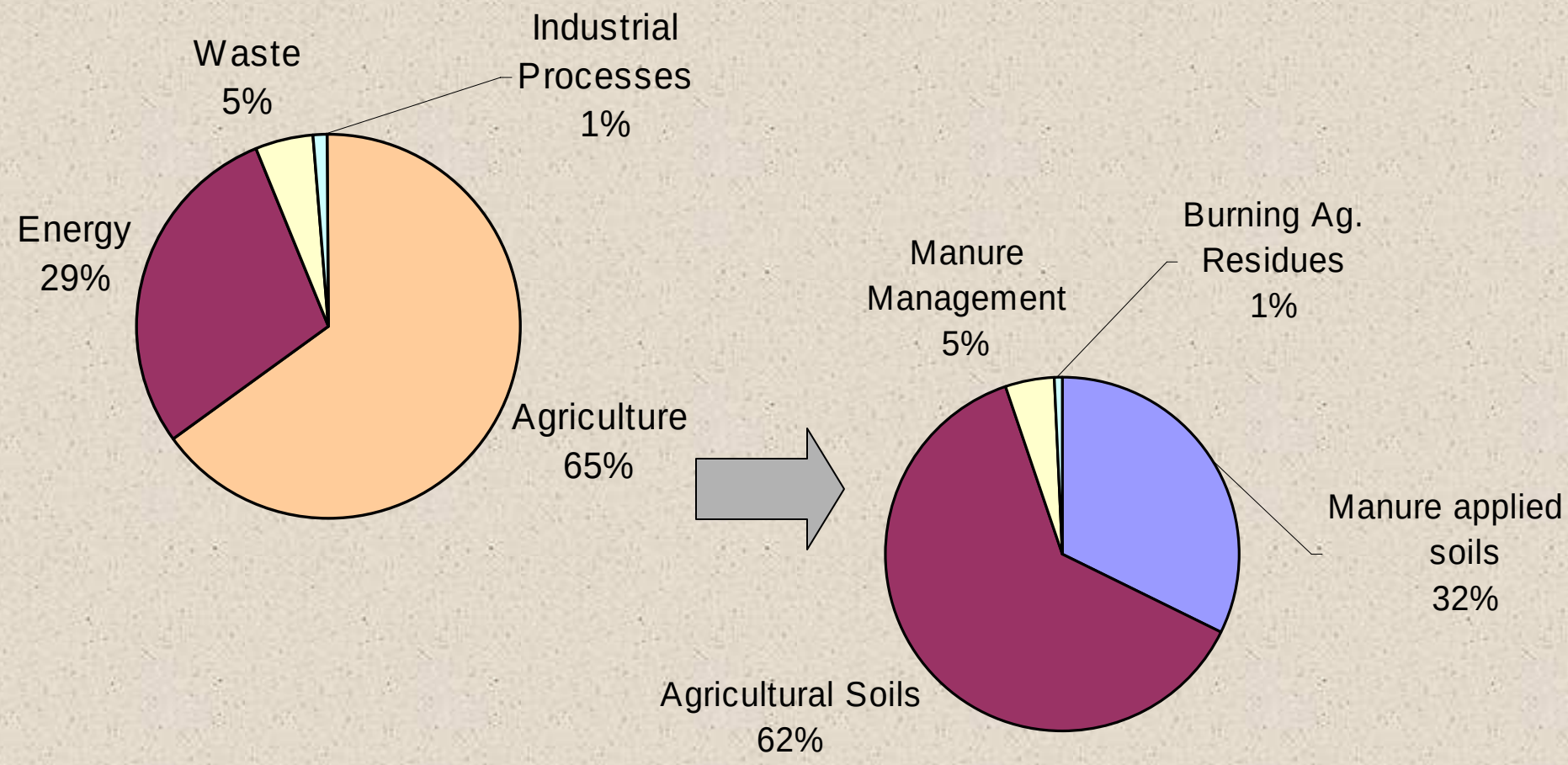
Source: CDFA 2004

1999 California CH_4 Emissions
31.65 $MMTCO_2eq$



Source: CEC 2002 GHG Inventory

1999 California N_2O Emissions
23.55 $MMTCO_2eq$



Source: CEC 2002 GHG Inventory

Project Goals

- Modify an existing "process-based" biogeochemical model (DNDC) for estimating CH4, NH3, NO, N2O emissions from dairy systems in California.
- Collect field data to calibrate and validate this model
- Build GIS databases on soils, climate, dairy locations, and manure management.
- Apply the model to estimate emissions across California. Note: model is designed for both regional and single farm simulations.

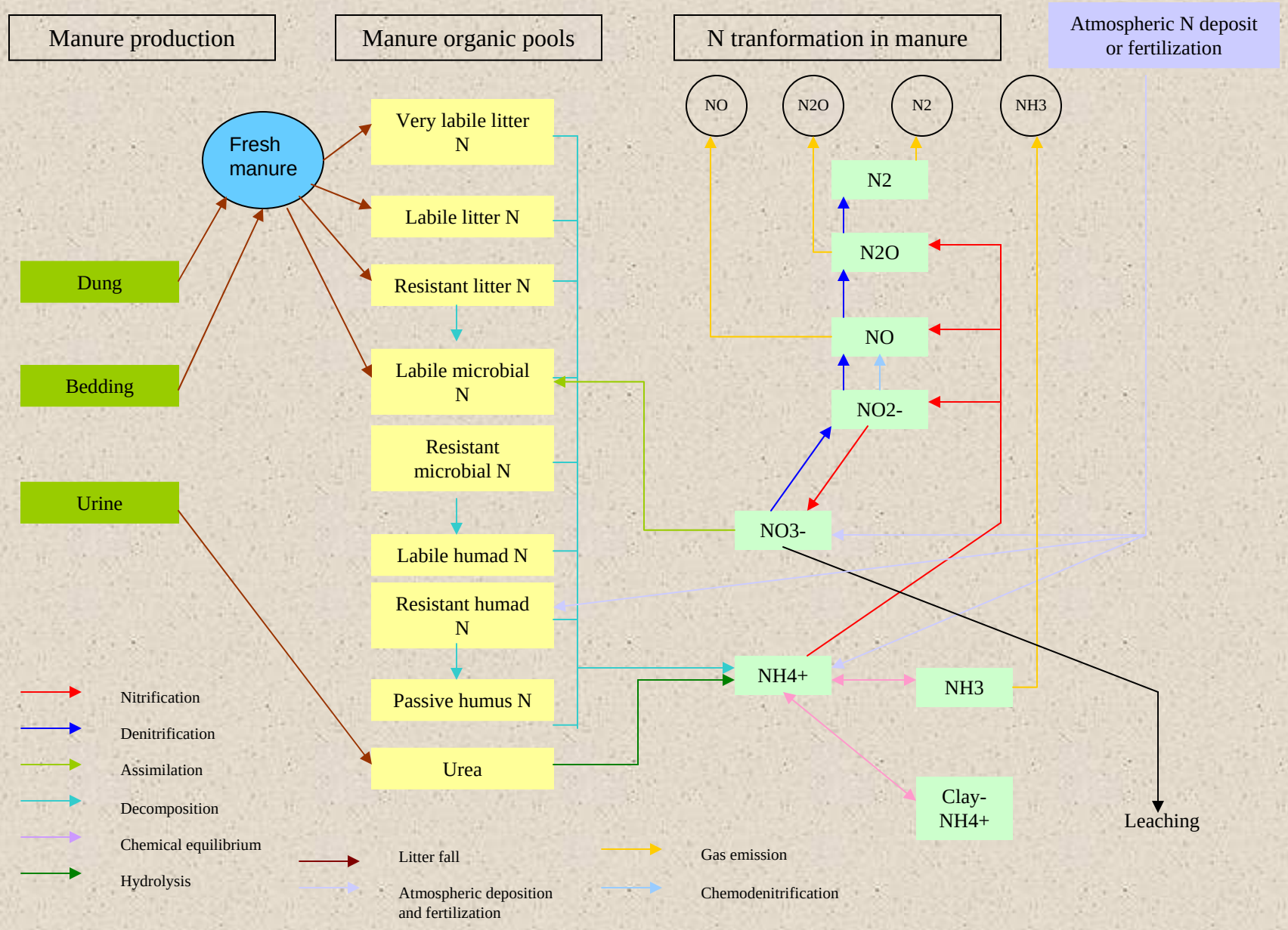
What are Process-based Models?

- Process-based modeling refers to biochemical and geochemical reactions or processes
  - Process modeling, in this case, does **not** refer to AFO practices or components (e.g. dairy drylots or manure lagoons) per se, but
- **Biogeochemical processes**… like decomposition, hydrolysis, nitrification, denitrification, etc…
- True process-based models **do not rely on constant emission factors**. They simulate and track the impact on emissions of varying conditions within components of the dairies (e.g., climate, flush lanes, storage facility, soils).

Role of Process-based Models

- Accurate assessment of air emissions from dairies with emission factors is difficult due to:
  1. high variability in the quality and quantity of animal waste, and
  2. numerous factors affecting the biogeochemical transformations of manure during collection, storage and field application.
- Measurement programs are essential but expensive and thus not feasible for monitoring, emission inventories, mitigation analyses and “what if” scenario analyses.
- Therefore, process-based models that incorporate mass balance constraints are needed to extrapolate air emissions in both space and time (NRC, 2003).

Nitrogen Biogeochemistry of Manure



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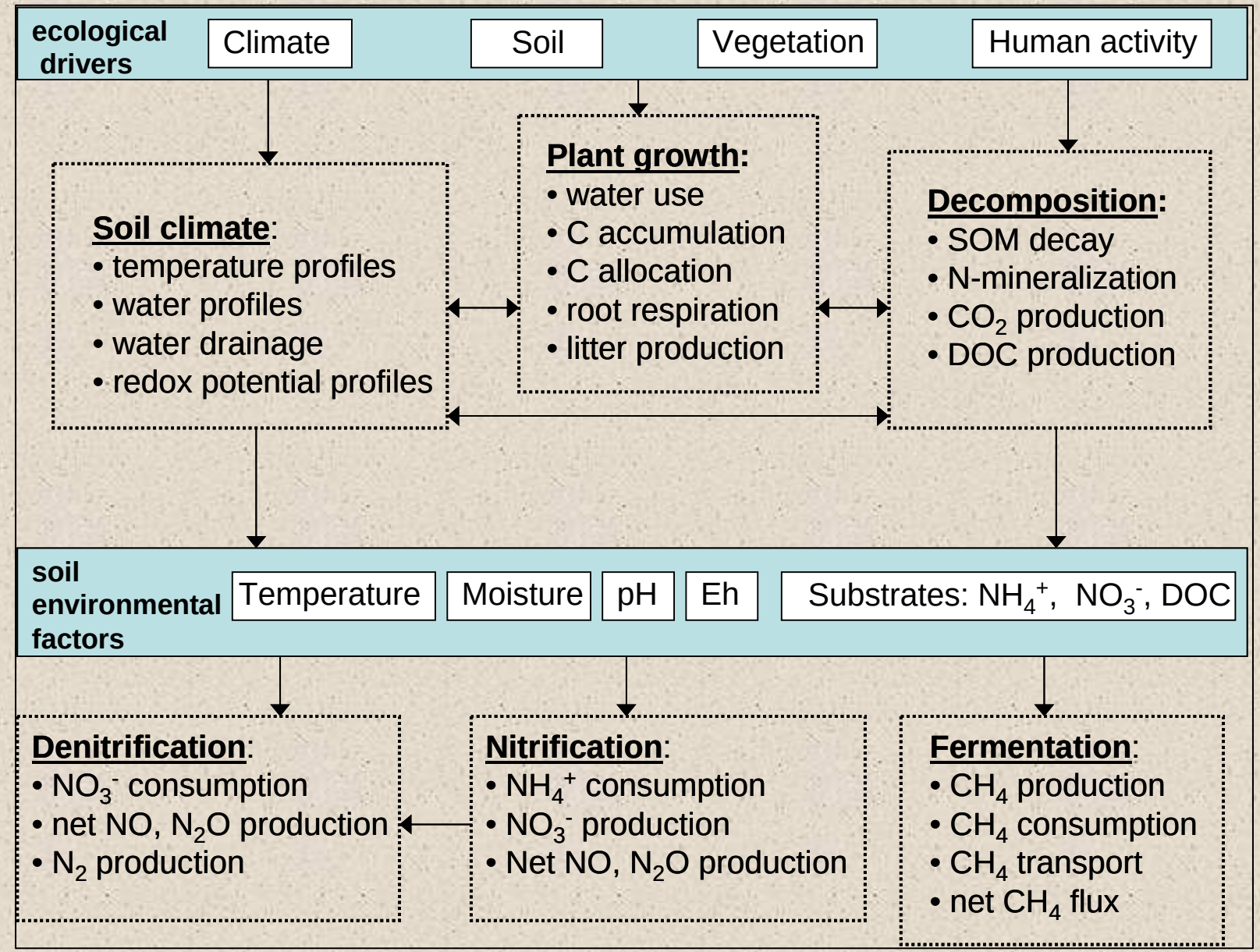
The DNDC Model



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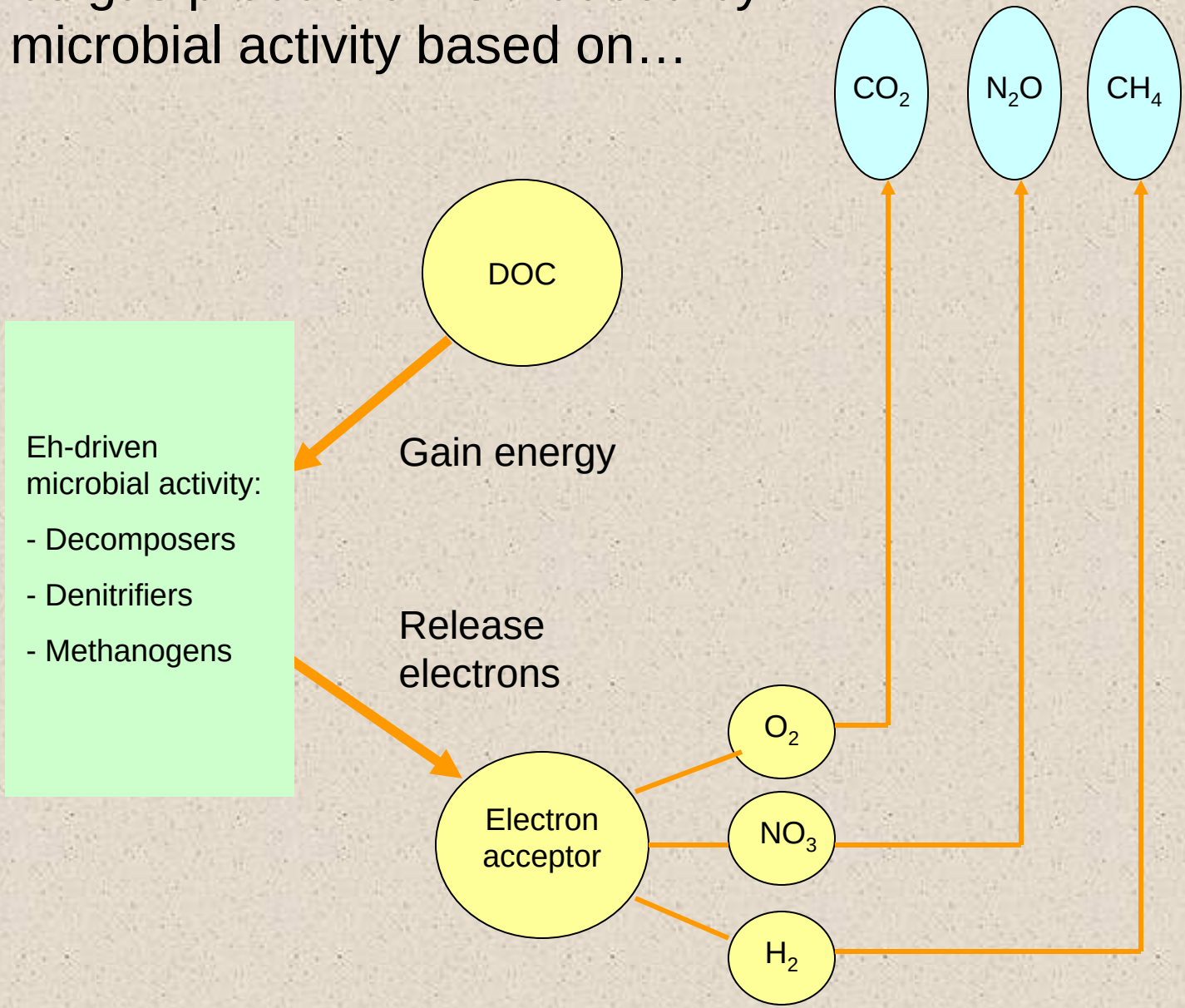
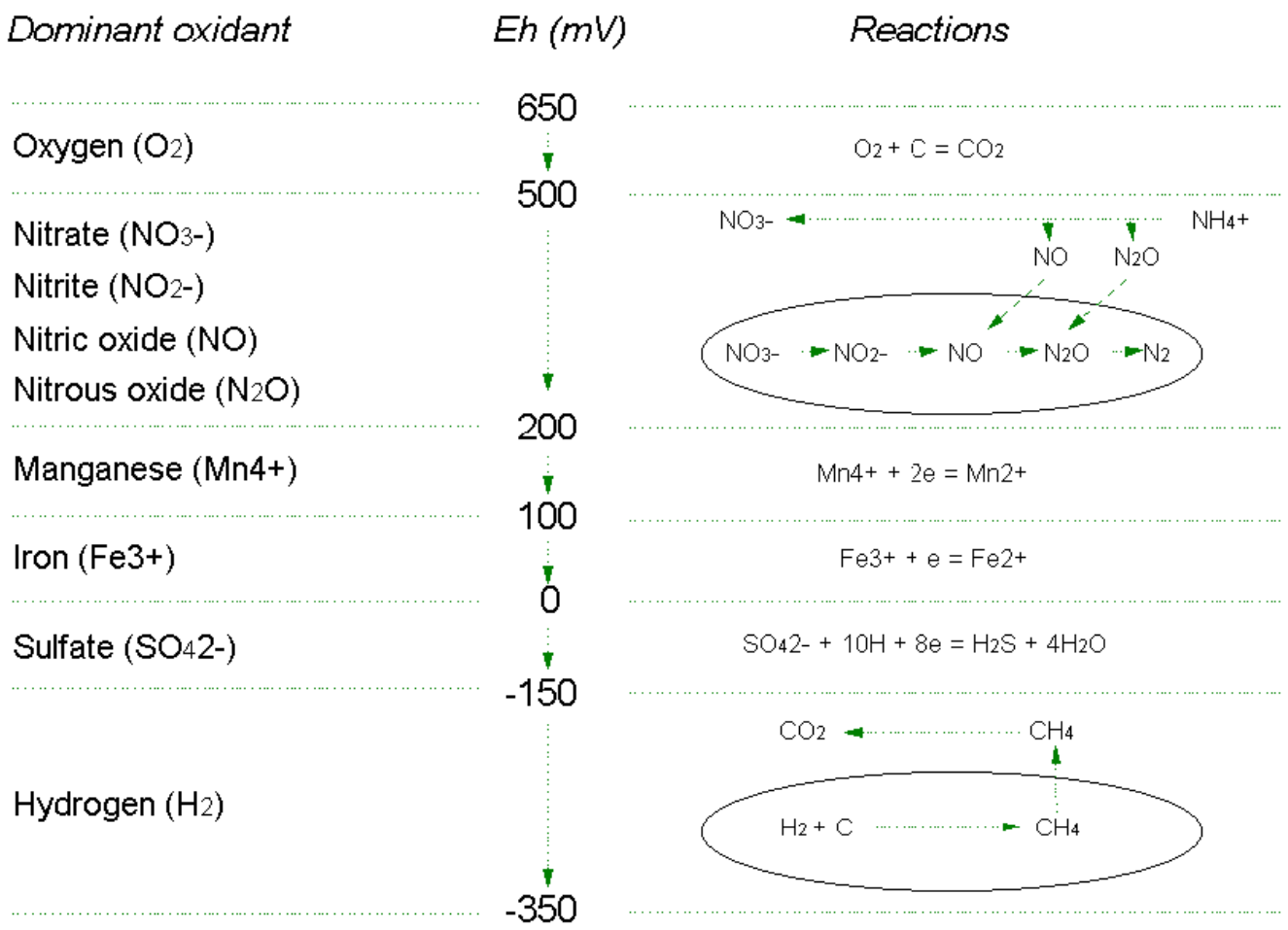
Trace gas production is induced by microbial activity based on…



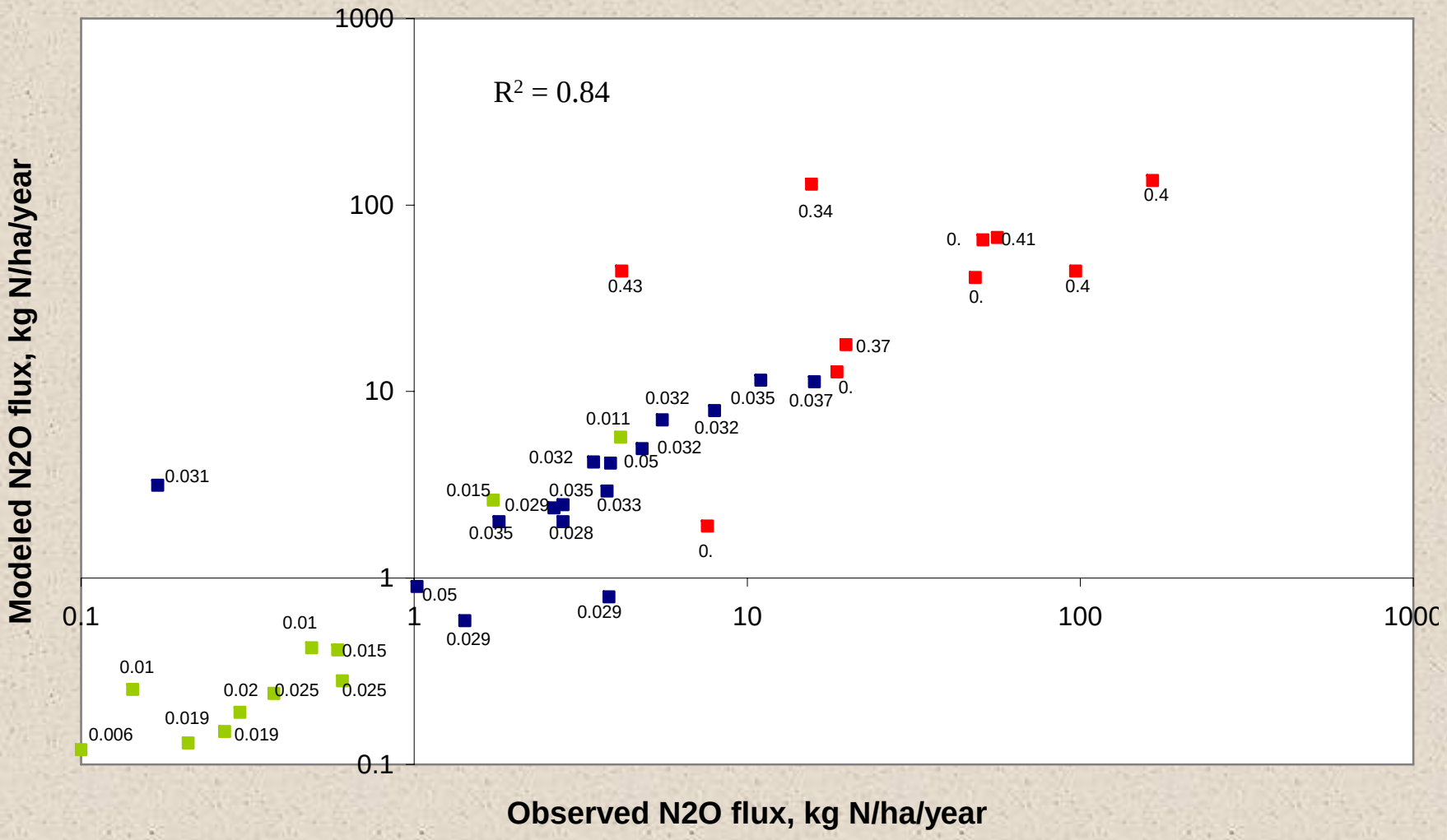
Soil CO_2, N_2O and CH_4 production is driven by the microbes demanding electron acceptors



Why DNDC Model?

- Contains algorithms for both anaerobic and aerobic soil environments
- Simulates full range of biogeochemical processes: decomposition, hydrolysis, nitrification, denitrification, ammonium adsorption, chemical equilibriums of ammonium/ammonia, fermentation, and gas diffusion
- Well validated across a wide range of agroecosystems and is currently being used for national GHG emission inventories and mitigation studies worldwide.

Observed and DNDC-Modeled N2O Fluxes from Agricultural Soils in the U.S., Canada, the U.K., Germany, New Zealand, China, Japan, and Costa Rica



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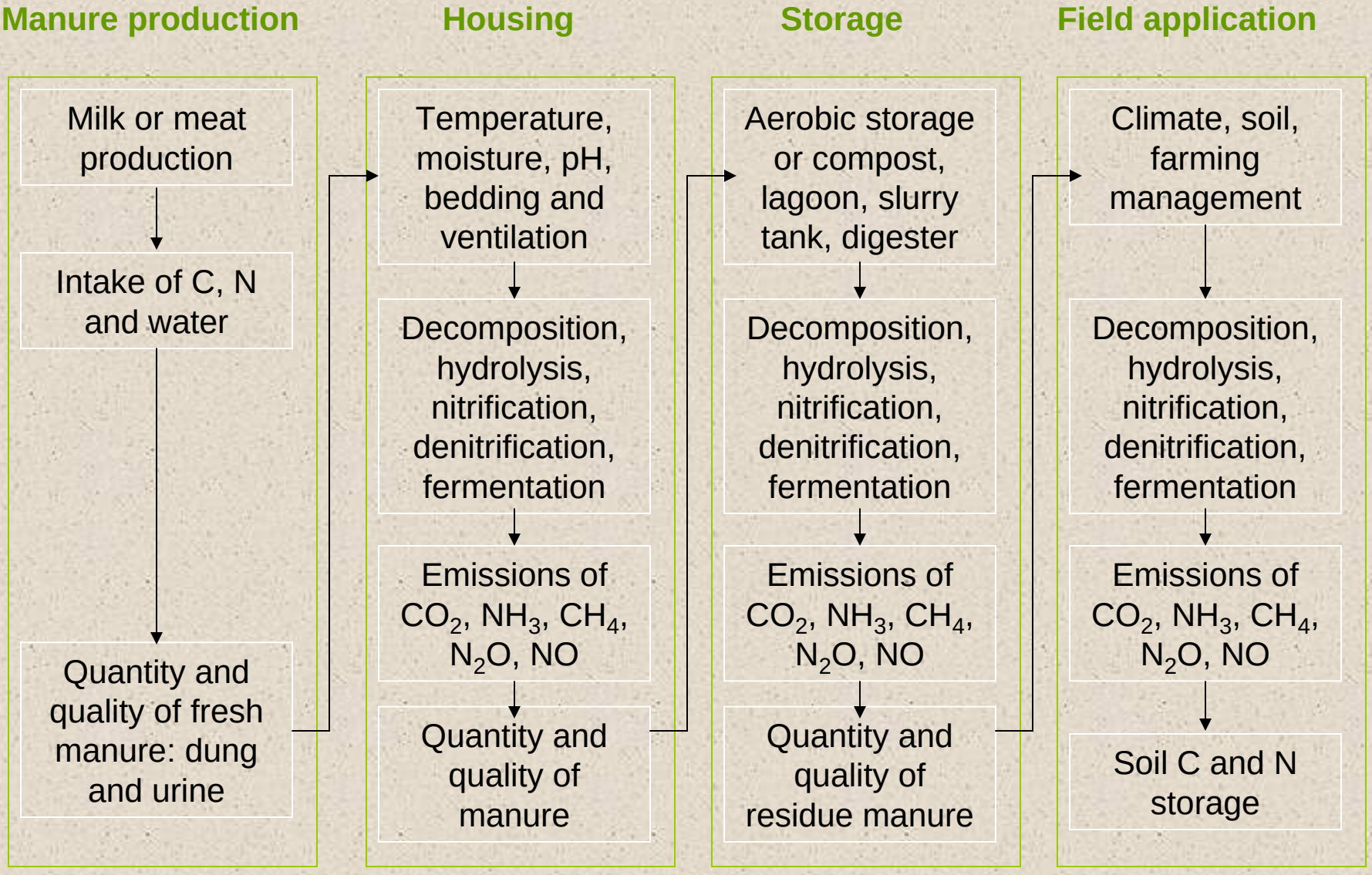
Structure of Manure-DNDC



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Model Status

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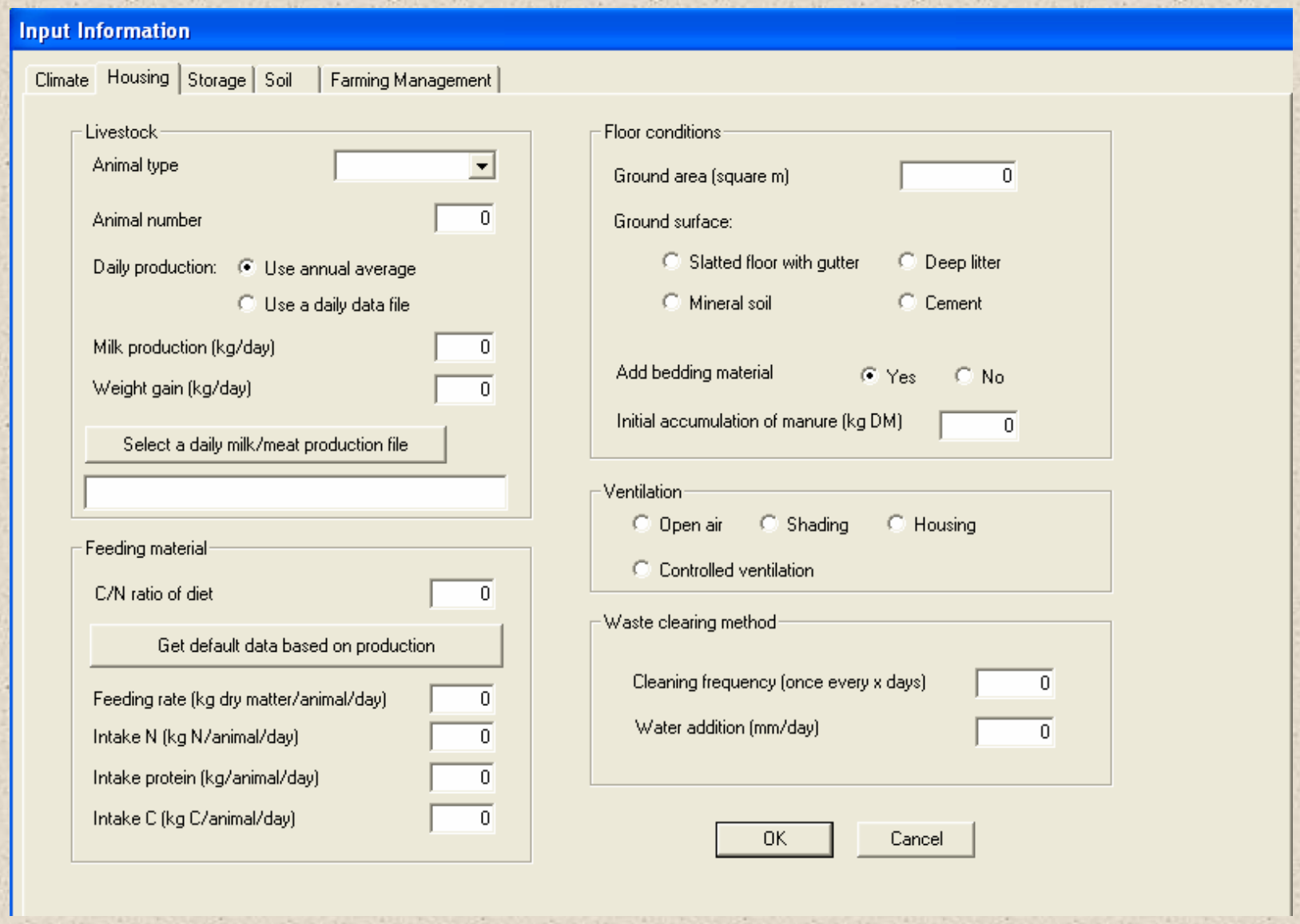
Easy to Use Input Interface for Defining Climate, Housing, Storage, Processing, Soil, and Field Application Conditions

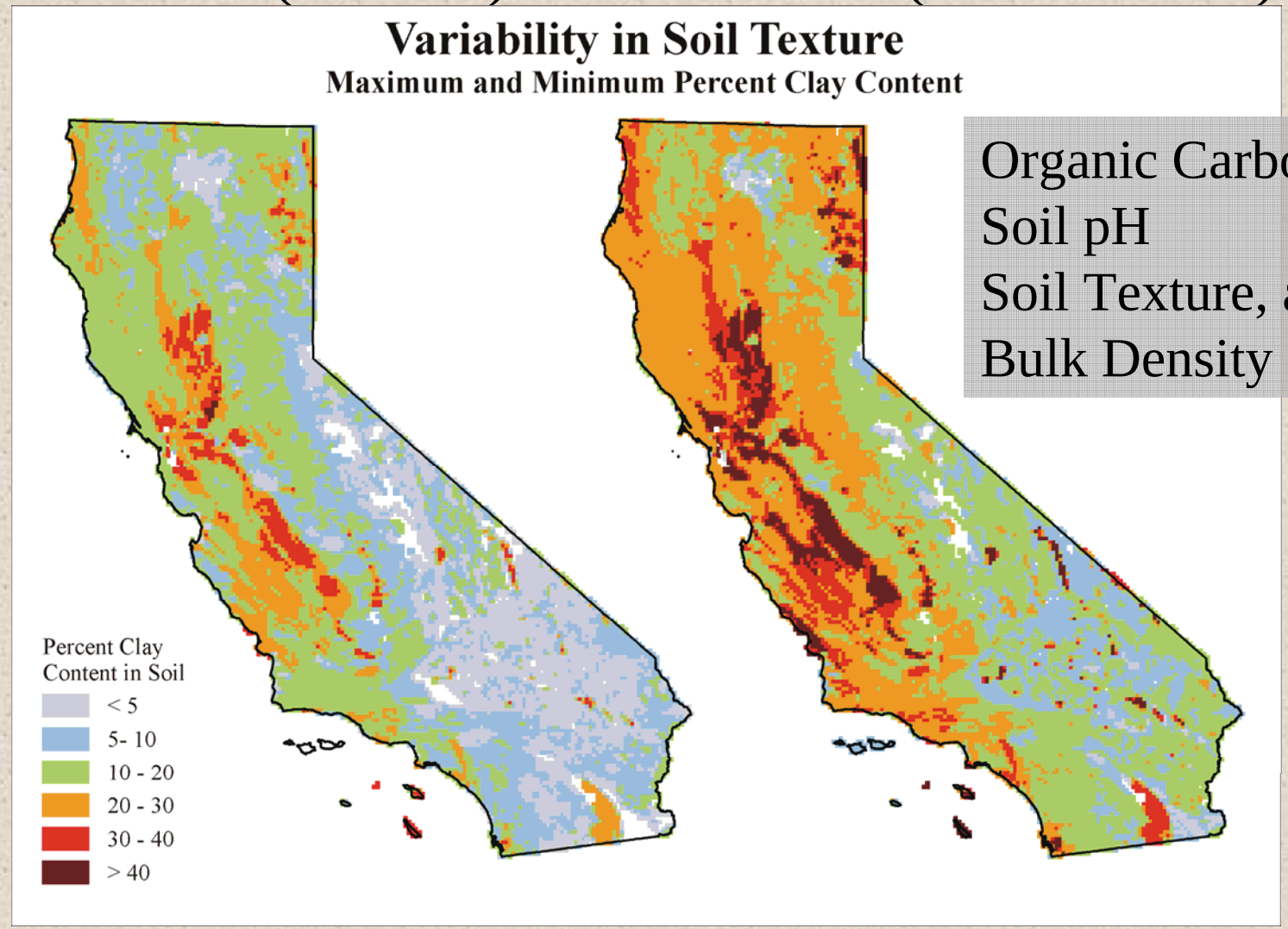


Manure-DNDC will be validated with datasets observed in housing, storage, treatment and field application.

Sampling and measurement are conducted at feed-lot, housing, storage, lagoon and field in 3-5 dairy farms in CA in 2006-2007

GIS Soils: NRCS Soil Surveys

- STATSGO (1:250K) and SSURGO (1:12k-1:63K)



Organic Carbon
Soil pH
Soil Texture, and
Bulk Density

Environmental Factors: Climate Data

- DAYMET: Gridded (1kmx1km) daily min/max T, precipitation, relative humidity, and solar radiation. Available from 1980.
- CIMIS (California Irrigation Management Information System): station data with hourly Temp, Precip, Radiation, Rel Hum, Wind Speed, …).
- Built automated routines for data mining, QA/QC and pre-processing into Manure-DNDC format.

GIS and Site Specificity: Dairy Locations: Aerial Photos

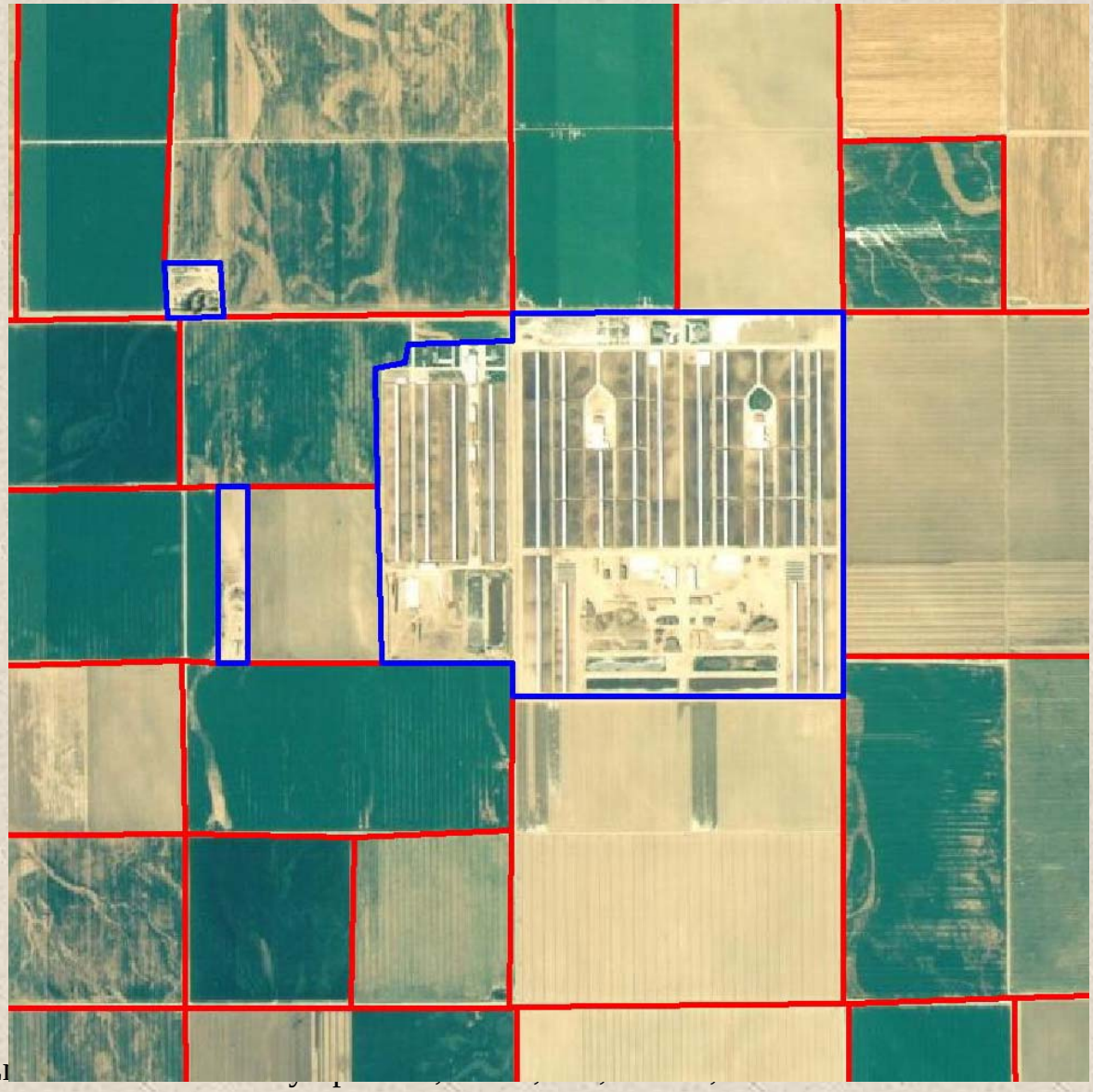
GIS Data on:

Dairy Locations

Soils (soil properties pH, SOC, texture, Bulk density)

Climate (daily/hr T, Precip, rel humidty, Wind, solar radiation)

Merced	429
Stanislaus	409
Tulare	338
Kings	199
San Joaquin	199



Manure Management Statistics

- Objective: build spatially explicit database on
  - Type of dairy: flush, scrape, vacuum, etc
  - Type of housing: free stalls, open corals, etc
  - Manure handling: anaerobic lagoon, aerobic lagoon, anaerobic digester, composting, setting basin, land application, etc.
  - Specifics on storage, treatment, and land application practices, etc.
- Source: Permits and surveys

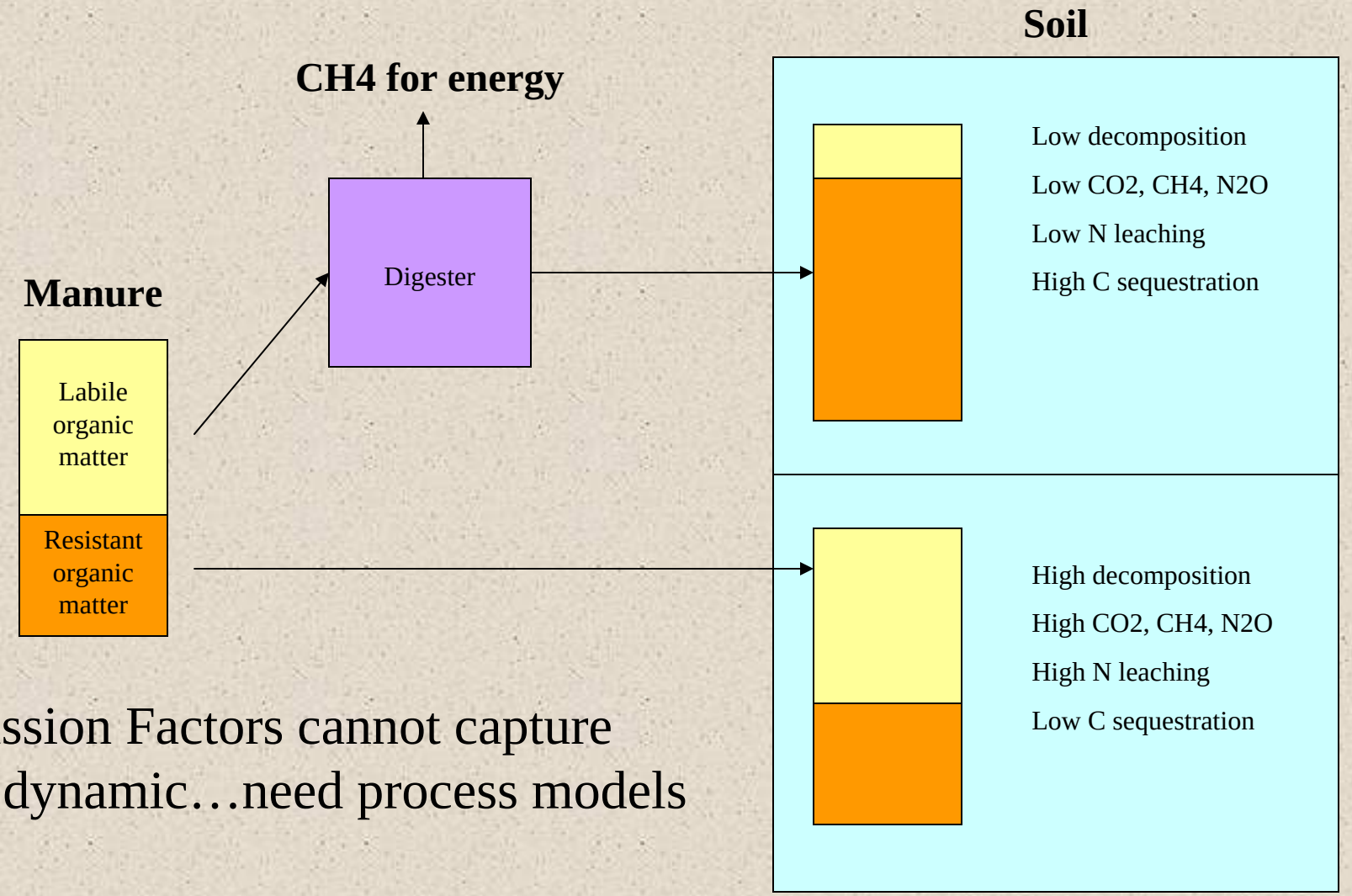
Expected Project Outcomes:

- Biogeochemical process modeling tool for estimating air emissions (CH_4, NH_3, N_2O, NO) and N leaching from California dairies;
- GIS databases on dairies (location, types, herd sizes, manure management, local soils, climate, etc);
- Improved understanding of manure management practices impact on GHGs.
- Regional estimates of NH_3 and GHG emissions from California dairies;
- Emission inventory tool for emission inventories ranging from project or facility level up to air-district and state level

AB 32

- Establishes statewide greenhouse gas emissions caps
- Animal feeding operations are an important source of non-CO_2 greenhouse gases (CH_4 and N_2O)
- Climate Action Team Report: changes in manure management may be an important GHG mitigation strategy - anaerobic digesters may be a viable reduction strategy…

By tracking changes in quantity and quality of manure in its life cycle, process-based model can assess impacts of digester or other treatment on environment in a comprehensive way



Emission Factors cannot capture this dynamic…need process models

Thank you!