MERES: Extending the CERES-Rice model to simulate methane emissions from rice fields

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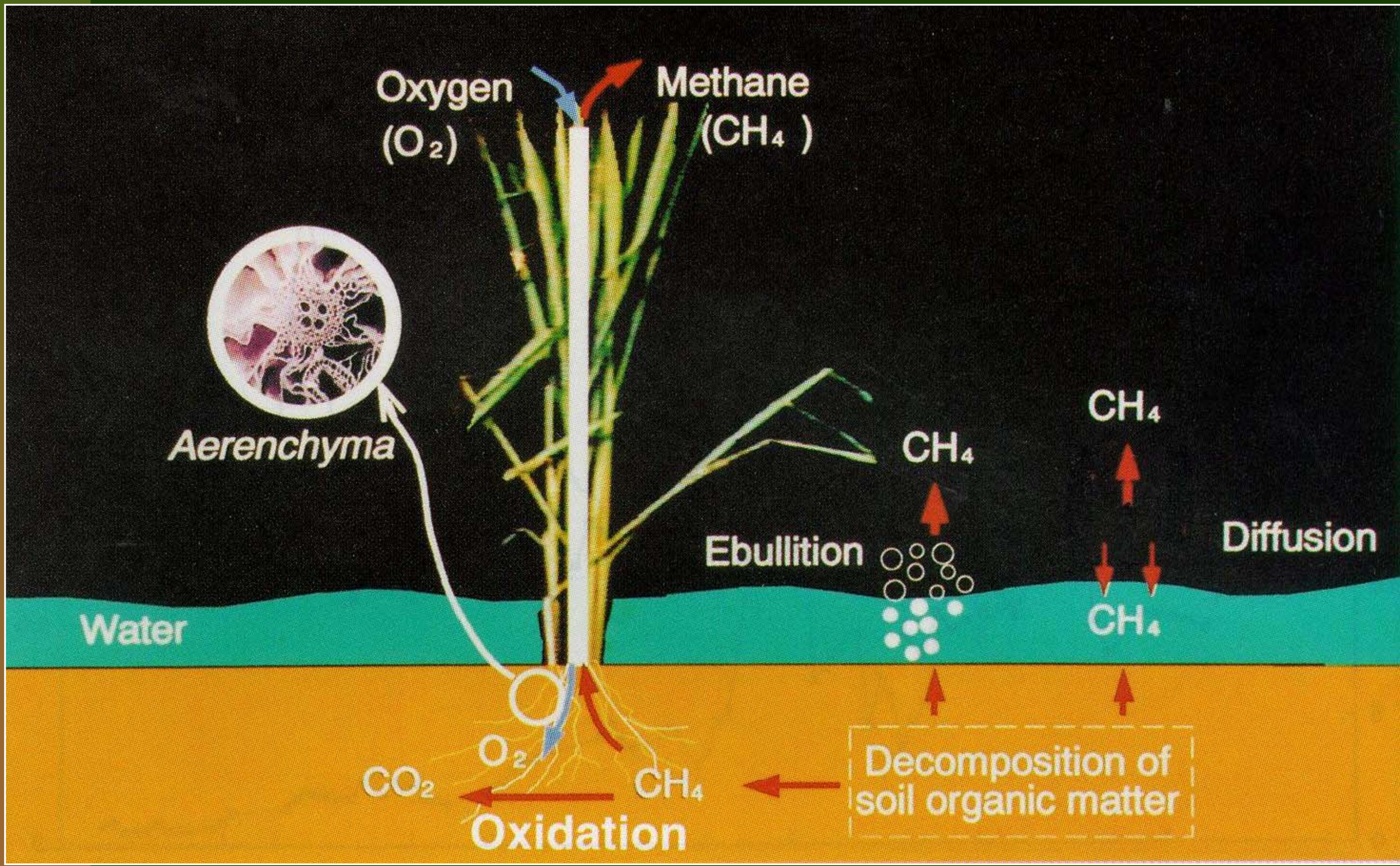
Source estimates of CH_4

Source	Tg CH_4 yr^{-1}	%
Natural sources		
Wetlands	100-115	23
Termites	20	4
Oceans	10	2
Anthropogenic sources		
Rice cultivation	40-70	9-14
Domestic animals	80	17
Sewage treatment	30	6
Landfills	20-25	5
Biomass burning	45	10
Fuel combustion	28	6
Coal and gas	60-92	16
Minor	9	2

(GEIA, 1993)

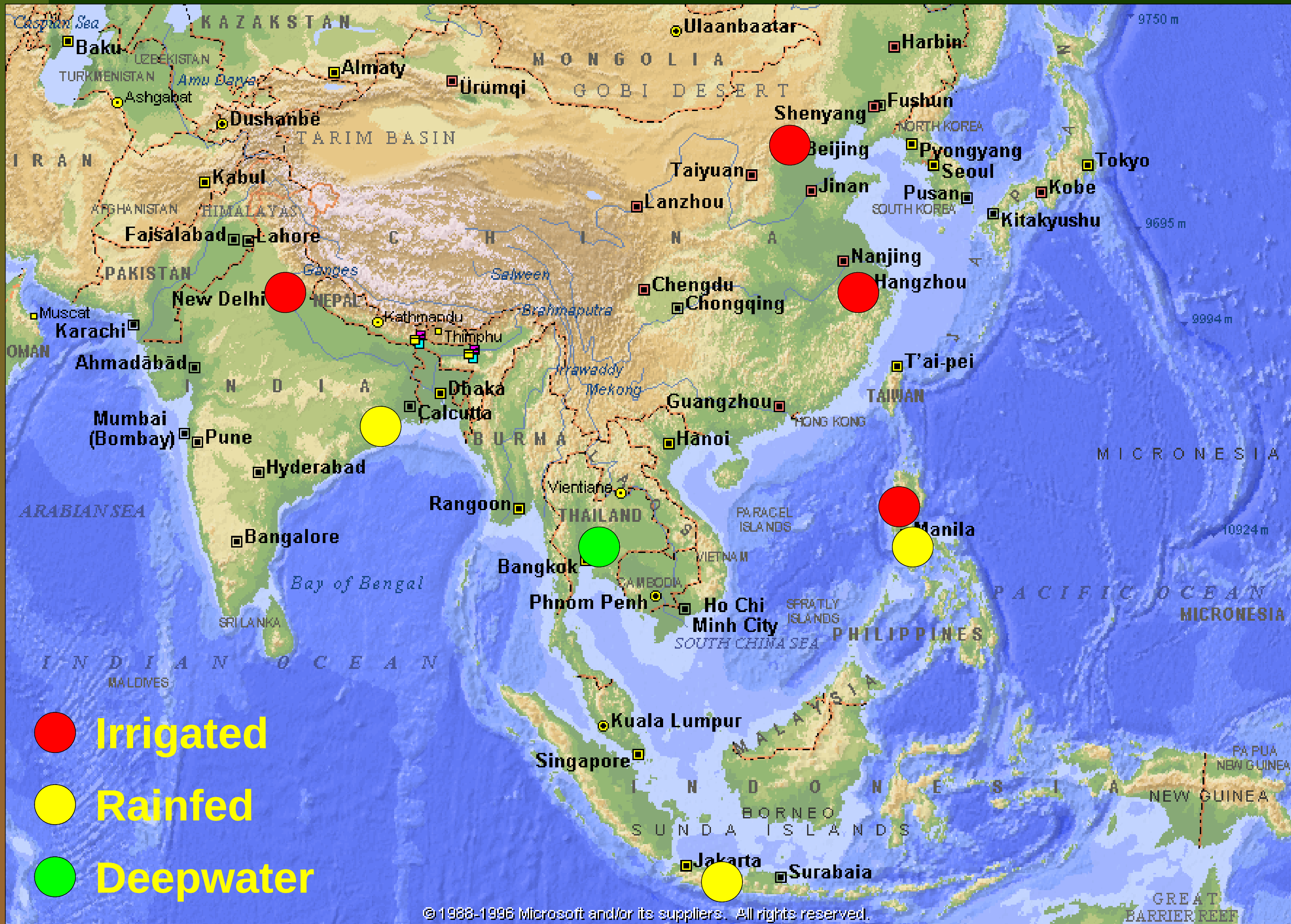
Methane in paddy fields



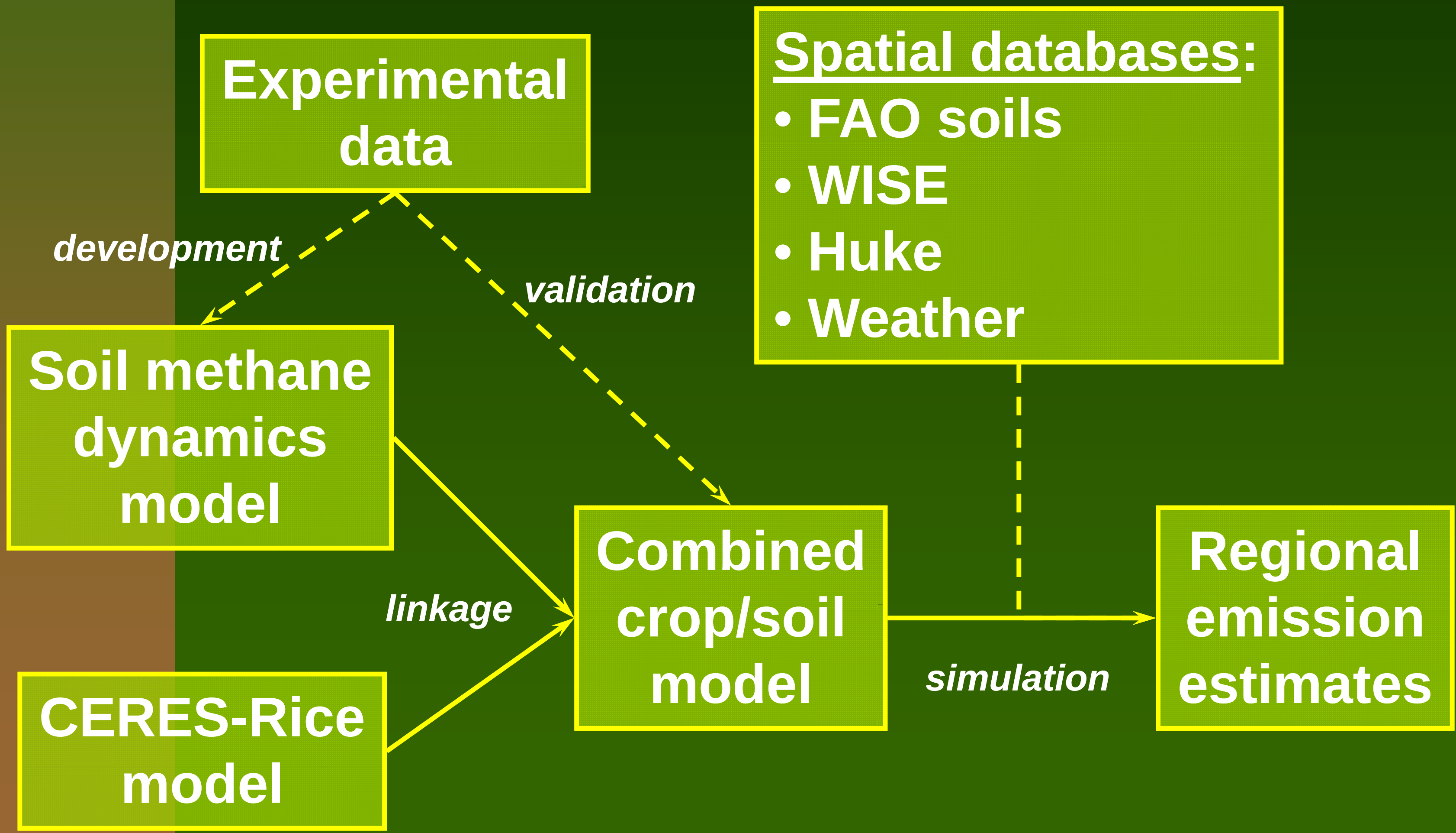
Aims of the UNDP Project

- to quantify CH_4 emissions from major rice ecosystems in Asia as affected by current and advanced cultivation technologies
- to evaluate processes that control CH_4 fluxes from rice fields
- to identify mitigation technologies that can reduce CH_4 emissions while maintaining crop productivity

The field stations of the Interregional Program on Methane Emissions from Rice Fields



Project Structure



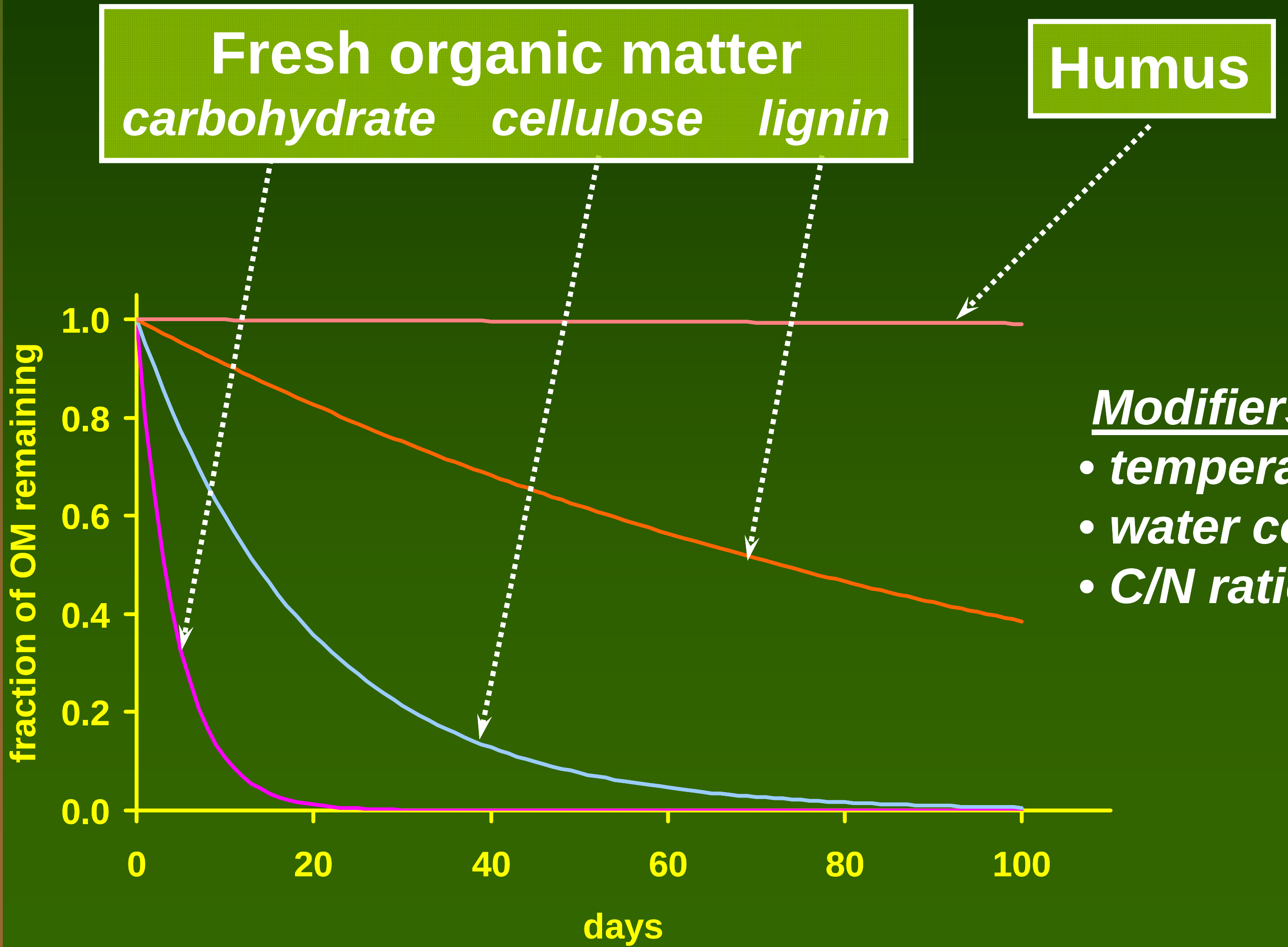
The CERES-Rice Model

- Process-based, daily time-step
- Simulates soil organic matter decomposition
- Describes root growth dynamically
  - root exudates
  - root death
- Contains routines for irrigation, fertiliser & org. mat. management

Sources of CH_4 substrate

- Soil organic matter
  - fresh organic matter (crop residues & organic amendments)
  - humus
- root exudates
- dead root tissue

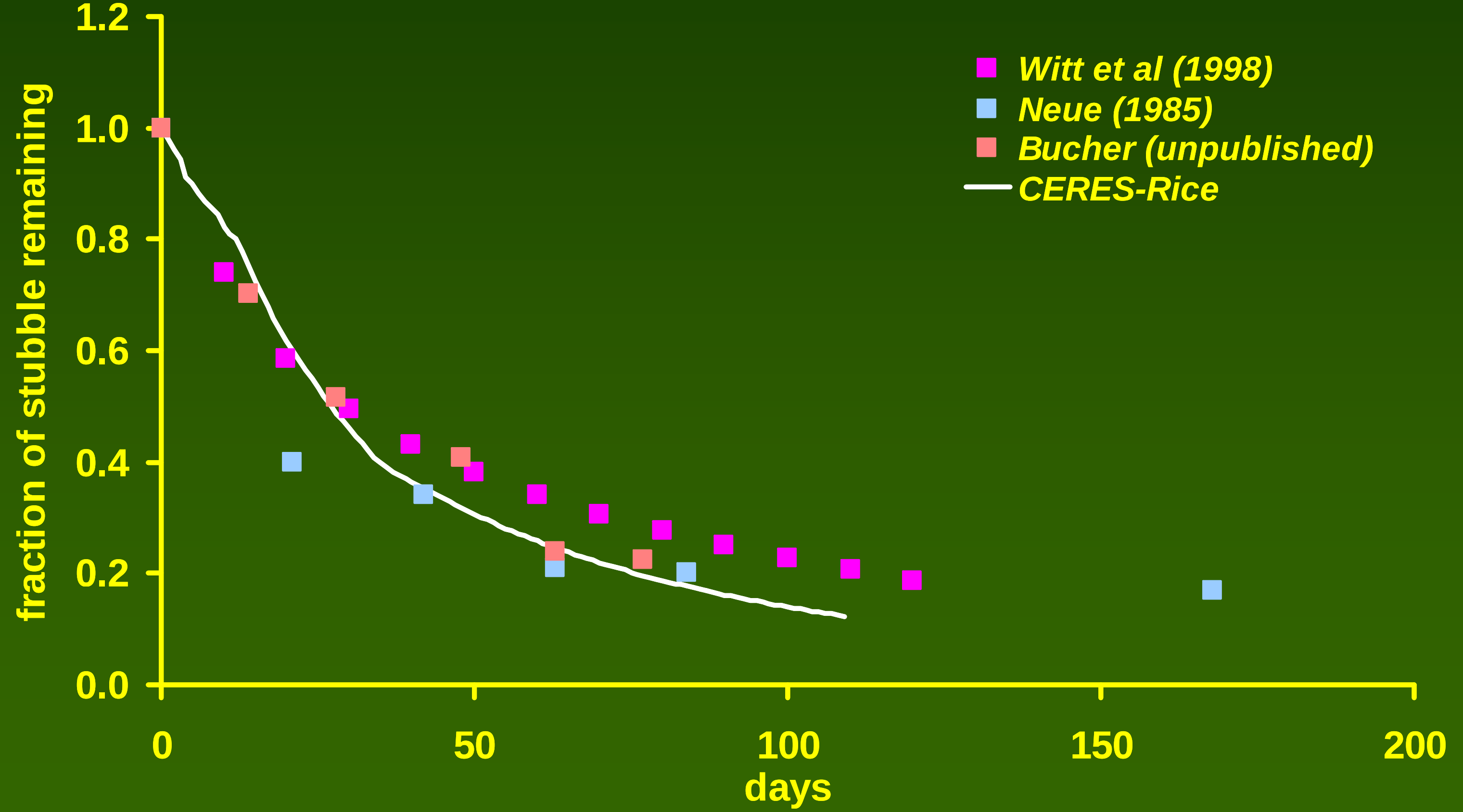
Soil organic matter decay



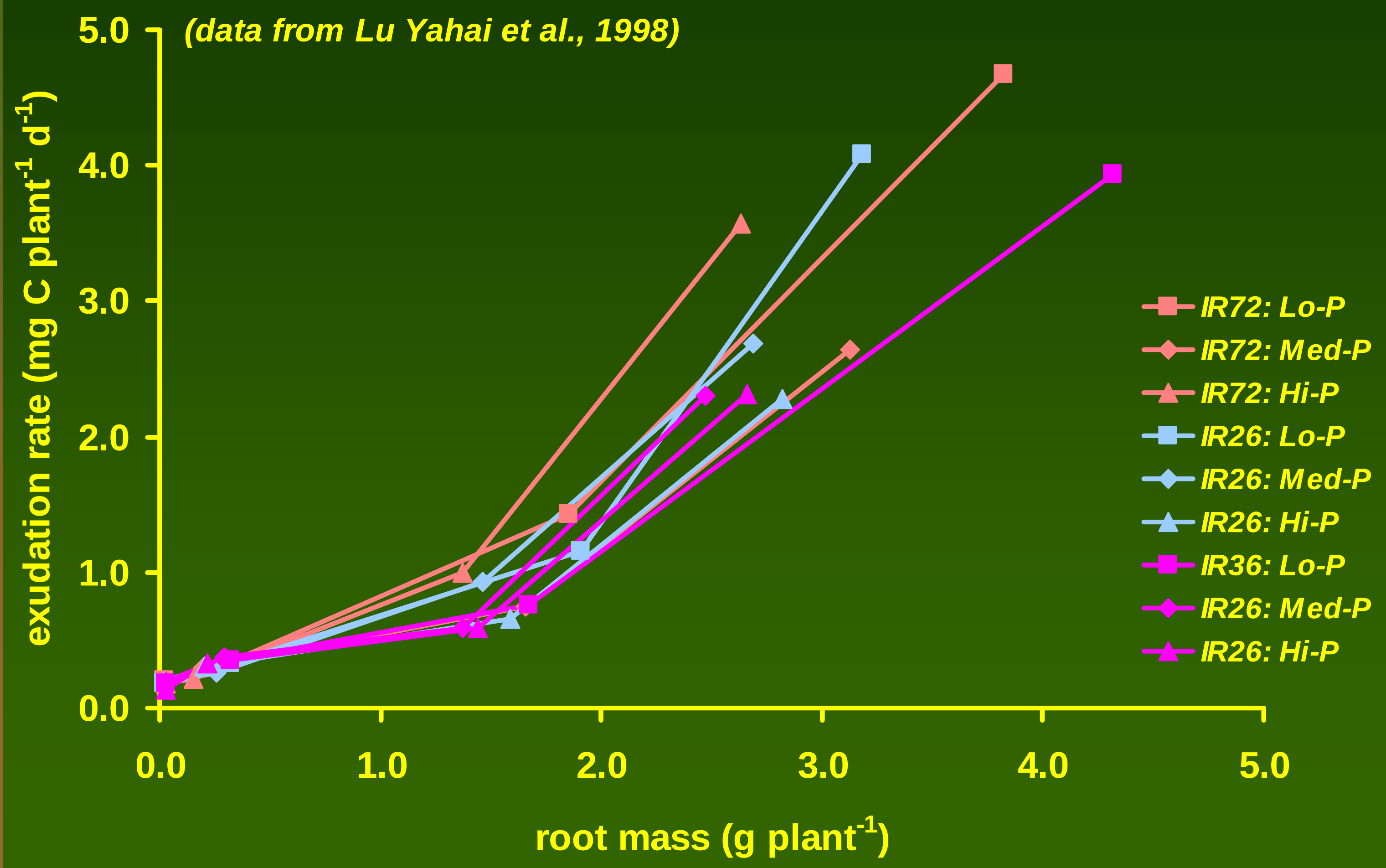
Modifiers

- *temperature*
- *water content*
- *C/N ratio*

Fresh organic matter decay



Root exudates

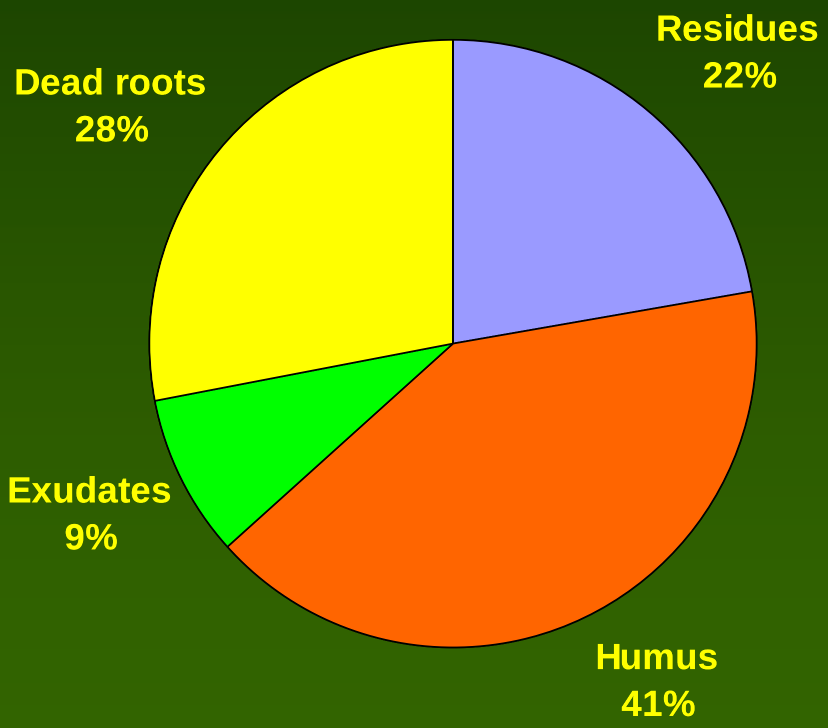


Root death

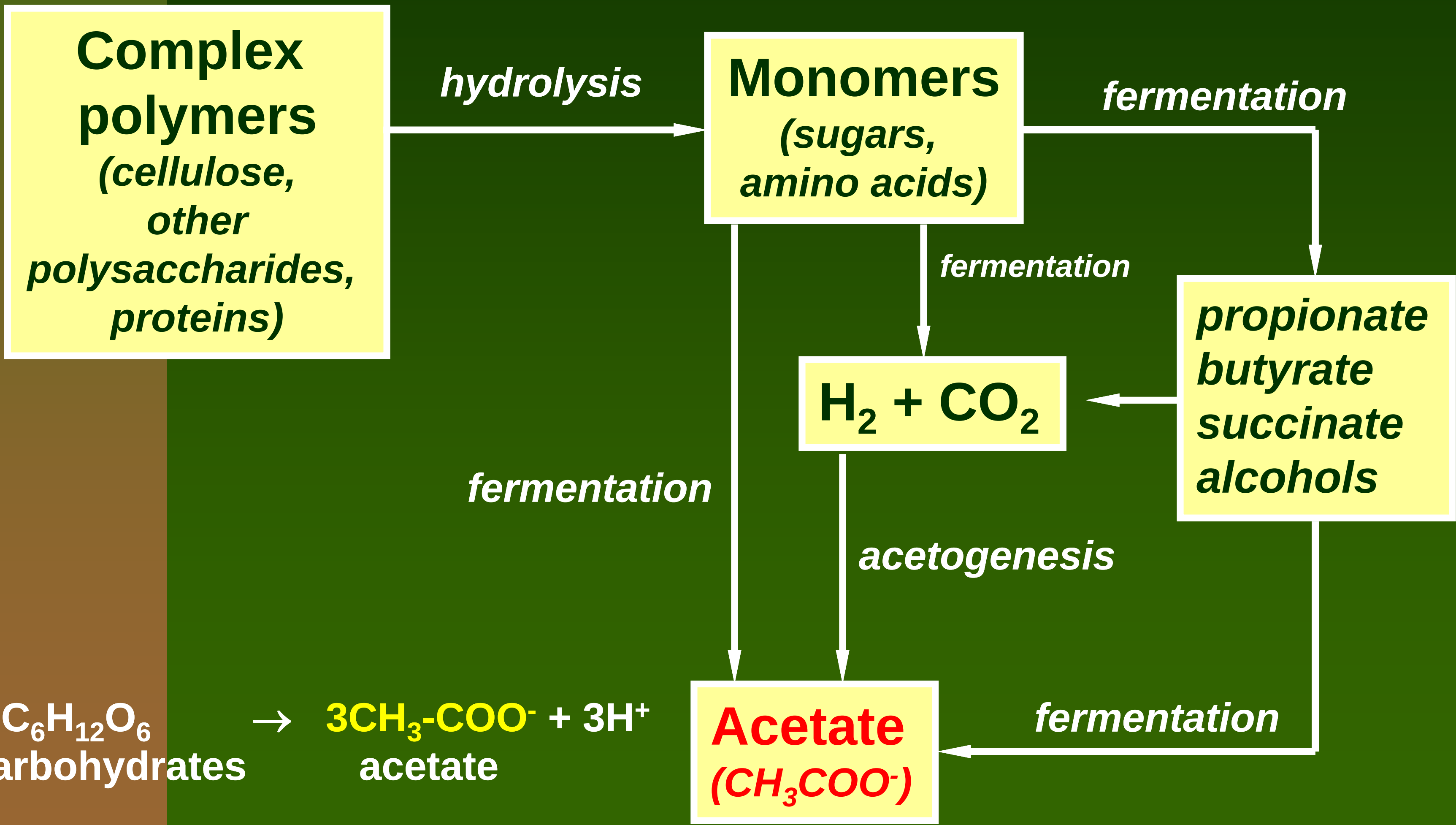
- scarcity of data on root turnover in rice
- Bronson *et al*., 1998: 15% rhizo-deposition over season (root death + exudates)
- assume 2% of existing root mass dies each day
- enters the fresh organic matter pools

C source contributions

Source	kg C ha^{-1}
Residues	227
Humus	418
Exudates	88
Dead roots	285
TOTAL	1018



Fermentation



$C_6H_{12}O_6 \rightarrow 3CH_3\text{-}COO^- + 3H^+$

carbohydrates → acetate

Methanogenesis

- carried out by the methanogens (*Archaic* bacteria)
- obligate anaerobes: inhibited by presence of oxygen
- overall reaction:

$$CH_3COO^- \rightarrow CO_2 + CH_4$$

Other electron acceptors

Oxidised		Reduced
$2NO_3^- + 12H^+ + 10e$	$\rightarrow$	$N_2 + 6H_2O$
$NO_3^- + 2H^+ + 2e$	$\rightarrow$	$NO_2^- + H_2O$
$Mn^{4+}O_2 + 4H^+ + 2e$	$\rightarrow$	$Mn^{2+} + H_2O$
$Fe^{3+}(OH)_3 + 3H^+ + e$	$\rightarrow$	$Fe^{2+} + 3H_2O$
$SO_4^{2-} + 10H^+ + 8e$	$\rightarrow$	$H_2S + 4H_2O$

Methane oxidation

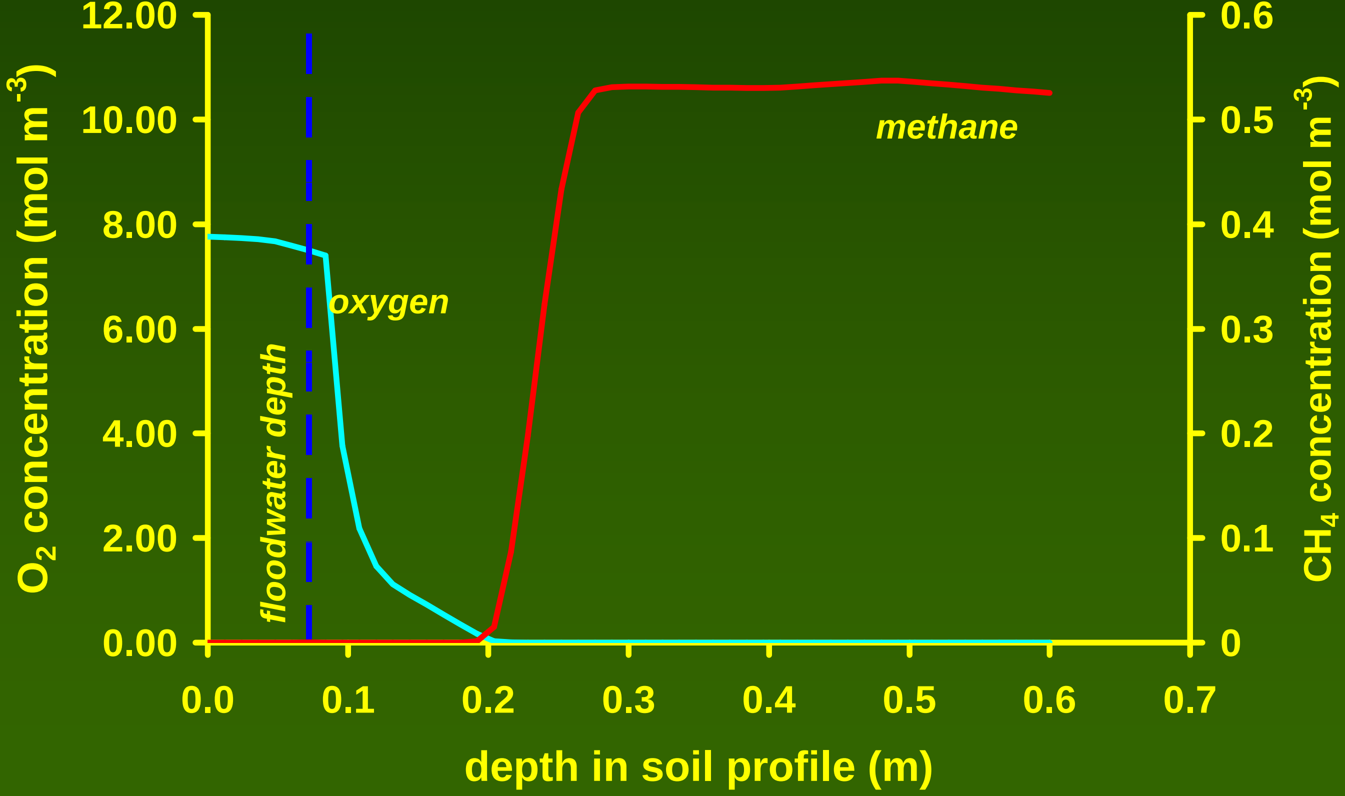
$$\frac{\partial \mathbf{y}}{\partial \mathbf{t}} = \frac{\partial}{\partial \mathbf{z}}\left(\mathbf{D}\frac{\partial \mathbf{y}}{\partial \mathbf{z}}\right) - \frac{\partial}{\partial \mathbf{z}}\left(\mathbf{L}\mathbf{y}_{\mathbf{s}}\right) + \mathbf{O} + \mathbf{P} - \mathbf{Q} - \mathbf{R} - \mathbf{S}$$

y	=	concentration (mol m^{-3})
D	=	aqueous diffusivity constant (m^2 s^{-1})
L	=	leaching rate (m^3 d^{-1})
O	=	root mediated influx (mol m^{-3} d^{-1})
P	=	production (mol m^{-3} d^{-1})
Q	=	consumption (mol m^{-3} d^{-1})
R	=	root mediated efflux (mol m^{-3} d^{-1})
S	=	ebullition (mol m^{-3} d^{-1})
z	=	depth in soil profile (m)

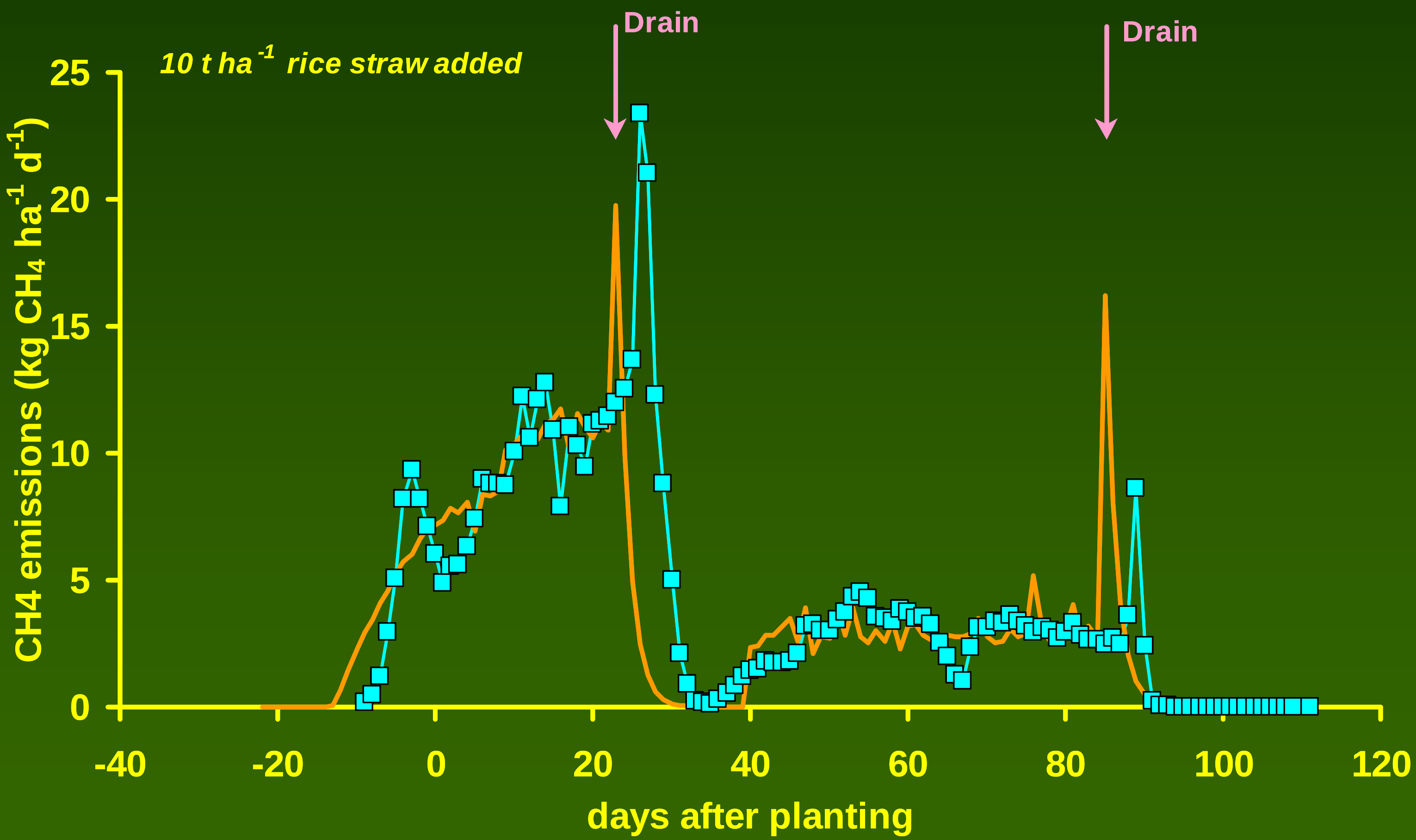
(Arah, 1998)

Methane and oxygen profiles

Arah (1998) model:

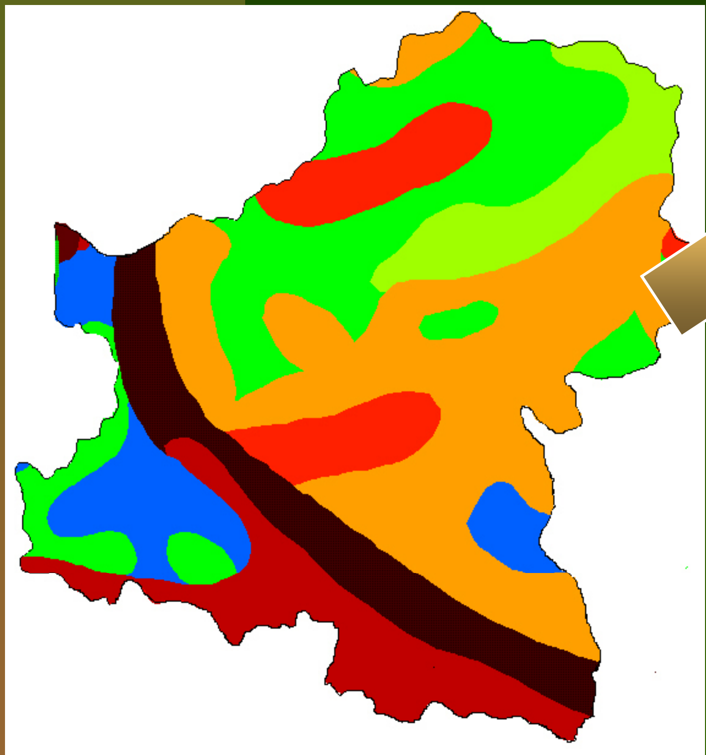


Model performance



Soils data: quantitative

e.g. Nakhon Ratchasima



FAO soils database

Soil association	Area (%)
Af59-1/2ab	15
Af60-1/2ab	7
Ag16-2a	19
Ag17-1/2ab	11
Ao108-2ab	11
Ao90-2/3c	9
o102-3ab	17
Ce56-3a	4
Nd55-2/3b	8

WISE database

or selected soil properties by 1974 FAO-UNESCO
N.H. (1997). A world dataset of derived soil prope
l unit for global modelling. Soil Use and Managm
10:

ID code	Soil Unit	pH (top)	pH (sub)	Org.C (top)	Org.C (sub)	CE (to
A	Acrisols	4.9	4.9	1.04	0.35	8
Af	Ferric Acrisol	5.0	4.9	0.75	0.28	6
Ag	Gleyic Acrisol	4.7	4.7	1.10	0.3	9
Ah	Humic Acrisol	4.9	5.1	2.30	0.76	13
Ao	Orthic Acrisol	4.9	5.0	0.78	0.26	7
Ap	Plinthic Acrisol	4.7	4.8	1.04	0.31	6
B	Cambisols	6.1	6.4	1.05	0.38	17
Bc	Chromic Cambisol	6.9	7.2	1.02	0.37	20
Bd	Dystric Cambisol	5.1	5.2	1.94	0.40	17
Be	Eutric Cambisol	6.7	6.9	0.90	0.30	18
Bf	Ferralic Cambisol	5.1	5.3	0.95	0.29	7
Bg	Gleyic Cambisol	5.8	6.2	0.91	0.36	15
Bh	Humic Cambisol	5.1	5.3	3.04	0.76	25
Bk	Calcic Cambisol	8.1	8.2	0.63	0.36	20
Bv	Vertic Cambisol	6.9	7.4	0.84	0.43	39

Predicted emissions - India