Interpreting Changes in Soil Quality and Root Health in the SRI

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Recent Changes in Rice Production and Rural Livelihoods - An International Workshop

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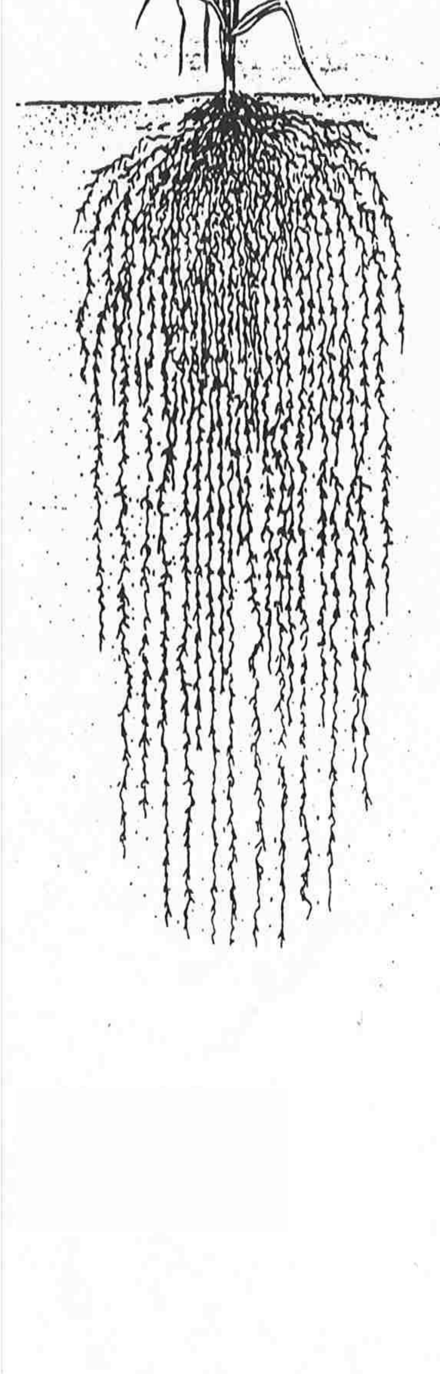
Outline

- Belowground Soil Processes
  - - redox-related nutrient issues
  - - oxygen-related pathogen issues
- Diagnostic tools to assess the etiology of soil health issues
- Research and training needs



Belowground Processes

- Organic matter turnover
- Plant nutrient supply
- Nutrient sequestration
- Nutrient acquisition
  - BNF and mycorrhizae
- Nutrient cycling
- Root pests and diseases
- Greenhouse gas release
- Toxicity, pollutants
- Genetic diversity

www-plb.ucdavis.edu/labs/rost/Rice/ricehome.html

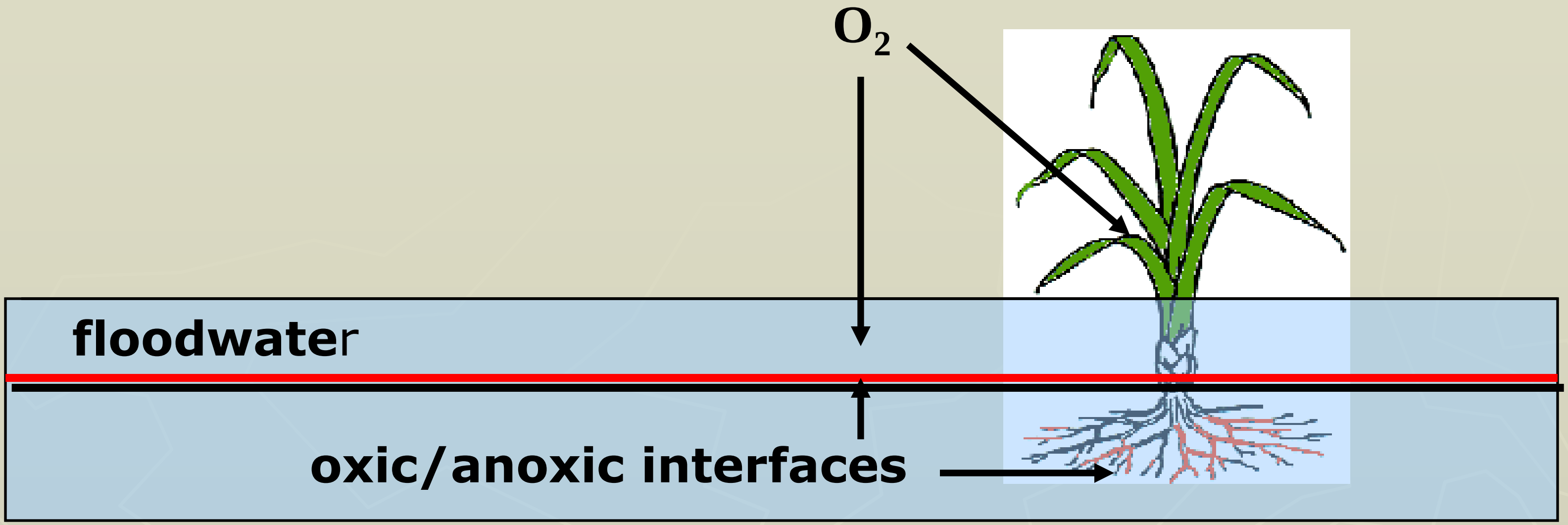
http://www.da.gov.ph/12%20Steps/12steps/rice3.jpg

Shift to more aerobic systems

Changes soil biogeochemistry

- Soil redox potential
- O_2, CO_2, CH_4
- Availability & forms of
  - P, Al, Fe, Ca
  - Zn, Mn
  - C, N and S
- Root traits and exudates (carbon)

Changes in redox change nutrient availability



Oxidized (root side)		Reduced (soil side)	
O_2	$\longrightarrow$	H_2O	
NO_3^-	$\longleftrightarrow$	NH_4^+, N_2	In anoxic soil and soluble
↓ Fe(III)	$\longleftrightarrow$	Fe(II)	
SO_4^{2-}	$\longleftrightarrow$	H_2S	
CO_2	$\longleftrightarrow$	CH_4	

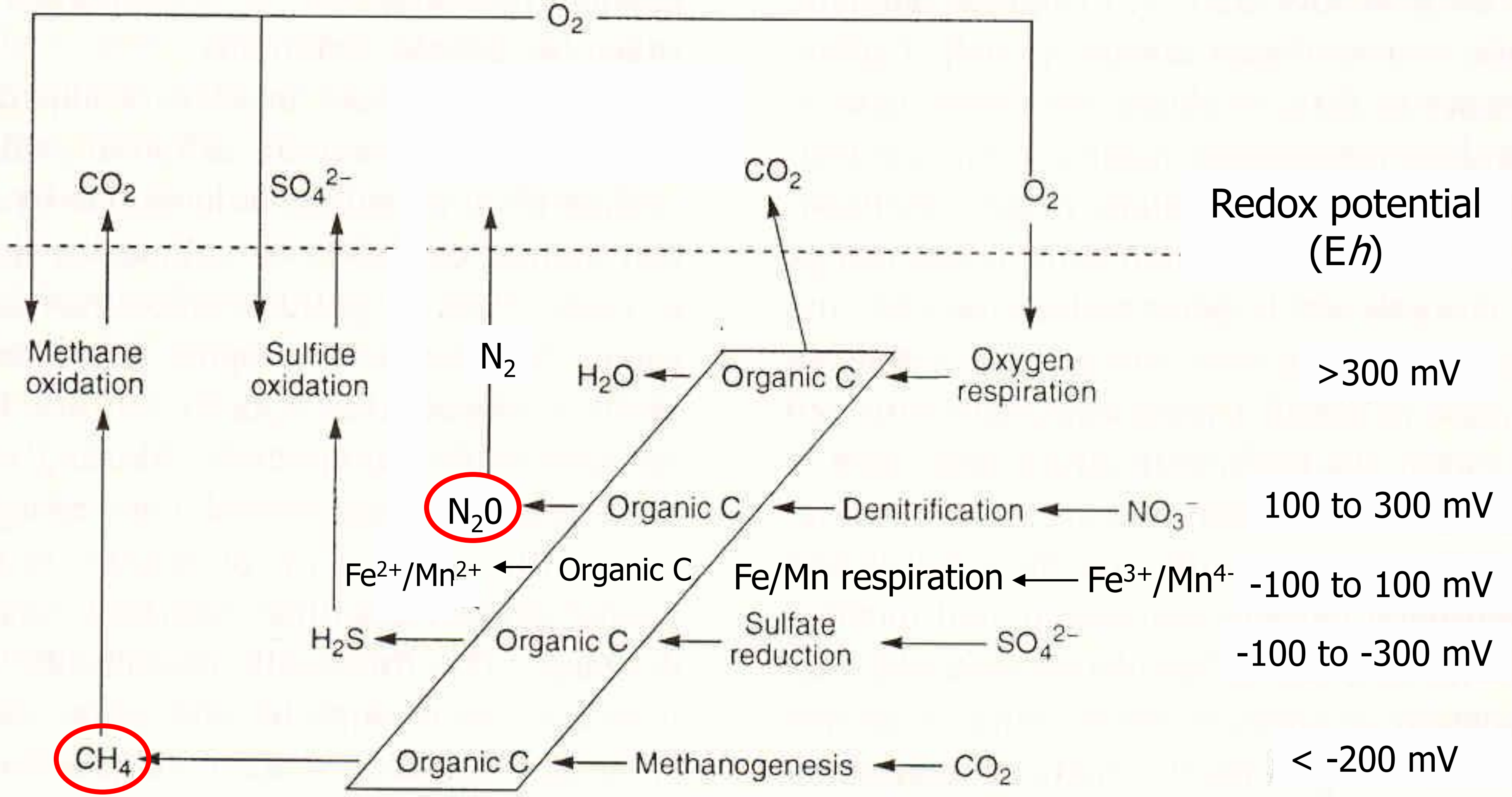
In rhizosphere as a precipitate (brackets NO_3^-, Fe(III), SO_4^{2-})

In anoxic soil and soluble (brackets NH_4^+, N_2, Fe(II), H_2S)

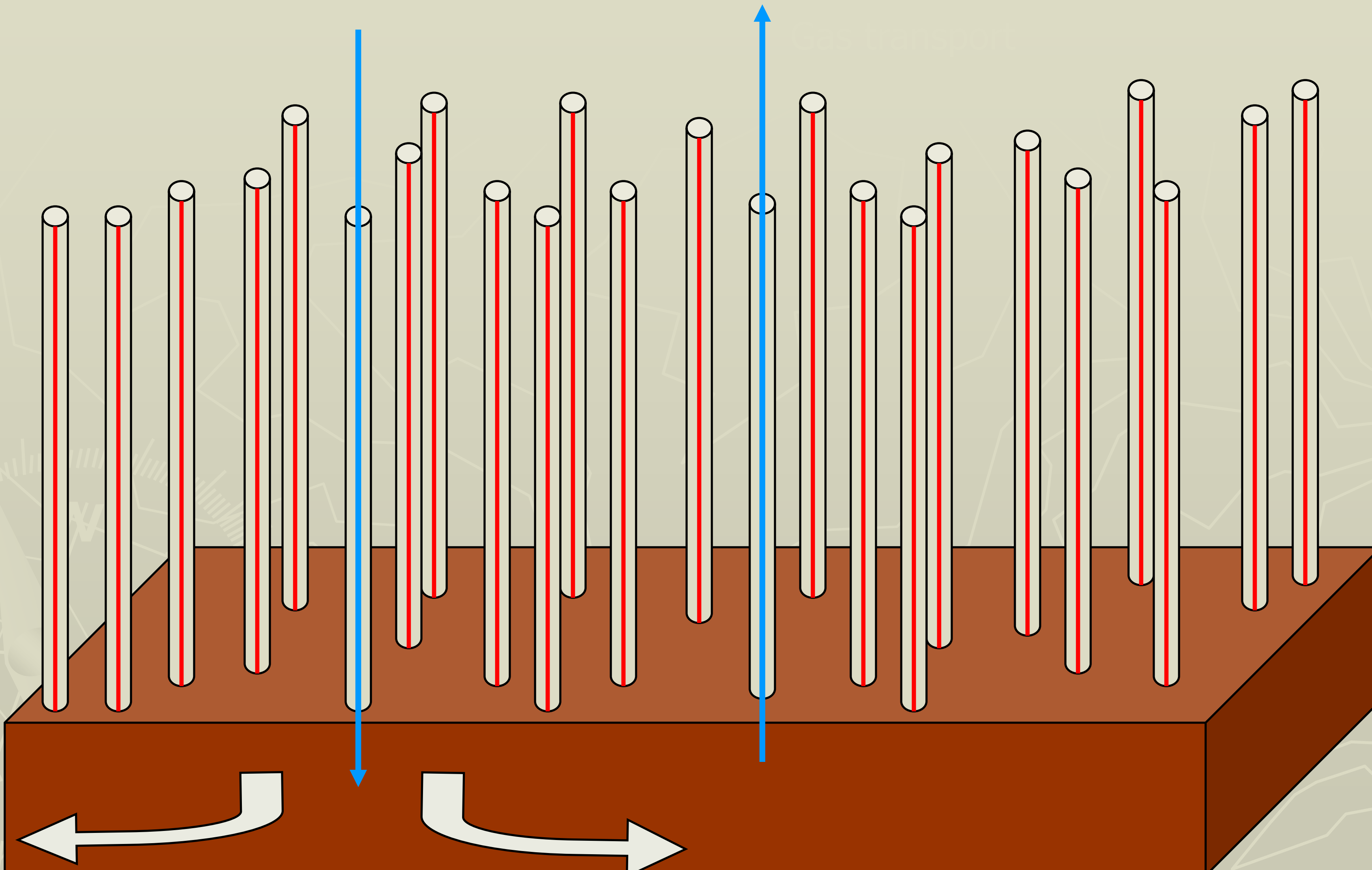
Megonigal, Emerson, Weiss and Neubauer

Anaerobic Respiration

fate of nutrient elements

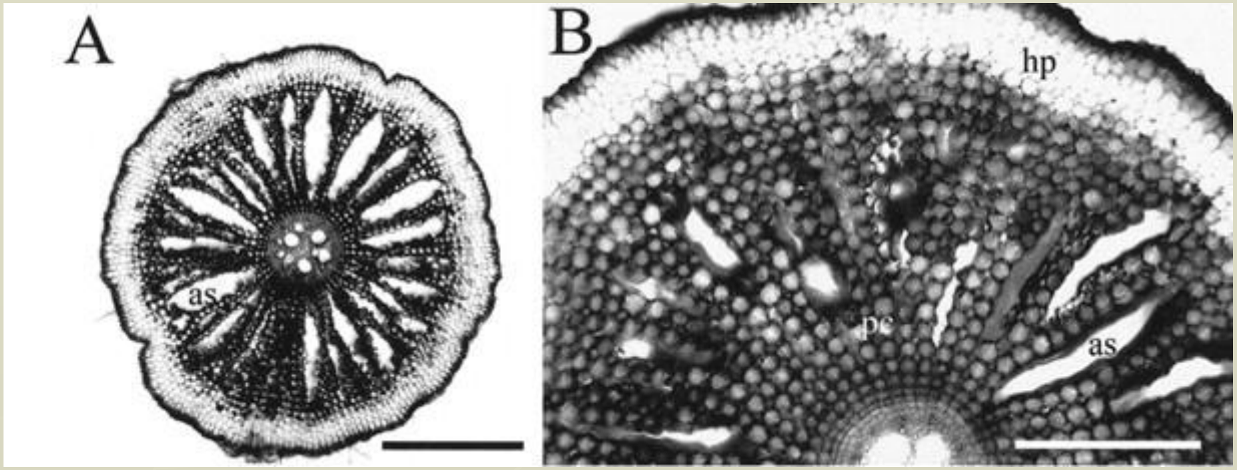


Wetland Plants – Straw Model

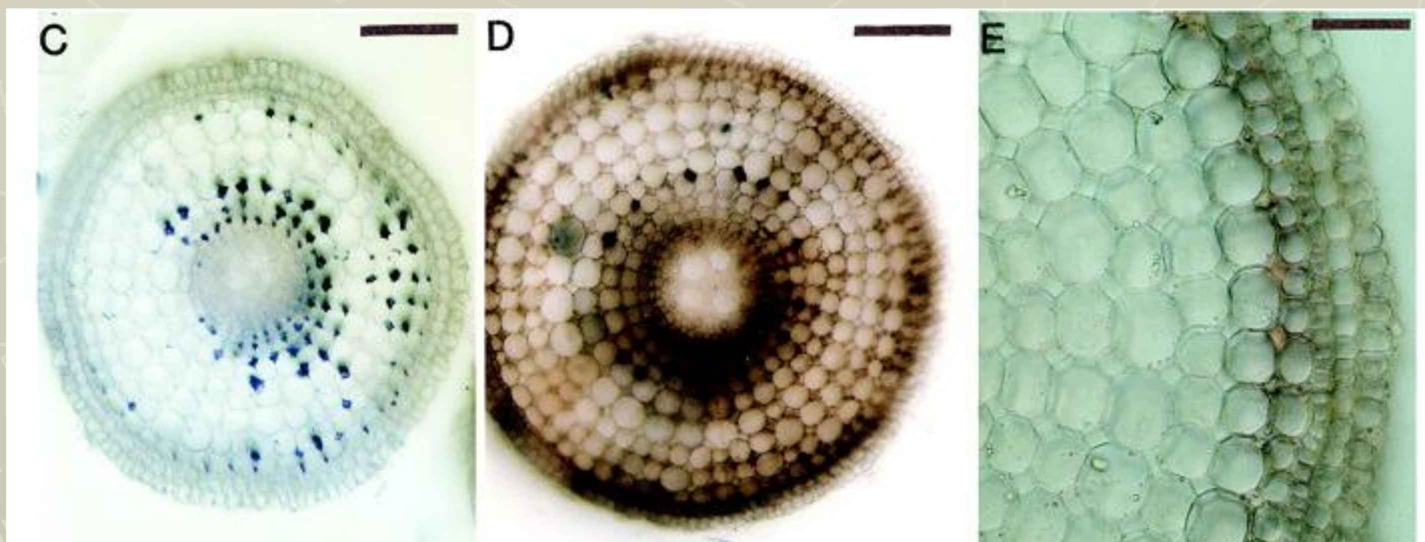


Oxygenation of the Rhizosphere

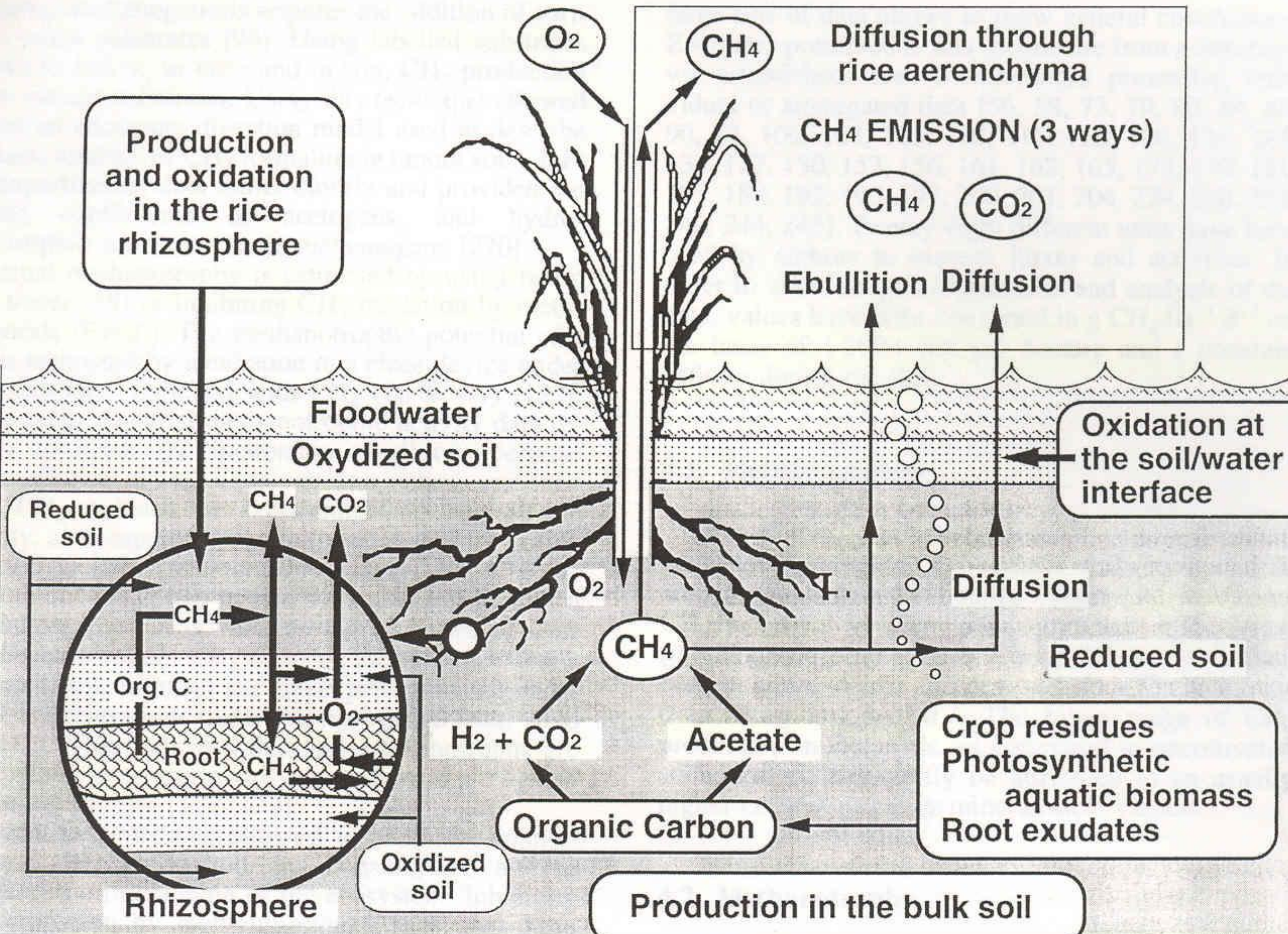
Ben Wolfe



Transverse sections of aerenchymatous roots of *Typha* sp.
(From Abad et al. 2000, Am. J. of Bot.)



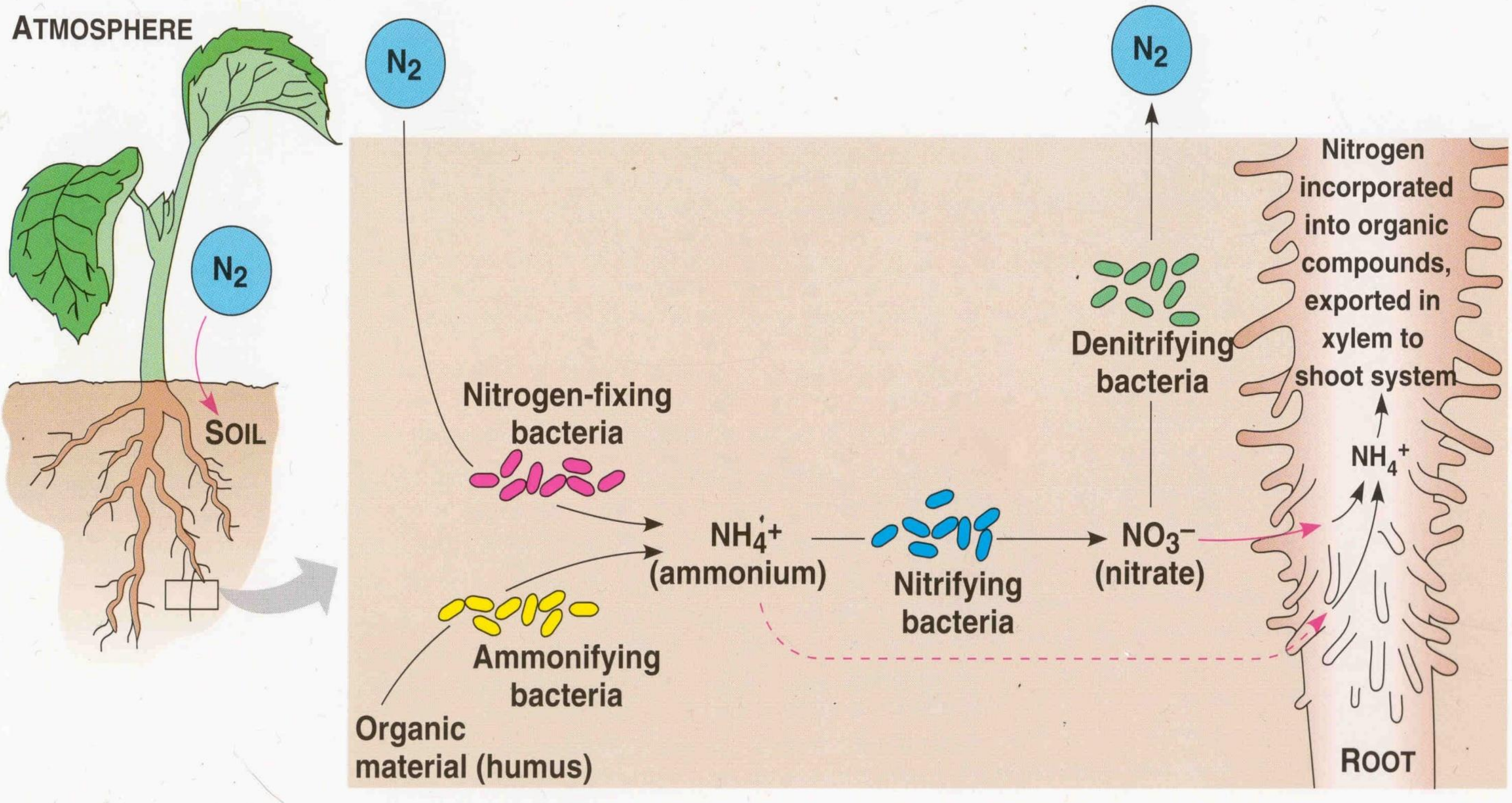
Transverse sections of aerenchymatous root tissue of rice
(From Alexander and Alexander 2001, Am. J. of Bot.)


O2
CH4
Diffusion through
rice aerenchyma
CH4 EMISSION (3 ways)
CH4
CO2
Ebullition
Diffusion
Production
and oxidation
in the rice
rhizosphere
Floodwater
Oxydized soil
Oxidation at
the soil/water
interface
Reduced
soil
CH4
CO2
CH4
O2
Diffusion
Org. C
O2
Root
CH4
CH4
Reduced soil
H2 + CO2
Acetate
Crop residues
Photosynthetic
aquatic biomass
Root exudates
Organic Carbon
Oxidized
soil
Rhizosphere
Production in the bulk soil

Methanogenesis – why care?

- High radiative absorbtion capacity
  - CH_4 (1.7 ppm) = 20-30 x that of CO_2 (365 ppm)
  - N_2O (0.3 ppm) = 150 x that of CO_2
- Chemically reactive

N cycling processes mediated by bacteria

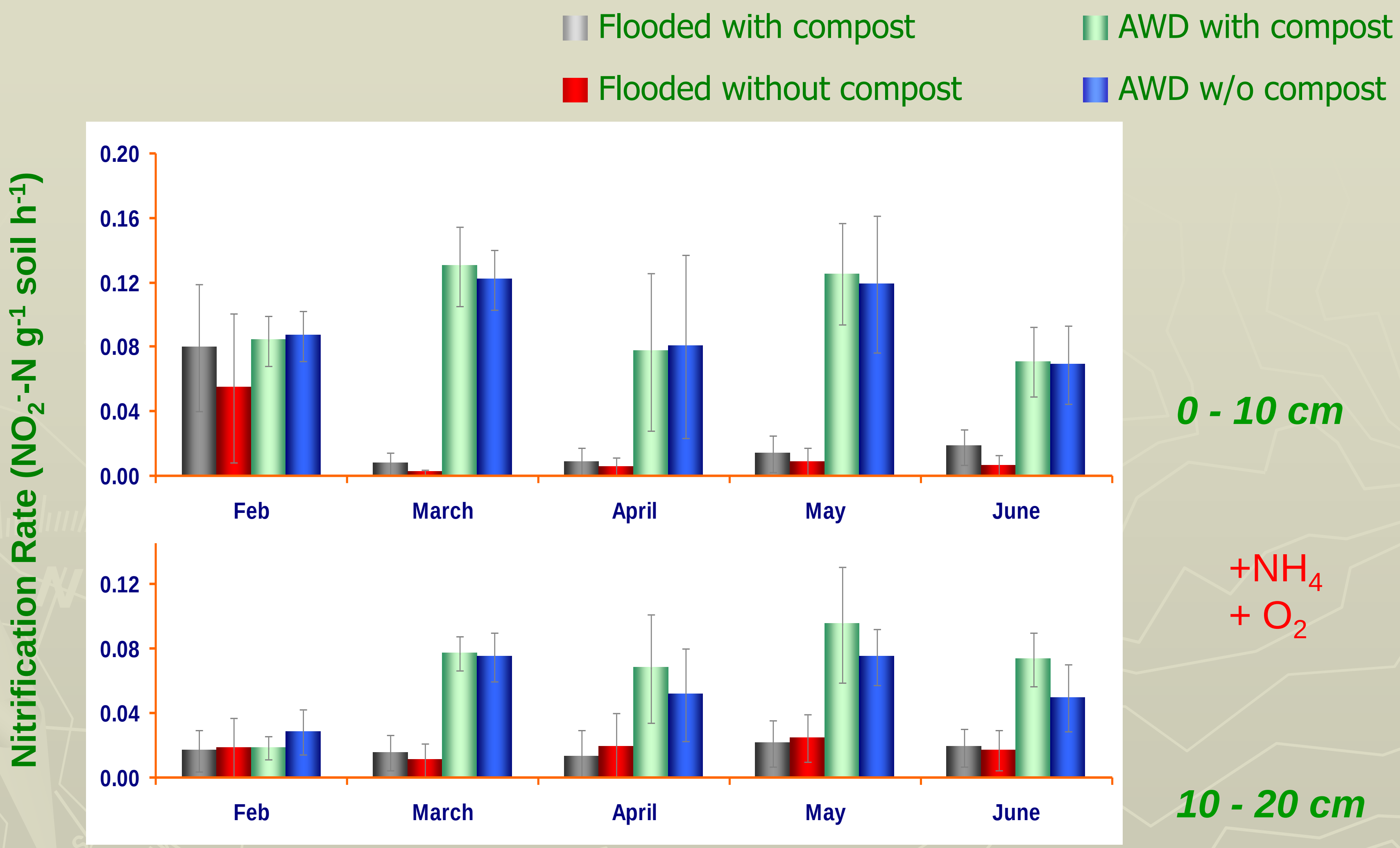


AWD Experiment

Multiple Cropping Center (MCC)
Chiang Mai, Thailand

Thanwalee Sooksa-nguan
Neung Teaumroong – Suranaree Univ.
Janice Thies – Cornell University
Phrek Gypmantasiri – Chaing Mai Univ.

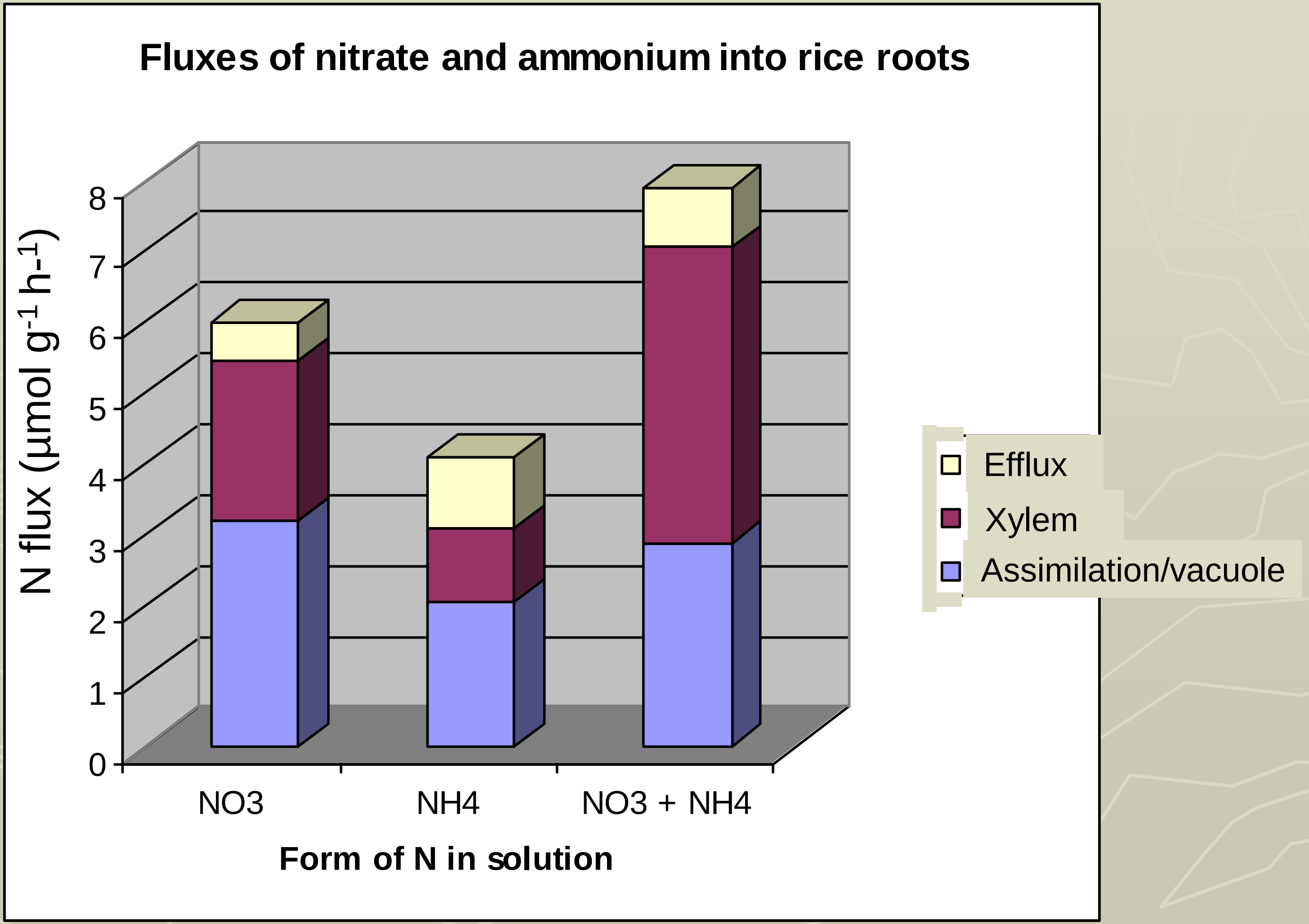
Short-term Nitrification potential



- **Nitrification potential was significantly higher in AWD treatments**
- **Nitrification potential was significantly higher in surface soils**

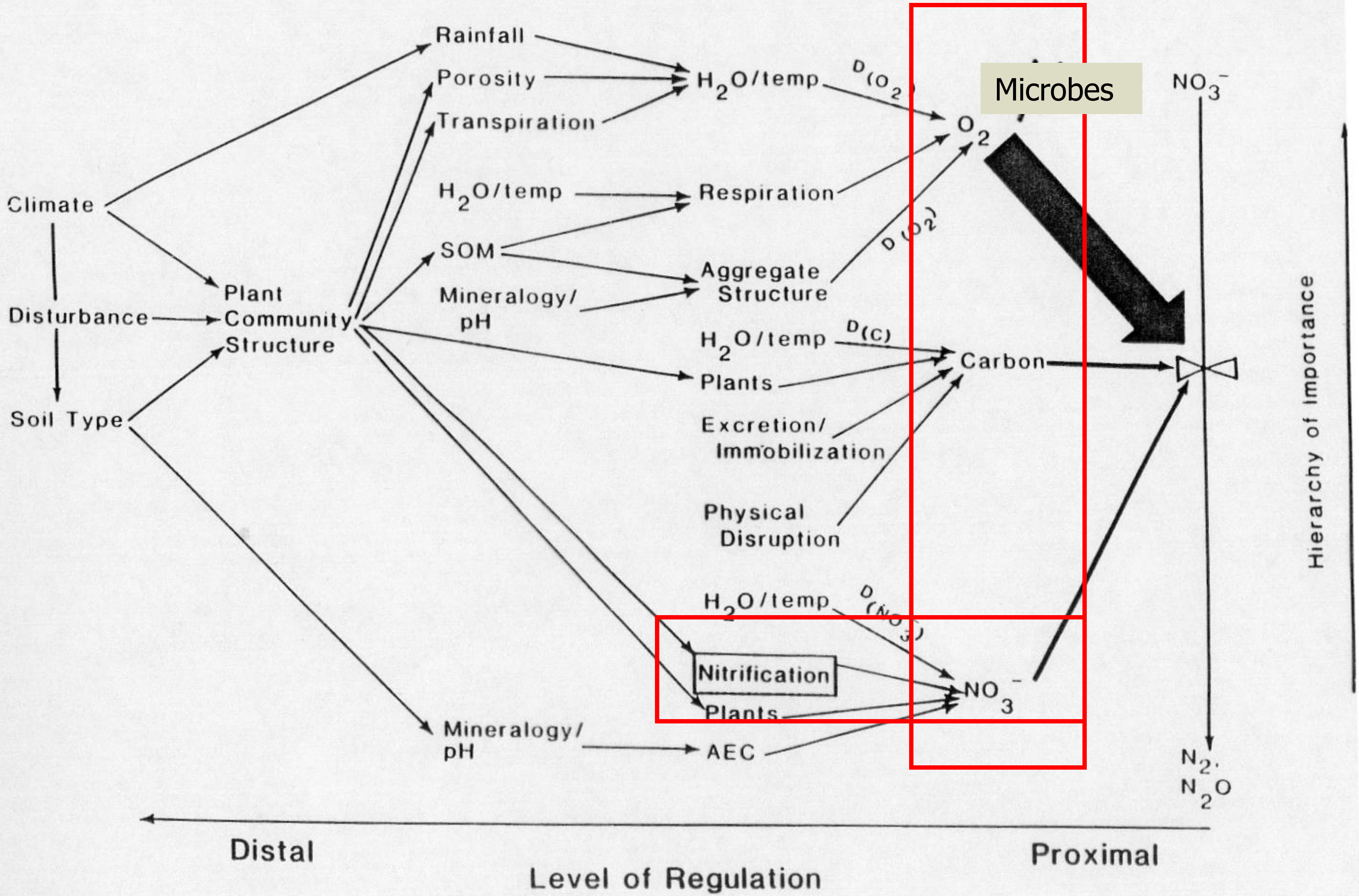
T. Sooksanguan et al.

Form of Inorganic N – Does it matter?

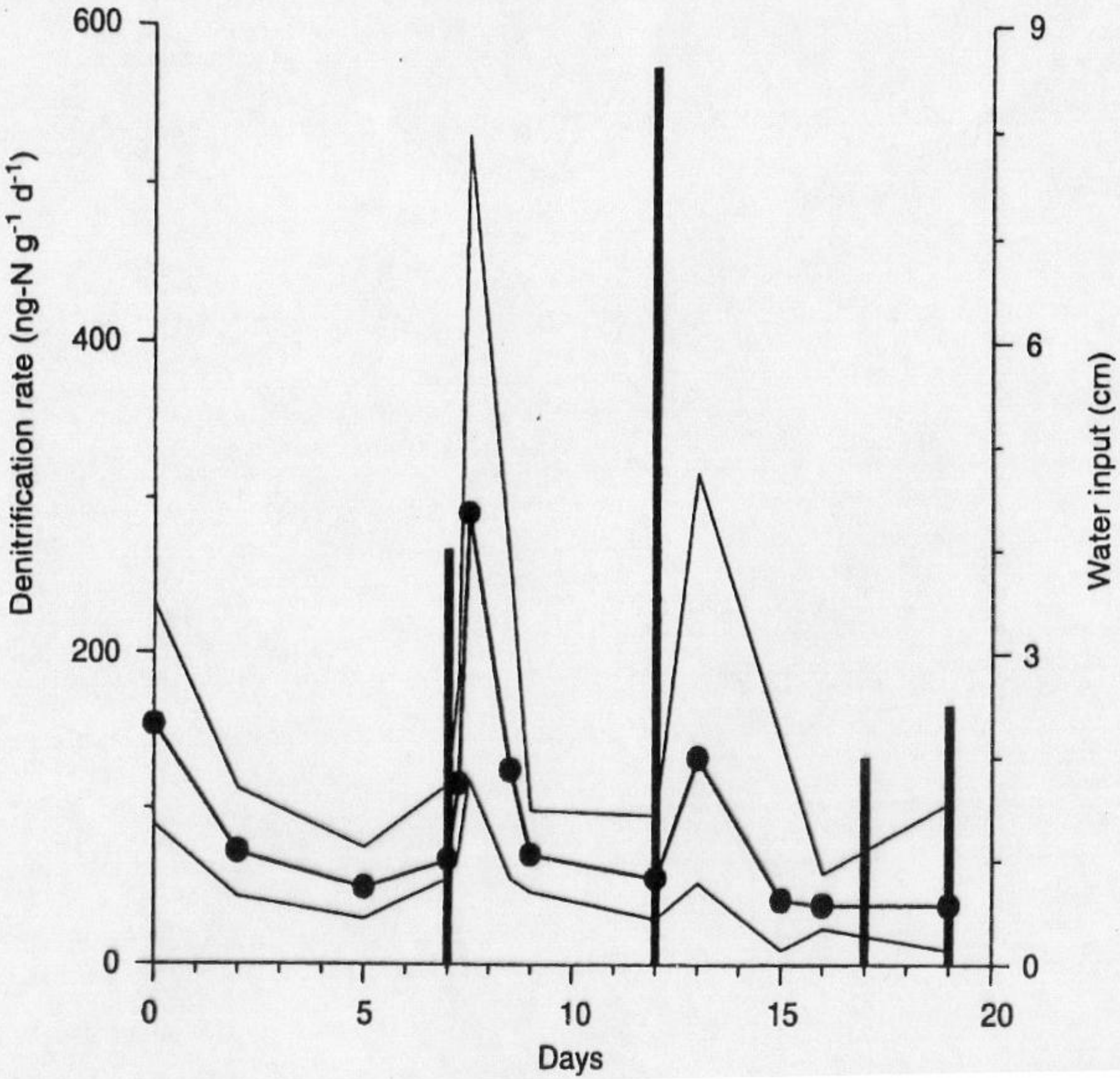


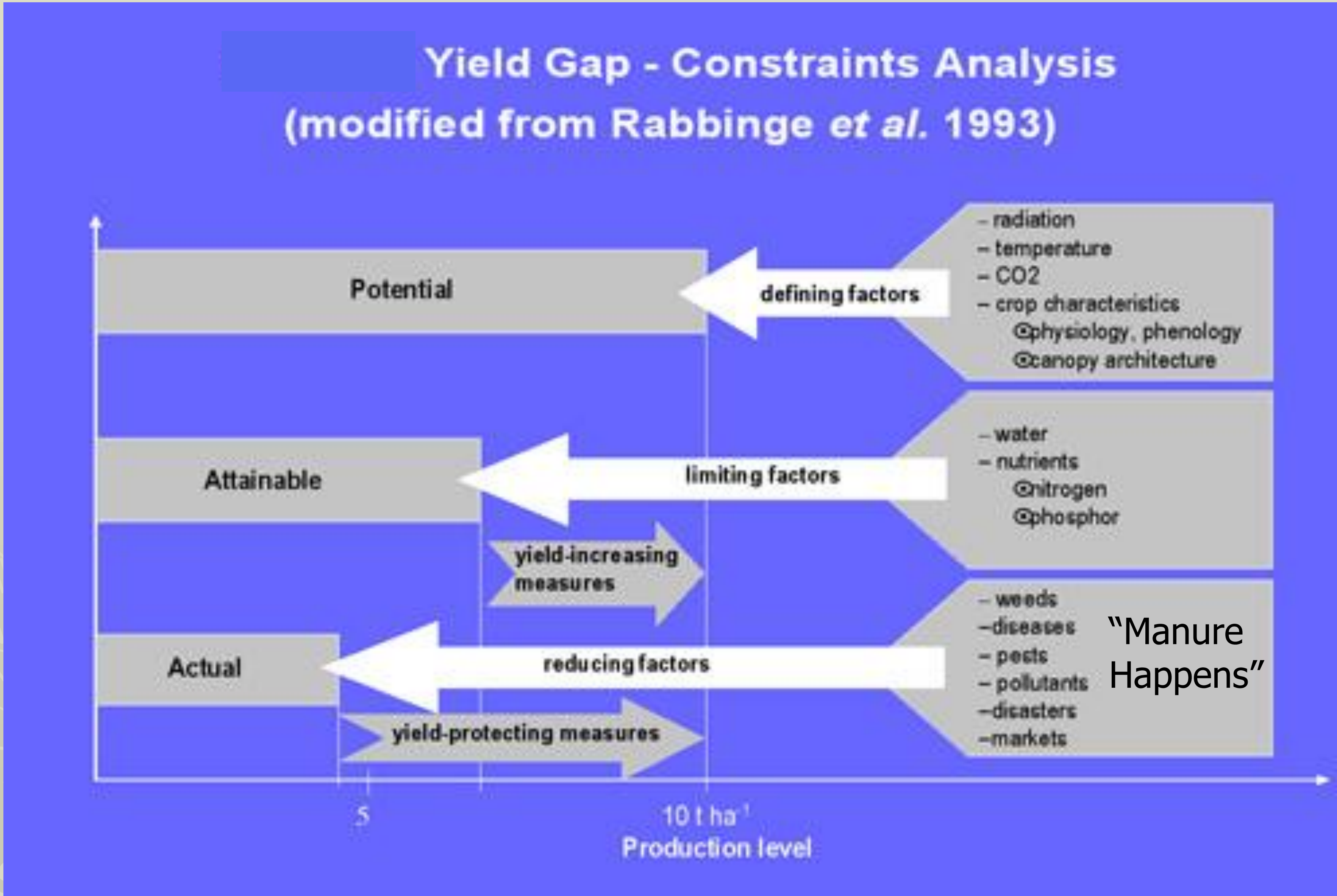
Kirk and Kronzucker, 2000

Controls on Denitrification

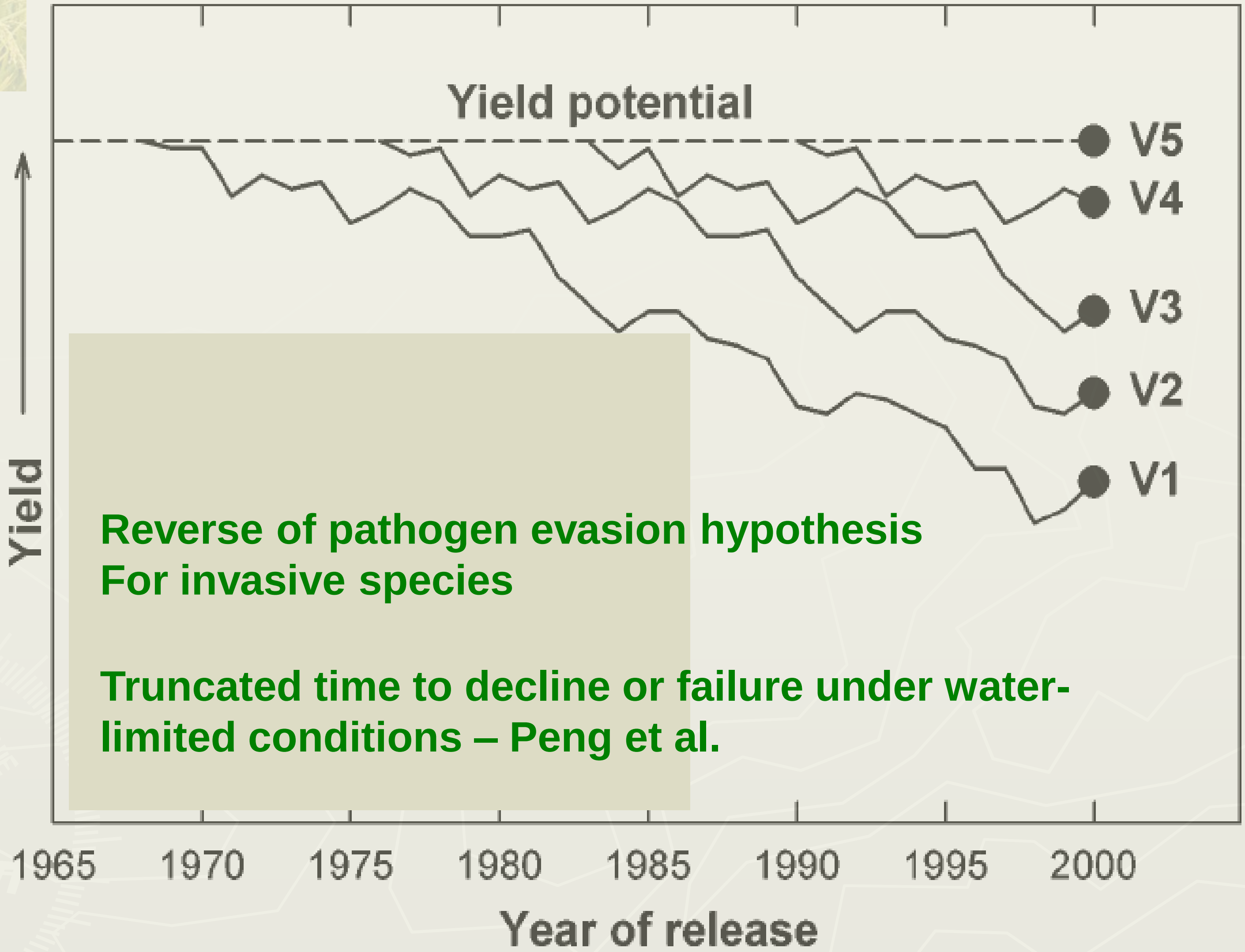


Spatial Variability of Denitrification. Denitrification is notorious for being highly variable in time and space. Denitrification rates can vary more than 100-fold from one day to the next.





http://epress.anu.edu.au/narayanan/html/ch09_fig3.jpg



Reverse of pathogen evasion hypothesis
For invasive species

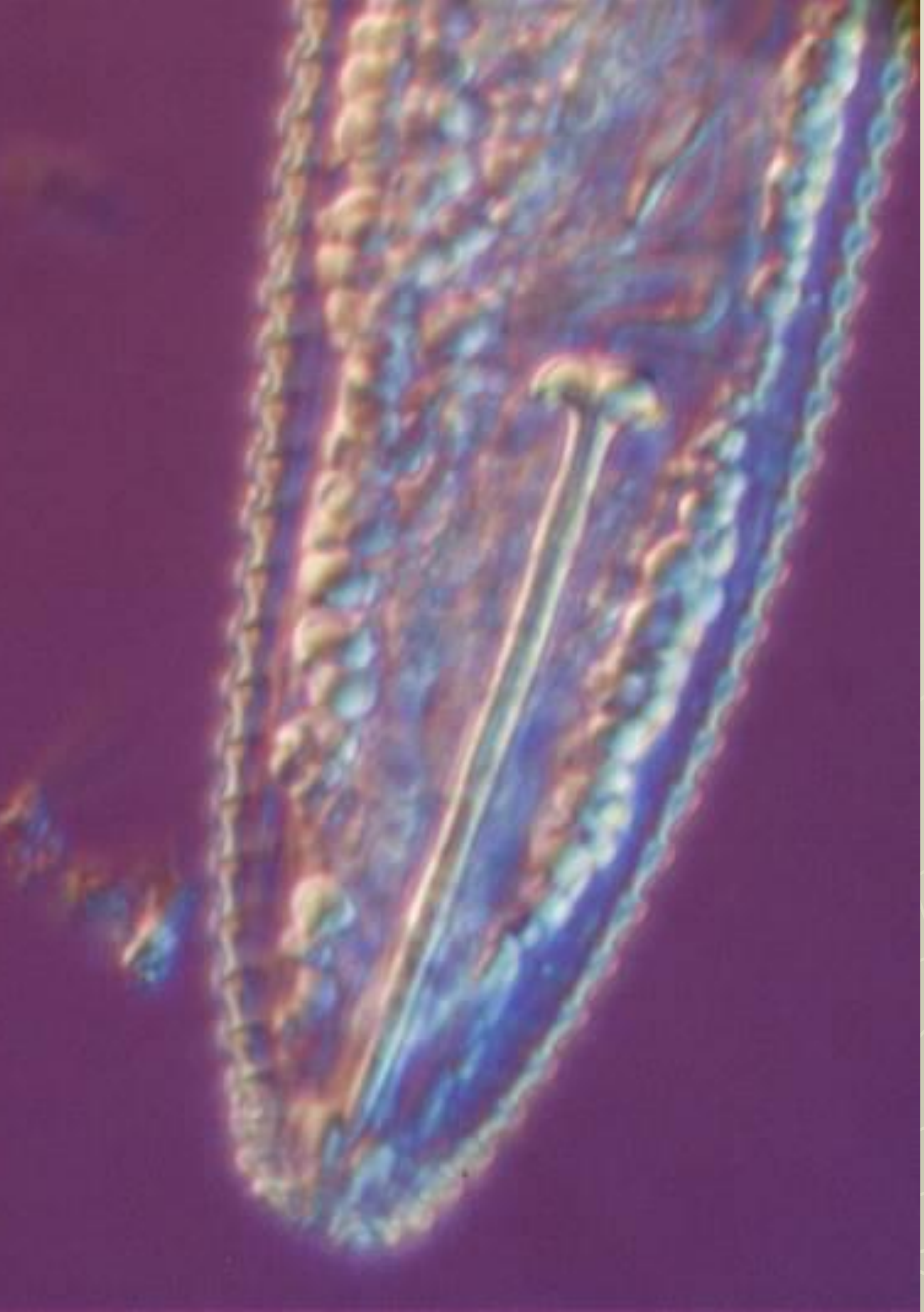
Truncated time to decline or failure under water-limited conditions – Peng et al.

Yield decline in irrigated rice - evolving sensitivity to pathogens, insect pests and abiotic environmental conditions over time

Cassman, Dobermann, Walters and Yang, 2003.
Annu. Rev. Environ. Resour. 28: 315-358.

Grain yields and yield components of rice with different management treatments ChiangMai, Thailand

Treatment	Rice production (t ha^{-1})	Total biomass (t ha^{-1})	Harvest index	Reproductive efficiency (%)	Seed fill (%)	Height (cm)
Conventional						
Compost	5.92 ± 0.21	10.42 ± 0.47	0.55 ± 0.03	98.1 ± 6.4	86.2 ± 9.0	102.3 ± 3.0
None	5.47 ± 0.25	9.71 ± 0.51	0.55 ± 0.02	99.7 ± 2.0	86.9 ± 9.0	101.4 ± 3.8
AWD						
Compost	3.76 ± 0.65	7.76 ± 1.38	0.47 ± 0.03	98.9 ± 3.4	83.8 ± 9.7	86.5 ± 4.6
None	3.58 ± 0.47	7.30 ± 0.83	0.45 ± 0.04	98.1 ± 5.2	84.2 ± 10.1	87.1 ± 3.1

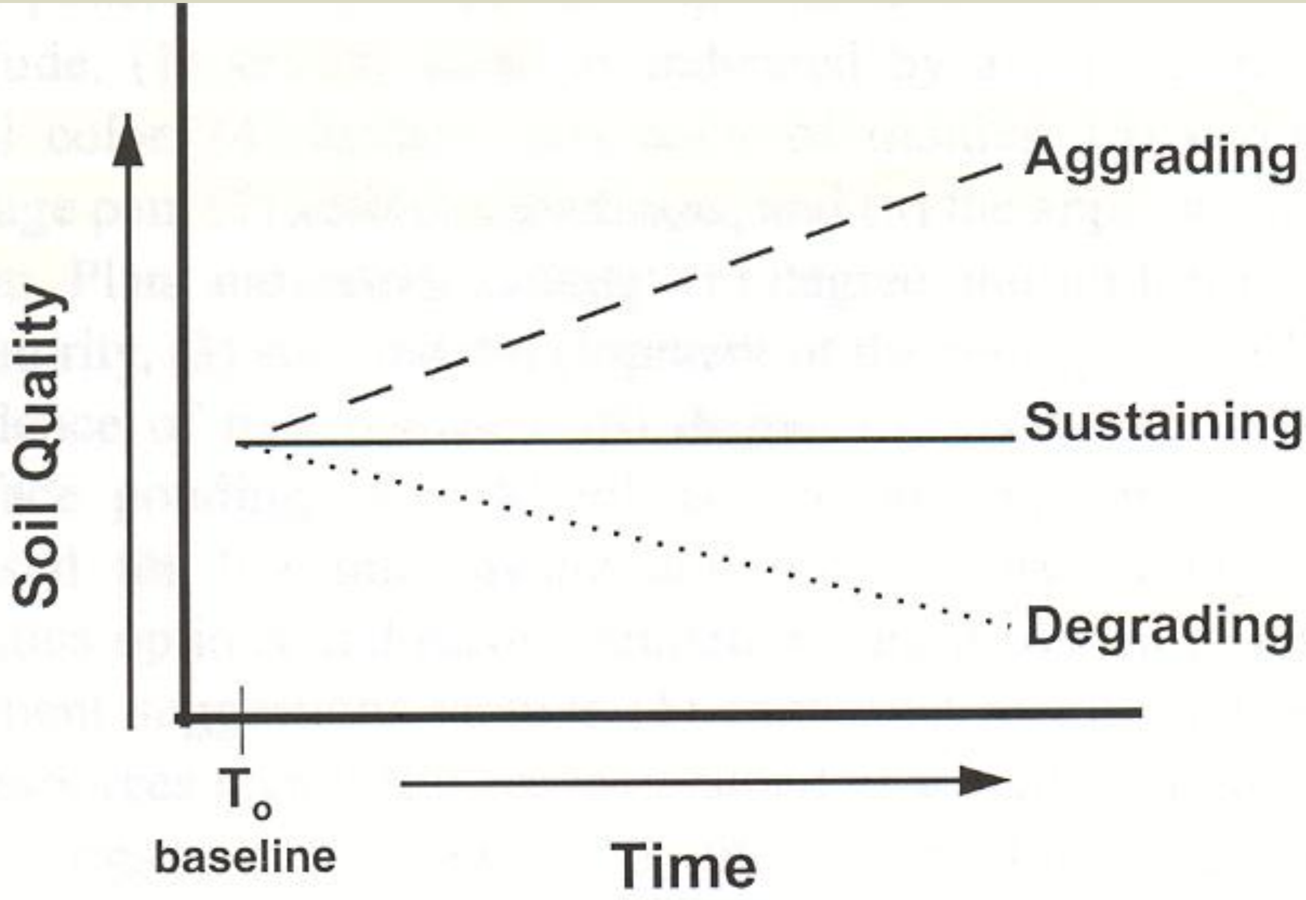


Plant parasitic nematode

Soil Health Assessment Framework

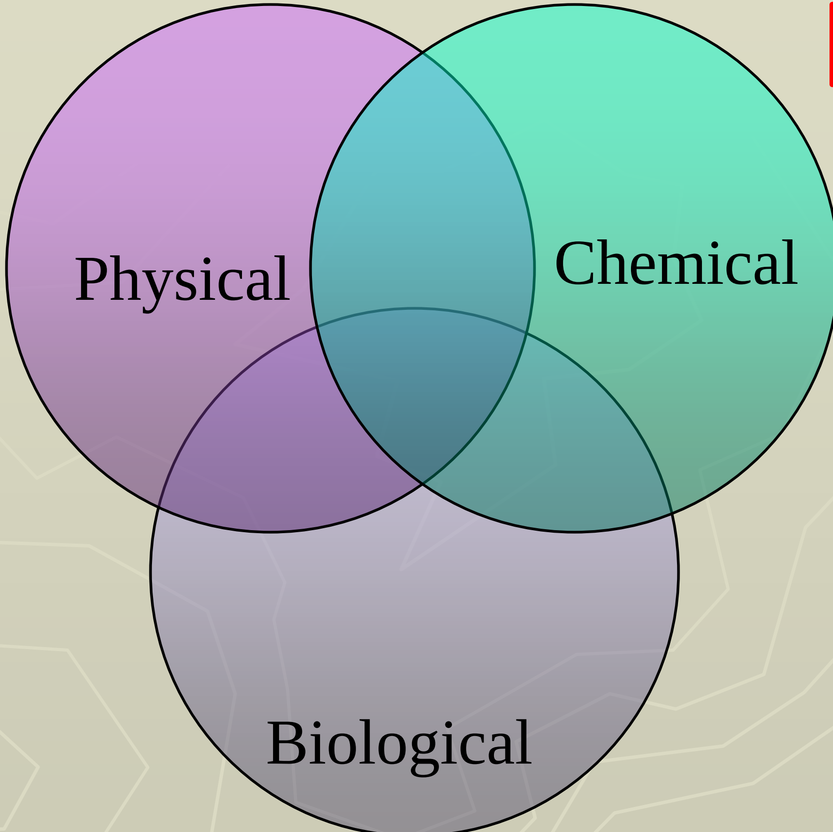
Diagnostics: needed to identify soil health related constraints to yield across the range of environments in which rice is grown

- Robust and reliable
- Easy and inexpensive to measure
- Comprehensible and useful for farmers
- Separate abiotic from biotic causal factors
- Assess distribution of the constraint


Aggrading
Sustaining
Degrading
Soil Quality
T_o
baseline
Time

Soil Health Indicators

- Bulk density
- Penetration resistance
- Aggregate stability
- Water infiltration rate
- Water holding capacity
- Pore size distribution



- % OM
- "Active" C, N in OM
- Cation exchange capacity
- N, P, K
- Micronutrients
- [Toxins, pollutants]
- Soil protein

- Soil disease suppressive capacity
- Beneficial and pathogenic nematodes, [other pathogens]
- N mineralization rate (PMN)

- Decomposition rate
- microbial biomass
- Respiration rate
- Earthworm counts
- Genetic diversity

Roots are good indicators of soil health…

- ✓ Poor drainage
- ✓ Poor nutrient availability
- ✓ Severe compaction
- ✓ Pathogen infections
  - *Rhizoctonia*
  - *Pythium*
  - Root-knot nematode
  - Etc.

Detailed Procedure for Assessing Root Health

① Soil sampling Collect at least 2 composite soil samples from the top 10 cm of soil from each field. Each composite sample consists of ~2L soil from 15 - 20 locations following a X or V pattern across the sampling area.

② Bioassay set-up Thoroughly mix each soil sample and place into two 500-800 cm^3 clay pots. Mix N-P-K-S fertilizers with the soil according to field recommendations and plant 10 rice seeds in each pot.

Maintain the pots in a greenhouse, nethouse or other protected area outside. Water the pots twice daily but avoid stagnated/flooded conditions. Rice plants should be grown under aerobic soil conditions for the duration of the bioassay.

④ & ⑤ Evaluation After 4 to 5 weeks, carefully remove the roots from the soil in the pots and wash roots free of soil. Examine and rate root health on a scale of 1 to 9 based on root color, texture and stage of decay. 1 = healthy, white roots with a coarse texture, no visible disease symptoms; 9 = > 75% root tissues diseased, reduced in size; advanced stage of decay (see guide below).

Root Health Scale:

Assessing Root-knot Nematode Galling

⑤ Examine, count, and record the total number of galls (up to 100 galls) on roots and root tips of the ten rice plants (see close-up of galls (left) and examples below).

Examples of Root-Galling on Rice Root Systems

0 galls visible on roots

2 galls visible on roots

40 galls visible on roots

> 100 galls on roots

Knowledge gaps and needs

- Mechanisms driving processes of interest
  - At a suitable scale based on constraints addressed
- Simple, but powerful soil diagnostics
- Training in identifying key limiting factors
  - Root and soil health training programs
- Identify accessible, affordable, sustainable methods that address site specific limiting factors

Take home messages

Pull up some plants and
look at their roots !

Make friends with (or hug)
a soil scientist
today !

Collaborators
(the short list)

Cornell University

George Abawi
John Duxbury
Julie Lauren
Warshi Dandeniya
Ryan Haden
Thanwalee
Sooksa-nguan
Harold van Es
John Idowu
David Wolfe
Bob Schindelback

http://rspas.anu.edu.au/blogs/rmap/files/2007/05/rice.jpg

Thailand

Phrek Gypmantasiri
Neung Teaumroong

Site specific nutrient management (SSNM)

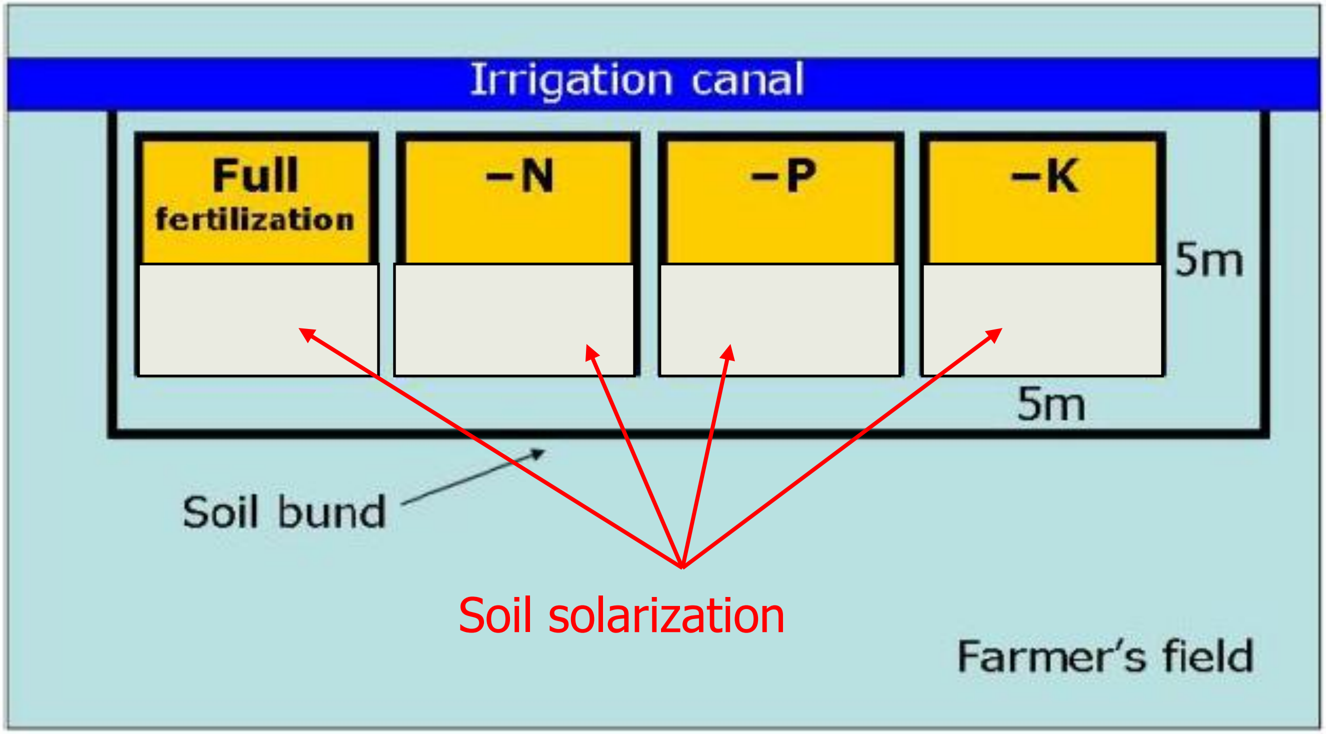


Fig. 2. An illustration of the field layout for nutrient omission plots in farmer's field.

http://www.irri.org/irrc/ssnm/Appendices/NutrientOP.asp

Adaptations for identifying micronutrient deficiency

Proposed adaptation to diagnose soil pest and pathogen inoculum potential

Proposed add back in the check plot for areas with higher soil fertility

Soil Health – Soil Function

Root proliferation

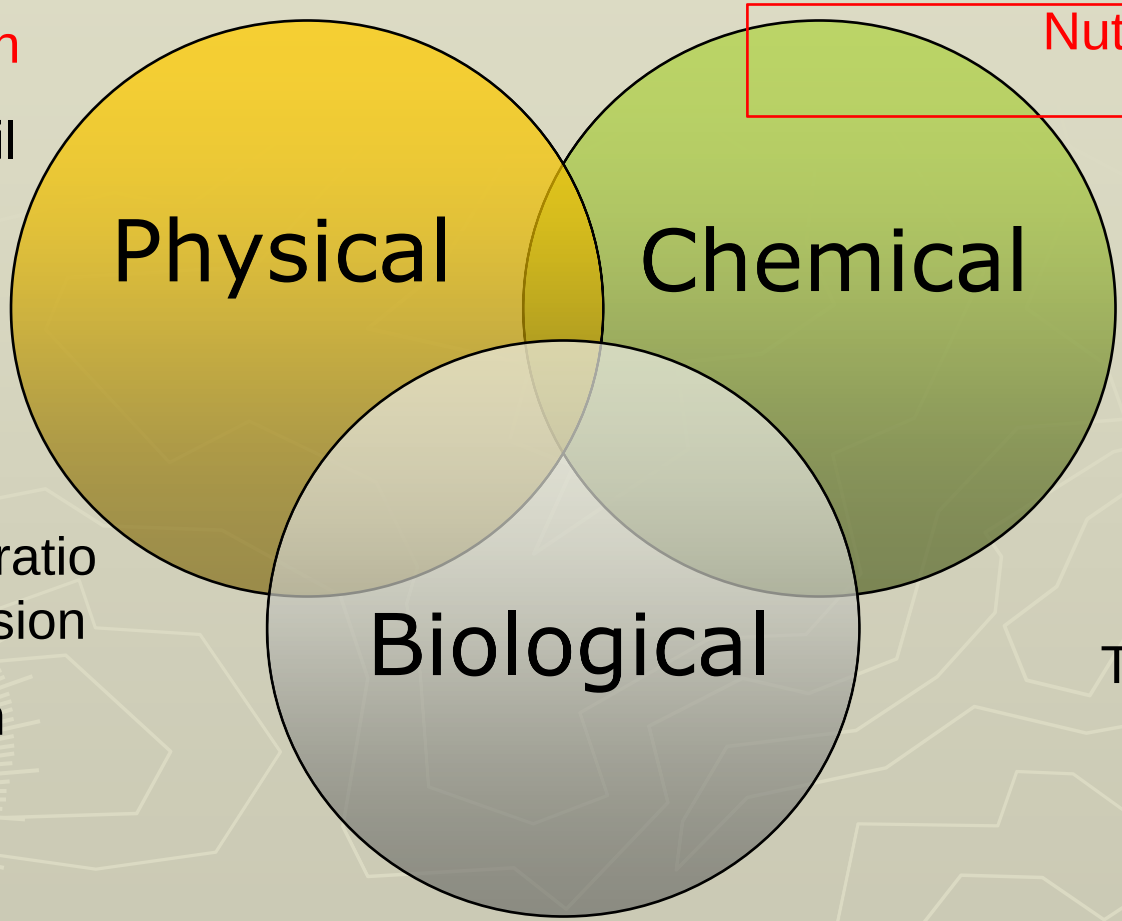
Movement of soil organisms

Aeration

Water retention

Water infiltration, filtration and transmission

Stability: erosion prevention



Nutrient content, retention & release

pH

Redox

Energy (C) storage

Toxicity mitigation

Nutrient cycling

OM decomposition

N_2 fixation

Cause/suppress disease

Consume/release GH gases

Bioremediate contaminants

Genetic reservoir

Relevant to what?

- Nutrient availability for crop production
  - Protected vs unprotected or labile fractions
- Greenhouse gas emissions or perhaps not?
  - Can these soils retain C longer, in more recalcitrant forms than traditional methods of soil management?
- Pathogen susceptibility – root health assessment