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Estimation of CH_4 and N_2O emissions from rice fields under AWD irrigation management through a DNDC model approach

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"Process, Measurements, Modelling and Mitigation of Greenhouse Gasses"
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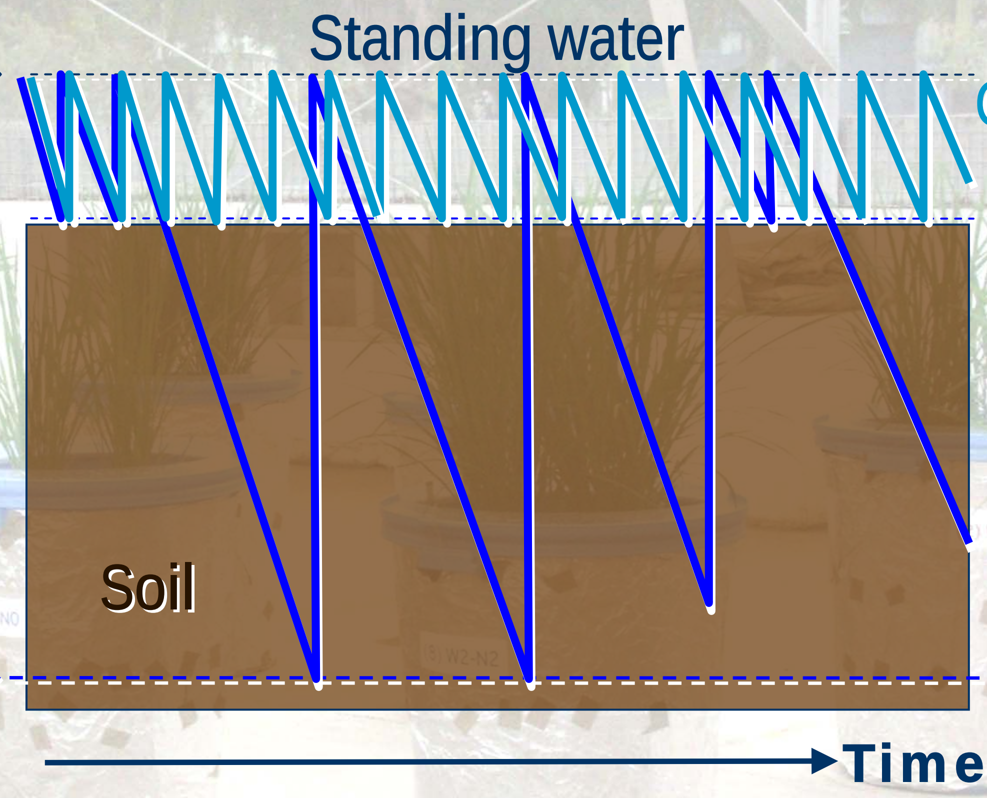
Alternate Wetting and Drying

- A Water-saving irrigation technique for rice cropping
- AWD has been investigated by International Rice Research Institute (IRRI) in Philippines since the early 1970's.
- With the technique:
  - 15-30% unproductive water outflow can be cut down
  - Water productivity can be increased without sacrificing yield.
- The main objectives of research for AWD technique are:
  - The spread of the technique
  - The evaluation of the technique from the viewpoint of its environmental impact

Irrigation Timing of AWD technique

Maximum height of standing water, e.g. + 50mm



Criteria of **driest** conditions,

e.g. Certain **soil water tension** at 150 mm depth

or

Water table down to 400 mm depth

Background

Instruments for monitoring hydrological conditions

Tensiometer

Field water tube

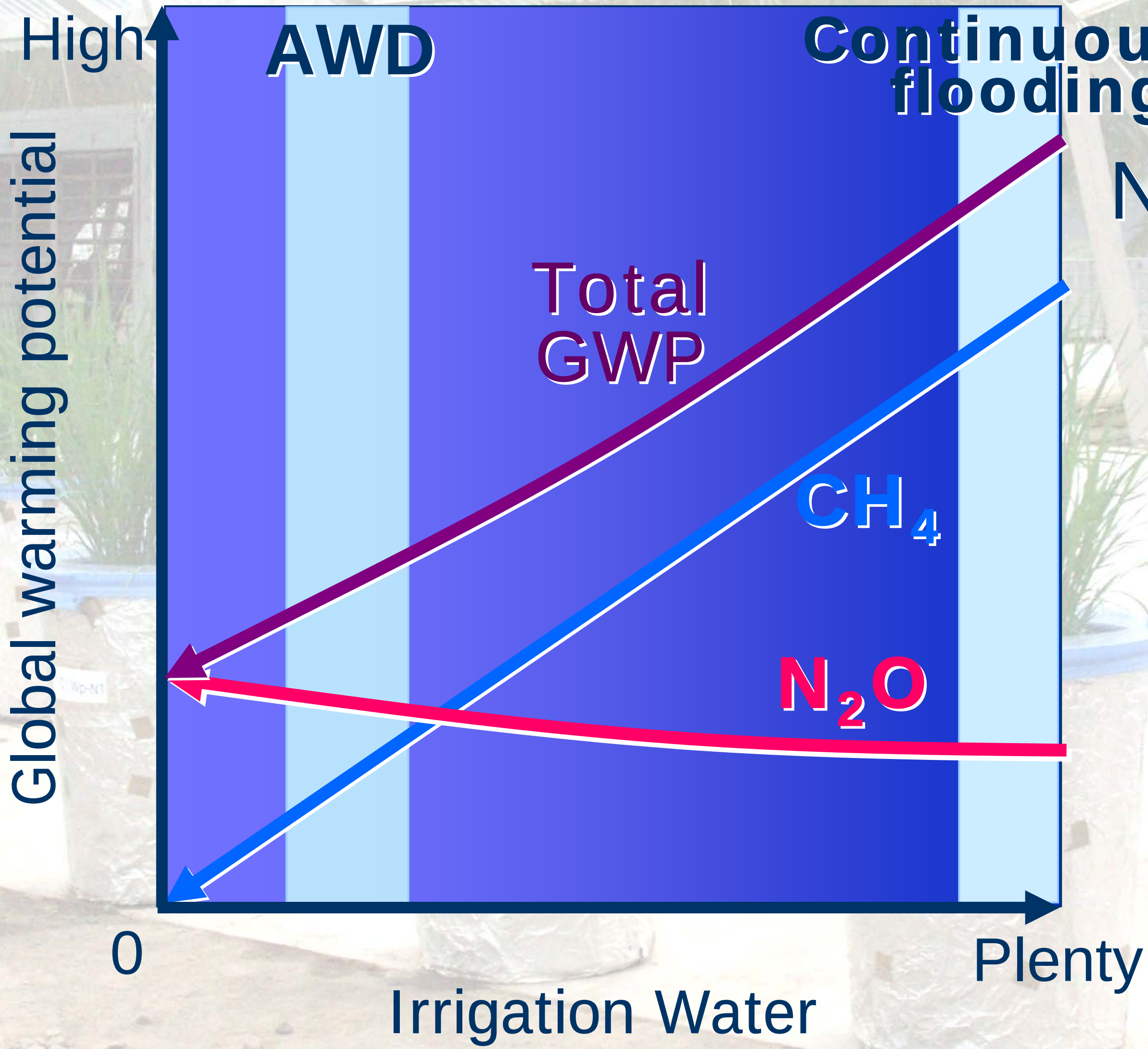
Background

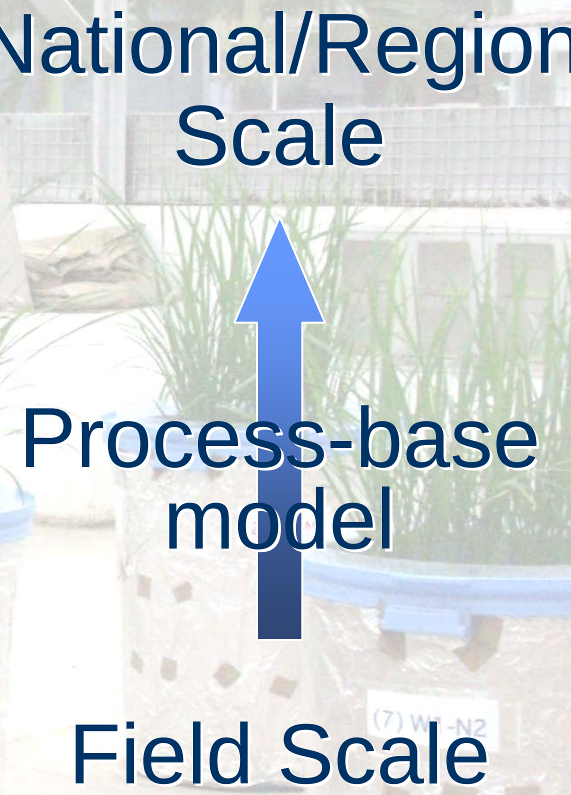
AWD management paddy rice field, IRRI

GHGs measurement conducted in IRRI since 2007

Background

AWD can decrease GWP of paddy fields





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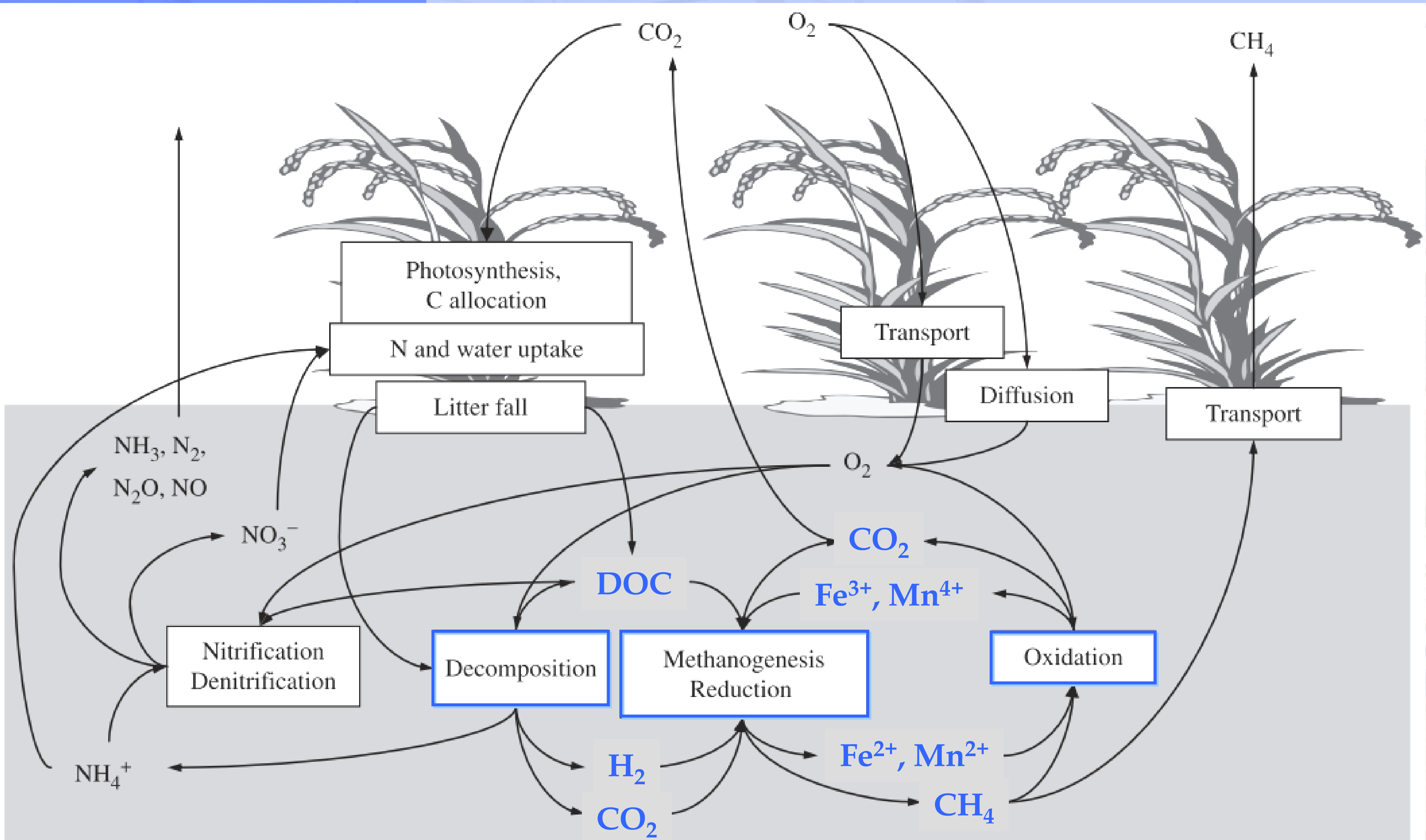
DNDC model for rice paddy fields

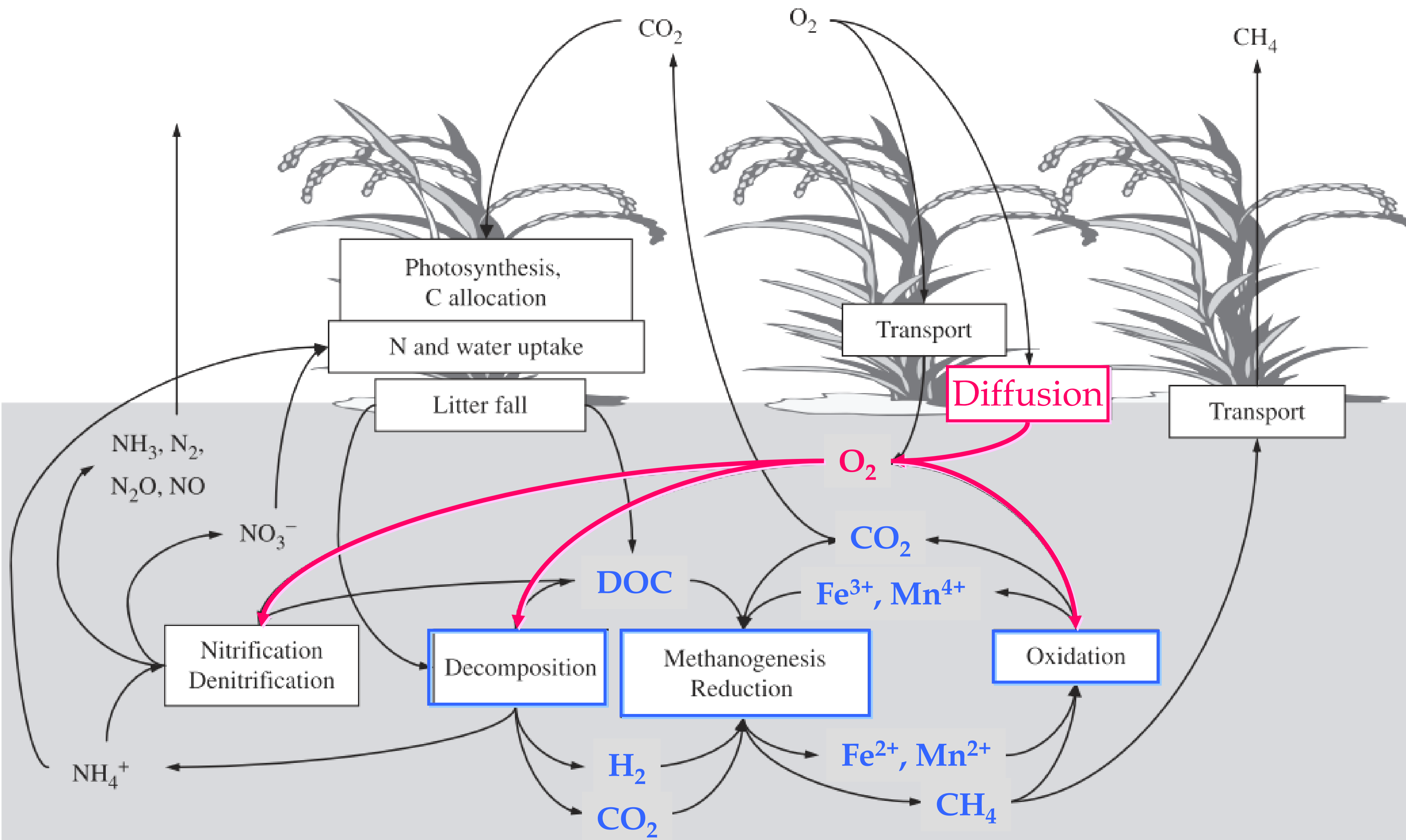
- **1992**: A DNDC model was developed by Li et al. (1992)
  - Process-based model for agroecosystems
    - simulates carbon and nitrogen dynamics based on biogeochemical processes
    - Non-flooded agricultural conditions
      - Carbon sequestration
      - GHGs (N_2O, CH_4, CO_2, NO and NH_3)
- **2004**: Anaerobic biogeochemistry was incorporated for rice paddy fields (Li et al. 2004)
- **2008**: DNDC 8.2 was modified for paddy ecosystems by Fumoto et al. (2008) →DNDC-Rice model
- **2009**: A regional scale evaluation of CH_4 emission using the DNDC-Rice model (Fumoto et al. 2009)

DNDC model



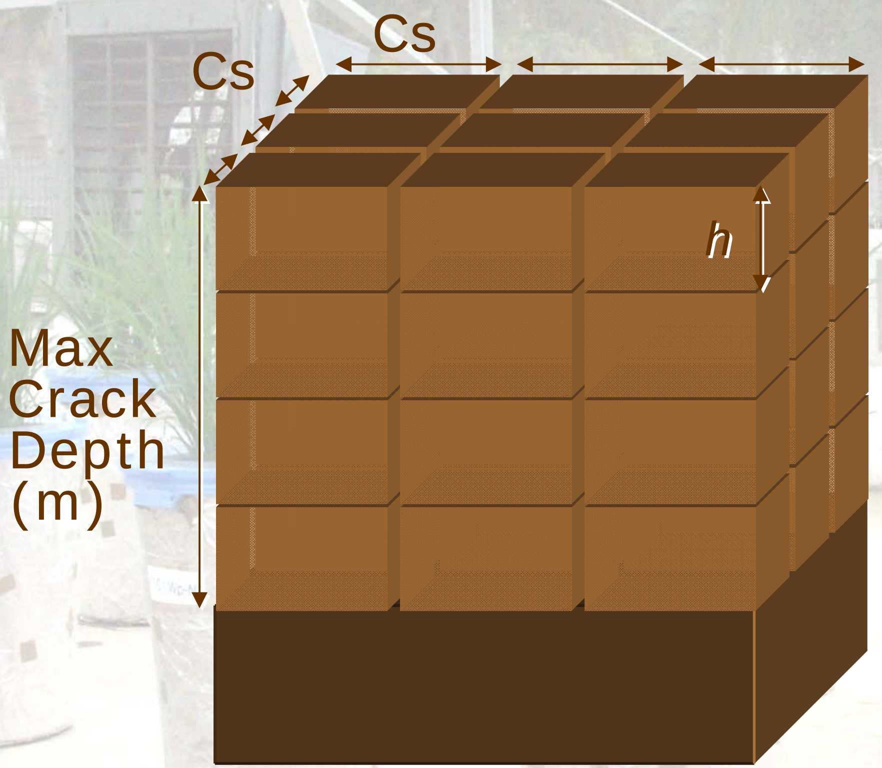
Schematic description of the soil biogeochemistry sub-model of DNDC-Rice (Fumoto et al. 2008 and 2009)

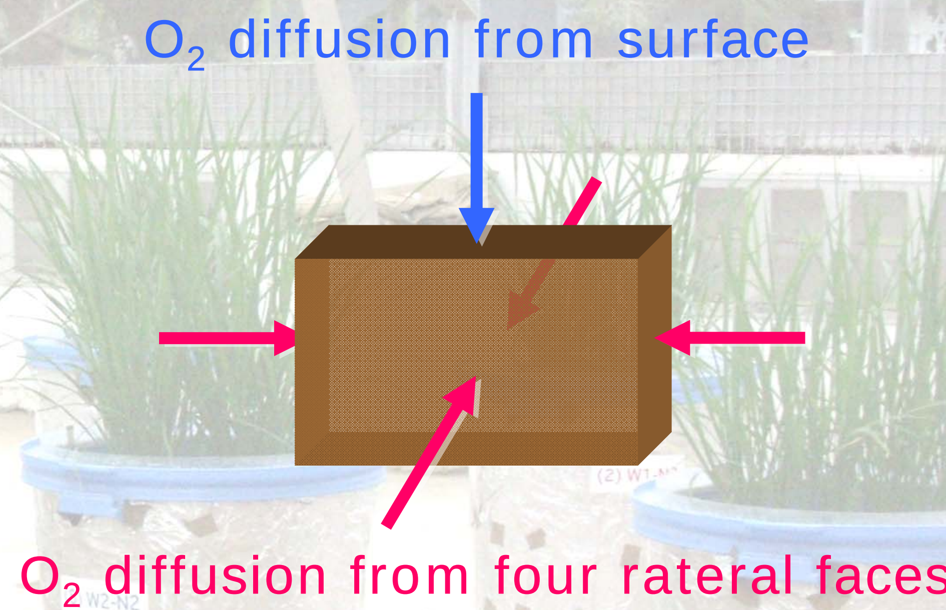
Modification



Schematic description of the soil biogeochemistry sub-model of DNDC-Rice (Fumoto et al. 2008 and 2009)

O_2 diffusion to soil





Crack_factor = 4/Cs * h

Cs: crack space (m)
h: thickness of a layer (m)

(Fumoto et al. 2008)

Gas diffusivity model – Osozawa 1987

- Osozawa (1987)

$$\boldsymbol{D_i = D_0\ \varepsilon_i^{2.7}}$$

D_i:	O_2-air diffusion coefficient in soil ($cm^2\ sec^{-1}$)
D_0:	O_2-air diffusion coefficient in air at 20℃, 1 atm (=0.201 $cm^2\ sec^{-1}$)
ε_i:	gas phase ($m^3\ m^{-3}$)

(Fumoto et al. 2008 and 2009)

Gas diffusivity model – BBC model

- Backingham-Burdine-Campbell (BBC) model (Moldrup et al. 1999, Rolston and Moldrup 2002)

$$\boldsymbol{D_i = D_{0,T}\, \phi_i^{2} \,(\phi_i / \varepsilon_i)^{2+3/b}}$$

$$\boldsymbol{D_{0,T} = D_{0,20}\,((273+T)/(273+20))^{1.72}}$$

$$\boldsymbol{b = 13.6\ \text{clay} + 3.5}$$

D_i:	O_2-air diffusion coefficient in soil ($cm^2\ sec^{-1}$)
$D_{0,\,T}$:	O_2-air diffusion coefficient in air at T ℃, 1 atm ($cm^2\ sec^{-1}$)
$D_{0,\,20}$:	O_2-air diffusion coefficient in air at 20 ℃, 1 atm (=0.201 $cm^2\ sec^{-1}$)
ϕ_i:	porosity ($m^3\ m^{-3}$)
ε_i:	gas phase ($m^3\ m^{-3}$)
b:	campbell pore-size distribution parameter

Other changes

- Decomposition factor (DRF) was changed from 0.82 to 0.2.
- Water table estimation
  - Water table was estimated using simulated WFPS values of each 2cm depth soil.
    - **Assumption1:**
      water content ≧ 0.94 → saturated
      water content < 0.94 → unsaturated
    - **Assumption2:**
      There is the water table at the top layer of the saturated layers.

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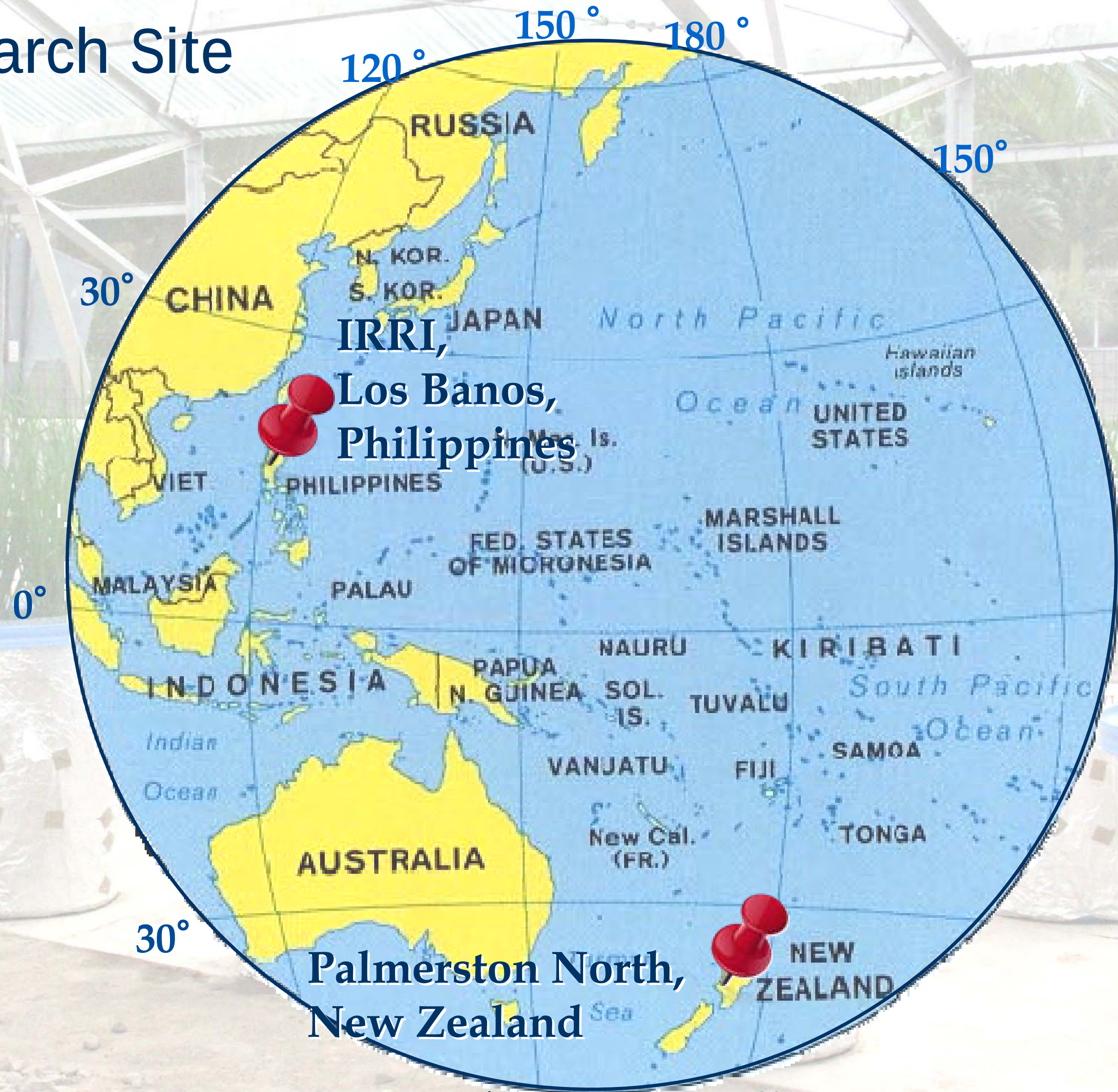
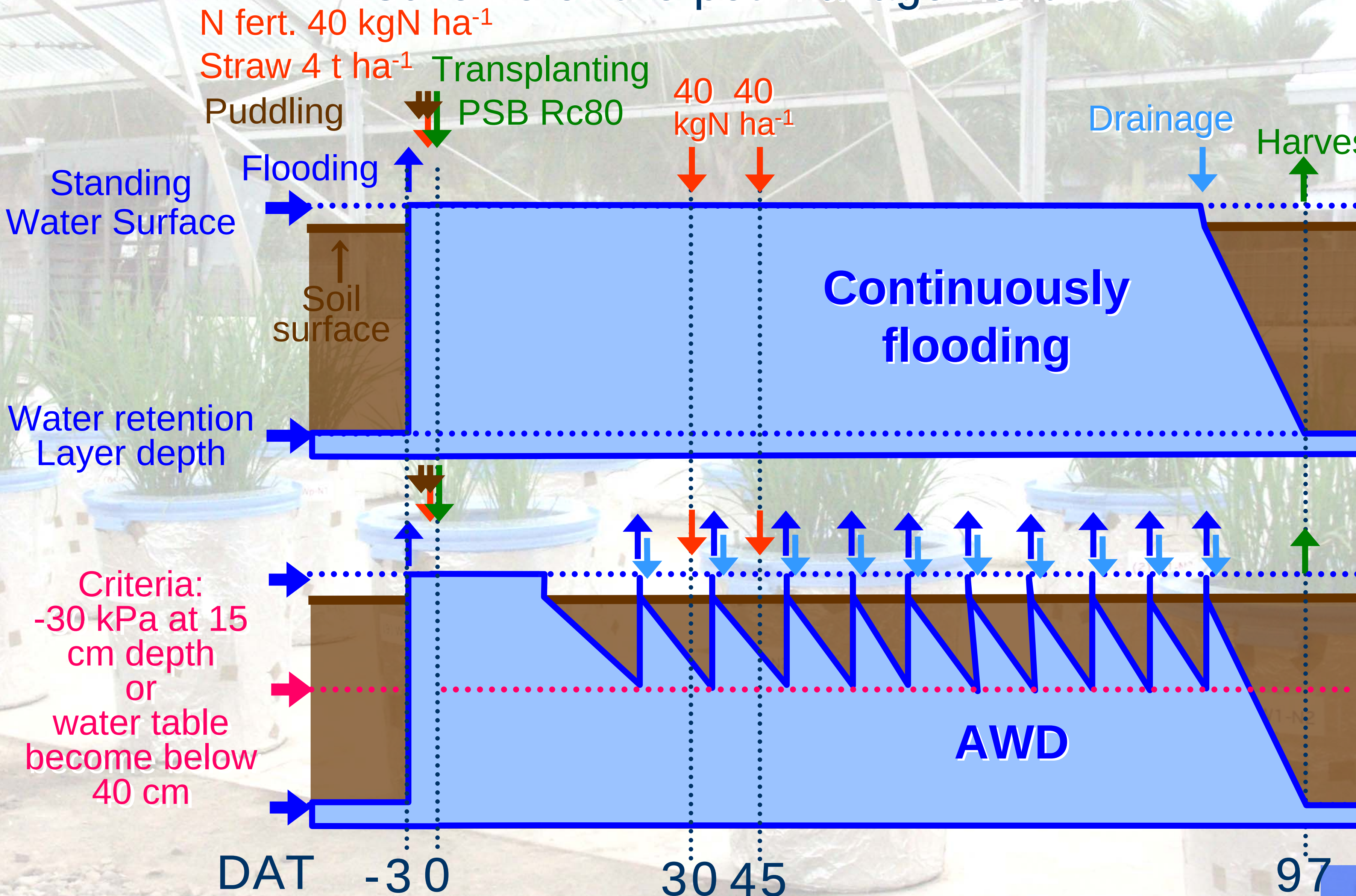
Research Site

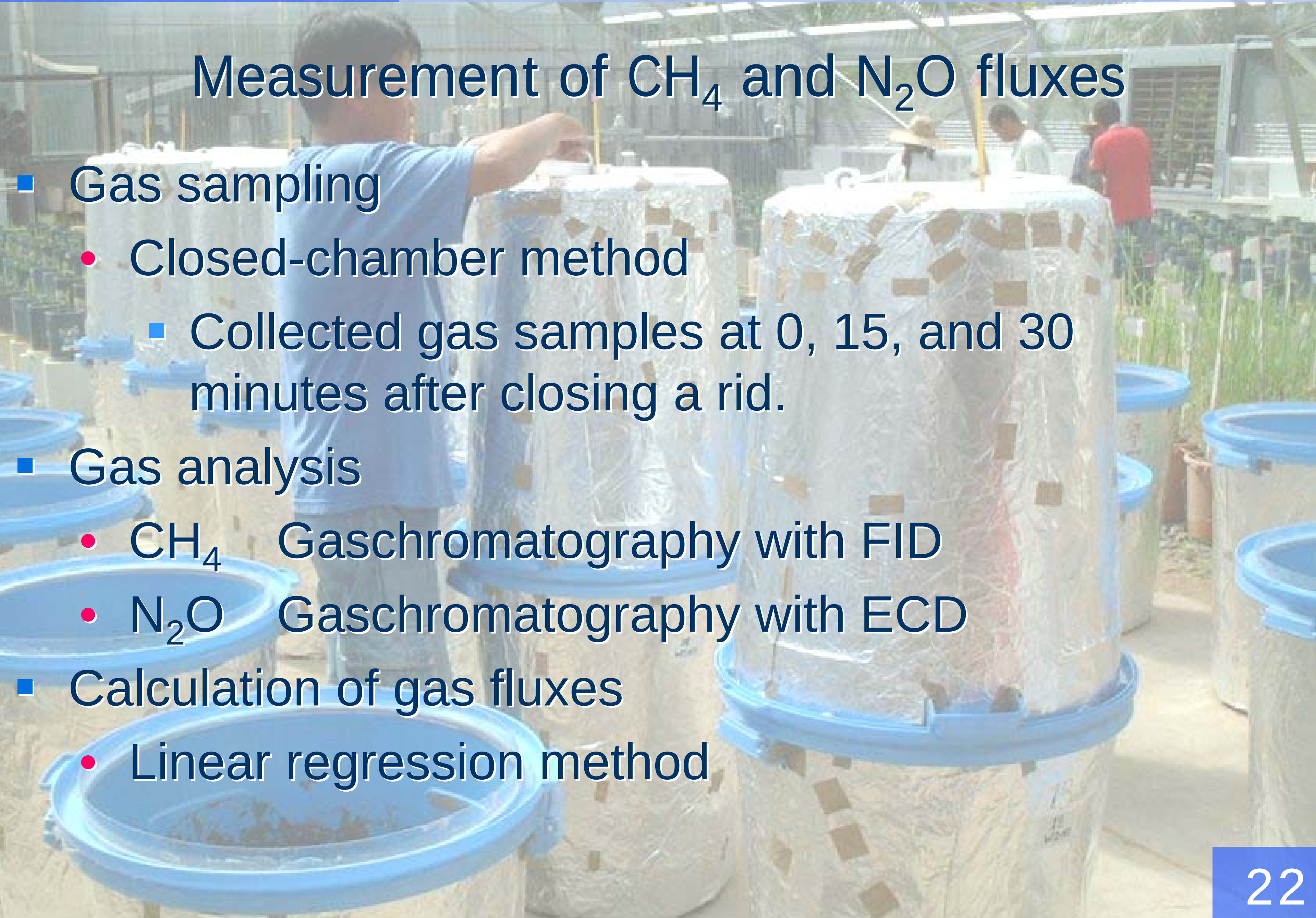


A pot experiment conducted in a screenhouse, IRRI

- **Size of the pot**
  700 mm height and 530 mm i.d.
- **Bulk density (0-15 cm)**
  0.82±0.53(Mg m^{-3})
- **Percolation rate** 1 (mm day^{-1})
- **Clay content** 59%
- **Soil organic C cont.** 2.4%
- **Soil pH** 6.2
- **Soil texture** Clay
- **Field water capacity** 0.8 (WFPS)
- **Wilting point** 0.4(WFPS)

Scheme of the pot management





Measurement of CH_4 and N_2O fluxes

- Gas sampling
  - Closed-chamber method
    - Collected gas samples at 0, 15, and 30 minutes after closing a rid.
- Gas analysis
  - CH_4 Gaschromatography with FID
  - N_2O Gaschromatography with ECD
- Calculation of gas fluxes
  - Linear regression method

Meteorological data

- Site: IRRI wetland
  - Daily maximum temperature
  - Daily minimum temperature
  - Solar radiation

  ※Precipitation was assumed zero because the measurement was conducted in a screenhouse.

Statictics

- Root Mean Square Error (RMSE)

$$RMSE = \sqrt{\frac{\sum (F_i - A_i)^2}{N}}$$

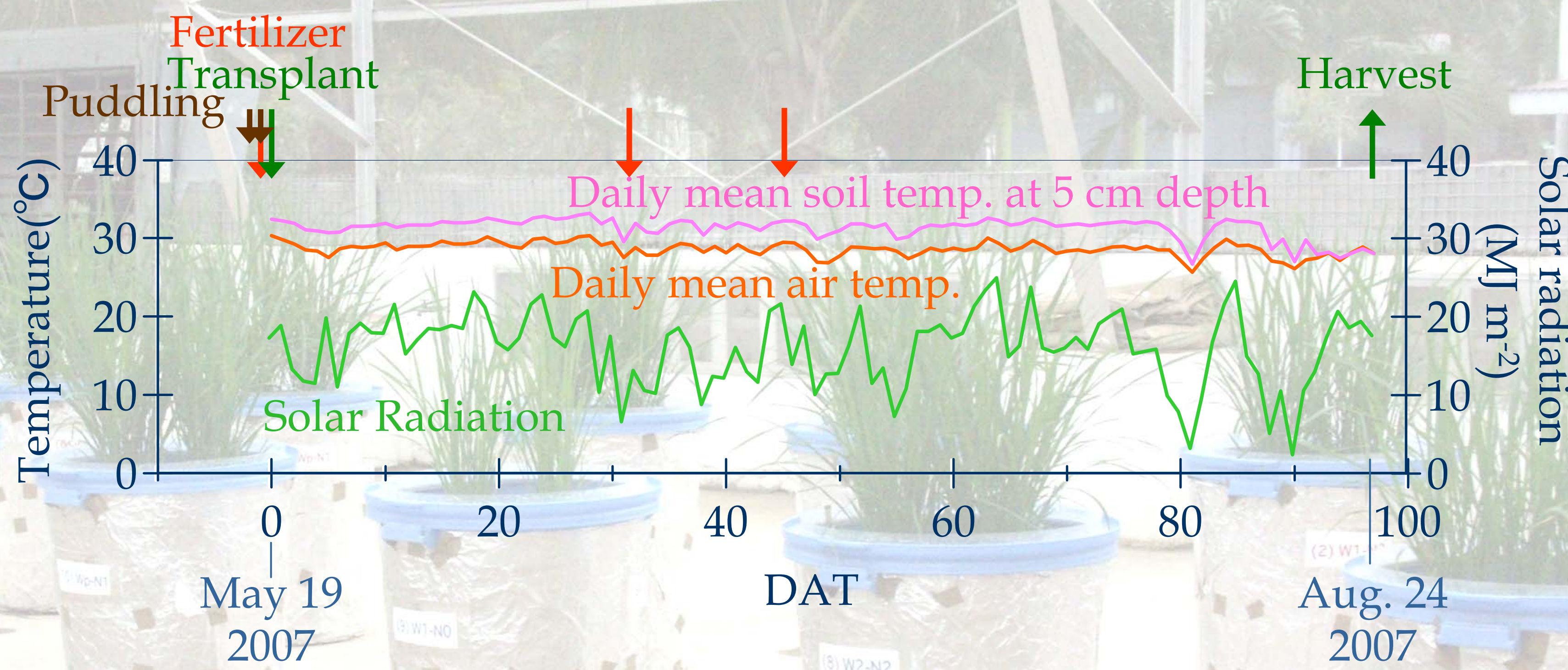
A_m: mean value of observed values

F_i: Simulated value

A_i: Observed value

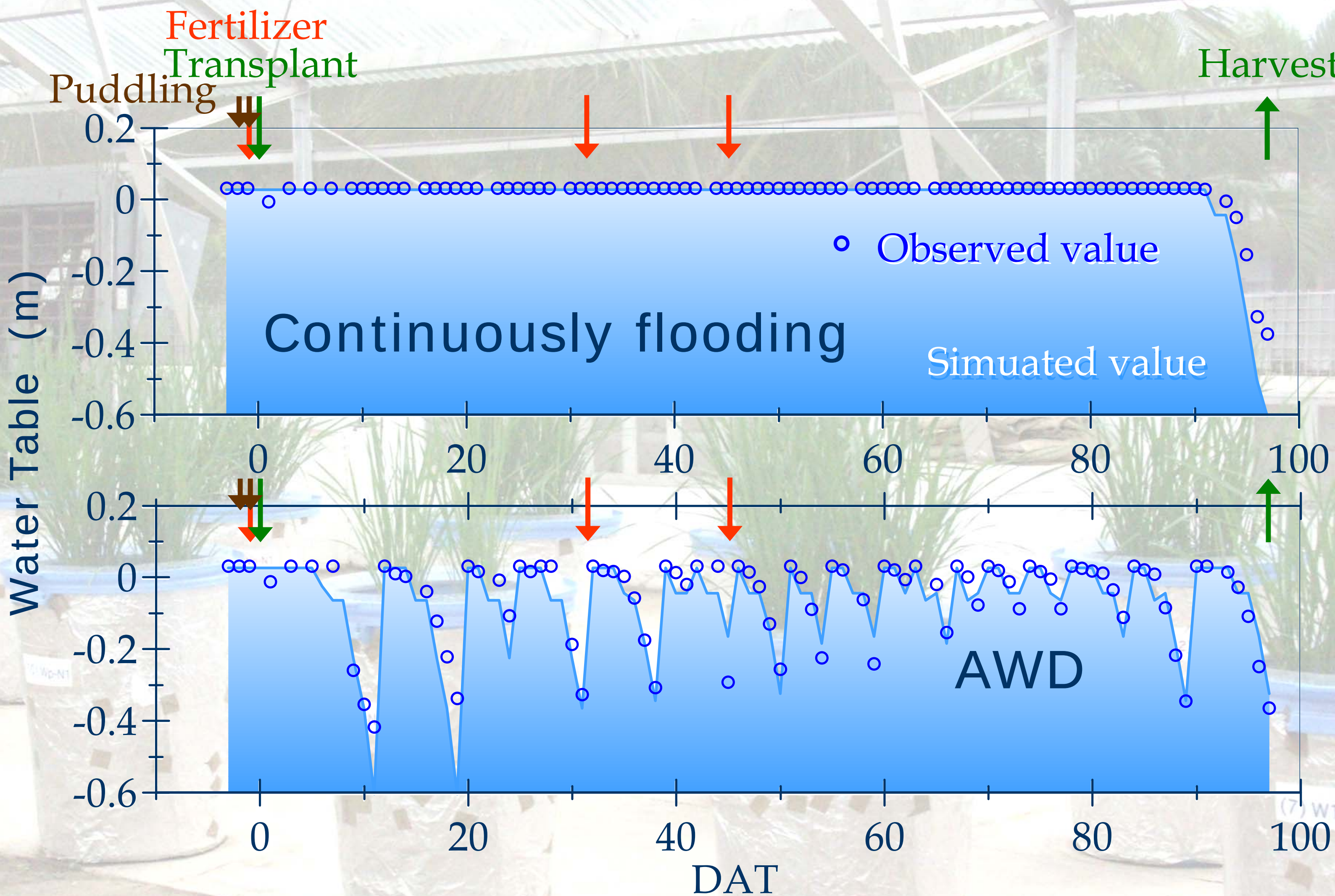
N: Number of sample

Validation

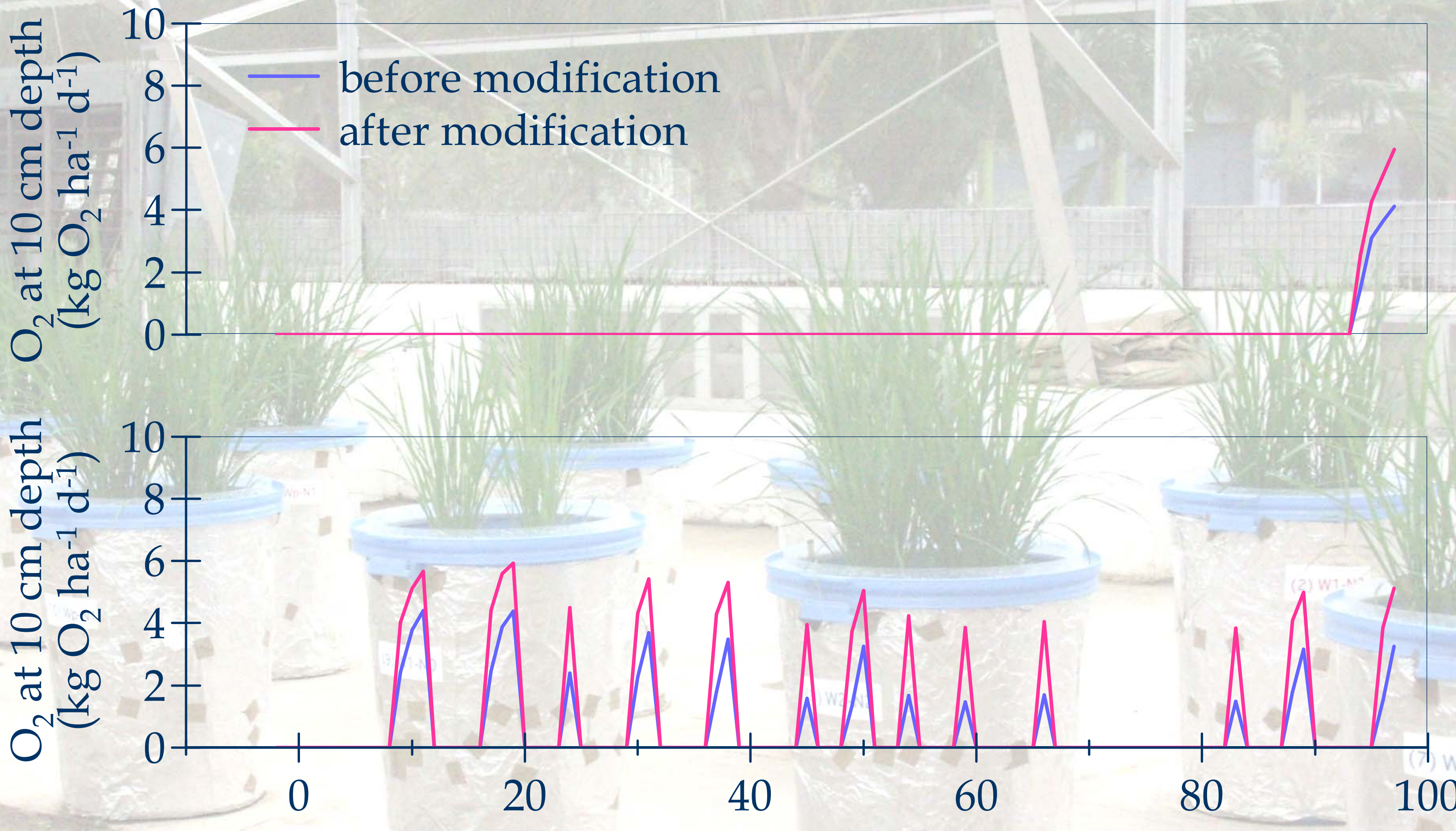


Observed daily maximum and minimum temperature and solar radiation during the cropping period

Validation

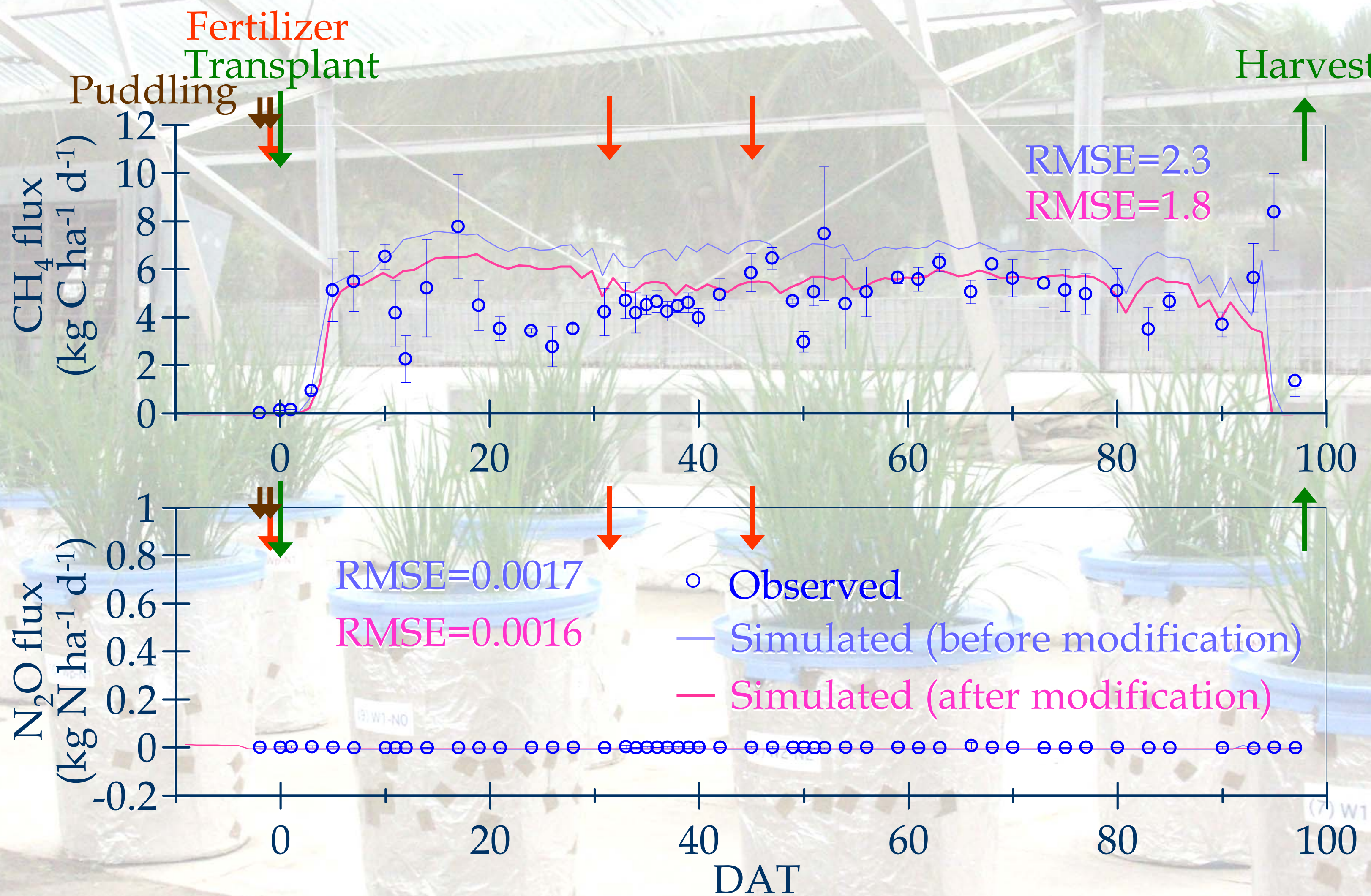


Observed and simulated water table for continuously flooding and AWD

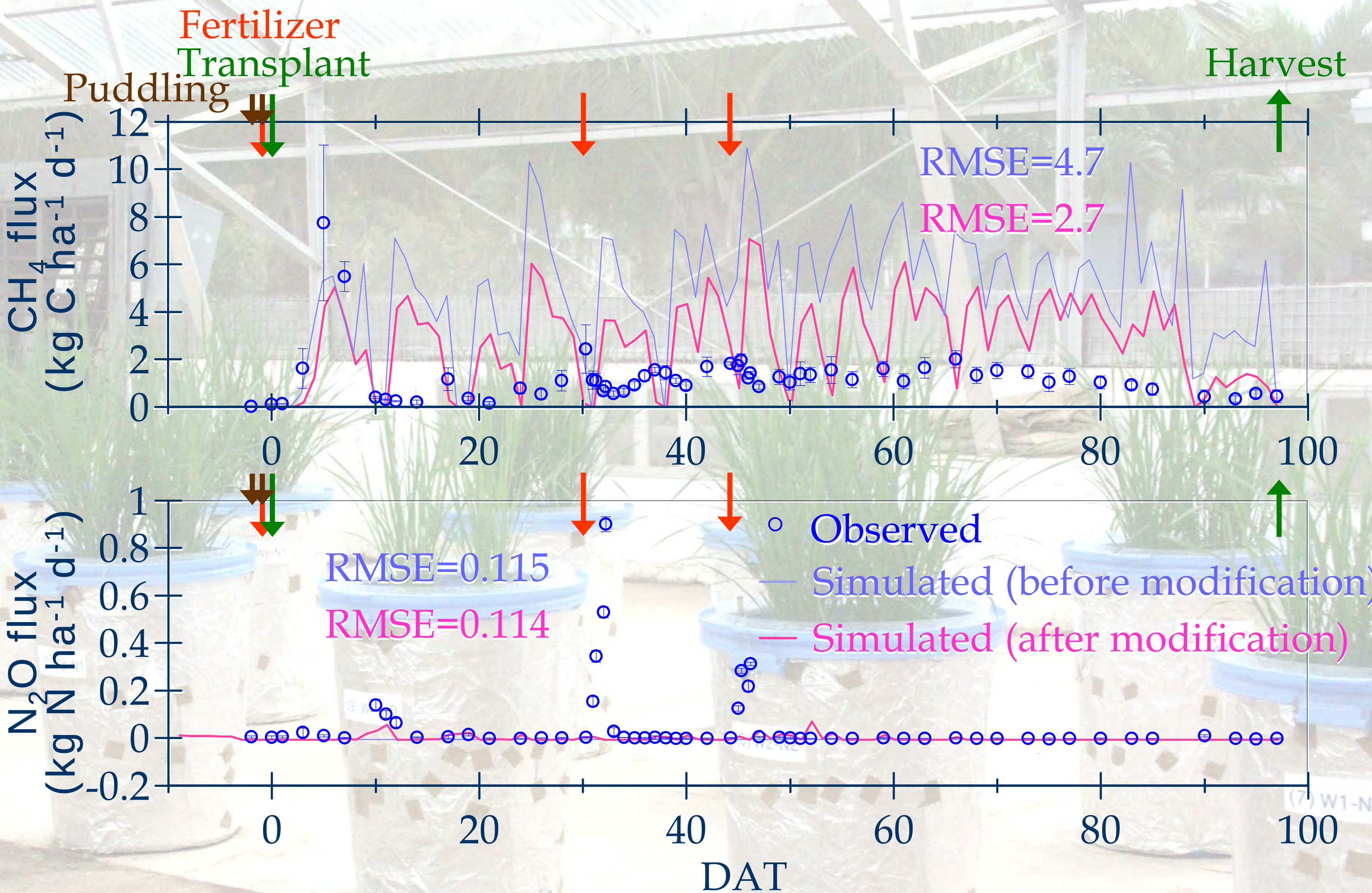


Simulated daily O_2 content at 10 cm depth soil under continuously flooding and AWD management fields.

Validation



Observed and simulated daily CH_4 and N_2O fluxes under continuously flooding (DRF=0.2)



Observed and simulated daily CH_4 and N_2O fluxes under AWD irrigation

Validation

Observed and simulated CH_4 and N_2O emission rates of paddy fields under continuously flooding and AWD during the cropping period

	Observed value (mean , SE)		Modification Before	Modification After
CH_4 emission (kg C ha^{-1})				
Continuously flooding	462	15.7	602	498
AWD	125	9.3	475	278
N_2O emission (kg N ha^{-1})				
Continuously flooding	0.00435	0.0416	0.0223	0.00930
AWD	2.046	0.0470	0.0314	0.604

Summary

Modification of calculation method for O_2 diffusion improved accuracy of simulation results of CH_4 and N_2O fluxes, even though more improvement must be added.

Plan

We are going to make more modification to the model using monitoring data collected in field.

Thank you for listeing !